9.0 Appendices

9.1 Acknowledgements

University of Washington Team

- Dave Woodson, Executive Director, Campus Energy, Utilities, and Operations (CEU&O)
- Mark Kirschenbaum, Assistant Director, CEU&O
- Norm Mentor Assistant Director, Energy & Resources Conservation, CEU&O
- Ryan Trickett, WCUP & Utility Distribution Utilities Manager, CEU&O
- Warren Midkiff, Power Plant Operations & Maintenance Manager, CEU&O
- Jeremy Park, Electrical Utilities Manager, CEU&O
- Guarrin Sakagawa, Environmental Controls Manager, CEU&O
- Kristine Kenney, Executive Director, Campus Architecture + Planning (CAP)
- Victoria Buker, Assistant Director of Campus Asset Renewal, CAP
- Julie Blakeslee, University Environmental & Land Use Planner, CAP
- Robbie Avila, Manager, Engineering Services
- Casey Cockerham, Engineering Services
- Alex Bruder, Engineering Services

Affiliated Engineers, Inc.

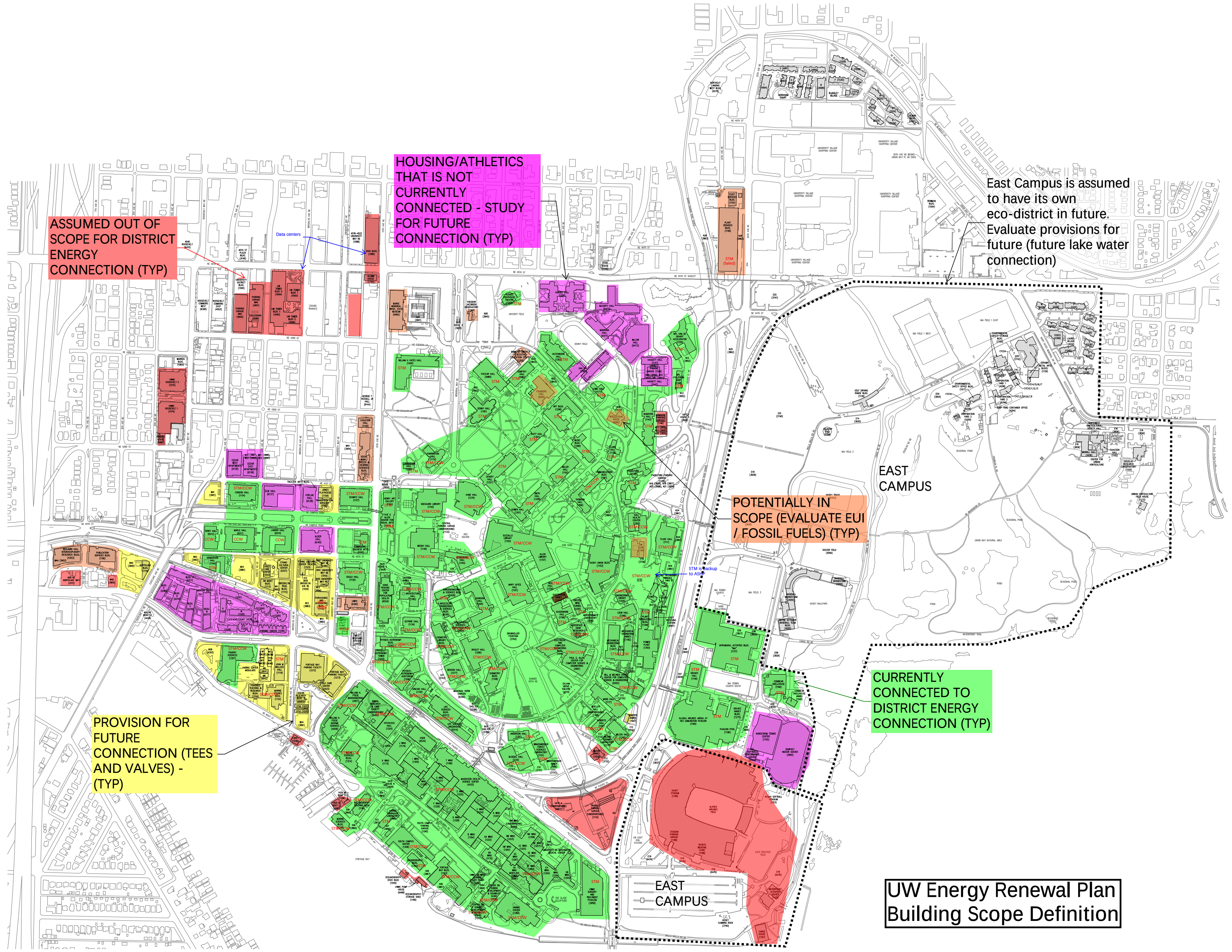
- Geoff McMahon – Principal in Charge and Lead Planner
- Robby Oylear – Project Manager, Mechanical Utility Systems
- Phillip Atwater – Electrical Engineer
- Bruce Colony – Electrical Utility Systems
- Tim Halder – Mechanical Engineer
- Lyle Keck – Building Performance
- Mike Prier – Building Performance

Subconsultant Team

- Shannon & Wilson – Amy Summe
- Whiting-Turner – Steve Thomas, Kodiak Waldal, Adam Smith, Jake Giannandrea
- KPFF Consulting Engineers – Marty Chase
- Ernst & Young – Tom Budescu
- Makai Ocean Engineering – Alex Le Bon
- Rolluda Architects – Alex Rolluda, Matthew Budinger

9.2 Energy Renewal Plan Building Scope Definition

The following site plan indicates which buildings are in or out of scope for the Energy Renewal Plan.



UW ERP BUILDING SCOPE DEFINITION

AUGUST, 2024

UNIVERSITY OF WASHINGTON - ENERGY RENEWAL PROGRAM

Affiliated Engineers®

9.3 Large Format Drawings and Diagrams

Section redacted for security reasons

9.4 Preliminary Permitting & Environmental Considerations - Phase 2

This report is superseded and removed to reduce file size - please see final report in Phase 3

9.5 Civil Technical Report

Section redacted for security reasons.

9.6 Lake Water Engineering report

UNIVERSITY OF WASHINGTON LAKE WATER COOLING AND HEATING

FEASIBILITY STUDY

Prepared For

AFFILIATED ENGINEERS, INC

1601 Fifth Ave, Suite 1400, Seattle, Washington, 98101

Prepared By

MAKAI OCEAN ENGINEERING, INC

PO Box 1206, Kailua, Hawaii 96734

15 August 2024

REVISION DESCRIPTION SHEET

Rev.	Para.	Revision Description
00	All	Initial release
01	All	Added more details to the pump and diffuser sections. Revised Figure 3-15.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Project Description

The University of Washington in Seattle is considering implementing a 22 MW lake water cooling and heating (LWCH) system as a part of the University's Energy Renewal Program. The system would consist of an approximately 1.25 mile (~2 km) long intake pipeline that will transport deep lake water from Lake Washington to the University. Two options for the discharge pipeline are being considered: discharging back to Lake Washington or discharging into the Montlake Cut.

Figure 1-1. *Vicinity map and project location.*

1.2 Similar Projects

The concept of using lake water or sea water for district cooling and heating has been demonstrated by several projects around the globe. Some of the notable examples of these include:

- 2004 - Toronto Deep Lake Water Cooling (207 MW, 4x 63" intake pipes)
- 2000 - Cornell Lake Source Cooling (51 MW, 1x 63" intake pipe)
- 1986 - Stockholm Sea Water District Cooling/Heating (180MW)

1.3 Scope of Work

The Scope of Work considered by the Subconsultant is to conduct a feasibility study for the proposed lake water cooling and heating system. This involves implementing the Subconsultant's METHOD Deep Water Source Cooling Model that has been adapted for heating operation and a lake water source. Outputs from the model will provide the Consultant with system costs and descriptions of the basic technical requirements of a deep lake water cooling configuration for the specified site.

The Consultant provided the Subconsultant with supporting design data. All other data was obtained through publicly available sources.

1.3.1 Battery Limit

The battery limit for this work is the lake water side of the heat exchanger. The Subconsultant was responsible for the technical and cost feasibility of the components on the lake water side and not including the heat exchanger. The heat exchanger, chilled water system, and other onshore components were assessed by the Consultant and others.

1.4 Definitions

Owner	The University of Washington
Consultant	Affiliated Engineers, Inc.
Environmental Subconsultant	Shannon & Wilson
Subconsultant	Makai Ocean Engineering, Inc.

1.5 Abbreviations

AEI	Affiliated Engineers, Inc.
ASCE	American Society of Civil Engineers
CAPEX	Capital Expenditures
CW	Chilled Water
DHA	Down Hill Assembly
DNR	Department of Natural Resources
HDD	Horizontal Directional Drill
HDPE	High Density Polyethylene
HLL	High Lake Level
HX	Heat Exchanger
LLL	Low Lake Level
LW	Lake Water
LWCH	Lake Water Cooling and Heating
LWHX	Lake Water Heat Exchanger
LWSC	Lake Washington Ship Canal
MOE	Makai Ocean Engineering, Inc.
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration

PE	Polyethylene
pIn	Pressure In
SWAC	Seawater Air Conditioning
tIn	Temperature In
USACE	United States Army Corps of Engineers
WRT	With Reference To

1.6 Standards and References

1.6.1 Project Reference Documents

[1] Ship Canal and Deep Lake Temps, Shannon & Wilson, February 2024

[2] Lake Interface Mechanical Performance Criteria, AEI, April 2024

[3] Distribution of Discharge from the Ballard Locks spillway, based on USACE Data Query, LWSC Daily Flow 2000-Present, Shannon & Wilson, May 2024

1.6.2 Other References

[4] Nautical Chart 18447- Lake Washington Ship Canal and Lake Washington, NOAA, 2012, https://charts.noaa.gov/PDFs/18447.pdf

[5] Electronic Navigational Chart US5WA13M, NOAA, November 2023, Chart Locator (noaa.gov)

[6] Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado, Boulder. 2014: Continuously Updated Digital Elevation Model (CUDEM) – 1/9 Arc-Second Resolution Bathymetric- Topographic Tiles. NOAA National Centers for Environmental Information. https://doi.org/10.25921/ds9v-ky35.

[7] WAC 173-201A-130 Specific Classifications- Freshwater, WSR 97-23-064, Permanent Rules, Department of Ecology, Washington State, https://lawfilesext.leg.wa.gov/law/wsr/1997/23/97-23-064.htm

[8] 2016 – 2017 PSLC Lidar DEM: King County, WA, OCM Partners, https://www.fisheries.noaa.gov/inport/item/53392

[9] Monthly Mean Avg Temperature for Seattle City Area, WA, Monthly Summarized Data- Avg Temp 2000-2024, NOAA Online Weather Data, Seattle Weather Forecast Office, https://w1.weather.gov/climate/xmacis.php?wfo=sew

[10] Reservoir Control Center, USACE- Seattle District, Water Management Section, https://www.nwd-wc.usace.army.mil/nws/hh/www/index.html#

[11] Prevailing Wage Rates for Public Works Contracts- King County, Washington State Department of Labor & Industries, https://secure.lni.wa.gov/wagelookup/

[12] RSMeans Heavy Construction Cost Data, RSMeans, 2024

[13] Recommended Standards for Wastewater Facilities, The Wastewater Committee of the Great Lakes – Upper Mississippi River, Board of State and Provincial Public Health and Environmental Managers, Health Research Inc, 2014

[14] Herrenknecht Direct Pipe Information Page, 2024 https://www.herrenknecht.com/en/products/productdetail/direct-pipe/

[15] Subsurface Geology, Washington Geologic Information Portal, Washington Department of Natural Resources, https://geologyportal.dnr.wa.gov/2d-view

[16] Lake Washington Wind Speed, ASCE 7 Hazard Tool, American Society of Civil Engineers, https://gis.asce.org/beta-7-22/

[17] C-2-4-344, Lake Washington Ship Canal Sounding Survey Map, US Army Corps of Engineers Seattle District, 2014

2 DESIGN DATA

2.1 Environmental Data

2.1.1 Projection and Datums

The projection and datums used for this analysis are shown in Table 2-1.

Table 2-1. *Projection and datums.*

Parameter	Value
Projection	State Plane 1983
Zone	4601 Washington North
Horizontal Datum	NAD83
Vertical Datum	Low Lake Level (NAVD88 +16.75’)

2.1.2 Lake Levels

Lake level data is shown in Table 2-2 with respect to (wrt) three vertical datums. The US Army Corps of Engineers (USACE) controls the Lake Washington outflow rate to maintain water levels between 20’ and 22’ relative to the Corps Datum [10]. The Corps Datum is 3.25’ above the North American Vertical Datum of 1988 (NAVD88). The Lake Washington Summary Hydrograph plot from 1985-2015 developed by USACE is shown in

Figure 2-1.

Table 2-2. *Lake level data [10].*

Parameter	Unit	Lake Level		
		wrt Corps Datum	wrt NAVD88	wrt LLL
Low Lake Level (LLL)	*ft*	+20.00	+16.75	0.00
High Lake Level (HLL)	*ft*	+22.00	+18.75	+2.00

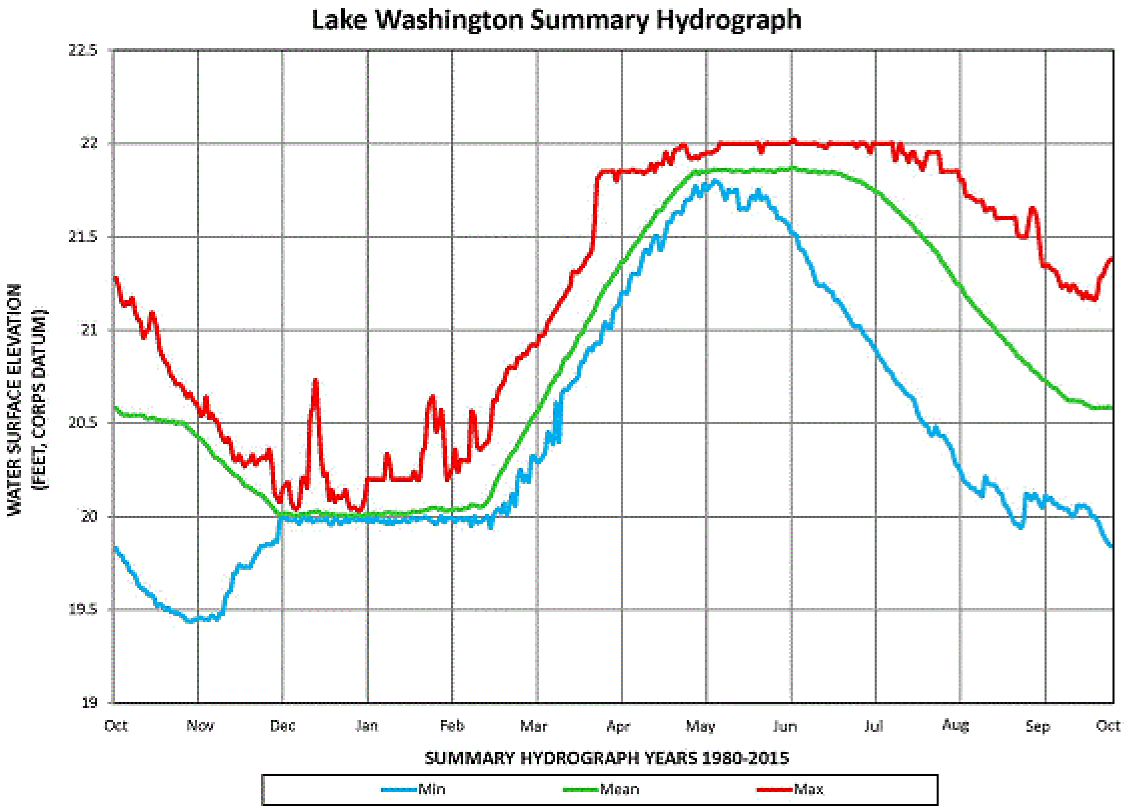


Figure 2-1. *Lake Washington summary hydrograph [10].*

2.1.3 Bathymetry

Lake bathymetry data was obtained from two sources. The first source is electronic navigational chart US5WA13M [5]. Nautical Chart 18447 [4] is shown in Figure 2-2 for reference, with depth soundings labelled in feet relative to Mean Water Level (MWL) of the lake.

The second bathymetry source is the NOAA NCEI Continuously Updated Digital Elevation Model (CUDEM) - Ninth Arc-Second Resolution [6]. This data is relative to the NAVD88 vertical datum and is shown in Figure 2-3 with the proposed intake pipeline path overlaid in black.

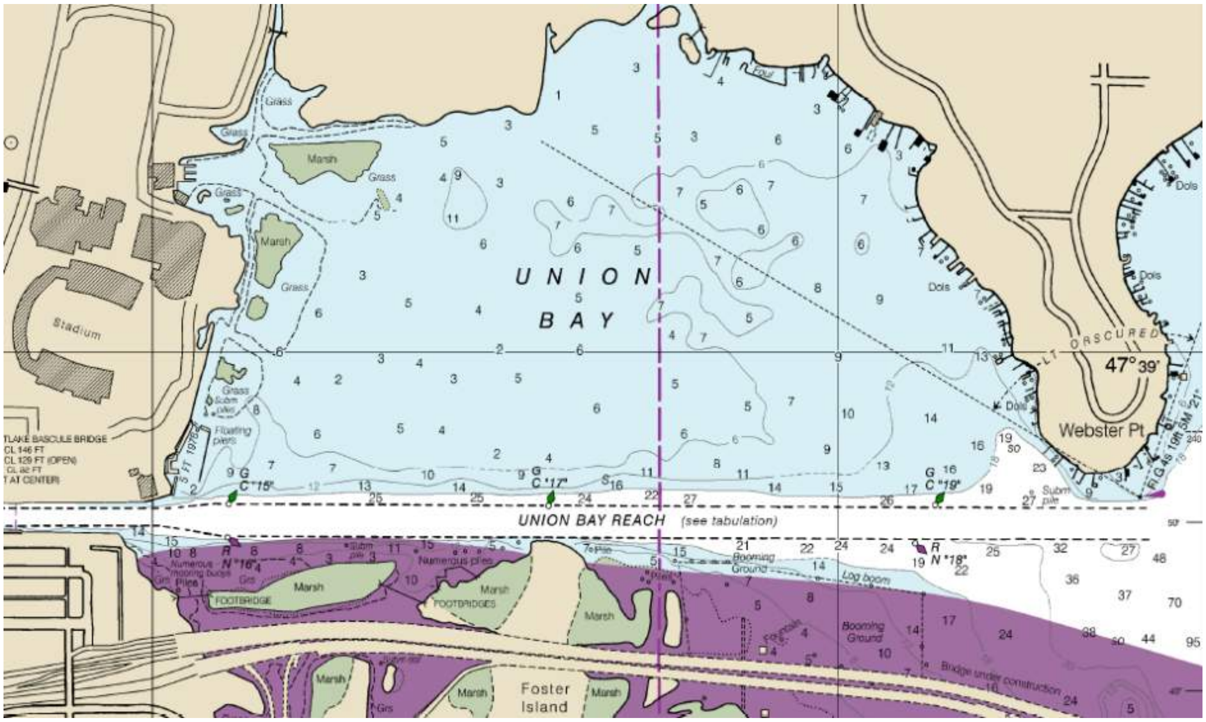


Figure 2-2. *Nautical Chart 18447 with Union Bay depth soundings and contours shown in feet [4]. Datum is Low Lake Level (LLL).*

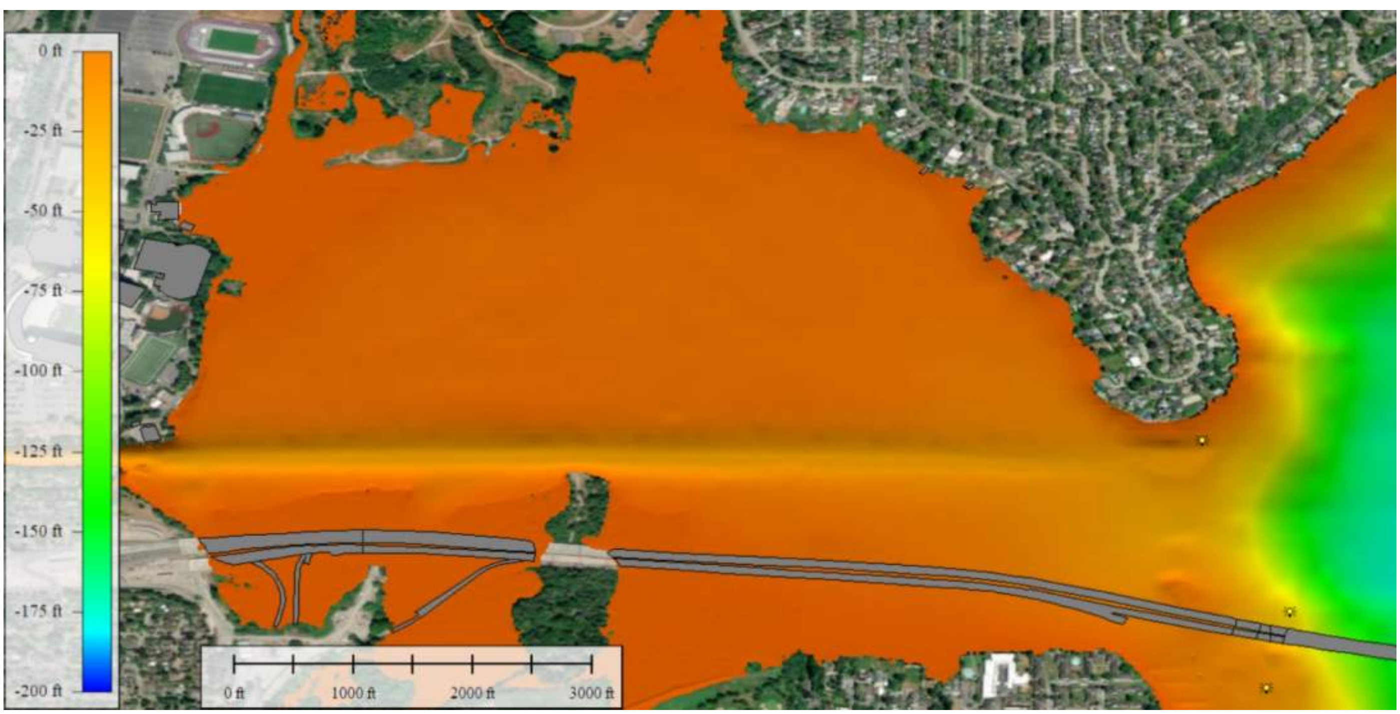


Figure 2-3. *Site elevation colormap (NAVD88 datum) where Lower Lake Level is +16.75 ft.*

2.1.4 Elevation Data

Data from a 2016-2017 Lidar study in King County, WA [8] was used to determine land elevations at the project site. The onshore site elevation colormap is shown in Figure 2-4 with the shoreline, power plant, and intake pipeline path shown in black.

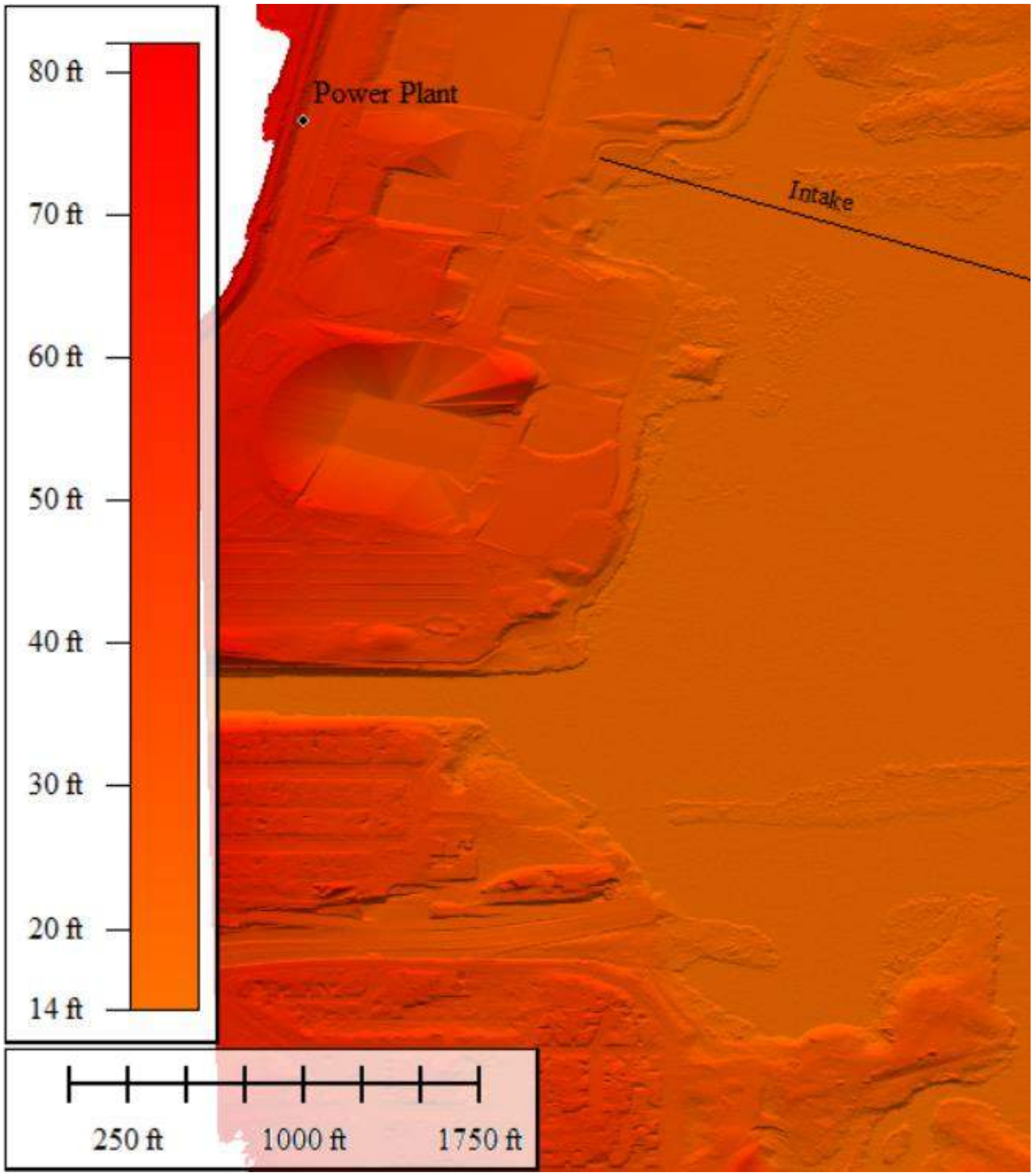


Figure 2-4. *Onshore site elevation colormap (NAVD88 datum).*

2.1.5 Lake Water Temperature and Salinity

Water temperature statistics for Lake Washington by depth and month were provided by Consultant's Environmental Subconsultant [1]. The water temperature data consists of modeled values from the publicly available DSI model, not measured data. Table 2-3 shows the average water temperature in Lake Washington for each month at various water depths. Minimum, maximum, and average temperature depth profiles for all months are shown in Figure 2-5 through Figure 2-7, respectively.

Table 2-3. *Average lake temperature values by month and depth [1].*

Temperature (°F)		**Month - - -**												***1993***	***2023***
		1	2	3	4	5	6	7	8	9	10	11	12	*Min*	*Max*
Depth (m)	0	46.2	45.1	45.5	49.3	56.8	63	69.6	71.4	67.4	61	54	49.1	*45.1*	*71.4*
	3	46.2	45.1	45.7	49.3	56.9	63.1	69.5	71.1	67.1	60.3	53.7	48.9	*45.1*	*71.1*
	6	46.1	45	45.5	49.1	56	62.1	68.2	70.7	66.9	60.1	53.6	48.9	*45*	*70.7*
	9	46.2	45	45.5	48.6	54	59.2	62.5	66.7	66.5	60.3	53.7	48.9	*45*	*66.7*
	12	46.1	44.9	45.4	48.3	52.1	55	56.2	58.2	61.6	60	53.6	48.9	*44.9*	*61.6*
	15	46.2	44.9	45.3	47.7	50.5	51.8	52.7	53.6	54.8	57.6	53.7	48.9	*44.9*	*57.6*
	18	46.2	45	45.3	47.3	49.1	50	50.6	50.9	51	53.6	53.3	48.9	*45*	*53.6*
	21	46.1	44.9	45.3	47.1	48.5	49	49.3	49.3	49.6	51	52.6	48.8	*44.9*	*52.6*
	24	46.3	44.9	45.1	46.9	47.9	48.2	48.5	48.5	48.6	49.6	51.4	49	*44.9*	*51.4*
	27	45.7	43.9	46	46	46.9	48.6	48	47.6	47.9	48.8	50.1	47.8	*43.9*	*50.1*
	30	46.3	44.9	45	46.6	47	47.3	47.4	47.6	47.7	48.2	49.3	49.1	*44.9*	*49.3*
	33	46.2	44.9	45	46.3	46.6	46.9	47.1	47.1	47.2	47.6	48.6	48.5	*44.9*	*48.6*
	36											48.4	49.4	*48.4*	*49.4*
	39	46.2	44.9	44.9	45.9	46.3	46.6	46.8	46.8	46.9	47.2	47.9	48.4	*44.9*	*48.4*
	42	46.2	43.2		46.5	45.4	47.5	46.5	46.9	46	47.1	48.1	47.9	*43.2*	*48.1*
	Min	*45.7*	*43.2*	*44.9*	*45.9*	*45.4*	*46.6*	*46.5*	*46.8*	*46*	*47.1*	*47.9*	*47.8*		
	Max	*46.3*	*45.1*	*46*	*49.3*	*56.9*	*63.1*	*69.6*	*71.4*	*67.4*	*61*	*54*	*49.4*		

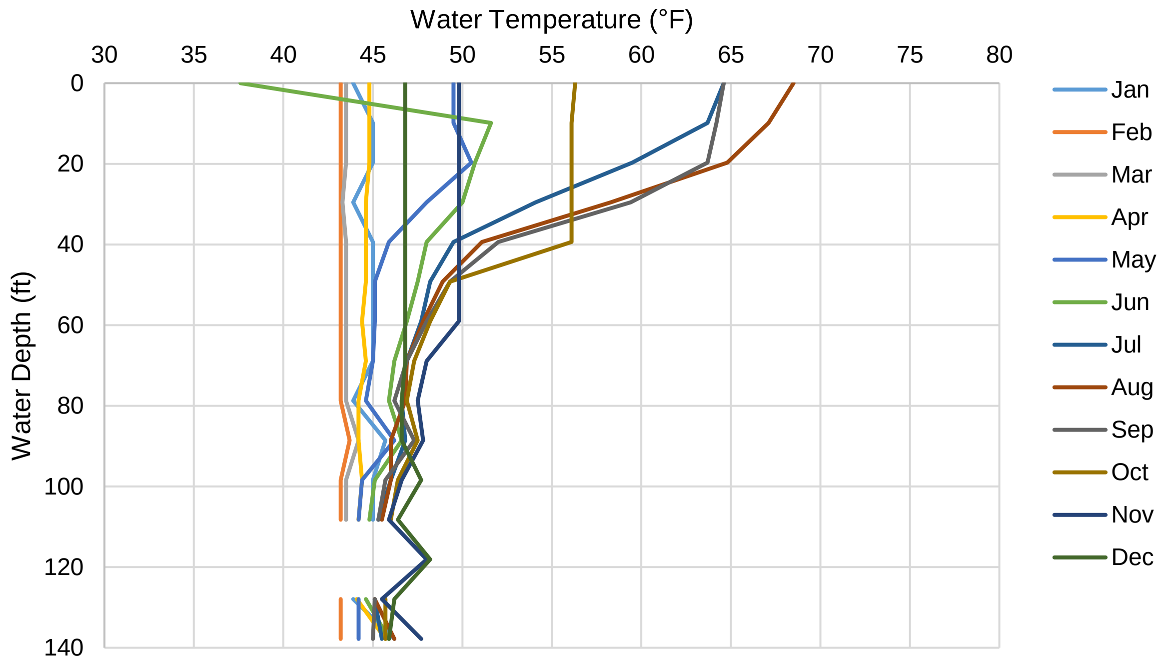


Figure 2-5. *Minimum temperature-depth profiles for each month [1].*

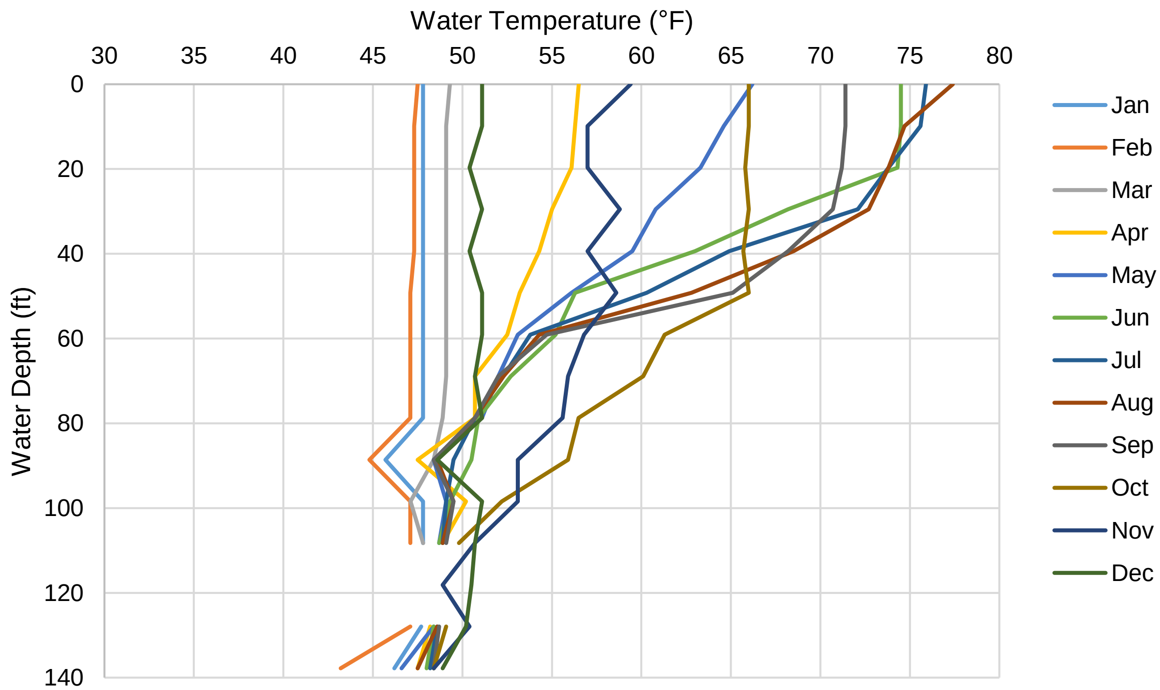


Figure 2-6. *Maximum temperature-depth profiles for each month [1].*

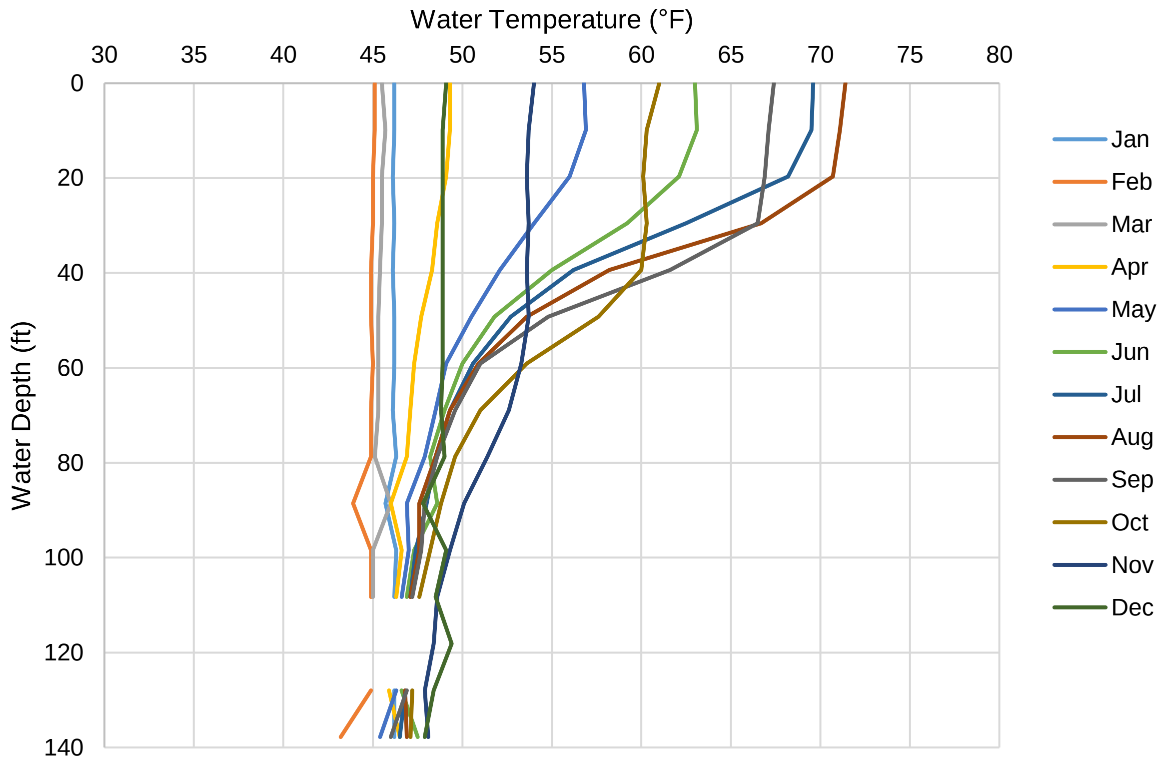


***Figure 2-7.** Average temperature-depth profiles for each month [1].*

According to the permanent rules of the Washington State Department of Ecology, there is a special condition stating that the salinity shall not exceed 1.0 ppt “at any point or depth along a line that transects the ship canal at the University Bridge” [7]. Since the lake water intake will be in Lake Washington which is much further upstream, this analysis assumes that that the salinity at the intake is 0 ppt.

2.1.6 Ambient Air Temperature Data

Ambient air temperature data for the Seattle City Area was taken from the NOAA Online Weather Data interface [9]. This dataset includes monthly mean average, minimum, and maximum temperatures for Seattle City Area, WA from 2000-2024. The average, minimum, and maximum air temperature for each month is shown in Table 2-4.

Table 2-4. *Ambient air temperature data by month for the Seattle City Area [9].*

Month	Average	Minimum	Maximum
-	°F	°F	°F
Jan	42.4	16	64
Feb	43.0	18	64
Mar	46.5	27	78
Apr	50.7	31	89
May	56.9	35	90
Jun	61.9	43	107
Jul	67.0	47	105
Aug	67.6	47	97
Sep	62.4	40	91
Oct	53.9	31	88
Nov	46.2	18	76
Dec	41.7	17	65
ANNUAL	53.0	16	107

2.1.7 Subsurface Geological Data

Publicly available subsurface geological data for Union Bay was accessed through the Washington Department of Natural Resources (DNR) web portal [15]. A map of the Union Bay borehole data is shown in Figure 2-8, with most of the borings dating to 1961. The boreholes data generally shows that the first 40-50’ is peat, followed by glacial soils. The layer lithology chart for borehole P-49, P-16, and P-95 are shown in Figure 2-9.

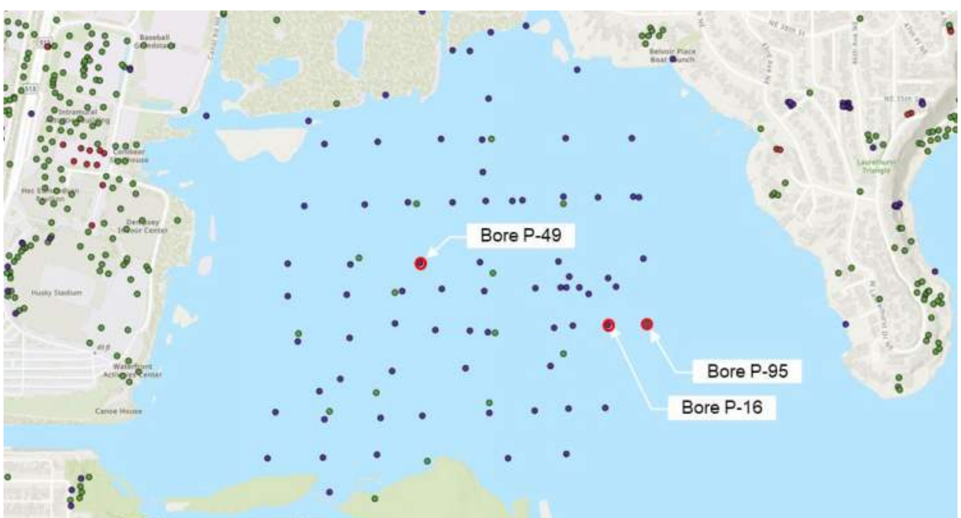


Figure 2-8. *Map of historical boreholes in Union Bay.*

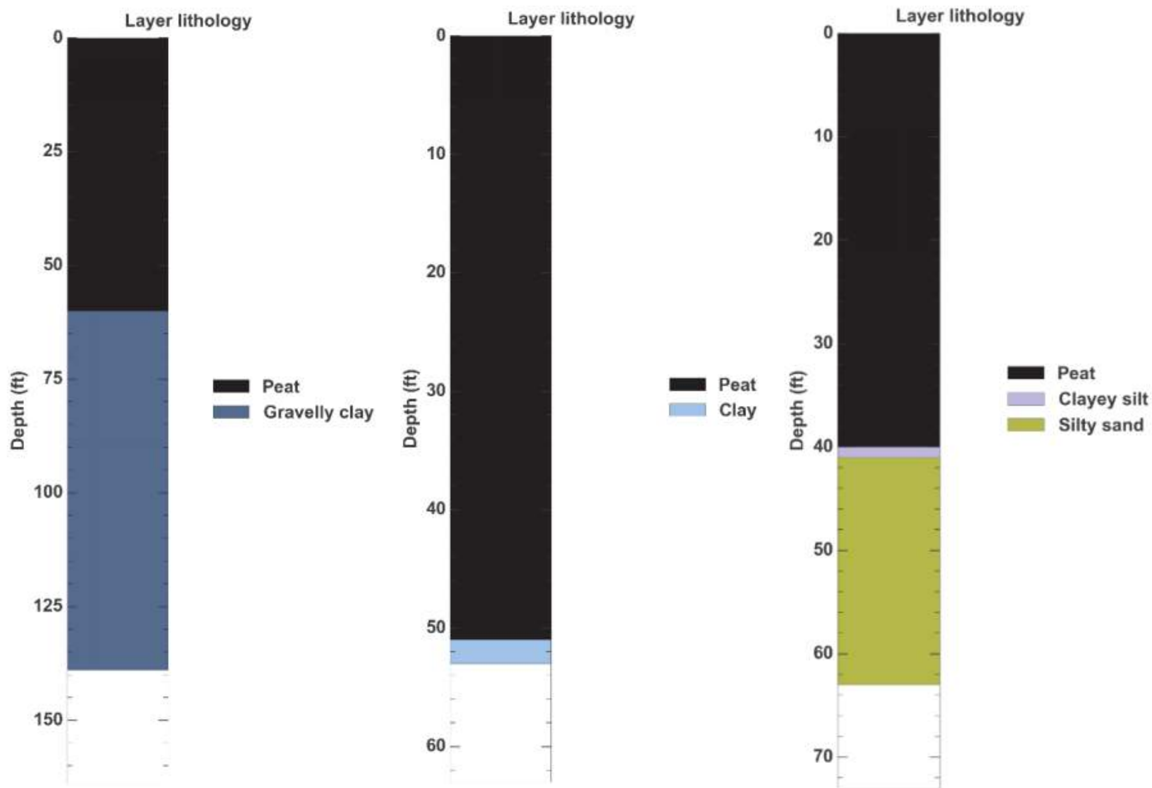


Figure 2-9. *Subsurface layer lithology for boreholes P-49 (left), P-16 (middle), and P-95 (right) in Union Bay.*

2.1.8 Wave and Current Data

There is no available wave or current data for Lake Washington. Significant wave heights and periods were estimated from 3 second, 10 meter wind gust speeds at various return periods based on methodologies presented in the Coastal Engineering Manual. Wind data for Lake Washington was obtained from the ASCE 7 Hazard Tool [16]. The fetch length used in the wave calculations is equal to the longest unobstructed path between the lake edge and the intake location, and is shown in Figure 2-10. All straight line paths to the south of the intake are obstructed by Seward Park and Mercer Island, so they were not chosen for this analysis. The ASCE wind gust speeds and results for significant wave heights and peak periods at different return periods are shown in Table 2-5. The 100-year wave is 3.6 feet at 2.8 seconds.

Table 2-5. *Lake Washington wave data based on wind speed.*

Return Period	3 s Wind Gust at 10 m Height, [16]	Significant Wave Height	Peak Wave Period
yrs	*mph*	*ft*	*s*
10	67	2.8	2.5
25	74	3.1	2.6
50	78	3.3	2.7
100	83	3.6	2.8

Figure 2-10. *Lake Washington map showing fetch path used in wave calculations.*

2.1.9 Montlake Cut Flow Rate

The Montlake Cut is a narrow channel that connects Union Bay to Portage Bay. The majority of the Montlake Cut consists of the Lake Washington Ship Canal (LWSC). This canal is owned by the US Army Corps of Engineers, and it connects Lake Washington to Puget Sound. USACE elevation data for the LWSC at the Montlake Cut is shown in Figure 2-11 [17]. Elevations are reported in feet relative to LLL. The average depth of the LWSC at the Montlake Cut is approximately 30'. A simplified cross-section drawing view of the Montlake Cut with dimensions labelled in feet is shown in Figure 2-12. Based on this geometry, the cross-sectional area of the Montlake Cut was found to be 4,050 ft^2. Volumetric water flow rates from the Ballard Locks (western end of LWSC) were provided by Environmental Subconsultant [3]. The flow velocity through Montlake Cut was determined by dividing the Ballard Locks spillway flow by the cross-sectional area of Montlake Cut. Various statistical percentiles of the Ballard Locks flow rates and Montlake Cut flow velocities are shown in Table 2-6. A photo of the Montlake Cut near the potential discharge location is shown in Figure 2-13.

Table 2-6. *LWSC daily flow 2000-present [3].*

Parameter	Ballard Locks Spillway Flow	Montlake Cut Flow Velocity
	cfs	*ft/s*
Minimum	43	0.01
1st Percentile	218	0.05
10th Percentile	261	0.06
25th Percentile	405	0.10
Median	754	0.19
Mean	1,254	0.31
75th Percentile	1,711	0.42
90th Percentile	2,747	0.68
99th Percentile	6,296	1.55
Maximum	13,381	3.30

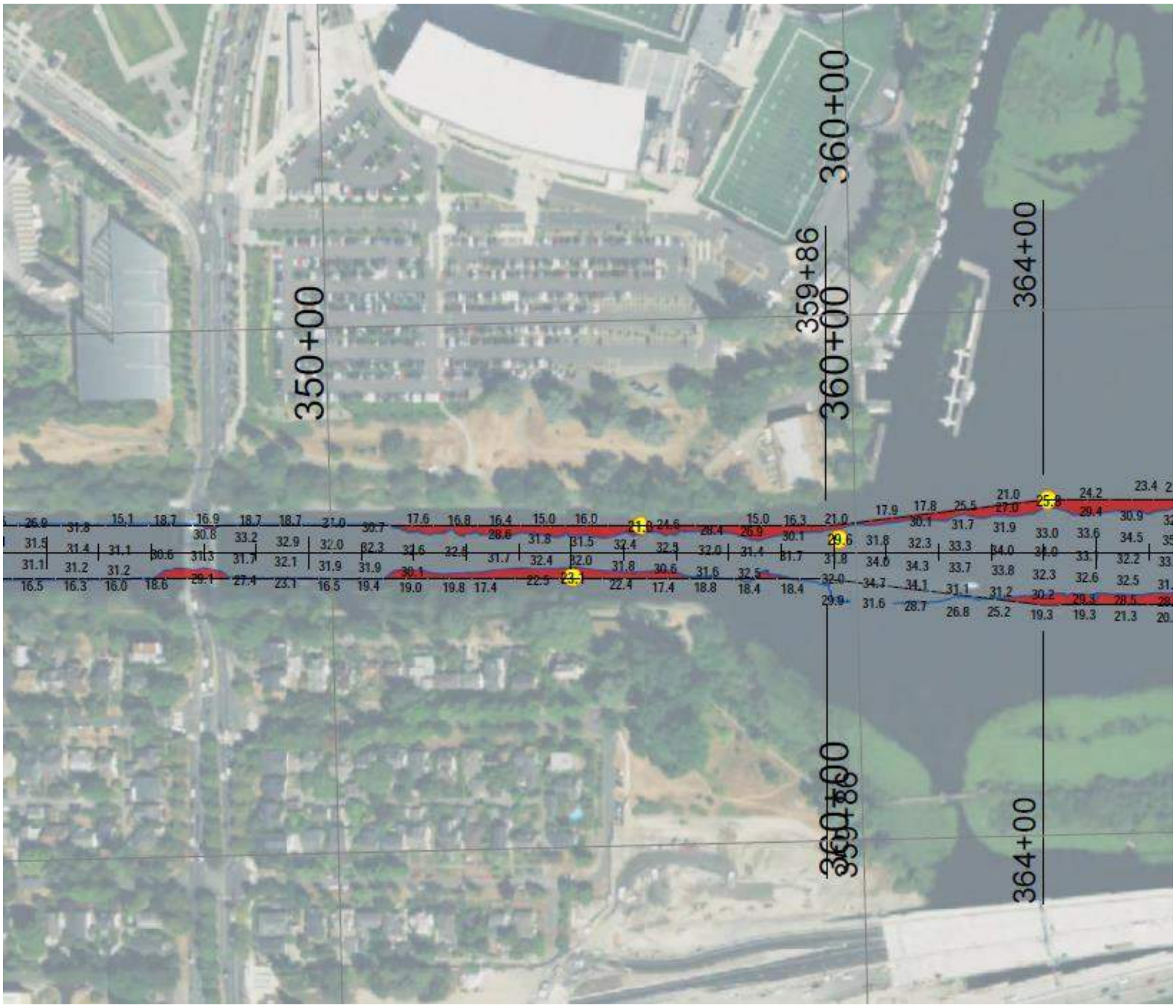


Figure 2-11. *LWSC LLL elevation data (in feet) at Montlake Cut, [17].*

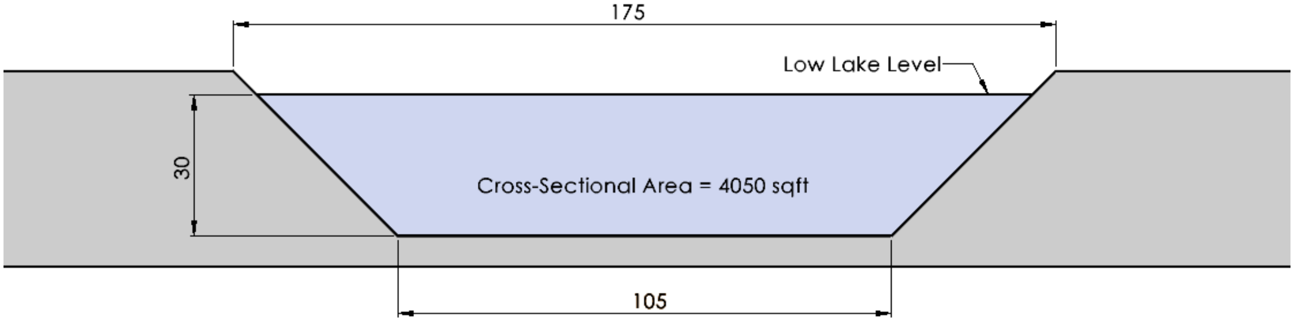


Figure 2-12. *Simplified cross-section of Montlake Cut with dimensions shown in feet.*

Figure 2-13. *Photo of Montlake Cut near potential discharge location.*

2.2 System Data

2.2.1 Design life

The desired system design life is 100 years.

2.2.2 Performance Criteria

The lake interface mechanical performance criteria provided by the Consultant for heating mode and cooling mode are listed in Table 2-7 and Table 2-8, respectively [2]. The heating mode criteria drives the system design. The design peak load experienced by lake value includes the heat of compression from the chillers. In the following tables, "Lake Water" is defined as the water that comes from and is discharged back into the lake. "Chilled Water" is defined as the fresh water that exists in the closed-loop piping between the lake water heat exchanger and the powerplant. The Lake Water and Chilled Water do not mix and the Chilled Water will never be discharged into the lake.

Table 2-7. *Lake interface mechanical performance criteria in Heating Mode [2].*

Parameter	Values	US Units	Values	SI Units
Lake Water Loop Flowrate	21,714	*GPM*	1,370	*kg/s*
Fluid	Lake Water	-	Lake Water	-
Lake Water Intake Temperature	45	*°F*	7.2	*°C*
Temperature Returned to Lake from Outfall Pipeline	38	*°F*	3.3	*°C*
Pressure Drop Through Lake Water Heat Exchanger	10	*psig*	68,950	*Pag*
Campus Chilled Water Loop Flowrate	21,714	*GPM*	1,370	*kg/s*
Fluid	Chilled Water	-	Chilled Water	-
Campus Supply Water Temperature	43	*°F*	6.1	*°C*
Campus Return Water Temperature	36	*°F*	2.2	*°C*
Pressure Drop Through Campus Heat Exchanger	10	*psig*	68,950	*Pag*
Design Peak Load Experience by Lake	22.3	*MW*	22.3	*MW*

Table 2-8. *Lake interface mechanical performance criteria in Cooling Mode [2].*

Parameter	Values	US Units	Values	SI Units
Lake Water Loop Flowrate	21,714	*GPM*	1,370	*kg/s*
Fluid	Lake Water	-	Lake Water	-
Lake Water Intake Temperature	50	*°F*	10	*°C*
Temperature Returned to Lake from Outfall Pipeline	57*	*°F*	13.9	*°C*
Pressure Drop Through Lake Water Heat Exchanger	10	*psig*	68,950	*Pag*
Campus Chilled Water Loop Flowrate	10,133	*GPM*	640	*kg/s*
Fluid	Chilled Water	-	Chilled Water	-
Campus Supply Water Temperature	60	*°F*	15.6	*°C*
Campus Return Water Temperature	75	*°F*	23.9	*°C*
Pressure Drop Through Campus Heat Exchanger	10	*psig*	68,950	*Pag*
Design Peak Load Experience by Lake	22.3	*MW*	22.3	*MW*

*Temperature will be controlled/regulated to not exceed the temperature of the receiving water body temperature.

2.2.3 Redundancy Criteria

The system redundancy criteria are listed in Table 2-9.

Table 2-9. *Redundancy criteria.*

Parameter	Value
Pumps	N+1
Heat Exchangers	N+1
Pipeline	N
Wet Well	N
Intake Screens	N
Discharge Diffuser	N

2.2.4 Intake and Discharge Depths

The depths of the lake water intake and discharge are shown in Table 2-10. The intake depth was specified by the Consultant and was determined based on the lake water temperature profiles. The discharge depth depends on the system configuration. If the lake water is returned to the lake, it should be discharged at a location and depth that is far enough from the intake to avoid re-ingestion.

In this analysis the discharge depth for the return-to-lake configuration was set to 50 ft to ensure sufficient clearance under the Union Bay Reach. Later adjustment of the discharge depth should not significantly impact technical or cost results, unless it results in a much longer pipeline. Final discharge location will also depend upon any permitting or regulatory requirements developed during the detailed design and planning stage.

Table 2-10. *Intake and discharge depths (below low lake level).*

Parameter	Value	US Units	Value	SI Units
Intake Depth	66	*ft*	20	*m*
Discharge Depth – Return to Lake Config. (1)	50	*ft*	15	*m*
Discharge Depth – Into Montlake Cut Config. (2&3)	3	*ft*	1	*m*

2.2.5 Piping Data

Materials and properties of the piping network are shown in Table 2-11. Minimum and maximum flow velocity requirements are based on Recommended Standards for Wastewater Facilities [13].

Table 2-11. *Piping data for the LWCH system.*

Component Description	Unit	Value
Minimum CW Piping Pressure	psia	19.7
Minimum Flow Velocity	ft/s	2
Maximum Flow Velocity	ft/s	8
LW Tunneled Pipe Material	-	HDPE
LW On-Bottom Pipe Material	-	HDPE
LW Buried Pipe Material	-	HDPE
CW Pipe Material (from LWHX to plant)	-	Insulated HDPE

3 CONCEPTUAL DESIGN

3.1 Shore Landing and Pump Station Site

The shore landing site is defined as where the lake water pipeline will cross the shoreline and also where the lake water pump station will be located. If the intake pipeline will be tunneled, then this site must also be large enough to support tunneling operations. Several shore landing sites were investigated and they are shown in Figure 3-1. After discussions with the Owner, it was decided that Parking Lot E-8 was the best shore landing site because of its proximity to the power plant, and because of the open space available for tunneling operations. Parking Lot E-8 was used as the shore landing and pump station site in the analysis.

Table 3-1. *Shore landing site options.*

Location	Distance to Powerplant (ft)	Space for Pump Station?	Space for Tunneling Equip.?	Notes
Parking Lot E-8	1220	Yes	Yes	-
Waterfront Activities	2820	Yes	Yes	Socially Sensitive Area
Union Bay Natural Area	2750	Yes	Yes	Enviro. Sensitive Area
Shoreline Between Birch and No. 2 Island	2200	No	No	Insufficient space

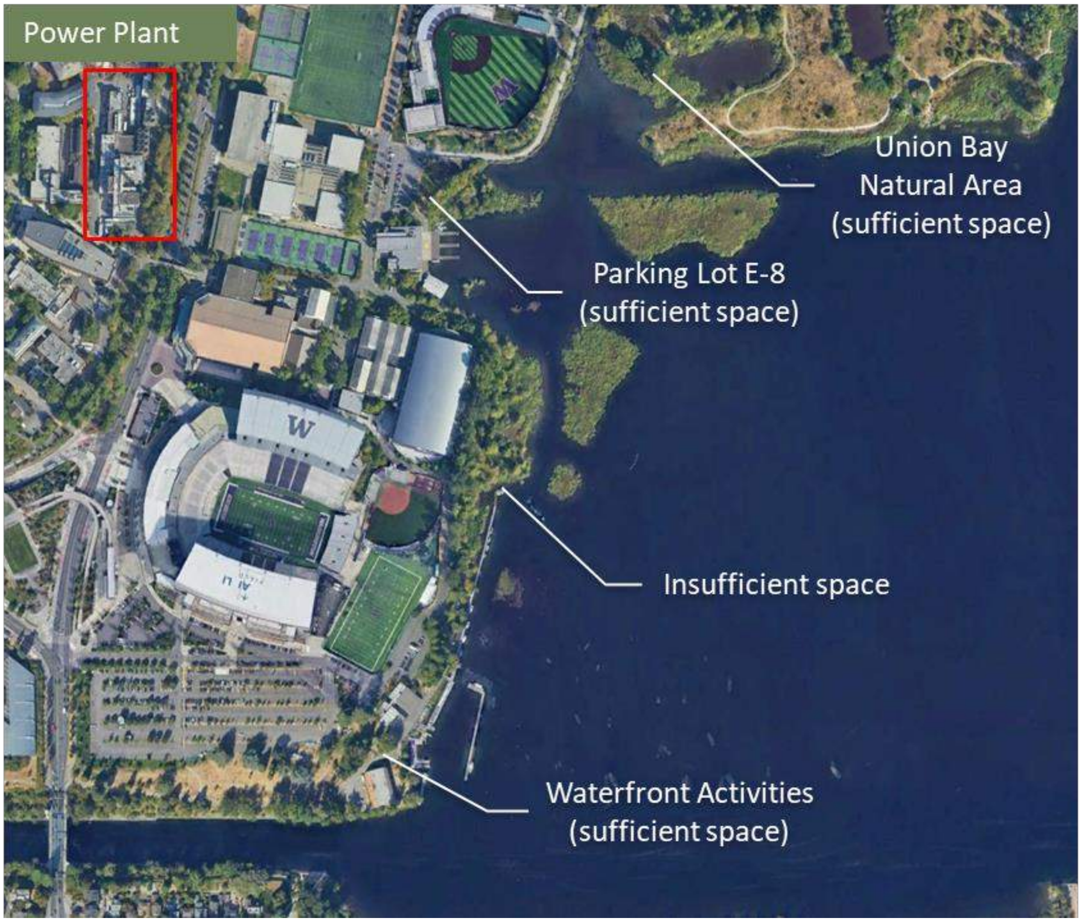


Figure 3-1. *Shore landing site options.*

3.2 Pipeline Routing

The straight-line distance from the University of Washington Campus through Union Bay to the desired intake depth (66’) in Lake Washington is approximately 6,600 ft (2,000 m). The pipeline routing options are quite limited by the area’s natural geography. The area is bound by Union Bay

Natural Area to the north, Webster point to the northeast, and Evergreen Point Floating Bridge to the south.

The west side of Union Bay is shallow with a depth ranging between 2-5 feet. This shallow depth prohibits the placement of the pipeline(s) directly on top of the lake bed, since the top of the required ~4’ diameter pipe would be above the lake surface in certain locations, and slightly below in other locations, creating a hazard to navigation, and potentially interfering with recreational activities such as rowing. Since the crown of the pipeline(s) should not be placed at the lake surface, the pipeline should be tunneled or trenched.

3.2.1 Baseline Route

The most direct route from the shore landing site to deep water in Lake Washington would be a straight line that crosses the Union Bay Reach as shown in Figure 3-2 and Figure 3-3. Since the depth of the reach is approximately 30’ below lake level, the pipeline(s) would need to be routed under the reach. Based on conversations with the USACE, the pipeline(s) should be routed an additional 12-15’ underneath the reach to mitigate the risk of them being damaged during future dredging of the reach.

The advantages of this route are: 1) placing the intake some distance south of the Union Bay Reach minimizes the risk of anchor strikes, 2) placing the intake some distance from Webster Point minimizes the impact to that residential community during construction and future pipeline maintenance.

The majority of the shallow Union Bay can be easily crossed by a placing the pipeline in a shallow ~9’ deep trench. Building this trench can be accomplished with relatively minimal removal of dredged material since the trench depth is shallow, and the peat material is expected to sustain a steep trench slope of 1 in 1 or less, resulting in an approximate trench width of ~26 feet. The challenge arises when the pipeline needs to be routed under the reach. The trench through the reach would need to be approximately 20’ deep. This section of trench would require significantly more dredging because the trench is deeper, and the glacial soils are only expected to sustain a side slope of 1 in 3, resulting in a required trench width of ~130’. Once the reach is crossed, the trench depth can be reduced back to the standard 9’ or the pipeline could be transitioned to on-bottom. The fully-trenched route elevation profile is shown in Figure 3-4. While requiring discussions and coordination with the necessary agencies causing other challenges, it may be technically viable to design the crossing of the reach with flanged pipeline connections to remove sections during the infrequent dredging operations, rather than bury below the dredge depth.

The alternative method to cross Union Bay and/or the reach would be to tunnel under it. If tunnelling is used, it would be preferable to start on the north side of the Union Bay Reach and continue to break out of the tunnel at the intake depth (66’) in Lake Washington. The fully-tunneled and hybrid trench and tunnel route elevation profiles are shown in Figure 3-5 and Figure 3-6.

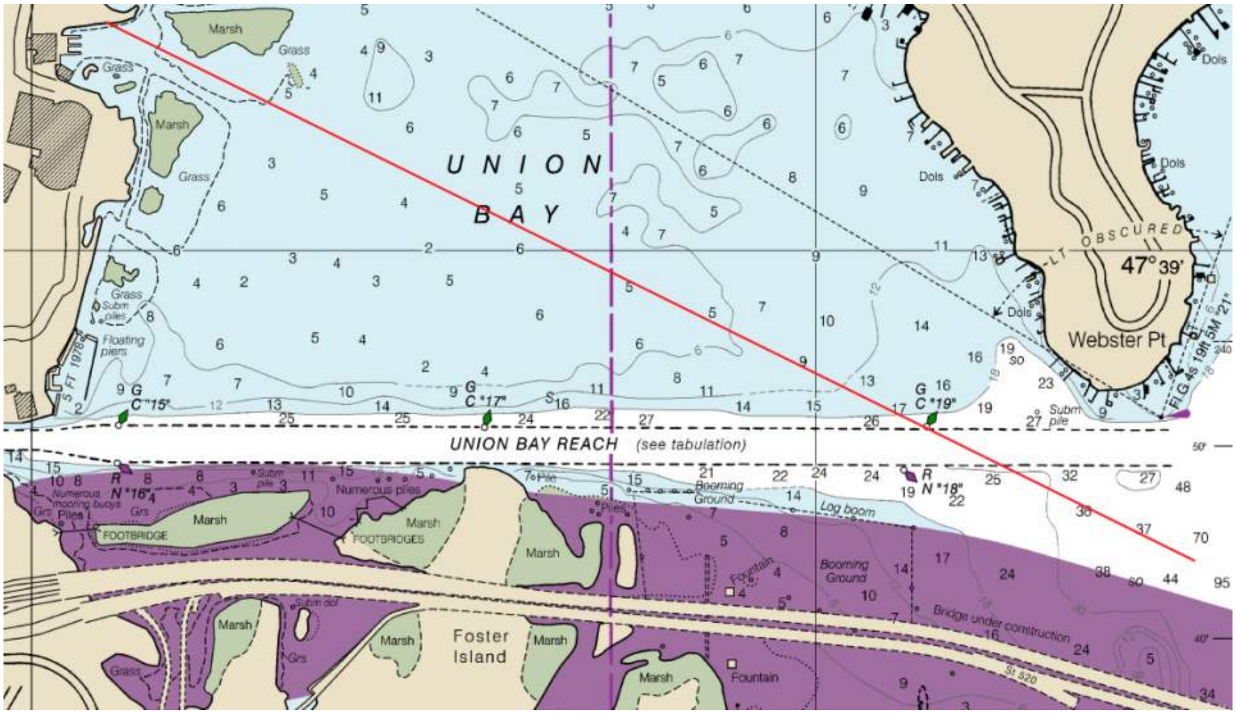


Figure 3-2. *Nautical chart showing the pipeline route (red line). Datum is Low Lake Level (LLL).*

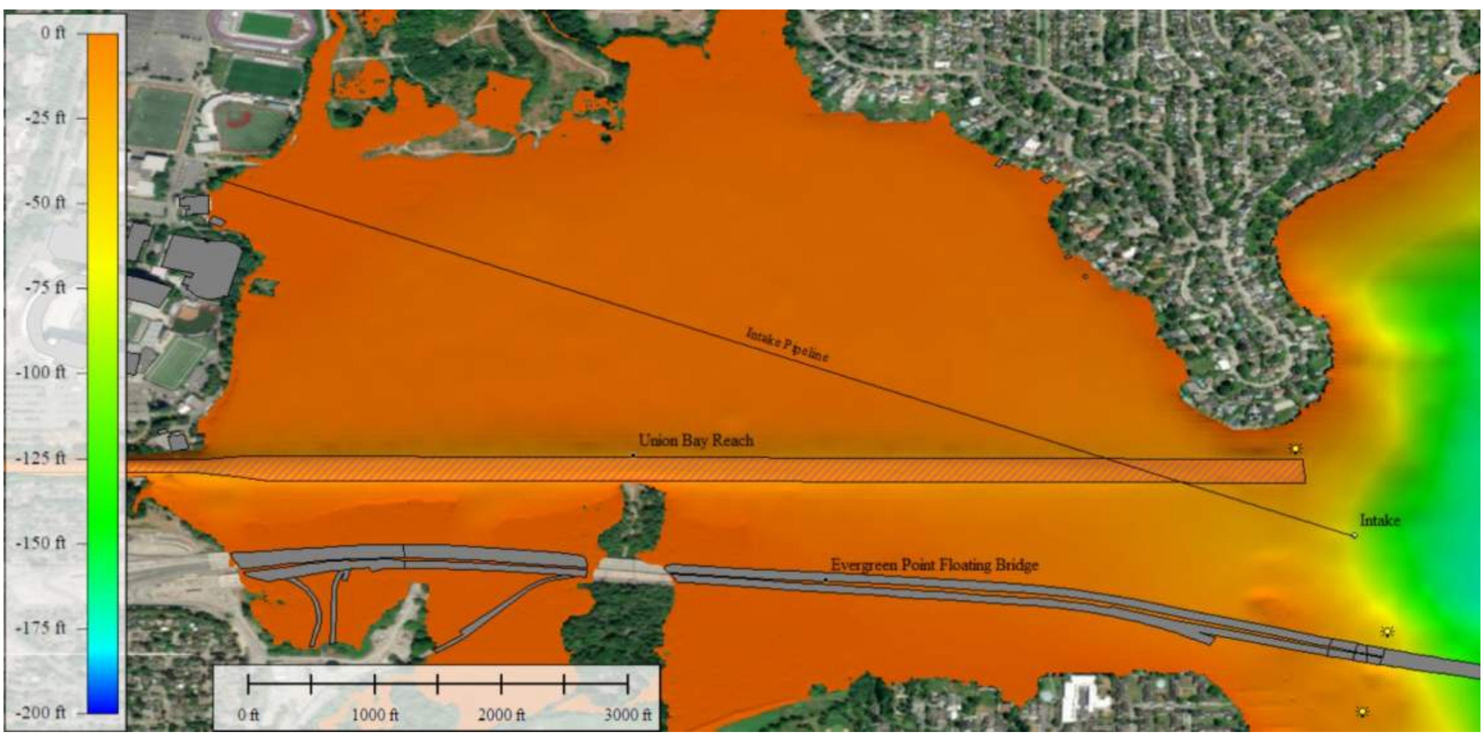


Figure 3-3. *Proposed tunneled pipeline route going under Union Bay Reach (NAVD88 datum).*

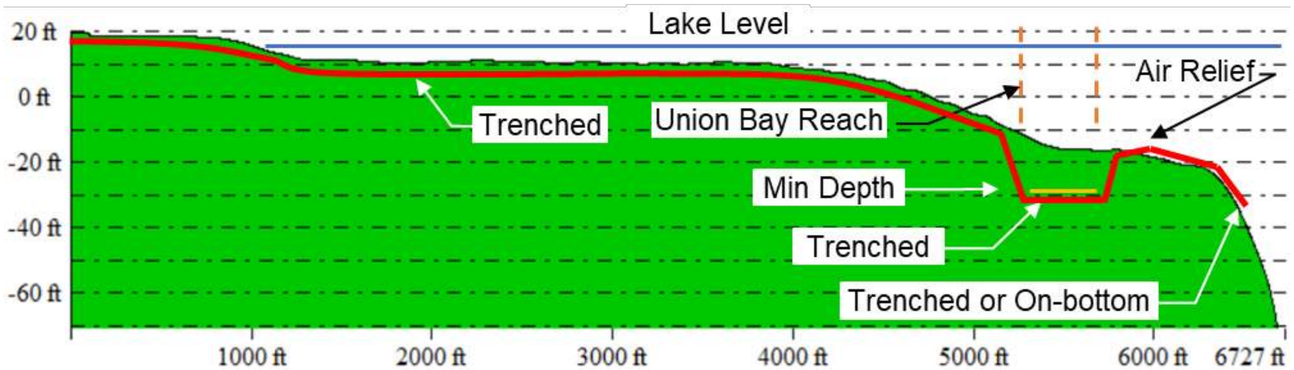


Figure 3-4. *Trenched pipeline elevation profile (NAVD88 datum) where Low Lake Level is +16.75 ft.*

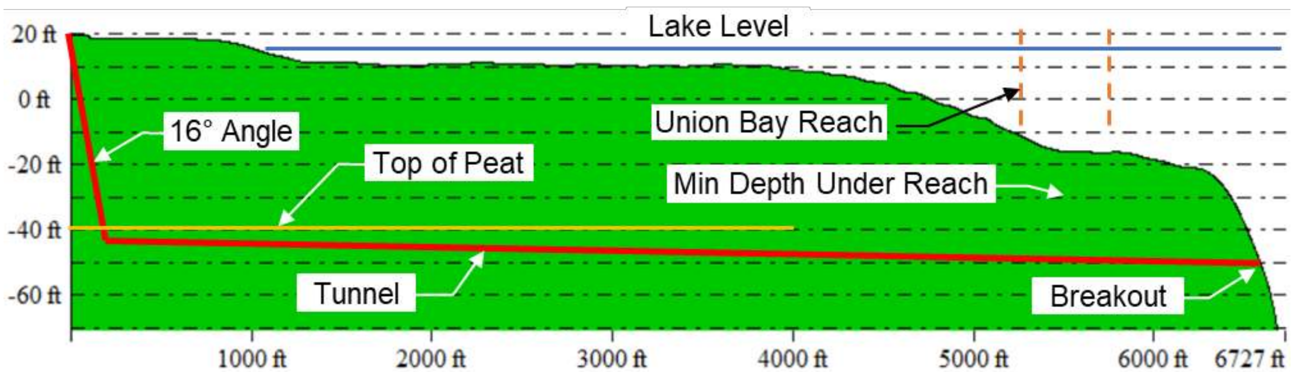


Figure 3-5. *Fully tunneled pipeline elevation profile (NAVD88 datum) where Low Lake Level is +16.75 ft.*

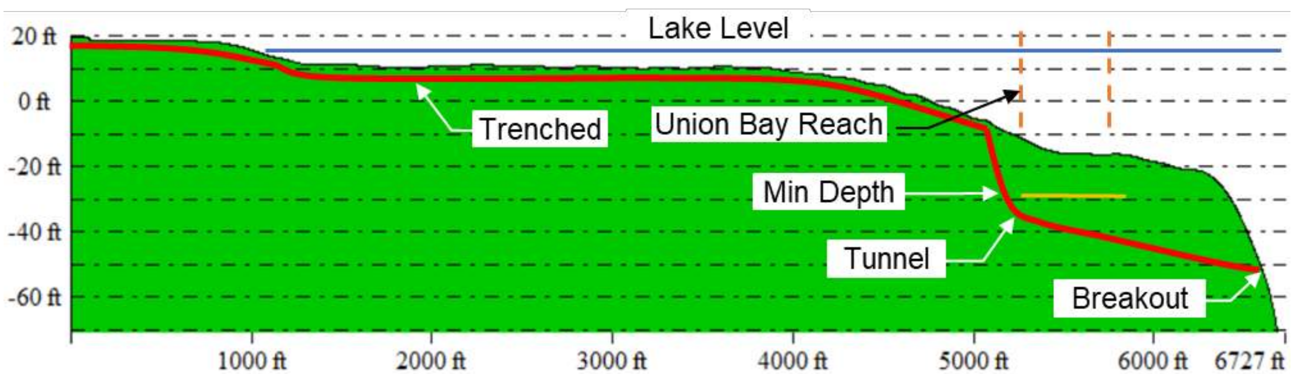


Figure 3-6. *Hybrid trench and tunnel pipeline elevation profile (NAVD88 datum) where Low Lake Level is +16.75 ft.*

3.2.2 Alternate Route

It may be possible to avoid the Union Bay Reach by routing the pipelines through the narrow 200’ gap between Webster Point and the Union Bay Reach (Lake Washington Ship Canal); see Figure 3-7 and Figure 3-8. The trenched route elevation profile is shown in Figure 3-9.

This option has the advantages of 1) less required dredging, 2) less environmental impact, and 3) the reduced risk of damage from ship anchors and USACE dredgers. The disadvantages are 1) the route passes within 130’ of the shoreline, 2) the route interferes with the Webster Point Light (mounted on a pile), and 3) the intake will be close to the shipping lane, increasing the risk of anchor strikes. The homeowners on Webster Point may object to dredging operations being conducted so close to their homes and the Webster Point Light will most likely need to be temporarily removed during trenching operations and replaced afterwards.

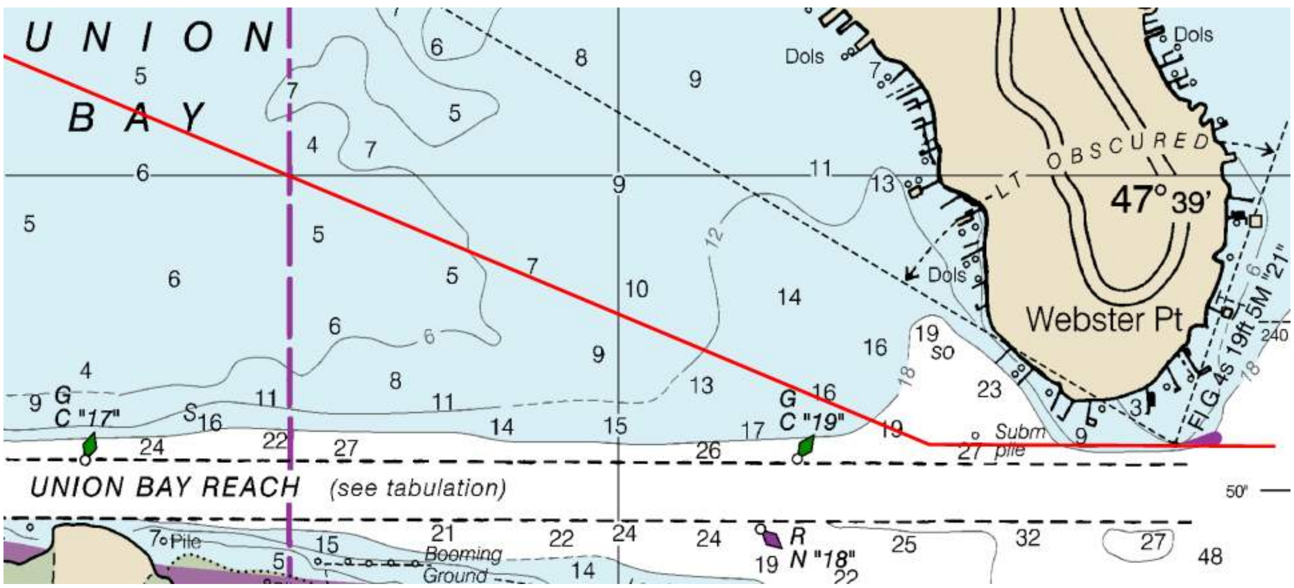


Figure 3-7. *Nautical chart showing the pipeline route (red line) passing between Webster Point and the Union Bay Reach (LLL Datum).*

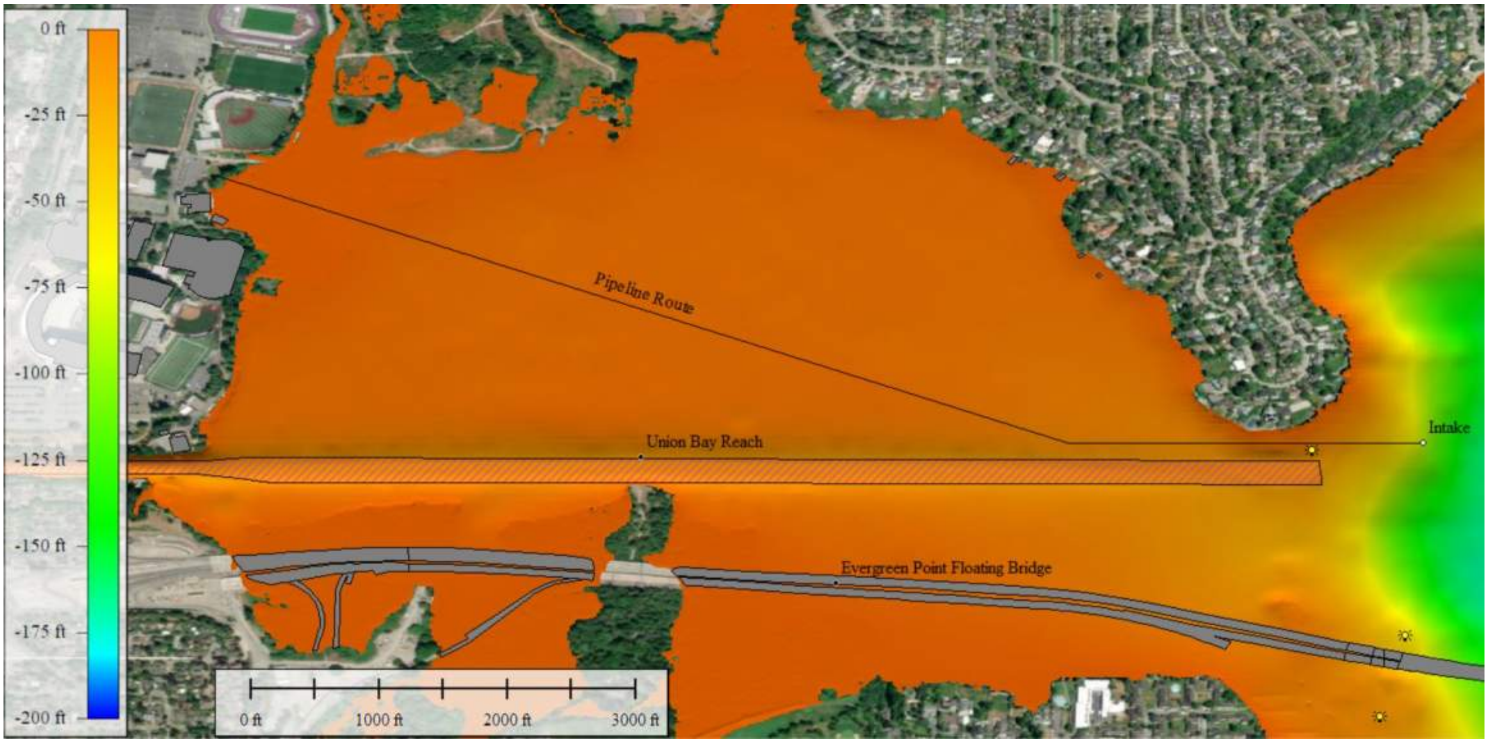


Figure 3-8. *Proposed trenched pipeline route (black line) passing between Union Bay Reach and Webster Point (NAVD88 datum).*

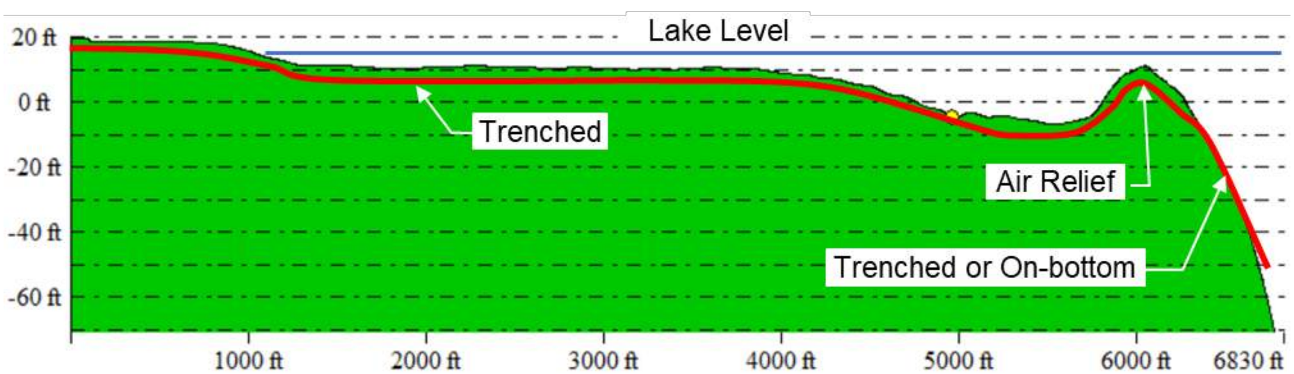


Figure 3-9. *Proposed trenched pipeline elevation profile (NAVD88 datum) where Lower Lake Level is +16.75 ft.*

3.2.3 LWCH Network Layout

Two options for the location of the discharge pipeline were considered in this study. Configuration 1 consists of discharging water back into Lake Washington, following the same route as the intake pipeline. Configurations 2 and 3 consist of discharging water into the Montlake Cut.

3.2.3.1 Configuration 1: Return-to-Lake

The Return-to-Lake system is shown in Figure 3-10 and Figure 3-11. In this configuration, the lake water is returned to Lake Washington after it has passed through the pumps and heat exchangers onshore and heat has been added or removed. The main lake water heat exchangers will be located inside the lake water pump station near the shoreline. In this configuration, the intake is located at 66' depth and the discharge is located at 50' depth in Lake Washington. This discharge depth was chosen to ensure sufficient clearance below the 30' deep Union Bay Reach.

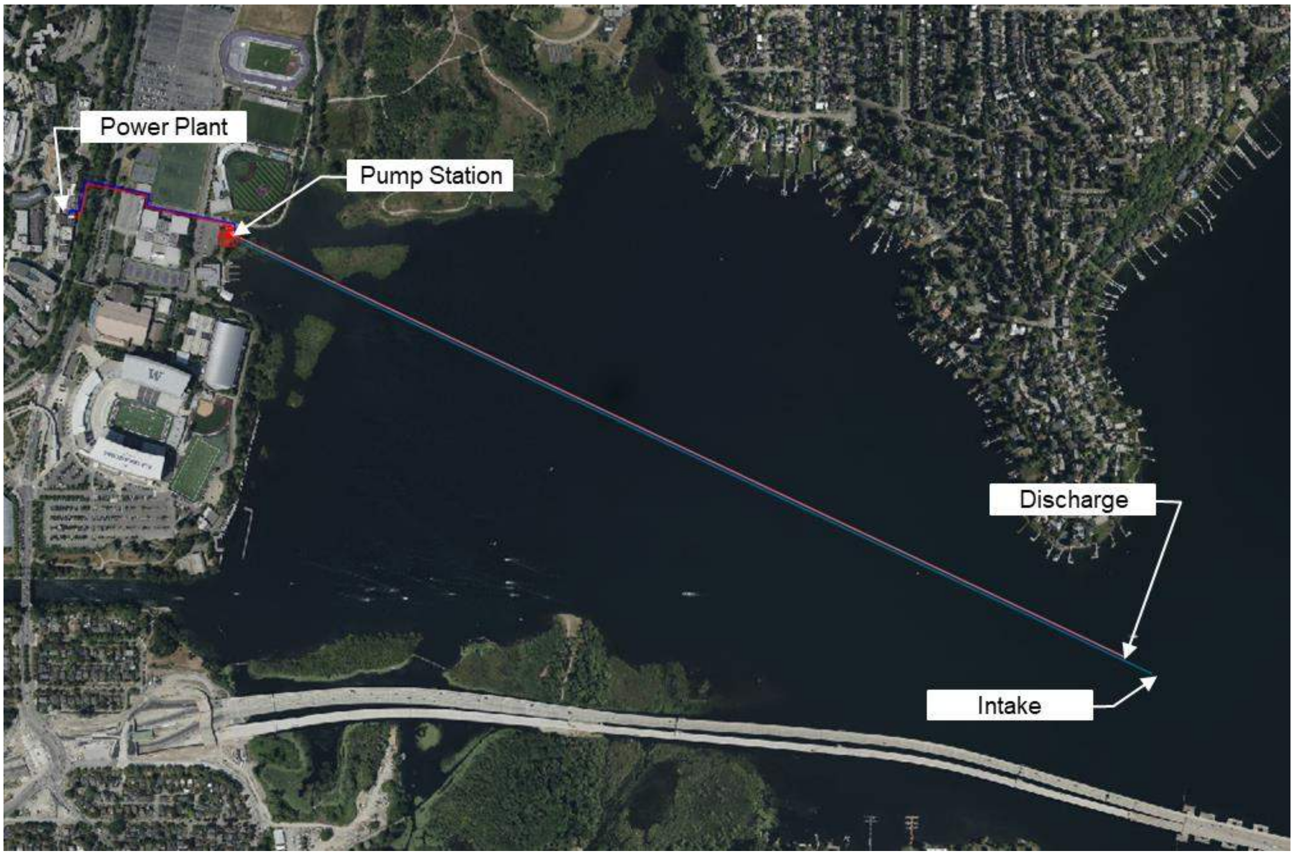


Figure 3-10. *Plan view of the Return-to-Lake system configuration 1.*

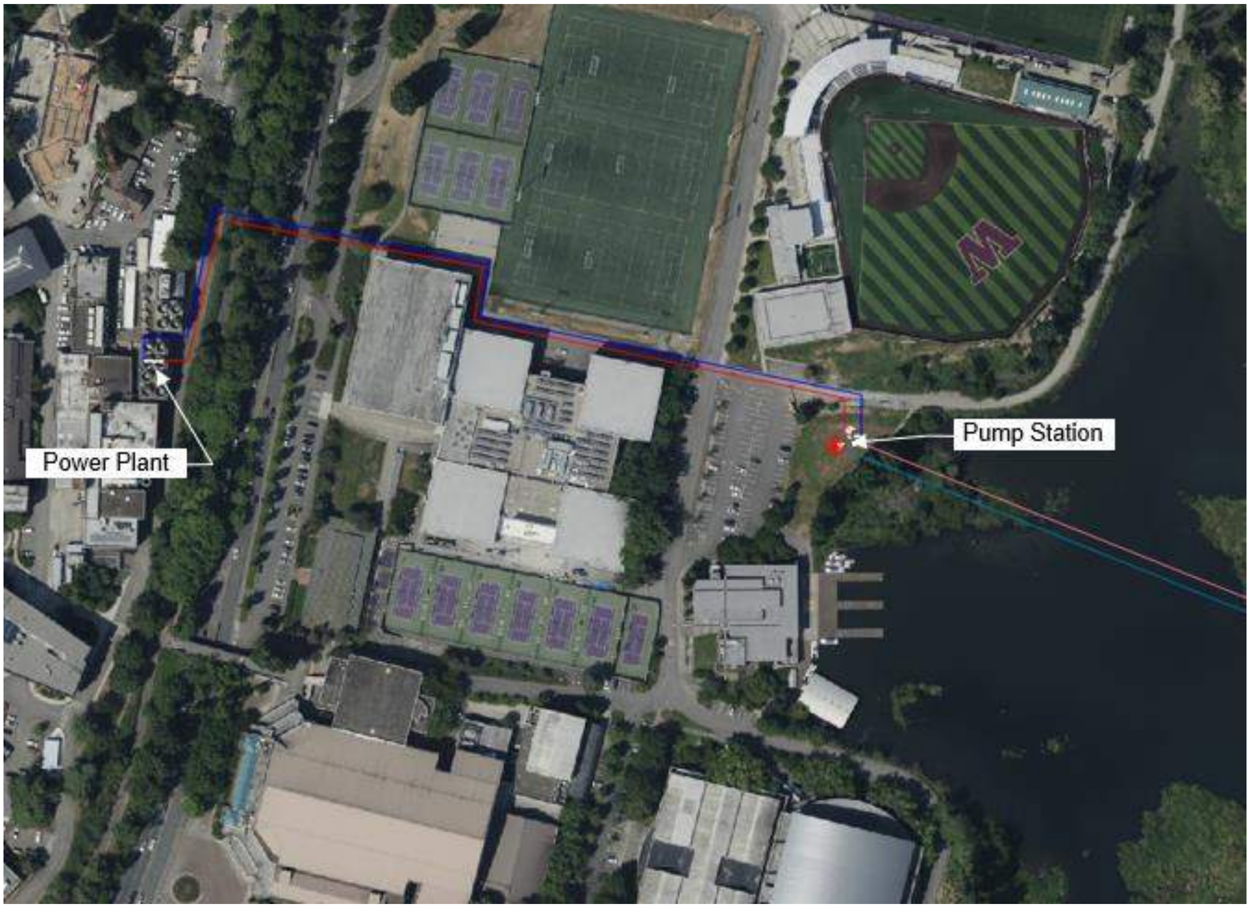


Figure 3-11. *Plan view of the Return-to-Lake onshore network (config. 1).*

3.2.3.2 Configuration 2 and 3: Discharge into Montlake Cut

The lake water cooling and heating network for Configurations 2 and 3 is shown in Figure 3-12 and Figure 3-13 with labelled locations of the discharge, deep water intake, pump station, and power plant. The main lake water heat exchangers will be located inside the lake water pump station near the shoreline. In this configuration, the intake is located at 66’ depth in Lake Washington and the discharge is located at 3’ depth in the Montlake Cut.

The only difference between Configurations 2 and 3 is the total load analyzed. The network layout is exactly the same between both configurations.

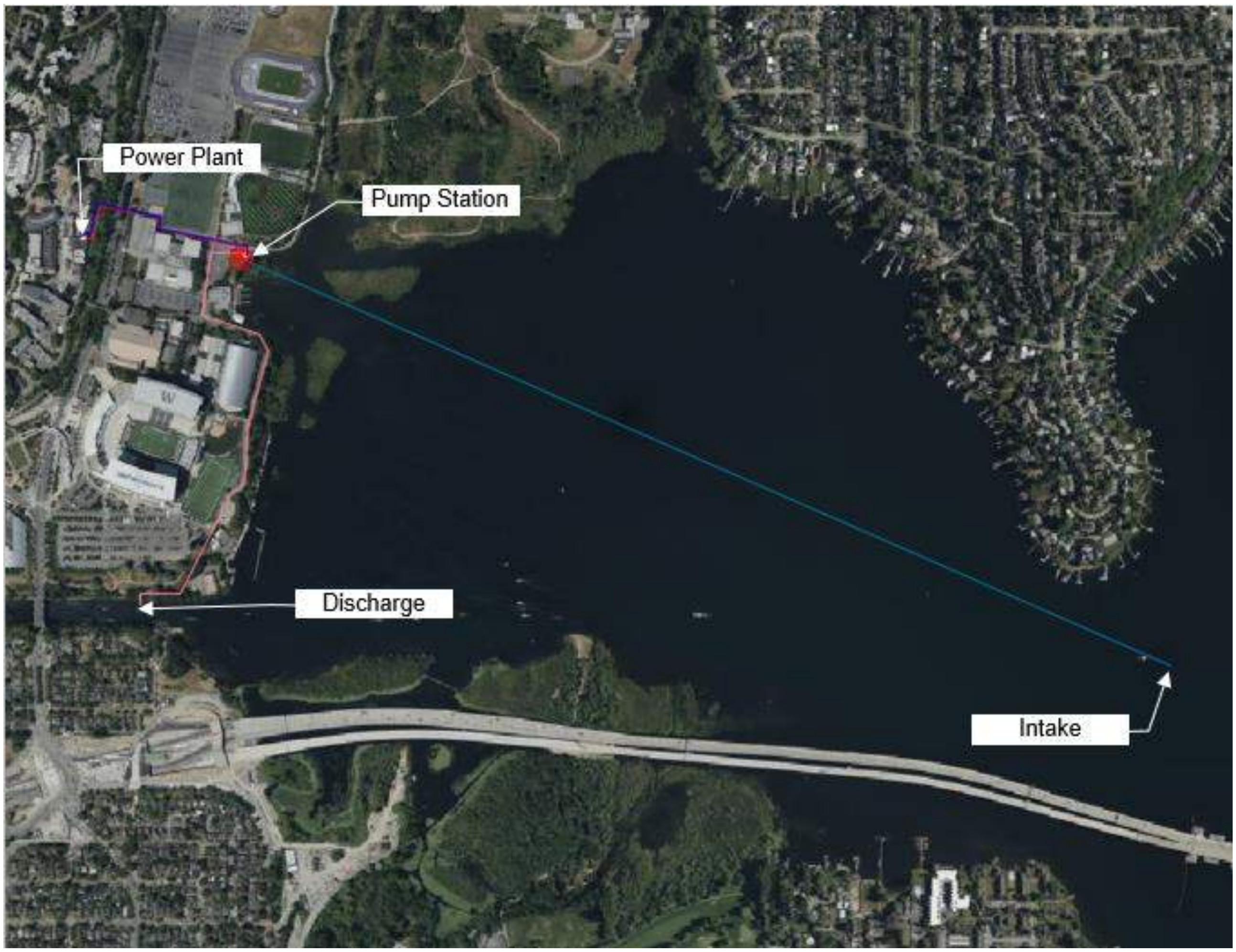


Figure 3-12. *Plan view of Discharge to Montlake Cut system configuration 2.*

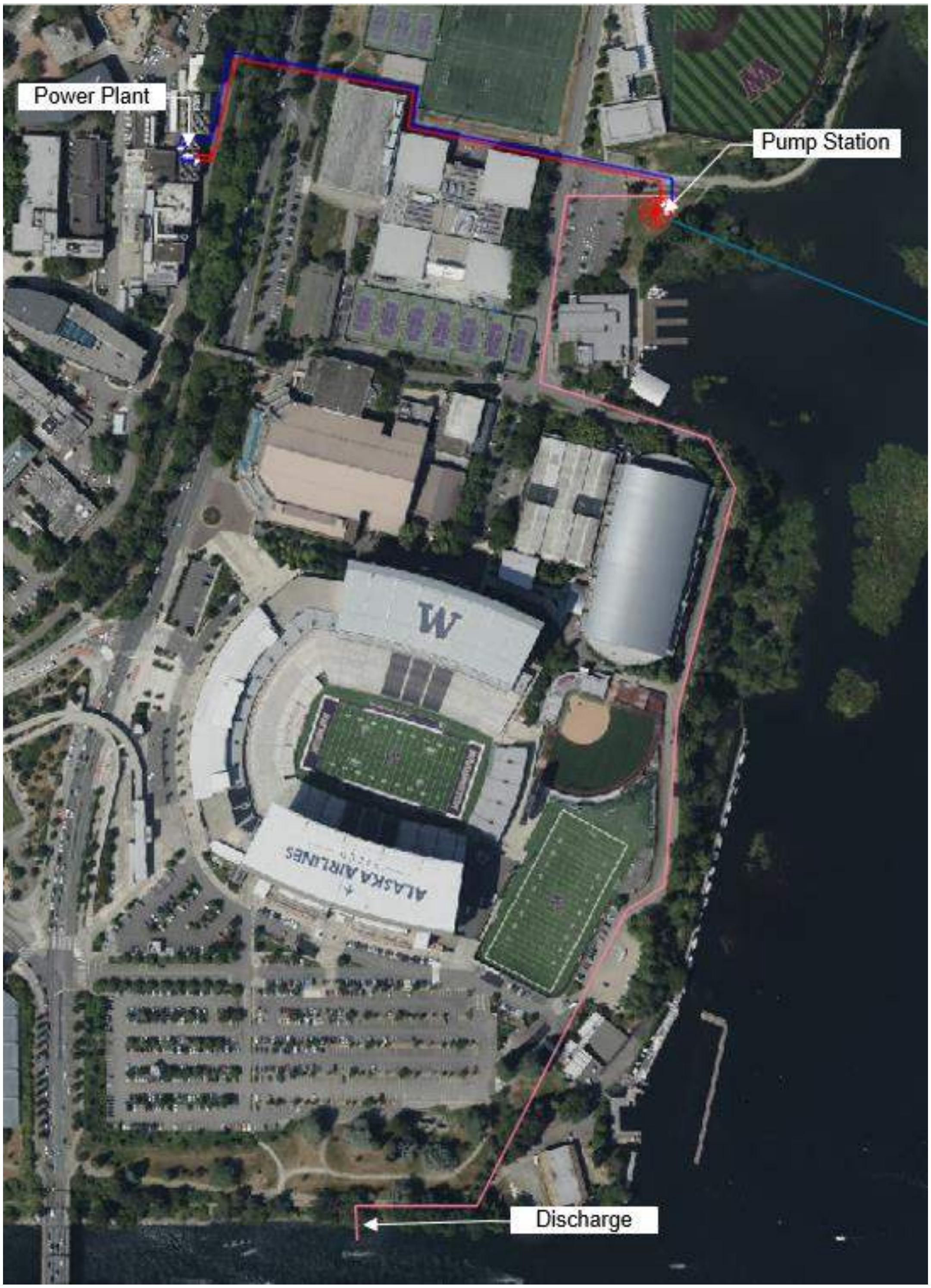


Figure 3-13. *Plan view of Discharge to Montlake Cut onshore network and discharge pipeline.*

3.3 Pump Station

There are several pump station configurations that could be used in this system. To maximize performance and minimize the risk of a poor design, the pump station should be designed following Hydraulic Institute standards. The most traditional design is the “rectangular intake” wet well which was used at Cornell University’s Lake Source Cooling (LSC); see Figure 3-14. Approximate rectangular intake wet well dimensions are shown in Figure 3-15.

3.3.1 Layout and Wet Well

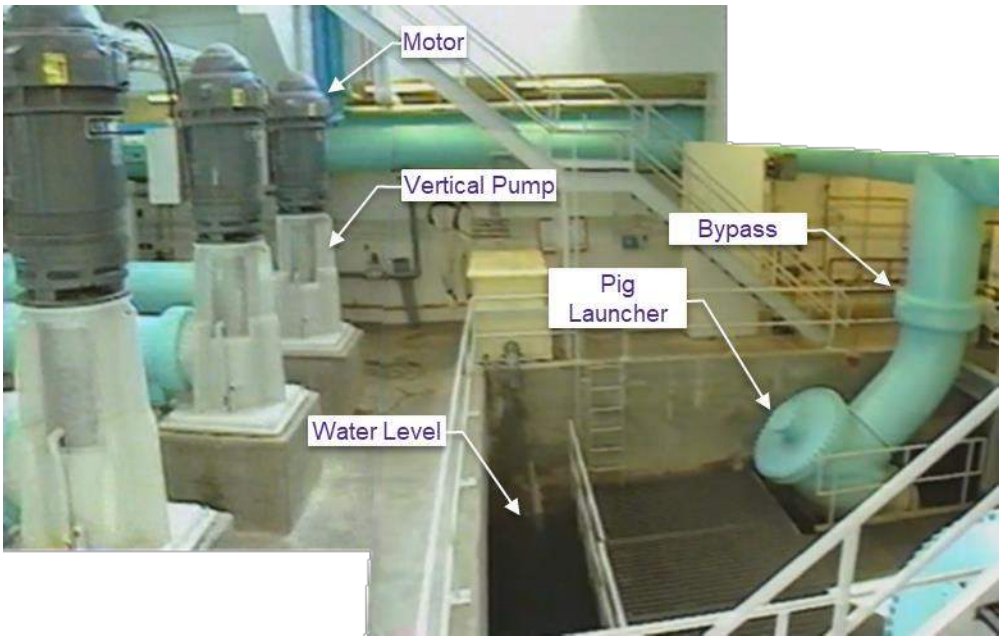


Figure 3-14. *Photo inside the Lake Source Cooling pump station courtesy of Cornell University.*

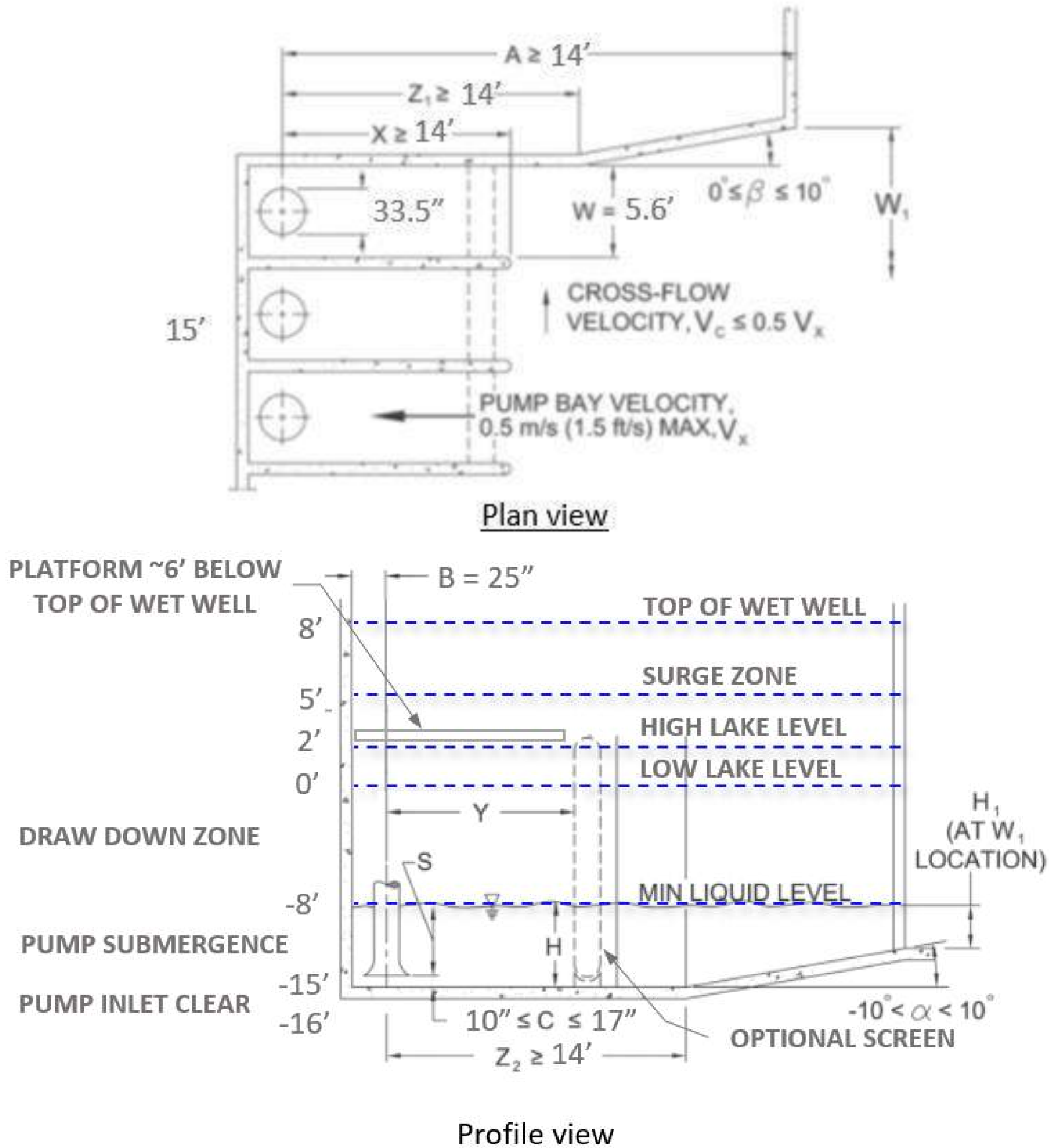


Figure 3-15. *Approximate wet well dimensions.*

3.3.2 Pumps

We recommend using either vertical axial flow or horizontal split case type pumps. The vertical axial flow type pumps are more efficient and cost less in electricity to operate, but they are slightly more complex and difficult to maintain. To perform maintenance on them, the pump is removed from the wet well by crane. Cornell LSC uses vertical pumps. An example of a vertical axial flow pump that would work for the UW LWCH system is shown in Figure 3-16. Horizontal split case type pumps are slightly less efficient, but are easier to maintain, because the pump can be disassembled an maintained in-place without removing it as shown in Figure 3-17. Pump design data is shown in Table 3-2.

Table 3-2. *Pump data for the LWCH system.*

Component Description	Unit	Value
Number of Active Pumps	-	2
Number of Standy Pumps	-	1
Total Number of Pumps	-	3
Pump Design Flow Rate[1]	*GPM*	5,426 to 10,857*
Total Dynamic Head[2]	*ft*	39 to 43*
Pump Power[3]	*kW*	53 to 116*
Pump Type	-	Vertical Axial Flow or Horizontal Split Case
Body Material	-	Steel or Cast Iron
Impeller Material	-	Bronze

[1] *Equivalent to half of the total lake water flowrate from Table 2-7.*

[2] *Equivalent to “Total Lake Water Pump Head” reported in Section 5.2.*

[3] *Equivalent to “Lake Water Pumping Power” reported in Section 5.2 divided by the No. of Pumps.*

** Varies by system config., see Section 5.2.*

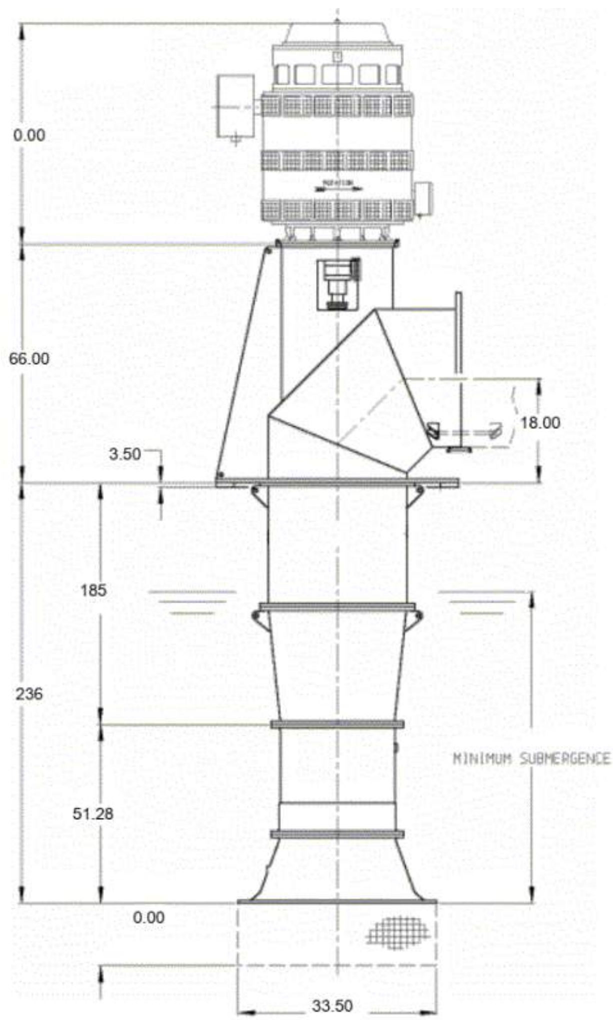


Figure 3-16. *Vertical axial flow pump photo (left) and drawing (right).*

Figure 3-17. *Photos of a horizontal split case pump assembled (left) and disassembled (right).*

3.4 Heat Exchangers

The main lake water heat exchangers can be located inside the lake water pump station near the shoreline or in a separate building. The Heat exchanger data is shown in Table 3-3. The University of Cornell’s lake water cooling system heat exchanger facility is shown in Figure 3-19 and Figure 3-20.

Table 3-3. *Heat exchanger data for the LWCH system.*

Component Description	Value
Heat Exchanger Type	Gasketed Cross-Flow Plate Frame
Heat Exchanger Material	304 Stainless Steel

Figure 3-18. *Photo of a Makai engineer next to a 0.8 MW plate frame heat exchanger (PFHE). The UW LSCH project is 22.3 MW for comparison, requiring a series of PFHEs.*

Figure 3-19. *Photo of the 7 Lake Source Cooling heat exchangers (51 MW total), courtesy of Cornell University.*

Figure 3-20. *Photo of heat exchanger plate replacement inside the Lake Source Cooling facility, courtesy of Cornell University*

3.5 Intake Screen and Structure

In many deep water pipelines, an intake screen has historically not been required, or in some cases has been limited to a velocity cap. For shallower intakes, an intake screen has often been required. For this study, an intake screen was assumed to be required at the offshore end of the intake pipeline to comply with environmental regulations. To support the screen, a structure consisting of piles and steel framing is typically used. An intake structure concept is shown in Figure 3-21. A closeup of the wedge wire intake screen is shown in Figure 3-22. Intake screen data is shown in Table 3-4.

Table 3-4. *Screen data.*

Component Description	Unit	Value
Through Screen Velocity	fps	0.5
Approach Velocity	fps	0.25
Percent Open Area	%	50
Screen Surface Area	ft^2	193.6
Screen Type	-	Wedge Wire
Screen Configuration	-	Cylindrical or Conical
Body Material	-	Stainless Steel
Cleaning Method	-	Electric Powered Brushes or Divers

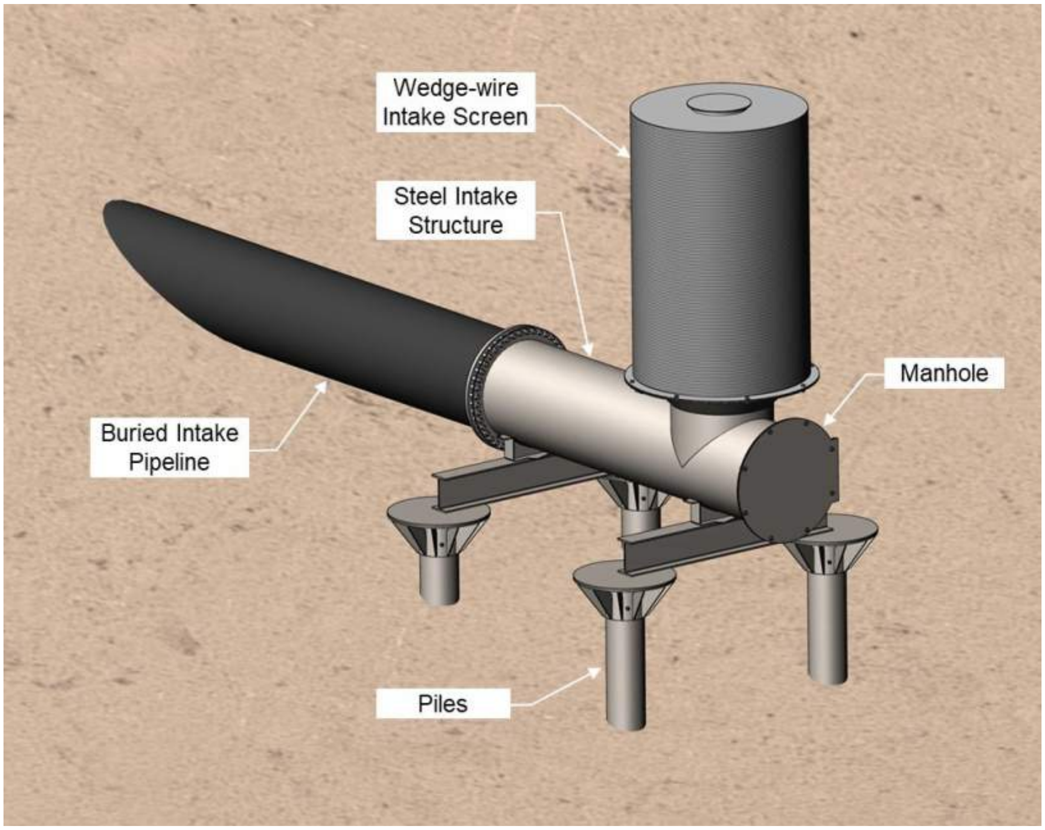


Figure 3-21. *Intake screen and structure concept.*

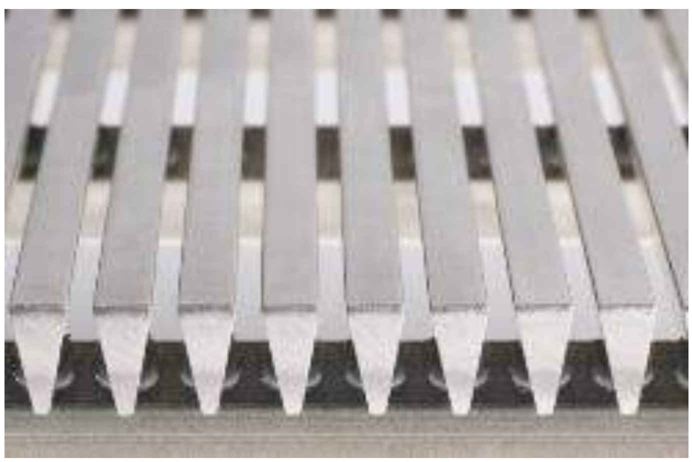


Figure 3-22. *Closeup photo of a wedge wire screen. The external surface is the top in this photo.*

The intake screen will become fouled over time and require cleaning. Self-cleaning wedge wire intake screens are commercially available and widely used today. The four cleaning options are:

3.5.1 Air Burst

Fixed screen cleaned by large bursts of compressed air. For this system, air burst is not recommended because the intake is deep and far from shore, and would require large amounts of compressed air to function properly. Additionally, any air leaks could result in large air pockets forming inside the pipeline, causing flow disruption and risk resurfacing the pipeline.

Figure 3-23. *Photo of a T-screen, courtesy of Johnson Screens.*

3.5.2 Electric Brushed

These rotating screens are powered by electric motors. The rotating screen surface is cleaned as it goes past fixed internal and external brushes. The screen cleaning interval can be set, and is usually done only once per day. These brushes are designed to last 10 years. This is an elegant solution that will keep the intake screen very clean. For this project, the disadvantage is that the power cable will be quite expensive.

Figure 3-24. *Photo of Makai and ISI engineers in front of a 6' diameter intake screen installed on a Makai designed intake system. A single screen this size could satisfy the UW LWCH requirements.*

3.5.3 Flow Brushed

These rotating screens are powered by the flow passing through a propeller in the center of the screen. The propeller causes the screen to continuously rotate when the intake is in use, and the screen surface is cleaned as is goes past fixed internal and external brushes. These brushes are designed to last 10 years. This is an elegant low-cost solution that will keep the intake screen clean as long as the intake is pumped at regular intervals. The manufacturer recommends that the screen should be rotated for one hour every two weeks, or once per month.

Figure 3-25. *Photo of a flow brushed screen, courtesy of Intake Screens Incorporated.*

3.5.4 Diver Cleaned

Fixed Screen cleaned by divers at regular intervals. This is the lowest capital cost option, but usually costs more to maintain.

3.6 Piping

Since the early 1960's polyethylene (PE) piping has been increasingly used for various marine applications such as effluent outfalls, river and lake crossings, and lake and ocean intakes. Extended life and reduced cost are the major reasons for selecting PE.

To meet the LWCH project's design life requirement of 100 years, we recommend using PE piping material. The design life of PE piping is typically much longer compared to other piping materials due to PE's resistance to galvanic corrosion. This resistance, combined with leak-proof joints and smooth inner surface yield a piping system that requires minimal maintenance and costs less to operate. Installation costs are often lower than alternative piping materials in the marine environment due primarily to PE's light weight and flexibility, which allows it to be installed using a float-and-sink method. This installation method is fast and requires a minimum amount of heavy equipment.

3.7 Pigging

An efficient and established technique to clean a pipeline is called pigging. A "pig" is essentially a bullet shaped piece of foam with a diameter approximately equal to the inside diameter of the pipeline and a length that is approximately two times the diameter of the pipeline. The pig is inserted into a "pig launcher" (an oversized access port), and then the pig is pumped through the pipeline. As the pig moves through the pipeline, it collects debris in front of it, and finally pushes the debris out the other end. It is typical to send multiple pigs down the pipeline during cleaning, starting with a small diameter pig and ending with a larger diameter pig. This gradual increasing of diameter minimizes the risk of a pig getting stuck in the pipeline.

An example of pipeline pigging is shown in Figure 3-26 and Figure 3-27. Since most intake pipelines in lakes foul over time and require periodic cleaning (approximately every 10-20 years), it is recommended that the intake pipeline be designed to be pigged. A pig launching port should be placed on shore, either near or inside the pump station. It is typical to hire a specialty pigging contractor to clean the pipelines. The pigs can either be pumped by the pigging contractor's pump, or by the LWCH pumps with the system operating in reverse (this functionality will need to be designed into the pump station).

Figure 3-26. *Loading a pig into the pig launcher, courtesy of Cornell University*

Figure 3-27. *Pipeline pigging, courtesy of Enduro Pipeline Services*

3.8 Tunnels

A typical tunnel cross-section for the Return-to-Lake system (config. 1) is shown in Figure 3-28. For this configuration, two tunnels are required: one for the intake line and one for the discharge line. A typical tunnel cross-section for the Discharge to Montlake Cut system (config. 2) is shown in Figure 3-29. For this configuration only one tunnel is required since the discharge pipeline will be routed onshore. The steel casing pipe and grouting of the annulus is only required if the Direct Pipe method is used to bore the tunnels.

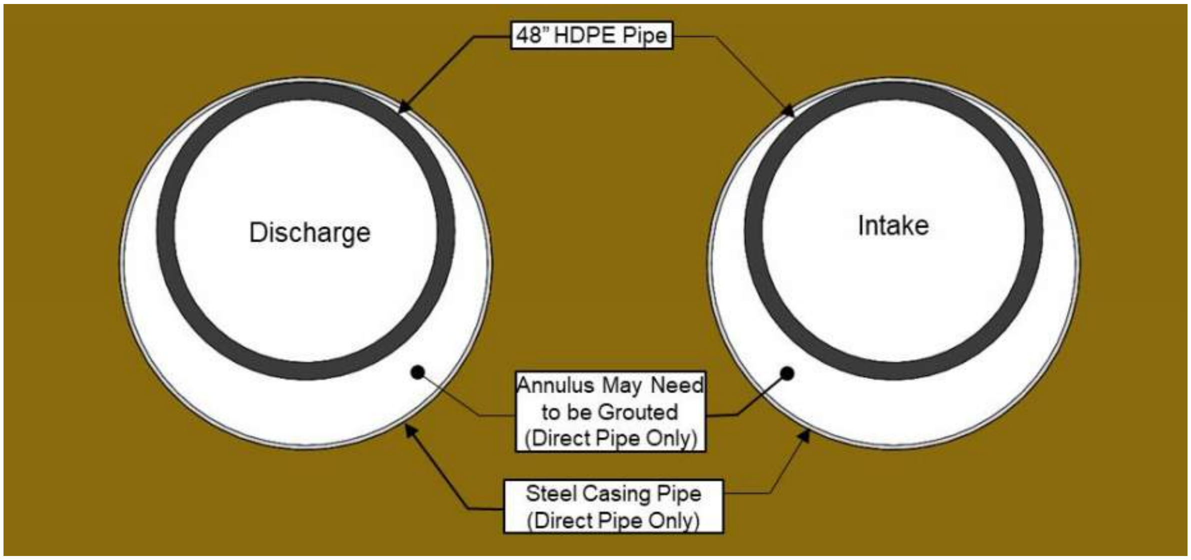


Figure 3-28. *Return-to-Lake system (config. 1) tunnel cross-section.*

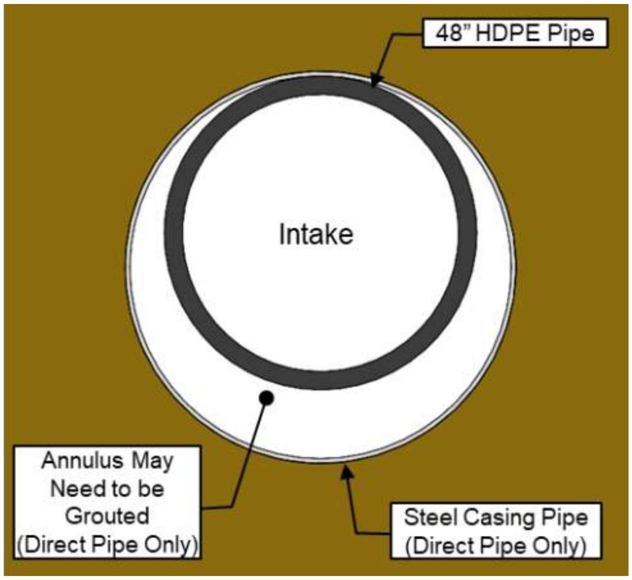


Figure 3-29. *Discharge to Montlake Cut system (config. 2) tunnel cross-section.*

3.9 Tunneling Methods

Two viable boring methods are presented to install tunneled pipeline(s) under Union Bay:

- Horizontal Directionally Drilling (HDD) Method
- Direct Pipe Method

The Micro Tunnel Bore Method was not considered due to the need for service pits along the tunnel route, and the higher cost of this method. Micro Tunnel methods generally become more cost competitive for larger diameter systems.

3.9.1 Horizontal Directional Drilling Method

Typical Horizontal Directional Drilling (HDD) operations from land and water are shown in Figure 3-30 and Figure 3-31 respectively. A directional drill is set up at the entry location and drills a pilot bore along a predetermined bore path to the exit location.

Figure 3-30. *HDD drill rig, pipe, and support equipment on land.*

Figure 3-31. *HDD drill rig, pipe, and support equipment on a barge.*

The pilot bore is guided by a steering system that tracks the forward progress of the drill path along the designed bore profile. The steering system has a power supply wire that is attached to the guidance system. This wire supplies power to the steering head and the same wire returns the location data from the drill head to a steering hand. The steering hand (operator) uses this information to determine the exact XYZ location of the drilling head known as the Down Hole Assembly (DHA). Figure 3-32 shows a typical DHA with the drill head (left end) and non-magnetic steering section (right end). The DHA steering system transmits back to the steering hand the pitch or angle of the DHA, its compass heading, temperature, and downhole annular pressure, this information combined with the measured distance away from the launch pit allows the steering hand and the drill operator to determine the DHA's position and make adjustments to the DHA's position and angle to maintain alignment with the predesigned bore path.

Figure 3-32. *HDD DHA on temporary wheels.*

Once the pilot bore is completed, subsequent reaming passes are needed to enlarge the bore path to the diameter required for the conduit to be installed. Figure 3-33 shows progression from pilot hole bore to pipeline pullback stage.

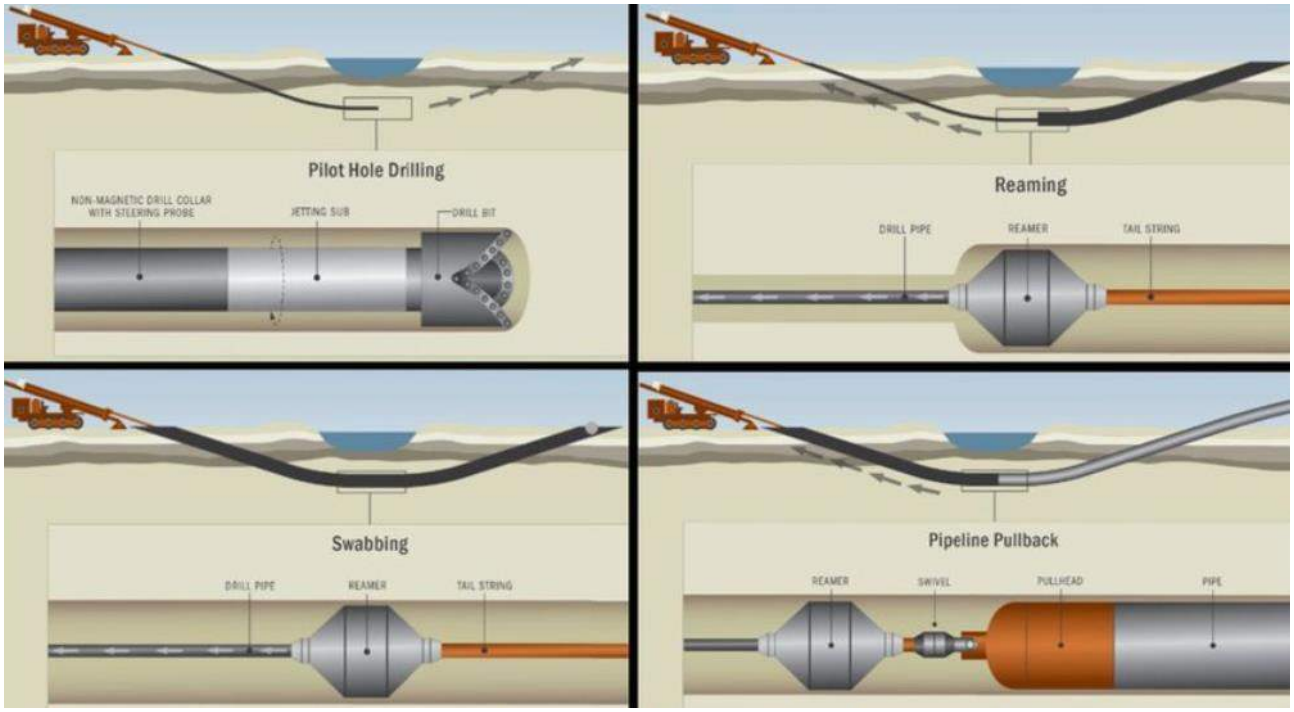


Figure 3-33. *Typical HDD conduit installation.*

The additional equipment spread consists of a drilling fluid pump, a drilling fluid cleaning system with drilling fluid storage tanks, mud transfer pumps, fresh water storage tanks, a drill stem storage trailer, and an excavator set up at the entry side of the project. Figure 3-34 shows a typical drilling fluid cleaning system and pump with screens of decreasing mesh size to remove solids from the returned drilling fluid.

Figure 3-34. *Typical drill fluid cleaner and pump system*

The HDD operation is estimated to require a large HDD drill rig similar to the Jack-Up Barge shown in Figure 3-35. The entry HDD rig on shore would drill a pilot bore along a predesigned bore profile to the exit location. At the exit location, a Jack up Barge or spud barge would be positioned to receive the drill head from the shoreside drill. The Jack-up barge would set a conductor casing that will be driven into the lake floor around the exit location to contain the drilling fluid. This creates a closed-loop drilling fluid containment system to prevent the drilling fluid from escaping into the environment.

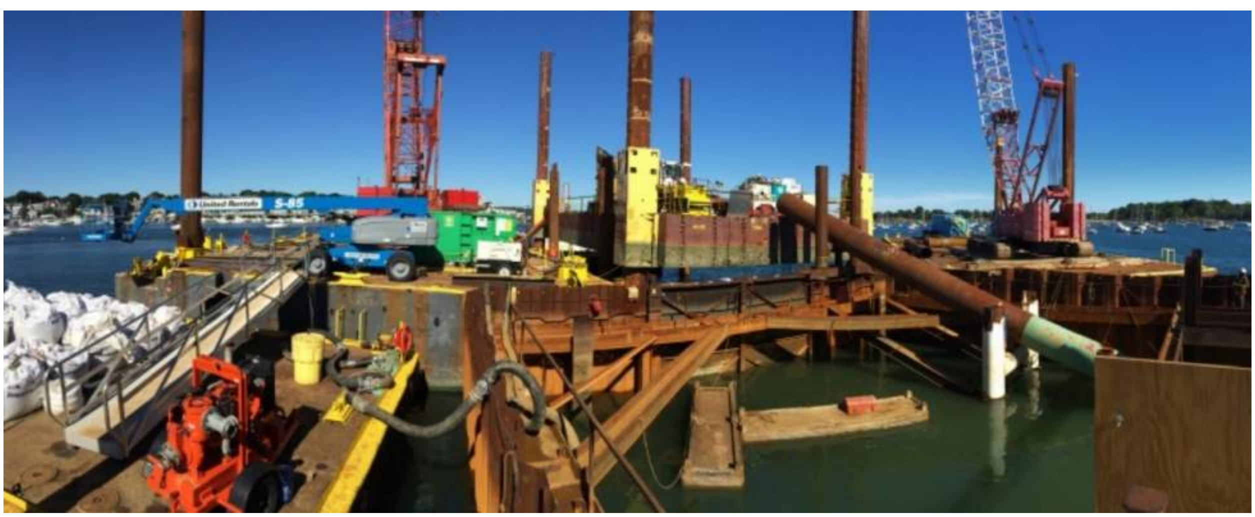


Figure 3-35. *Jack-up barge work site*

The Jack-up barge also has a drill rig and drilling fluid cleaning and storage equipment spread. The two HDD drill spreads would work in tandem as a push-and-pull system. Two drill rig setups allow every pass forward from the entry side or back from the barge to the entry to be a reaming pass to enlarge the inside diameter of the bore.

The reclaiming systems on each side clean the cuttings from the drilling fluid and the drilling fluid can be reused in the drilling process. The cutting taken on board at the barge location would be loaded onto a Hopper barge and when the barge is full the cuttings are taken dockside and the cuttings hauled to the disposal site onshore.

All boring options will use a drilling fluid specifically tailored to the type of equipment used, composition of the substrate being drilled through, and local environmental requirements. Drilling fluid is commonly a mixture of water, a naturally occurring Wyoming clay called sodium bentonite, soda ash for balancing the pH, and small amounts of other non-toxic additives, if required, based on the geology encountered. None of the material generally utilized in the makeup of the drilling fluid is toxic. Almost all drilling fluid will be recovered to the shore drilling site; however minor discharges may occur at breakout. The exact drilling fluid composition and containment method will be determined by the boring contractor and should be included in the contractor's proposal. Additionally, fresh water may be used to flush drilling fluid from the bore immediately prior to breakout so only fresh water is released at breakout.

Inadvertent drilling fluid release is more likely with the HDD option without the steel casing that is used for the Direct Pipe method. The drilling fluid is pumped to the Direct Pipe cutting head under much lower pressure and volume than the HDD system would utilize. The spent drilling fluid and drill cuttings are then pumped back to the drilling fluid cleaning/separation unit through internal supply lines. This system reduces the annular pressure around the drill casing to near zero. High annular pressure in the borehole, needed for HDD, is the leading cause of drilling fluid spills.

After the HDPE conduit is installed a dive team will seal and secure the offshore end of the conduit. The Dive team can also set concrete blankets of anchor blocks to stabilize the exit location.

3.9.2 Direct Pipe Method

The direct pipe method combines the advantages of microtunnelling and HDD technology. In one step only, a prefabricated pipeline can be installed and the required borehole excavated at the same time. This allows speedy and highly economic installation of pipelines with lengths of more than one mile [14].

From the launch pit, the soil is excavated using a slurry-supported Herrenknecht Microtunnelling Machine (AVN). It pumps the excavated material through a slurry circuit inside the prefabricated pipeline, to a separation plant located aboveground. The pipeline, which is laid out on the surface on rollers and welded to the end of the microtunnelling machine, is pushed into the borehole at the same time as excavation takes place. The necessary thrust force is provided by the Pipe Thruster. It pushes the microtunnelling machine forward together with the pipeline – with a thrust force of up to 827 tons in increments of 16 feet. The push force is transferred to the pipeline through the Pipe Thruster's clamping unit and then to the machine's cutterhead. During excavation, the tunnel face can be controlled consistently and safely using slurry-supported tunnelling technology even in heterogeneous, water permeable soils. Uphill and downhill gradients as well as precise curve drives along the alignment can be managed with the gyro-based navigation system. Other navigation technologies can only be used to a limited extent due to the restricted visibility in pipelines [14].

With this system, the casing or conduit can be welded and the internal pumps and supply lines can be preassembled before the drilling operation begins. Sections can be preassembled in lengths of up to 2200 feet or more depending on the laydown area available at the site. For this project, the maximum expected preassembly length of both steel pipe casing and HDPE pipe is 300 feet. The preassembled section would be positioned onto rollers and supports to maintain the required bend radius of the product to be installed. The forward progress would stop only when new sections of the casing are added to the bore. The ability to preassemble and pre-weld the conduit eliminates the need to stop forward progress every 16 feet for welding additional casing.

The Direct Pipe method requires larger laydown space for pre-assembled material, but requires less drilling spread, minimizes offshore operations, and requires fewer days of full drilling operation than the HDD method as longer sections of steel and HDPE pipe can be be-assembled (welded and staged) with a smaller crew.

Figure 3-36. *Microtunneling machine starting a borehole, courtesy Herrenknecht.*

Figure 3-37. *Photo of a high angle Direct Pipe launch showing the microtunnelling machine (yellow) and pipe thruster (red and yellow).*

Figure 3-38. *Photo of a low angle Direct Pipe launch showing the pipe thruster and pre-assembled steel casing pipe on land, courtesy Michels.*

Figure 3-39. *Tunneling machine in-water recovery after borehole completion, courtesy Mears.*

Direct Pipe installation has been around for several years and projects of over 6000 feet in length have been completed. The Direct Pipe solution has been gaining significant market share over the field of large pipeline crossing in rural areas where laydown and work site area are large and extended sections of pipe can be preassembled. The Direct Pipe installation will use 60 inch outside diameter steel casing with a wall thickness of between ¾ to 1 inch. The Direct Pipe steel section can be delivered by truck and can be preassembled in lengths of up to 300 feet (as long as space allows). Weld time per joint of 60 inch casing will take 2 welders 12 to 15 hours per weld. The casing needs to be wrapped and cooled to ambient temperature and coated for corrosion resistance.

The Pipe thruster and clamp forces the microtunnelling machine cutting face into the formation in 16 foot strokes. Boring stops to weld new sections of the casing to the system are determined by the available space at the work site. As the microtunnelling machine moves forward drilling fluid will be pumped to the cutting face via pressurized supply lines with a small volume pumped to the annular space between the formation and the steel casing to reduce friction on the casing. The microtunnelling machine drill cutting and slurry would be augured and pumped back through the steel casing in the drilling fluid return lines inside the sections of the casing.

The returned drilling fluid is then pumped into a drilling fluid recycling system. The recycling system is located on land next to the bore entry and designed to contain drilling fluid to the on-shore work area. The recycling system will remove the cuttings from the drilling fluid to allow it to be used again in the drilling system similar to the system shown in the HDD section. The Direct Pipe installation is usually operated on a 24/7 work schedule. This schedule keeps fresh drilling fluid around the steel casing but at a lower pressure than required for HDD since the drilling fluid around the steel casing is not forced to return to the surface under pressure.

Once the 60 inch steel casing is installed the internal drilling fluid supply lines and control wires are disconnected. When supply lines are removed the divers would attach Lift bags to the microtunnelling machine and unbolt it from the leading edge of the casing. The microtunnelling machine is then raised to the surface and towed to a dock for recovery.

At this point, the Gripping Jaws on the Pipe thruster are changed to match the 48” HDPE conduit. The Pipe thruster pushes the 48” HDPE into the flooded 60 inch casing. The sea-end of the HDPE is open to allow water to enter as it is pushed into the casing to reduce the buoyancy of the pipe. The openings can be vents cut into the bullnose on the leading edge of the conduit so fresh or salt water can be pumped into the casing during installation.

Once the HDPE has exited the sea floor, divers could attach a swivel and anchor line to the HDPE to hold it in place. Once the HDPE is secured to the anchor line, the clamps on the pipe thruster could be changed back to the 60 inch steel clamps and the 60 inch steel casing could be recovered and salvaged.

Overall project time is estimated at 6 months using 24/7 around-the-clock operation, or 12 months if the operation is limited to day shifts only.

3.10 Trench

Trenching is an economical, fast, and low risk method to install pipeline(s) across Union Bay. The shallow water and assumed soft peat soil of Union Bay make for quick dredging using excavators mounted onto barges. Environmental clamshell buckets can be used to remove contained sediments if they are present. Sunken logs and other obstructions can be easily removed during the dredging process. A photo of typical dredging setup is shown in Figure 3-40. Photos of a pipeline trench, and pipeline installation into a trench are shown in Figure 3-41 and Figure 3-42 respectively.

Figure 3-40. *Photo of an excavator dredge on a barge next to a material barge, courtesy of Pacific Pile & Marine.*

Figure 3-41. *Aerial photo of the trench made for the City of Pasco outfall pipeline in the Columbia River, courtesy of Advanced American Construction.*

Figure 3-42. *Installation of City of Pasco outfall pipeline in the Columbia River, courtesy of Advanced American Construction.*

Based on historical borings, the top 40-50’ layer of soil in Union Bay is believed to be peat. The peat is expected to sustain a steep trench wall slope since it is highly fibrous and interwoven by nature. Since the top layer of peat is likely uncompacted, the weighting and backfill of the pipeline needs to be carefully considered. Marine pipelines are typically backfilled with gravel and a typical trench cross-section is shown in Figure 3-43. In uncompacted peat, the weight of the pipeline and gravel backfill may cause a large (>4 ft) and undesirable amount of settlement of the pipeline, in which case gravel backfill is not recommended. Side casting the excavated peat materials, and then backfilling them over the pipeline would be a technical solution to minimize pipeline settlement, but would cause a lot of turbidity and is unlikely to be allowed by the regulatory agencies.

Since the top layer of soil in union bay cannot sustain much weight, and since large vessels do not enter the shallow areas, it may be advantageous to leave the pipeline uncovered. Leaving the pipeline uncovered provides several advantages; 1) it reduces the likelihood of pipeline settlement, 2) it reduces the amount of dredging required, and 3) it significantly reduces installation time and cost by about 2.5 months and $10 million. The trench cross-section assumed for the crossing of Union Bay is shown in Figure 3-44. The trench cross-section proposed for the crossing of the Union Bay Reach (ship canal) is shown in Figure 3-45. The native soils under the reach are unknown and so a nominal trench slope of 1 in 3 was assumed. The backfill will likely be new clean gravel.

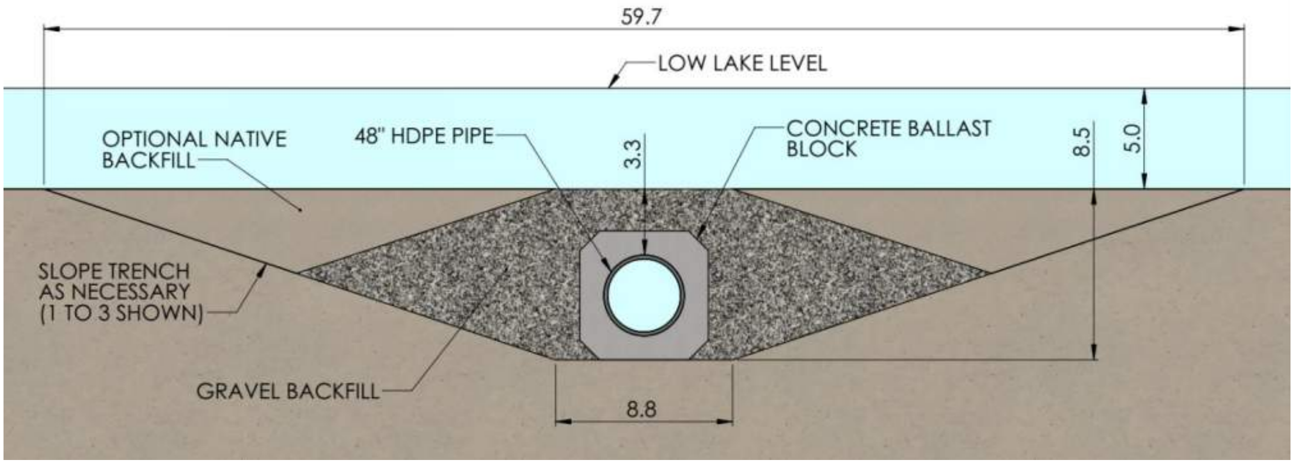


Figure 3-43. *A typical marine pipeline trench cross-section with dimensions (units in feet). If the native soil under the pipeline is peat, the weight of the gravel may cause a large and undesirable amount of settlement of the pipeline, in which case this configuration is not recommended.*

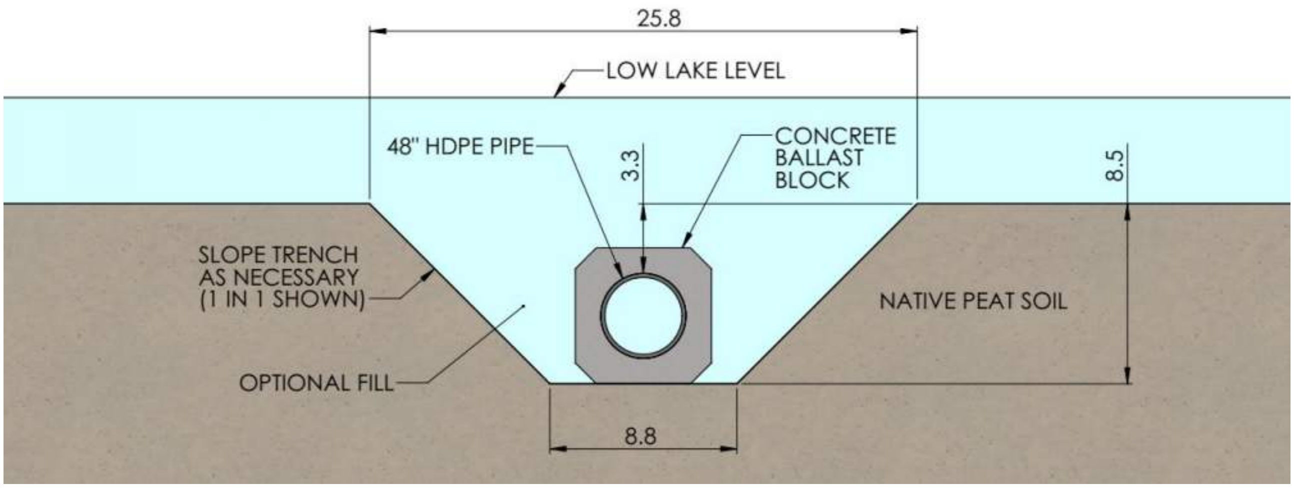


Figure 3-44. *The trench cross-section with dimensions (units in feet) proposed for the crossing of Union Bay considering that the native soil under the pipeline is uncompacted peat. The peat is expected to sustain a steeper trench wall slope since it is highly fibrous and interwoven by nature. No backfill can be used to minimize the dredging and pipeline settlement.*

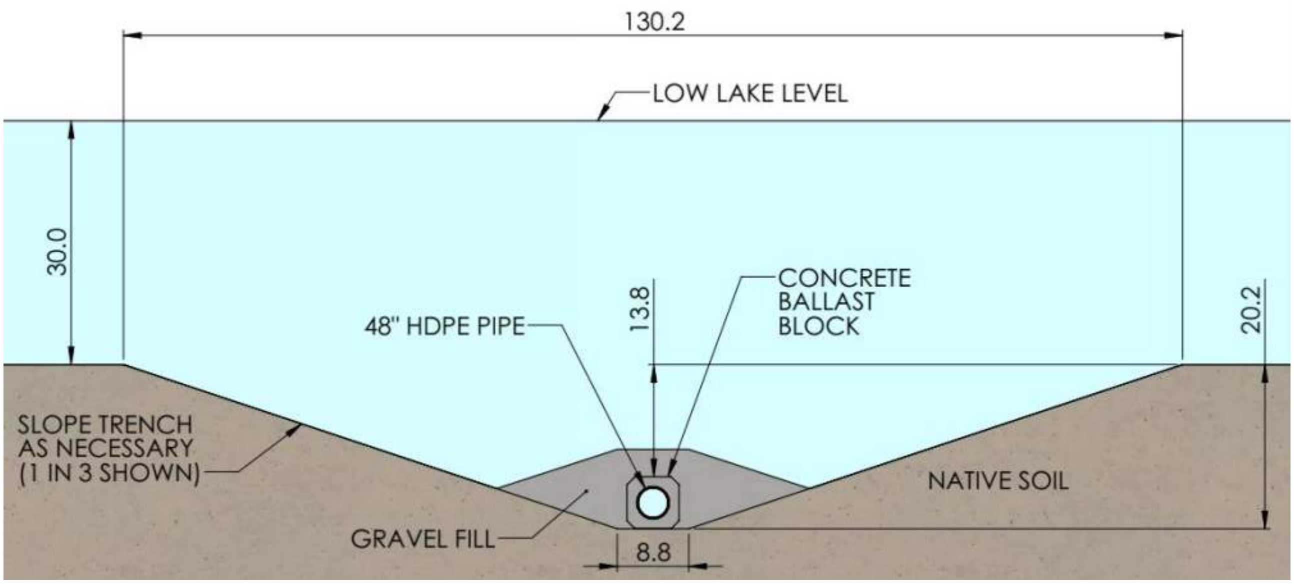


Figure 3-45. *The trench cross-section with dimensions (units in feet) proposed for the crossing of the Union Bay Reach. It is uncertain whether the soils under the reach are peat, clay, silt, sand, or gravel, therefore a nominal trench slope of 1 in 3 was assumed. It is likely that the backfill will be new clean gravel.*

3.11 Diffuser

A diffuser is required at the end of the discharge pipeline to disperse the water back into the lake or cut. An example diffuser drawing is shown in Figure 3-46. The number and locations of the diffuser ports are typically determined in a dispersion modelling study.

Diffuser design considerations include:

- Avoiding lakebed scouring by choosing an appropriate elevation above the lakebed, exit velocity and exit angle.
- Avoiding fountaining on the lake surface choosing an appropriate depth and exit velocity.
- Achieving good flow balancing between the diffuser ports by selecting an appropriate area ratio between all the ports and the main pipeline.
- Achieving good mixing by choosing an appropriate port layout and exit velocity.
- The diffuser should be designed to be cleaned by pigging in case fouling impacts hydraulic performance.

Table 3-5. *Conceptual Diffuser Data.*

Component Description	Unit	Value
Desired Total Port Area to Pipe Area	-	0.5
Approx. Number Ports Required	-	22
Typical Port Spacing	*ft*	5
Typical Riser Diameter	*in*	8
Typical Port Diameter	*in*	6.5
Typical Port Type	-	Duckbill check valve
Typical Port Angle from Seabed	*deg*	30-60

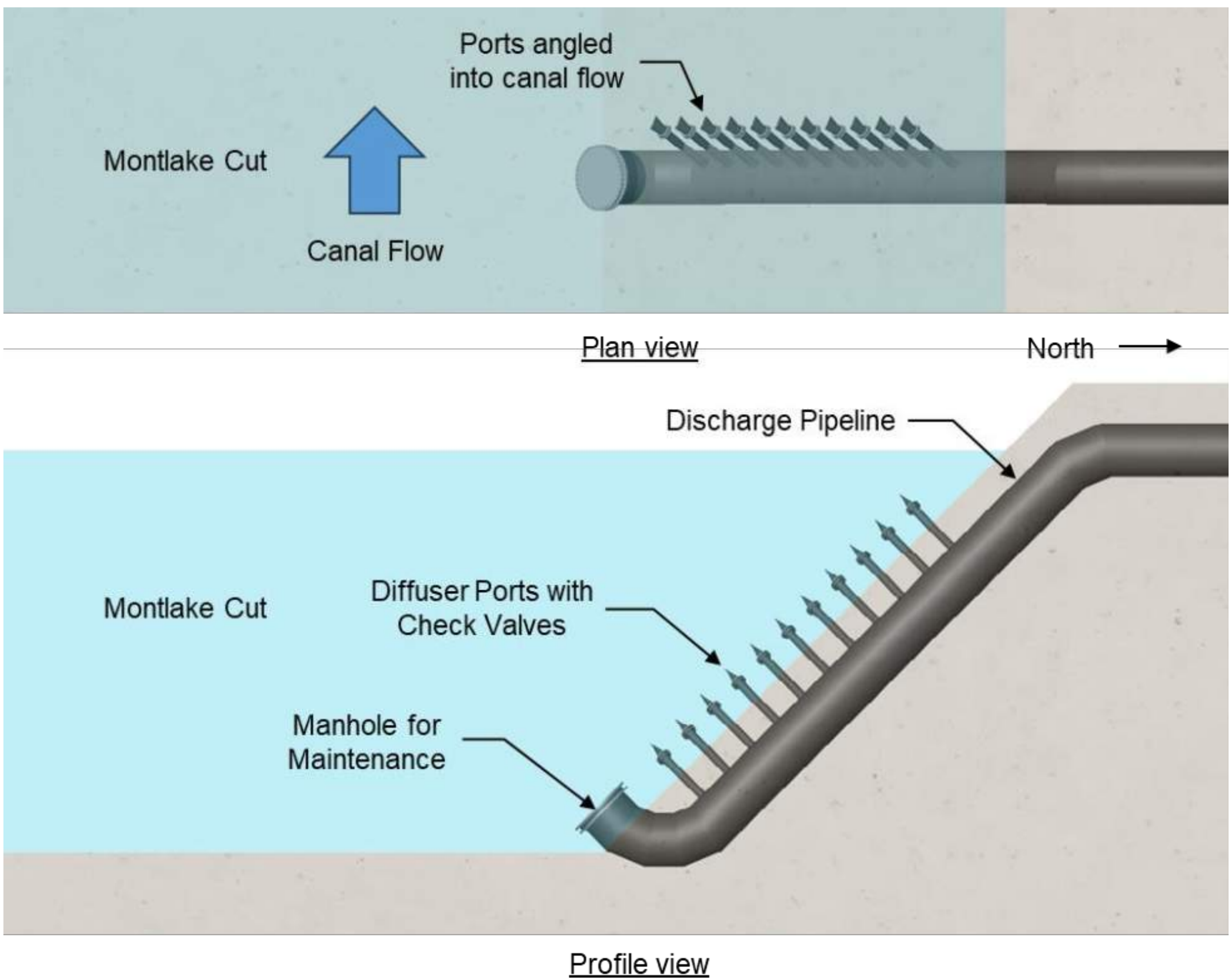


Figure 3-46. *Example Montlake Cut diffuser configuration.*

3.12 Controlled Submergence Installation

If the trenching method is used to cross Union Bay, the pipeline will be installed using the controlled submergence (float and sink) method. Makai has used this method successfully to install challenging deep water marine pipelines for the past 40 years, down to depths of 3,000 ft. This method has since become industry standard for installing HDPE marine pipelines.

A pipeline can be controllably submerged by pumping water into the pipe from the shore end. The overall procedure can be quick and accomplished in less than 8 hours. The figure below illustrates the process. At any given time, the buoyancy of the air-filled pipe supports the S-shaped pipeline; it is stable at all times and the process is reversible. The speed of laying is controlled by the rate of pumping in seawater. It is important to control the water pumping rate to keep the pipeline sinking rate under control. The internal air pressure can be regulated such that the external pressure on the pipeline does not exceed the internal pressure; air is vented from the far end during submergence. A pull tension is typically exerted on the end of the intake pipeline in order to keep alignment and to minimize bending in the pipeline. The process is stable and reversible.

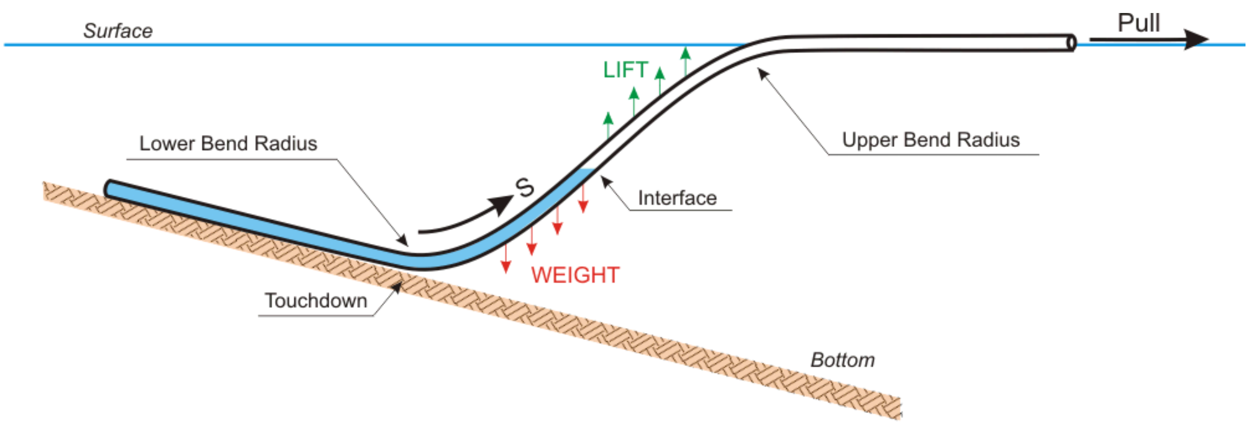


Figure 3-47. *Schematic of an HDPE pipe installation during flooding. Pipeline is shown in the S-shape and flooding may be stopped and reversed at any point during installation, if necessary.*

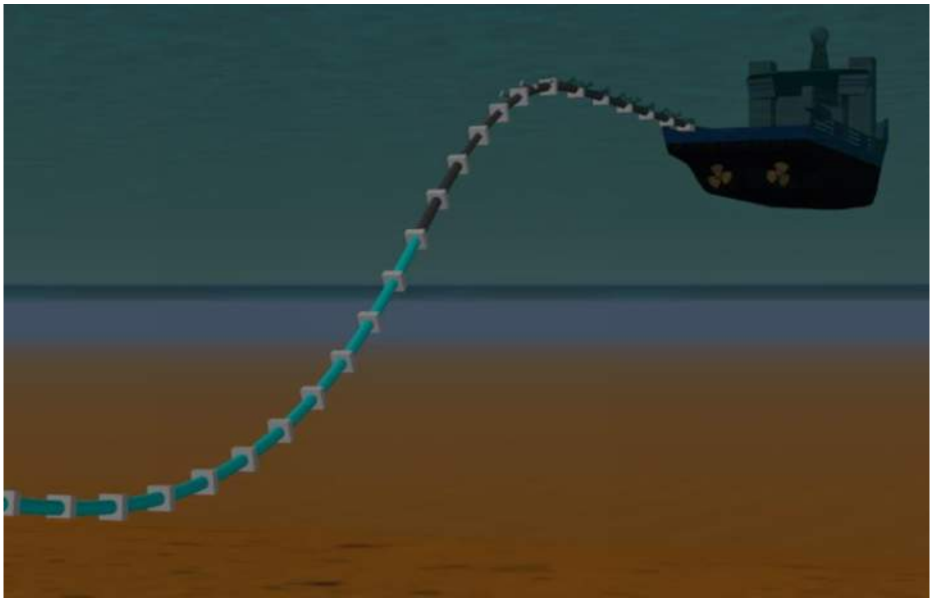


Figure 3-48. *Screen shot of a pipeline controlled submergence simulation.*

3.13 Corrosion

Lake water and lake soils are typically moderately corrosive and will cause the degradation and eventual failure of susceptible components over time if measures are not taken to mitigate this risk. The use of corrosion-resistant materials and coatings, along with corrosion control measures are essential to ensure the durability and reliability of LWCH system.

To meet the LWCH project's design life requirement of 100 years, we recommend using Polyethylene (PE) piping material. Polyethylene is resistant to corrosion, and will last 100 years without any noticeable degradation due to corrosion.

For metallic components that are exposed to lake water (but not lake soil) such as pumps, heat exchangers, valves, and intake screens, corrosion resistant stainless steel can be used. Stainless steel should not be used in any application where it could be partially or fully embedded in soil. This is because stainless steel depends on free access to oxygen to maintain its passive film. Any restriction in oxygen access can lead to severe localized pitting and crevice corrosion. Carbon steel and cast-iron components should be protected from corrosion using a coating with cathodic protection using sacrificial magnesium anodes.

4 MODEL METHODOLOGY

This chapter describes the methodology and assumptions used in the feasibility level LWCH modeling study for the University of Washington. The goal of the feasibility study was to use the Makai LWCH Model to develop a physical design and estimate the feasibility level CAPEX costs for evaluation of LWCH for the site. The feasibility study required analysis of existing infrastructure and application of supplied heating and cooling loads, and development of site specific LWCH modeling parameters. These are described in this chapter.

4.1 Modeling Process

Makai's modeling process was carried out in the following steps:

1. Data collection
   a. Bathymetric data
   b. Lake water temperature and salinity profiles
   c. Cooling and heating loads of customer
   d. System performance criteria
2. Model building
   a. Draw simplified onshore network
   b. Assemble LWCH model input
3. Model finalization
   a. Detailed economic and technical output for each configuration

4.1.1 Data Collection

Supporting design data provided by the Consultant and Environmental Subconsultant were used when available. All other data was obtained through publicly available sources. The data used is described in detail in Section 2.

4.1.2 Model Building

Usually, once the potential cooling customers at each site are identified, they are linked via a chilled water pipe network. The network is drawn on top of a georeferenced aerial image in AutoCAD. Makai's LWCH model contains functions that can extract the geometric network data from AutoCAD and assemble it into a logical representation of the network for analysis in the MATLAB based LWCH model. For this study, the network only contains a single customer which is the University's power plant. The networks used in this feasibility study are shown in Section 3.2.3.

The AutoCAD drawings only represent one portion of the input required by the model. The remaining data is entered via a Microsoft Excel spreadsheet that serves as an interface to the MATLAB LWCH model. The bathymetric data and seawater profiles collected during the data collection phase were entered into the model from the spreadsheet. Other input data stored in the input spreadsheet include cooling/heating customer loads, load curves, chilled water supply temperatures, chilled water temperature rises, and pressure drop requirements; pump efficiencies and net positive suction head requirements; pump station topography; and a wide variety of unit costs covering the various aspects of LWCH system construction, installation, and operation.

4.1.3 Model Finalization

Once each model was built, the technical and economic output was reviewed by Makai engineers. Although not an exhaustive list, some of the points checked include:

- Reality-check on capital costs based on experience with previous projects.

- Review of intake pipe diameter, length, and depth.
- Review of lake water and chilled water suction and discharge head.
- Review of chilled water temperatures throughout the system.

Once all the checks are complete, the base model is finalized.

4.1.4 LWCH Model Cost Estimates

The LWCH model cost estimating function provides the basis for optimization of a given LWCH system design and ultimately determines a LWCH project's feasibility. While the technical design of a LWCH system requires a strong understanding of HDPE pipeline design, pipeline hydraulics, hydrodynamics, heat transfer and other fundamental physical relationships, the cost estimate requires a broad breadth of understanding of all aspects of project development, pipeline assembly, offshore construction, marine vessel operations, pipeline anchoring, trench and backfill, pump station layout and construction, and many more topics. Much of Makai's design and construction observation experience related to all aspects of deep seawater pipelines, pump stations and onshore construction are encompassed in the LWCH model cost estimation process.

Makai has provided detailed and accurate cost estimates for LWCH, seawater air conditioning (SWAC) and deep seawater pipeline clients for years. These cost estimates were performed in a manner identical to the way a contractor would perform them; costs were broken into categories and numerous detailed itemized costs were estimated for each category. Such detailed cost estimates have proven accurate and have provided a strong rational basis for absolute project cost budgets. Cost data include vendor quotes, downloads from internet sources, and data from cost estimating handbooks e.g. RS Means Heavy Construction Cost Data [12]. Over many projects, Makai has accumulated detailed cost information to support our estimating work.

The cost categories used are as listed below:

1. Contractor costs (insurance, bonds, mobilization)
2. Pre-engineering (surveys, permitting)
3. Offshore lake water pipes (pipelines, anchors, deployment)
4. Shore crossing (trenching, tunneling)
5. Pump station (structure, pumps, heat exchangers, etc.)
6. Onshore utility network (pipes, trenching, etc.)

The cost equations are based on fundamental pipe/system design parameters appropriate for the given cost category. Thus, costs were parameterized based on variables such as: pipe diameter, pipe length, lake water or chilled water flow rate, pipe wall thickness, head loss, number of pipes, number of pumps, type of onshore pipe used, etc. Each construction step includes estimates for the number of laborers, amount of materials and equipment, and schedule. Schedule calculations then drive total labor and equipment costs, which are based on per hour or per week rates.

4.2 Construction Cost Estimate

This section describes the cost methodology and assumptions used in developing a concept layout and opinion of probable cost using the Makai LWCH model. The Makai LWCH model computes the optimal LWCH configuration (intake depth, pipe sizes, and heat exchangers) that supplies all clients with adequately chilled water at the lowest levelized cost ($/ton/year). Capital costs are computed in the process as well.

4.2.1 Notes on Costs

While the LWCH model cost estimates provide an approximation of total project development costs, it represents only an opinion of probable cost that is based on a LWCH cost estimating algorithm and conceptual design. Important assumptions applied to the LWCH model's cost analysis for the University of Washington LWCH site are as follows:

General: The cost analysis assumes that construction is carried out by contractors who have bid competitively for the work. Thus, these contractors are trying to complete the work as efficiently as possible.

Labor: Labor costs used in the model are based on the Washington State Department of Labor & Industries prevailing wage rates for public works in King County, WA [11]. In the cost analysis, prices for installed reinforced concrete are used. As these are "installed" prices, labor costs are included.

Onshore: Shoreline pump station structure costs are based on a unit cost of $830/sqft. It is assumed that the distance from pumping station to the main electrical lines is 10 m (33 ft). The cost of the transmission of the 10 m distance was included in the cost of the pumping station. All lake water and chilled water pumps and chillers were assumed to be located at the shoreline pump station site. Lake water pump impellers must be located below low lake level to meet submergence and net positive suction head requirements. All lake water pumps were priced based on use of materials suitable for lake water service that have been successfully used on past projects. Onshore chilled water distribution pipelines were assumed to be insulated high density polyethylene pipe. These pipes were buried below the roadways by direct burial trenching assuming overnight working hours totaling 6 productive hours for excavation per 8-hour night shift.

Reliability: The reliability of the LWCH system is obtained through careful engineering of its systems. For both lake water and chilled water pumps, materials are selected to give long life and the pumping plants have redundant units to allow regular shutdown, maintenance and replacement without disrupting chilled water flows to customers. While electronic controls are used, manual overrides should be included to continue operations even if there is a control failure. With polyethylene pipes used in the distribution circuit, their natural flexibility and corrosion resistance will provide long life even if surrounded with brackish ground water or subjected to ground movement from earthquakes or other natural events. Most of the costs related to these reliability features are captured in the LWCH model. The only threat that is outside the immediate control of the designer is that from a future excavator cutting into a buried chilled water distribution pipe. This requires that the Owner puts sufficient controls in place that no excavation will occur in areas with chilled water pipes without prior review and agreement of the Owner.

Again, while the LWCH model cost estimates provide an approximation of total project development costs, it represents only an opinion of probable cost that is based on a LWCH cost estimating algorithm and conceptual design.

5 MODEL RESULTS

5.1 Summary Results

A summary of results for the following LWCH system configurations are shown in Table 5-1:

1. Configuration 1a- discharge into Lake Washington and install both pipes via tunnel
2. Configuration 1b- discharge into Lake Washington and install both pipes via trench
3. Configuration 2a- discharge into Montlake Cut and install intake via tunnel
4. Configuration 2b- discharge into Montlake Cut and install intake via trench
5. Configuration 3- discharge into Montlake Cut and install intake via trench with half load

Table 5-1. *Pipe diameters and cost comparison for different configurations and shore crossing methods.*

Parameter	Units	Config. 1a	Config. 1b	Config. 2a	Config. 2b	Config. 3
Discharge Location	-	Lake Washington	Lake Washington	Montlake Cut	Montlake Cut	Montlake Cut
Burial Method	-	Tunnel	Trench	Tunnel	Trench	Trench
Total Load	*MW*	22.3	22.3	22.3	22.3	11.2
Intake Pipe Diameter	*in*	48	48	48	48	36
Discharge Pipe Diameter	*in*	48	48	48	48	36
Underground Construction Capital Cost	*k$*	142,329	20,892	74,135	20,857	19,956
Total System Capital Cost	*k$*	175,270	67,270	108,670	61,780	47,350

5.2 Technical Results

Network schematics and technical output tables of the examined configurations are shown below. In the network schematics figures, the lake water pipes are represented as thick lines colored by temperature (red is hot and blue is cold) and are not drawn to scale (scaled drawings of the networks are shown in Section 3.2.3). The chilled water pipes are represented as thin lines colored by temperature. The technical parameters of each object are listed in the adjacent label.

5.2.1 Configuration 1: Return-to-Lake

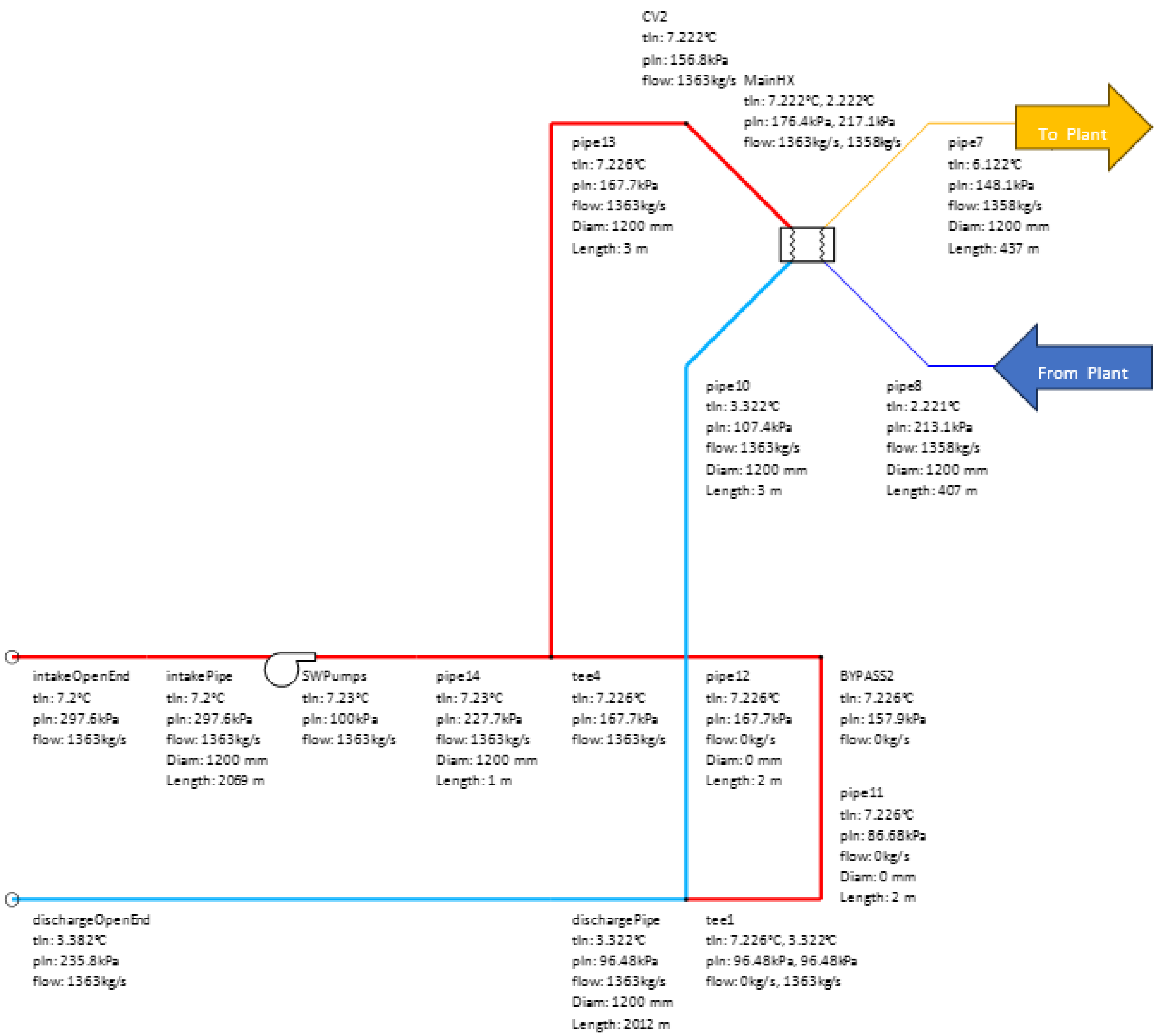


Figure 5-1. *Return-to-Lake system (config. 1) heating mode network schematic.*

Table 5-2. *Return-to-Lake system (config. 1) heating mode technical output.*

Technical Summary	
Peak AC Load (Tons)	-6341
Average AC Load (Tons)	-6341
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	1.20
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	7.20
Temperature at Pump Station (°C)	7.23
Shore Crossing Length (m)	2069
Shore Crossing Type	Tunnel
Average Flow Velocity (m/s)	1.5
Total Pipe Suction Head (kPa)	24.7
Static Head (kPa)	0.0
Flow Losses (kPa)	24.6
Return Pipe	
Depth of Return (m)	-14
Length of Return Pipe (m)	2012
Outside Diameter of Return Pipe (m)	1.20
Return Pipe DR	21
Max Temperature of Returned Water (°C)	3.38
Flow Velocity (m/s)	1.5
Total Return Pipe Head Loss (kPa)	24.4
Static Head (kPa)	0.0
Flow Losses (kPa)	24.4
Lake Water Pump Station	
Mass Flow (kg/s)	1362.6
Volumetric Flow (m3/s)	1.36
Total Lake Water Pump Head (kPa)	127.6
Suction Head (m)	2.5
Suction Head (kPa)	24.7
Cold Water Pipe (kPa)	24.7
Pressure (kPa)	103.0
Distribution Losses (kPa)	9.6
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	24.4
Pump Elevation (m)	-2.4
Lake Water Pumping Power (kW)	231.9

Lake Water Distribution System	
Maximum Pipe Pressure (kPa)	227.7
Minimum Pipe Pressure (kPa)	96.5
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	1358
Pump Return Head (kPa)	142
Pump Head (kPa)	153
Head Loss Through Distribution (kPa)	84
Chilled Water Pumping Power (kW)	278
Chilled Water Distribution System	
Maximum User CW Temperature (°C)	6.12
Minimum User CW Temperature (°C)	6.12
Maximum Pipe Pressure (kPa)	295.32
Minimum Pipe Pressure (kPa)	142.06
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
LW dT Across Heat Exchanger (°C)	-3.90
CW dT Across Heat Exchanger (°C)	-3.90
Lake Water Inlet Temperature (°C)	7.22
Lake Water Outlet Temperature (°C)	3.32
Chilled Water Inlet Temperature (°C)	2.22
Chilled Water Outlet Temperature (°C)	6.12
LW Flow (kg/s)	1362.64
CW Flow (kg/s)	1358.25
Heat Exchanger Area (m2)	5792.00
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

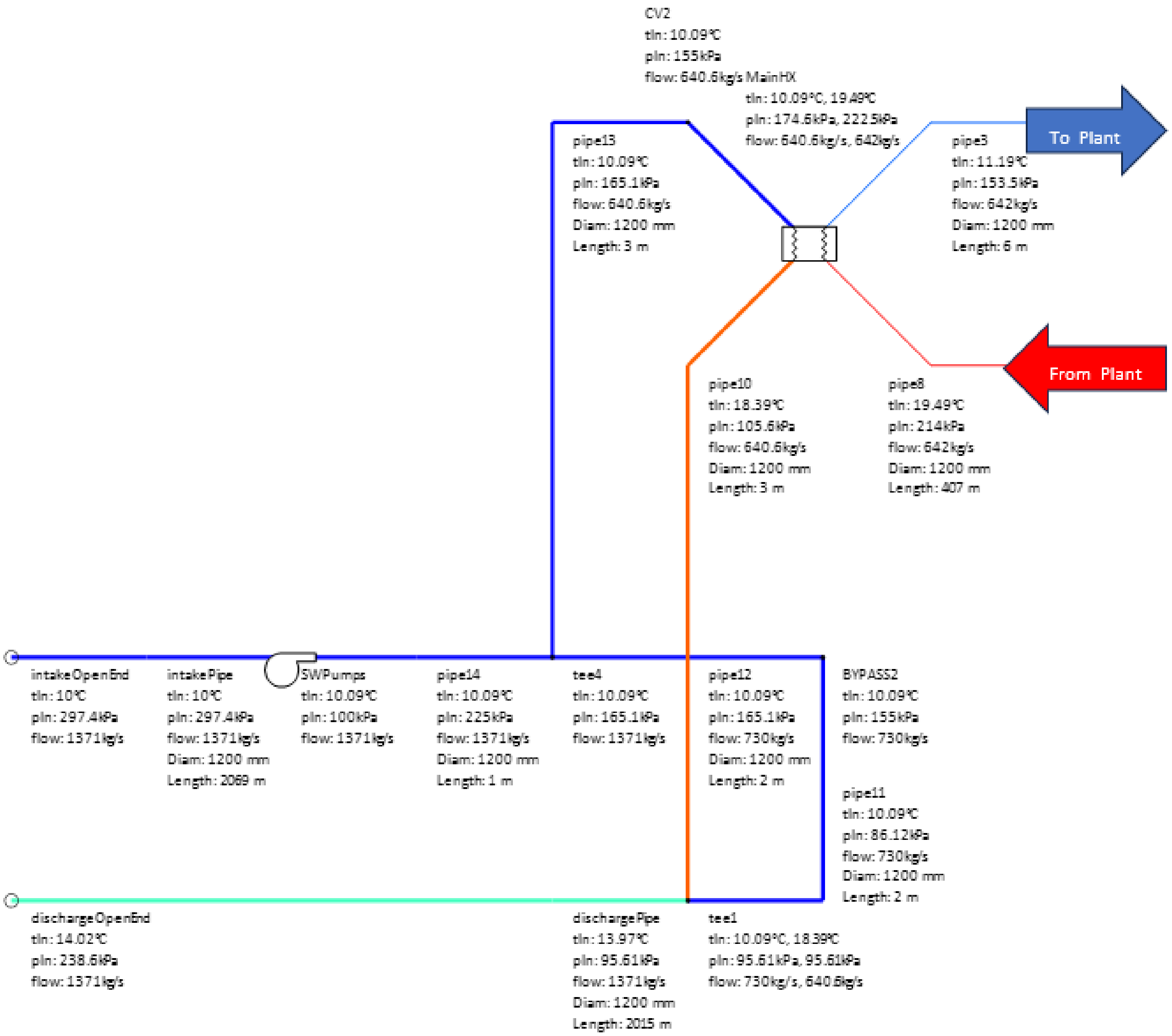


Figure 5-2. *Return-to-Lake system (config. 1) cooling mode network schematic.*

Table 5-3. *Return-to-Lake system (config. 1) cooling mode technical output.*

Technical Summary	
Peak AC Load (Tons)	6341
Average AC Load (Tons)	6341
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	1.20
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	10.00
Temperature at Pump Station (°C)	10.09
Shore Crossing Length (m)	2069
Shore Crossing Type	Tunnel
Average Flow Velocity (m/s)	1.5
Total Pipe Suction Head (kPa)	24.8
Static Head (kPa)	0.2
Flow Losses (kPa)	24.6
Return Pipe	
Depth of Return (m)	-14
Length of Return Pipe (m)	2015
Outside Diameter of Return Pipe (m)	1.20
Return Pipe DR	21
Max Temperature of Returned Water (°C)	14.02
Flow Velocity (m/s)	1.5
Total Return Pipe Head Loss (kPa)	23.5
Static Head (kPa)	-0.1
Flow Losses (kPa)	23.6
Lake Water Pump Station	
Mass Flow (kg/s)	1370.6
Volumetric Flow (m3/s)	1.37
Total Lake Water Pump Head (kPa)	125.0
Suction Head (m)	2.5
Suction Head (kPa)	24.8
Cold Water Pipe (kPa)	24.8
Pressure (kPa)	100.3
Distribution Losses (kPa)	7.8
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	23.5
Pump Elevation (m)	-2.4
Lake Water Pumping Power (kW)	228.5

Lake Water Distribution System	
Maximum Pipe Pressure (kPa)	225
Minimum Pipe Pressure (kPa)	95.6
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	642
Pump Return Head (kPa)	153
Pump Head (kPa)	142
Head Loss Through Distribution (kPa)	73
Chilled Water Pumping Power (kW)	121
Chilled Water Distribution System	
Maximum User CW Temperature (°C)	11.19
Minimum User CW Temperature (°C)	11.19
Maximum Pipe Pressure (kPa)	294.78
Minimum Pipe Pressure (kPa)	153.25
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
LW dT Across Heat Exchanger (°C)	8.30
CW dT Across Heat Exchanger (°C)	8.30
Lake Water Inlet Temperature (°C)	10.09
Lake Water Outlet Temperature (°C)	18.39
Chilled Water Inlet Temperature (°C)	19.49
Chilled Water Outlet Temperature (°C)	11.19
LW Flow (kg/s)	640.62
CW Flow (kg/s)	642.02
Heat Exchanger Area (m2)	5790.97
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

5.2.2 Configuration 2: Discharge into Montlake Cut

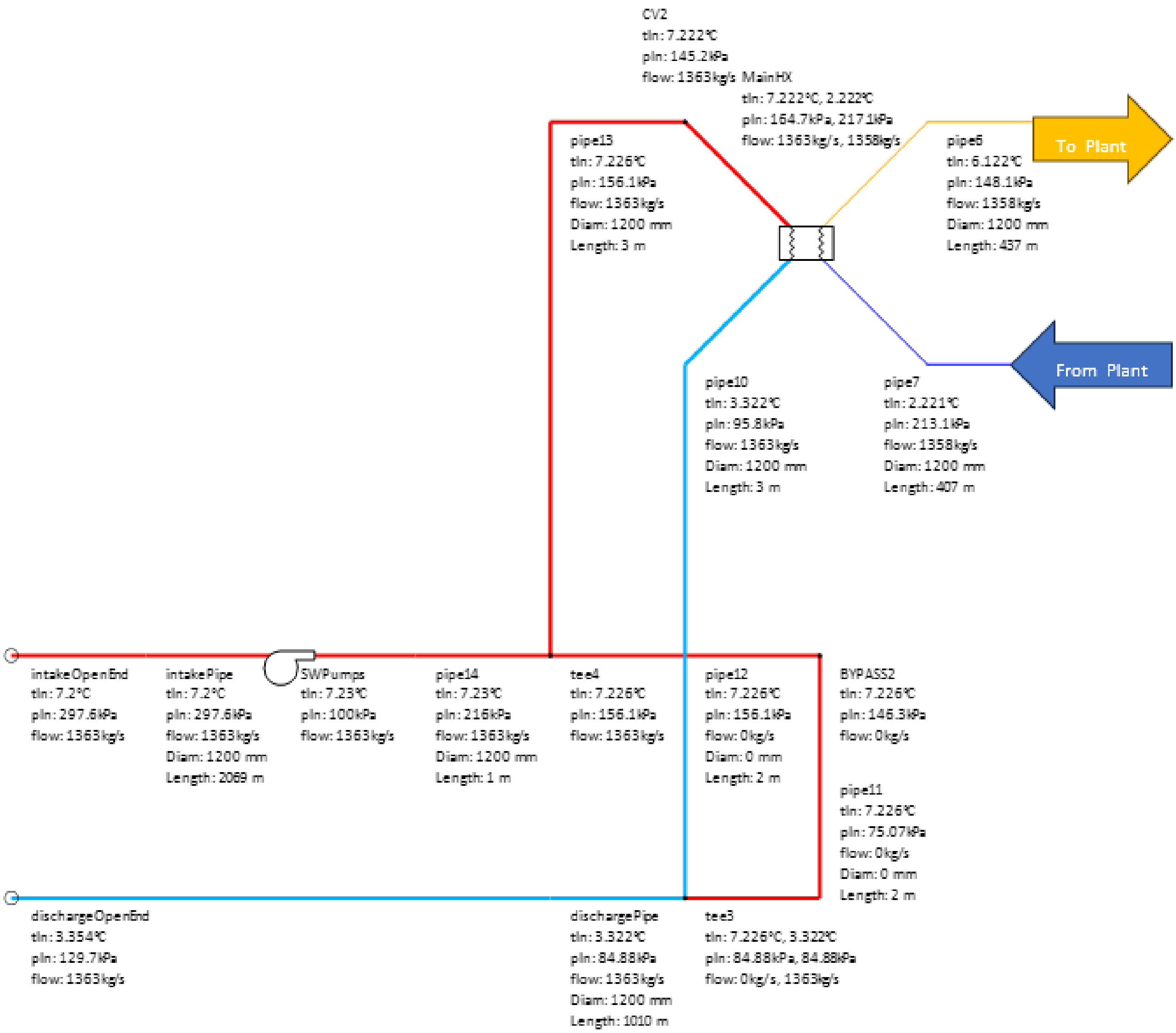


Figure 5-3. *Discharge into Montlake Cut system (config. 2) heating mode network schematic.*

Table 5-4. *Discharge into Montlake Cut system (config. 2) heating mode technical output.*

Technical Summary	
Peak AC Load (Tons)	-6341
Average AC Load (Tons)	-6341
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	1.20
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	7.20
Temperature at Pump Station (°C)	7.23
Shore Crossing Length (m)	2069
Shore Crossing Type	Tunnel
Average Flow Velocity (m/s)	1.5
Total Pipe Suction Head (kPa)	24.7
Static Head (kPa)	0.0
Flow Losses (kPa)	24.6
Return Pipe	
Depth of Return (m)	-3
Length of Return Pipe (m)	1010
Outside Diameter of Return Pipe (m)	1.20
Return Pipe DR	21
Max Temperature of Returned Water (°C)	3.35
Flow Velocity (m/s)	1.5
Total Return Pipe Head Loss (kPa)	12.8
Static Head (kPa)	0.0
Flow Losses (kPa)	12.8
Lake Water Pump Station	
Mass Flow (kg/s)	1362.6
Volumetric Flow (m3/s)	1.36
Total Lake Water Pump Head (kPa)	116.0
Suction Head (m)	2.5
Suction Head (kPa)	24.7
Cold Water Pipe (kPa)	24.7
Pressure (kPa)	91.4
Distribution Losses (kPa)	9.6
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	12.8
Pump Elevation (m)	-2.4
Lake Water Pumping Power (kW)	210.8

Lake Water Distribution System	
Maximum Pipe Pressure (kPa)	216.0
Minimum Pipe Pressure (kPa)	84.9
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	1358
Pump Return Head (kPa)	142
Pump Head (kPa)	153
Head Loss Through Distribution (kPa)	84
Chilled Water Pumping Power (kW)	278
Chilled Water Distribution System	
Maximum User CW Temperature (°C)	6.12
Minimum User CW Temperature (°C)	6.12
Maximum Pipe Pressure (kPa)	295.32
Minimum Pipe Pressure (kPa)	142.06
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
LW dT Across Heat Exchanger (°C)	-3.90
CW dT Across Heat Exchanger (°C)	-3.90
Lake Water Inlet Temperature (°C)	7.22
Lake Water Outlet Temperature (°C)	3.32
Chilled Water Inlet Temperature (°C)	2.22
Chilled Water Outlet Temperature (°C)	6.12
LW Flow (kg/s)	1362.64
CW Flow (kg/s)	1358.25
Heat Exchanger Area (m2)	5792.58
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

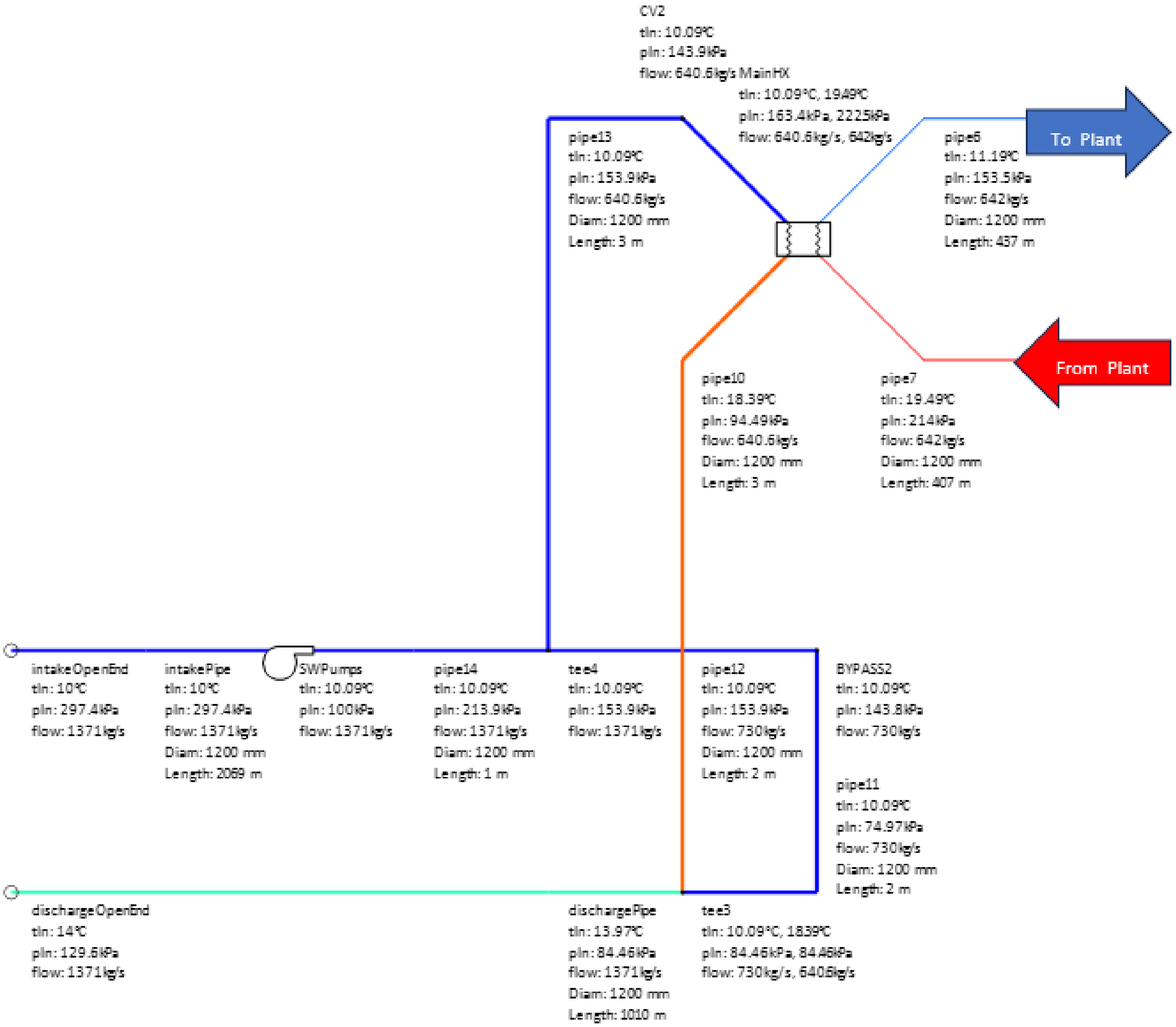


Figure 5-4. *Discharge into Montlake Cut system (config. 2) cooling mode network schematic.*

Table 5-5. *Discharge into Montlake Cut system (config. 2) cooling mode technical output.*

Technical Summary	
Peak AC Load (Tons)	6341
Average AC Load (Tons)	6341
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	1.20
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	10.00
Temperature at Pump Station (°C)	10.09
Shore Crossing Length (m)	2035
Shore Crossing Type	Tunnel
Average Flow Velocity (m/s)	1.5
Total Pipe Suction Head (kPa)	24.8
Static Head (kPa)	0.2
Flow Losses (kPa)	24.6
Return Pipe	
Depth of Return (m)	-3
Length of Return Pipe (m)	1010
Outside Diameter of Return Pipe (m)	1.20
Return Pipe DR	21
Max Temperature of Returned Water (°C)	14.00
Flow Velocity (m/s)	1.5
Total Return Pipe Head Loss (kPa)	12.3
Static Head (kPa)	0.0
Flow Losses (kPa)	12.4
Lake Water Pump Station	
Mass Flow (kg/s)	1370.6
Volumetric Flow (m3/s)	1.37
Total Lake Water Pump Head (kPa)	113.9
Suction Head (m)	2.5
Suction Head (kPa)	24.8
Cold Water Pipe (kPa)	24.8
Pressure (kPa)	89.1
Distribution Losses (kPa)	7.8
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	12.3
Pump Elevation (m)	-2.4
Lake Water Pumping Power (kW)	208.2

Lake Water Distribution System	
Maximum Pipe Pressure (kPa)	213.9
Minimum Pipe Pressure (kPa)	84.4
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	642
Pump Return Head (kPa)	152
Pump Head (kPa)	142
Head Loss Through Distribution (kPa)	73
Chilled Water Pumping Power (kW)	121
Chilled Water Distribution System	
Maximum User CW Temperature (°C)	11.19
Minimum User CW Temperature (°C)	11.19
Maximum Pipe Pressure (kPa)	293.57
Minimum Pipe Pressure (kPa)	152.03
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
LW dT Across Heat Exchanger (°C)	8.30
CW dT Across Heat Exchanger (°C)	8.30
Lake Water Inlet Temperature (°C)	10.09
Lake Water Outlet Temperature (°C)	18.39
Chilled Water Inlet Temperature (°C)	19.49
Chilled Water Outlet Temperature (°C)	11.19
LW Flow (kg/s)	640.62
CW Flow (kg/s)	642.02
Heat Exchanger Area (m2)	5790.39
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

5.2.3 Configuration 3: Discharge into Montlake Cut with Half Load

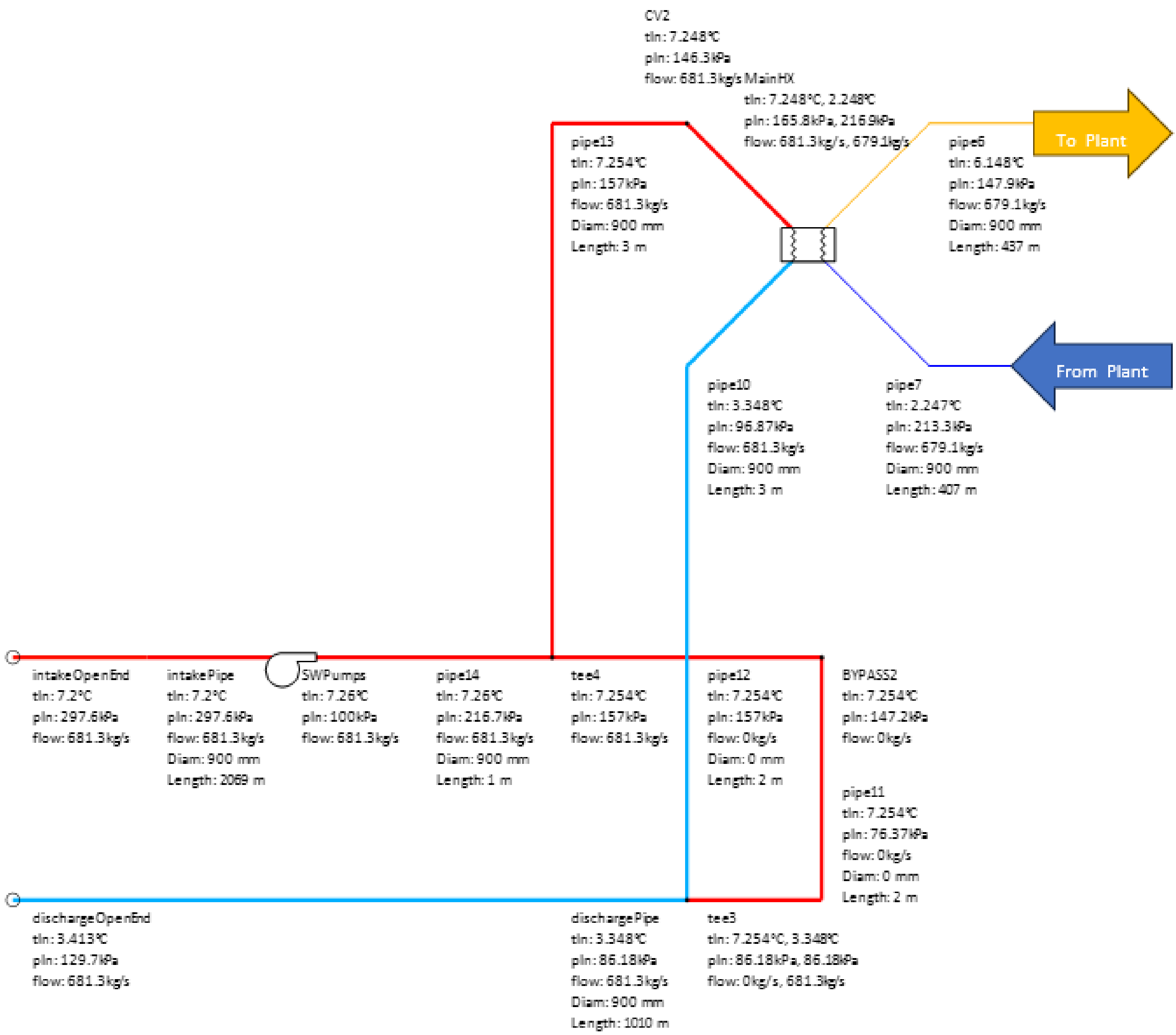


Figure 5-5. *Discharge into Montlake Cut half load system (config. 3) heating mode network schematic.*

Table 5-6. *Discharge into Montlake Cut half load system (config. 3) heating mode technical output.*

Technical Summary	
Peak AC Load (Tons)	-3171
Average AC Load (Tons)	-3171
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	0.90
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	7.20
Temperature at Pump Station (°C)	7.26
Shore Crossing Length (m)	2069
Shore Crossing Type	Trench
Average Flow Velocity (m/s)	1.3
Total Pipe Suction Head (kPa)	27.5
Static Head (kPa)	0.0
Flow Losses (kPa)	27.5
Return Pipe	
Depth of Return (m)	-3
Length of Return Pipe (m)	1010
Outside Diameter of Return Pipe (m)	0.90
Return Pipe DR	21
Max Temperature of Returned Water (°C)	3.41
Flow Velocity (m/s)	1.3
Total Return Pipe Head Loss (kPa)	14.1
Static Head (kPa)	0.0
Flow Losses (kPa)	14.1
Seawater Pump Station	
Mass Flow (kg/s)	681.3
Volumetric Flow (m3/s)	0.68
Total Sea Water Pump Head (kPa)	116.7
Suction Head (m)	2.8
Suction Head (kPa)	27.5
Cold Water Pipe (kPa)	27.5
Pressure (kPa)	89.2
Distribution Losses (kPa)	6.1
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	14.1
Pump Elevation (m)	-2.7
Seawater pumping power (kW)	106.0

Seawater Distribution System	
Maximum Pipe Pressure (kPa)	216.7
Minimum Pipe Pressure (kPa)	86.2
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	679
Pump Return Head (kPa)	141
Pump Head (kPa)	153
Head Loss Through Distribution (kPa)	84
Freshwater pumping power (kW)	139
Freshwater Distribution System	
Maximum User CW Temperature (°C)	6.15
Minimum User CW Temperature (°C)	6.15
Maximum Pipe Pressure (kPa)	294.88
Minimum Pipe Pressure (kPa)	141.46
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
SW dT Across Heat Exchanger (°C)	-3.90
FW dT Across Heat Exchanger (°C)	-3.90
Seawater Inlet Temperature (°C)	7.25
Seawater Outlet Temperature (°C)	3.35
Chilled Water Inlet Temperature (°C)	2.25
Chilled Water Outlet Temperature (°C)	6.15
SW Flow (kg/s)	681.32
FW Flow (kg/s)	679.12
Heat Exchanger Area (m2)	2896.40
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

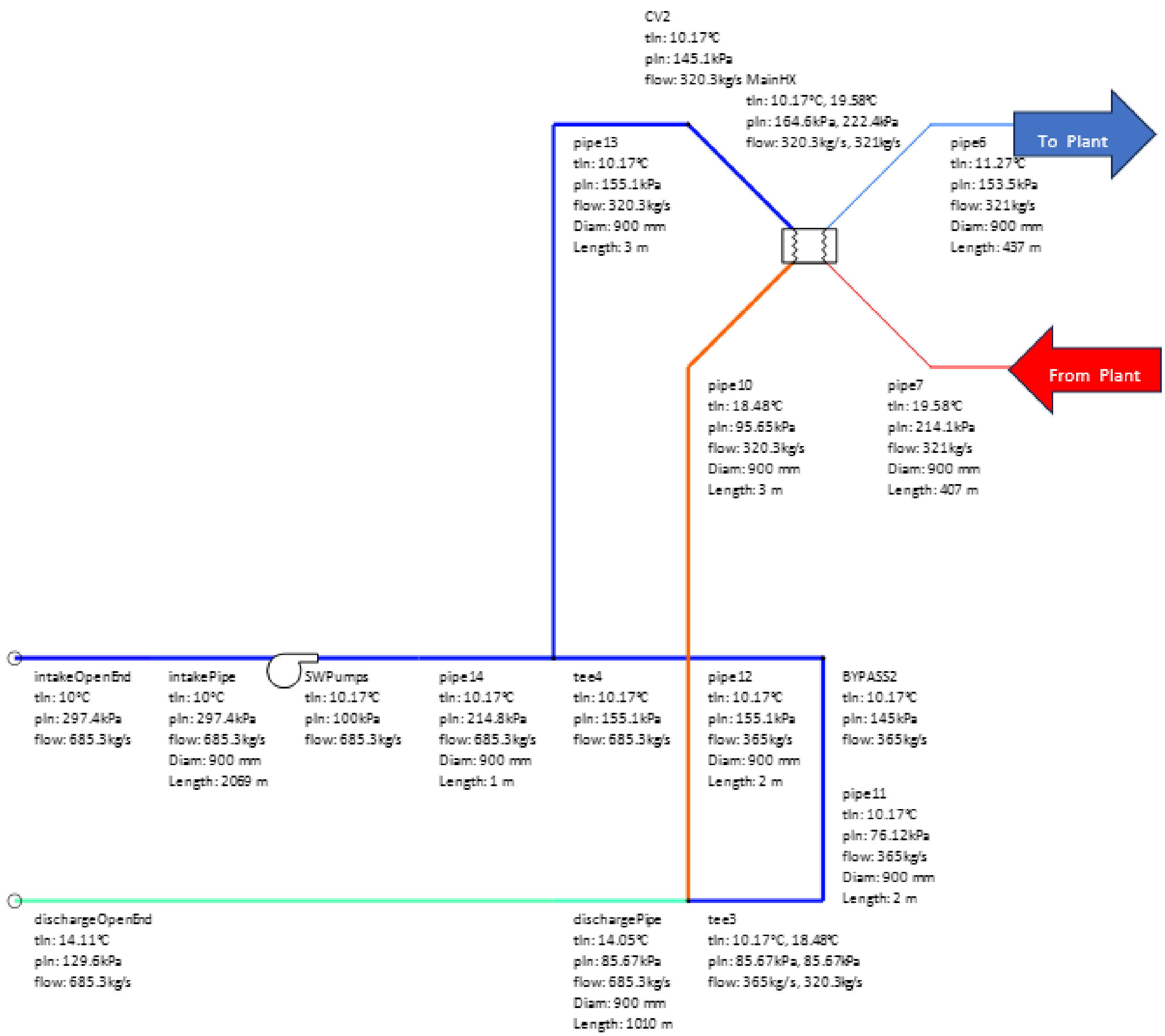


Figure 5-6. *Discharge into Montlake Cut half load system (config. 3) cooling mode network schematic.*

Table 5-7. *Discharge into Montlake Cut half load system (config. 3) cooling mode technical output.*

Technical Summary	
Peak AC Load (Tons)	3171
Average AC Load (Tons)	3171
Intake Pipe	
Depth of Intake (m)	-20
Length of Intake Pipe (m)	2069
Outside Diameter of Intake Pipe (m)	0.90
Shoreline DR	21
Intake DR	21
Deep Water Temperature (°C)	10.00
Temperature at Pump Station (°C)	10.17
Shore Crossing Length (m)	2035
Shore Crossing Type	Tunnel
Average Flow Velocity (m/s)	1.3
Total Pipe Suction Head (kPa)	27.6
Static Head (kPa)	0.1
Flow Losses (kPa)	27.4
Return Pipe	
Depth of Return (m)	-3
Length of Return Pipe (m)	1010
Outside Diameter of Return Pipe (m)	0.90
Return Pipe DR	21
Max Temperature of Returned Water (°C)	14.11
Flow Velocity (m/s)	1.3
Total Return Pipe Head Loss (kPa)	13.6
Static Head (kPa)	0.0
Flow Losses (kPa)	13.6
Seawater Pump Station	
Mass Flow (kg/s)	685.3
Volumetric Flow (m3/s)	0.69
Total Sea Water Pump Head (kPa)	114.8
Suction Head (m)	2.8
Suction Head (kPa)	27.6
Cold Water Pipe (kPa)	27.6
Pressure (kPa)	87.2
Distribution Losses (kPa)	4.7
Heat Exchanger (kPa)	69.0
Return Pipe (kPa)	13.6
Pump Elevation (m)	-2.7
Seawater pumping power (kW)	104.9

Seawater Distribution System	
Maximum Pipe Pressure (kPa)	214.8
Minimum Pipe Pressure (kPa)	85.7
Maximum User dH (kPa)	0.0
Minimum User dH (kPa)	0.0
Chilled Water Pump Station	
Total Flow (kg/s)	321
Pump Return Head (kPa)	152
Pump Head (kPa)	142
Head Loss Through Distribution (kPa)	73
Freshwater pumping power (kW)	61
Freshwater Distribution System	
Maximum User CW Temperature (°C)	11.28
Minimum User CW Temperature (°C)	11.28
Maximum Pipe Pressure (kPa)	293.47
Minimum Pipe Pressure (kPa)	151.87
Maximum User dH (kPa)	68.95
Minimum User dH (kPa)	68.95
TES Tank Capacity (Mliters)	0.00
Heat Exchangers	
SW dT Across Heat Exchanger (°C)	8.31
FW dT Across Heat Exchanger (°C)	8.31
Seawater Inlet Temperature (°C)	10.17
Seawater Outlet Temperature (°C)	18.48
Chilled Water Inlet Temperature (°C)	19.58
Chilled Water Outlet Temperature (°C)	11.27
SW Flow (kg/s)	320.31
FW Flow (kg/s)	321.01
Heat Exchanger Area (m2)	2895.76
Heat Transfer Coefficient (kW/m2/°C)	3.50
Head Loss including control valve (kPa)	68.95
LMTD (°C)	1.10

5.3 Capital Costs

A total capital cost comparison between the following five UW LWCH options is shown in Table 5-8 and Table 5-9:

1. Configuration 1a- discharge into Lake Washington and install both pipes via tunnel
2. Configuration 1b- discharge into Lake Washington and install both pipes via trench
3. Configuration 2a- discharge into Montlake Cut and install intake via tunnel
4. Configuration 2b- discharge into Montlake Cut and install intake via trench
5. Configuration 3- discharge into Montlake Cut and install intake via trench with half load

Table 5-8. *Cost output comparison.*

Capital Costs					
	Config 1a *Return to Lake - Tunnel* (k$)	**Config 1b** *Return to Lake-Trench* (k$)	**Config 2a** *Discharge to Cut-Tunnel* (k$)	**Config 2b** *Discharge to Cut-Trench* (k$)	**Config 3** *Discharge to Cut-Half Load* (k$)
Contractor					
P&P Bonds	88	166	78	115	84
CAR Insurance	227	481	194	315	214
General Mob	94	199	80	130	89
Site Specific Mob	0	0	0	0	0
Grand Total	409	847	352	560	387
Pre Engineering					
Route Survey	938	938	938	938	938
Permitting	670	670	670	670	670
Total	1,608	1608	1,608	1,608	1,608
Offshore Lake Water Pipes					
Pipe and Fittings	3,155	3,155	1,599	1,599	963
Pipe Fusion	2,507	2,507	2,128	2,128	1,632
Anchors and Stiffeners	0	7,682	0	3,616	1,993
Intake Structure	800	800	800	800	800
Deployment Preparations	1,735	1,736	1,626	1,622	1,555
Deployment	2,365	3,420	1,718	2,261	1,164
Post Deployment	1,180	1,180	1,180	1,180	1,012
Contractor Markup	1,947	4,131	1,663	2,702	1,839
Engineering	259	532	216	346	235
Contingency	2,400	4,202	1,853	2,710	1,871
Total	16,347	29,345	12,782	18,963	13,063

Table 5-9. *Cost output comparison continued.*

Capital Costs	Config 1a *Return to Lake - Tunnel* (k$)	Config 1b *Return to Lake-Trench* (k$)	Config 2a *Discharge to Cut-Tunnel* (k$)	Config 2b *Discharge to Cut-Trench* (k$)	Config 3 *Discharge to Cut-Half Load* (k$)
Shore Crossing					
Tunnels	97,153	0	50,604	0	0
Offshore Trench	0	13,732	0	13,708	13,236
Onshore Trench	0	508	0	508	370
Contractor Markup	24,288	3,560	12,651	3,554	3,402
Engineering	1,214	203	633	203	189
Contingency	19,673	2,889	10,247	2,884	2,759
Total	142,329	20,892	74,135	20,857	19,956
Pump Station					
Main Lake Water Pumps and Motors	1,341	1,341	1,341	1,341	889
Main Heat Exchanger	2,254	2,254	2,254	2,254	1,127
Chillers	0	0	0	0	0
TES Tanks	0	0	0	0	0
Electrical Service	1,279	1,279	1,233	1,233	659
New Power Line Installation	35	35	34	34	17
Structure	1,844	1,844	1,837	1,837	1,761
Contractor Markup	1,125	1,125	1,111	1,111	832
Engineering	237	237	233	233	175
Contingency	1,398	1,398	1,386	1,386	926
Total	9,513	9,513	9,429	9,429	6,385
Distribution Network					
Pipe	2,654	2,654	5,687	5,687	3,160
Fittings and Valves	21	21	21	21	13
Trench and Install	1,983	1,987	4,247	4,247	2,548
Pumps	279	279	279	279	161
Heat Exchangers	0	0	0	0	0
Contractor Markup	69	69	69	69	40
Contingency	56	56	56	56	32
Total	5,062	5,067	10,359	10,359	5,954
Total LWCH Capital Cost (k$)	**175,270**	**67,270**	**108,670**	**61,780**	**47,350**

6 CONCLUSIONS

Several configurations for the intake and discharge systems for the LWCH at the University of Washington were considered in this feasibility study. In conclusion, a trenched pipeline through Union Bay appears to be the lowest risk and lowest cost option. Model estimates of cost for the trenched 1.25 mile (2 km) long intake and discharge pipelines, that provide 22.3 MW of peak cooling/heating, are estimated at roughly $62 million.

6.1 Technical Feasibility

Installing a LWCH system at the University of Washington appears to be feasible with low overall technical risk. The main technical challenges identified for this project include installation practicalities for tunneling under Union Bay, and trenching the pipelines in the soft peat soil (if the trenching method is used). For tunneling, the challenges are consistent with other systems of similar size and length, including the inherent risks associated with unknowns in subsurface geology and pushing up against state of the art for size and length limits of HDD and Direct Pipe. For trenching, the primary challenges are consistent but no more severe than similar dredging projects, including the regulatory approval and planning process, logistics for marine contractors in areas with limited vessel draft, and establishing best practices to mitigate dredge plume impacts during construction.

6.2 Pipeline Route

Two routes were proposed in section 3.2; the Baseline Route that crosses the Union Bay Reach, and the Alternate Route that avoids the reach. Both routes are roughly the same length, so the hydraulics are equivalent and the cost difference is minimal. They both have advantages and disadvantages that need to be further evaluated in the preliminary design phase after a high-resolution bathymetric survey has been completed.

6.3 Underground Construction Method

Two underground construction methods were analyzed in this feasibility study: tunneling and trenching. While both methods are technically feasible, trenching is lower risk and lower cost.

6.3.1 Trenching

Trenching is the preferred method for this pipeline installation because the technical risks and costs are both low, and the work will be completed faster compared to tunneling. The shallow water and assumed soft peat soil of Union Bay make for quick dredging using excavators mounted onto small barges. Trenching the entire route would take approximately half the time to complete compared to tunneling (~2.5 months). Environmental clamshell buckets can be used to remove contained sediments if they are present. Sunken logs and other obstructions can be easily removed during the dredging process.

The trenching option would also cause less disturbance on the University of Washington campus compared to tunneling. Nearly all trenching operations occur offshore using offshore equipment, so little campus space is required. The main disadvantage of trenching is the environmental impact. To mitigate this risk, silt curtains can be placed around the dredging operation.

6.3.2 Tunneling

Tunneling may or may not be technically feasible depending on the length of the tunneled section and the subsurface geology. Tunneling the entire 6600' route will be high risk, while tunneling only 1000' or 2000' under the Union Bay Reach would be lower risk.

The most important technical consideration for tunneling is the subsurface geological conditions. Historical borings within Union Bay show a thick peat layer with glacial soils underneath. It is not desirable to tunnel through peat, so the tunnel would need to be routed under the peat layer (about 40-55' deep) through the glacial soils underneath. Glacial soils pose a risk to tunneling because they are highly abrasive and could dull the cutting tool before a 6600' long tunnel is complete. It is also likely that sunken logs and other debris may be present in Union Bay that could obstruct the tunneling operation.

Tunneling the full 6600' from campus would likely take between 6-12 months, and would require a large worksite on campus. This long disturbance to the campus environment is undesirable.

The main advantage of tunneling over trenching is that it is more environmentally friendly, and it may be the only option available if the regulators do not allow trenching. If tunneling will be used, a geotechnical investigation with at least a dozen borings along the pipe route is recommended to better understand the subsurface geology.

6.4 Cost Feasibility

Detailed capital cost estimates were provided for the five LWCH system configurations and range between \$47 million to \$175 million depending on the configuration. The first driver of cost is the offshore pipeline burial method, and the second is the discharge location. Installing lake pipelines by tunneling is significantly more expensive than by trenching. Routing the discharge pipeline on land and into the Montlake Cut is significantly cheaper than routing it back to Lake Washington.

Tunneling an intake and a discharge pipeline to Lake Washington costs the most (\$175 million), while trenching an intake pipeline to Lake Washington and discharging into Montlake Cut costs the least (\$62 million) for the full 22.3 MW load. To minimize the cost of the trenched option, it was assumed that no backfill would be placed over the pipe across Union Bay, except where it goes under the Union Bay Reach ship canal. If backfilling was required, the cost and duration of the trenching option would increase by about \$10 million, and 2.5 months respectively. A hybrid trench trench-tunnel system will likely have a cost somewhere in between these numbers.

The full load case is only about 30% more expensive than the half load case when all other parameters are kept the same. This suggests that there is a lifetime cost-benefit to the full load system.

7 RECOMMENDATIONS FOR FUTURE WORK

If this project moves forward, the following information will be required in the design and bid phases:

7.1 High Resolution Bathymetric Survey

A bathymetric survey with a spatial resolution of less than 3 feet is recommended in areas where the pipeline will be trenched, and resolution of less than 1 foot in any areas where the pipeline, intake, or diffuser would be installed directly on the lake bottom. For the shallow Union Bay, this data could be economically obtained by aerial drone. The maximum lake depth that can be surveyed by aerial drone depends on the clarity of the water. For deeper water depths that cannot be surveyed by aerial drone, a vessel with a multibeam sonar is recommended.

7.2 Geotechnical Survey

Since the geology of this site is important whether the pipelines are trenched or tunneled, a geotechnical investigation with at least a dozen borings along the pipe route is recommended. If tunneling will be used, the borings should extend down to an elevation of -60 feet relative to the NAVD88 vertical datum.

7.3 Soil Sampling and Testing

If the pipe will be trenched across Union Bay, understanding the soils near the lakebed will be important during the design phase. Soils should be tested to determine if they are contaminated, and should be chemically analyzed to determine their corrosiveness. Contaminated soils need to be specially handled and disposed of, which needs to be specified in the design, and will affect the cost. This study has assumed the soils are not contaminated.

7.4 Lake Water Testing

The lake water intake temperature is an important parameter for determining the required system flow rate. It is recommended that lake water temperature profiles be taken at the intake location over a long period of time (at least one year). This data will be used to determine the intake depth and intake flow rate during the detailed design phase.

9.7 Site Analysis & Zoning Study

UNIVERSITY of WASHINGTON

Energy Renewal Plan:
Sites Analysis & Zoning Study

Prepared by:

rolluda architects
architecture planning interior design

AEI Affiliated Engineers

Issued: August 16th, 2024

Table of Contents

Report Narrative

This report was commissioned by AEI Affiliated Engineers to provide site analysis, zoning studies, site design alternatives, conceptual building designs and renderings for a series of facility site locations and parcels of land around the University of Washington's Seattle campus for consideration of use for the University's Energy Renewal and Decarbonization Plan.

The facility types are as follows: Thermal Energy Storage tanks (hot and cold water), Utility Plants (WCUP South Expansion & South Plant Expansion), Sewer Water Heat Recovery Building, Electrical Receiving Station, and Lake Water Pump Equipment House Station. Conceptual building designs and renderings follow the site analysis for each site.

West Campus Utility Plant (WCUP)
South Expansion
Building

WCUP South Expansion Building (3 Options)

Address: 3949 15th Ave NE, 98105
Parcel Number(s): 1142002535 - 3900
Jurisdiction: Seattle

Property Legal Description: BROOKLYN ADD LOTS 1 THRU 9 & 14 THRU 32 BLK 25 LESS ALLEY ESTAB ORD #97911 TGW VAC ALLEY ADJ TGW POR VAC NE PACIFIC ST ADJ LESS POR LOTS 22 & 23 FOR ALLEY PER REC# 20150505001181 & LESS POR FOR ALLEYS PER REC# 20151009001183, Plat Block: 25, Plat Lot: POR

Zoning Area:	SMC 23.50A: MIO-200-NC3-75(M)
Building Height (MAX):	75 feet
Lot Size:	100 feet by 114 feet by 85 feet
Setbacks:	Additional upper-level setbacks are required for street-facing facades in zones with a height limit of 75 feet to 95 feet. Facades greater than 250 feet in width require additional setbacks for modulation.
FAR:	1.3 per SMC 23.50A.100, Table A

WCUP South Expansion Building (3 Options)

Current Site Use:	UW WCUP South Building
Design Review Board Requirements:	• Prominent intersection, visually impactful to the area, setbacks and modulation will need to be reviewed • Square footage expansion thresholds: all 3 options exceed 4,000 square feet and will require design review • Consideration to impact on the Burke Gilman Trail
Design Considerations:	• Impact on Burke-Gilman trail located South of the property • Re-route SCL electrical duct bank and Burke-Gilman trail to maximize use of the land for expansion to the south • ADA access to the building and elevator access to office locations if on a different story. • Protect existing buried fuel tank with concrete walls and shoring during construction (NE corner of building)
Burke-Gilman Trail:	Managed by City of Seattle, On-campus managed by UW
Proposed Building Occupancy & Construction Type:	• Occupancy: F-2 w/ B Accessory • TYPE IIB – Fully Sprinklered – up to 4 Stories above grade

Site Narrative

The area South of the existing WCUP has potential for expansion. There are limitations to expanding the site (electrical duct bank lines, site boundary constraints and the Burke-Gilman Trail) to consider.

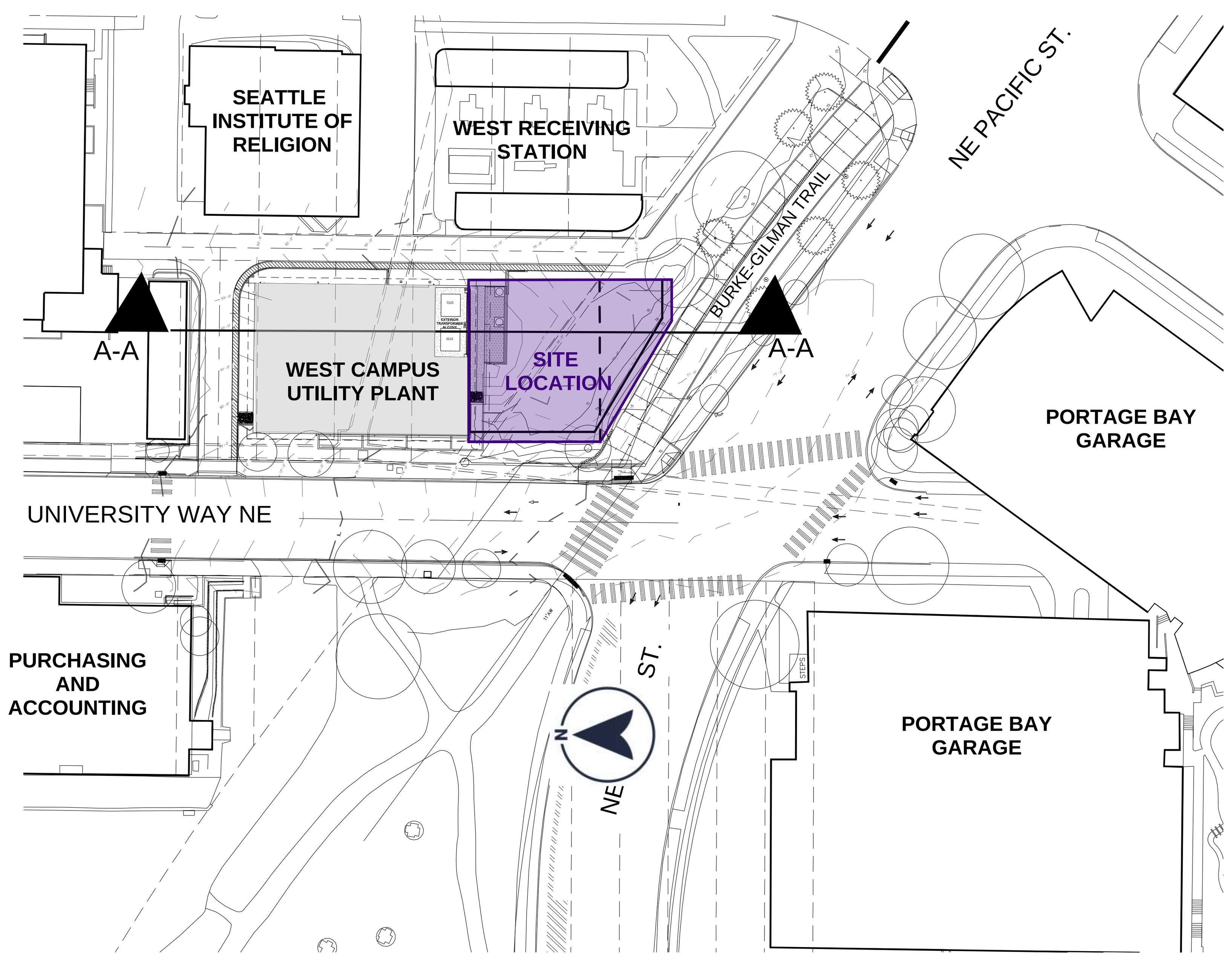
Option 1
This option maximizes the space for the building at ground level and provides a façade that follows the angle of the street and trail with some upper story setbacks. This will require moving the electrical duct bank lines and encroach on some of the Burke-Gilman property, but it will not displace the trail. The drawback is the lack of amenity space on the ground and the scale of the façade so close to the trail appears feels overwhelming from the perspective of people on the trail.

Option 2
This option is essentially the same as option 1, except that the upper stories are not setbacks. Like option 2 there is a lack of amenity space on the ground, but it does allow for some

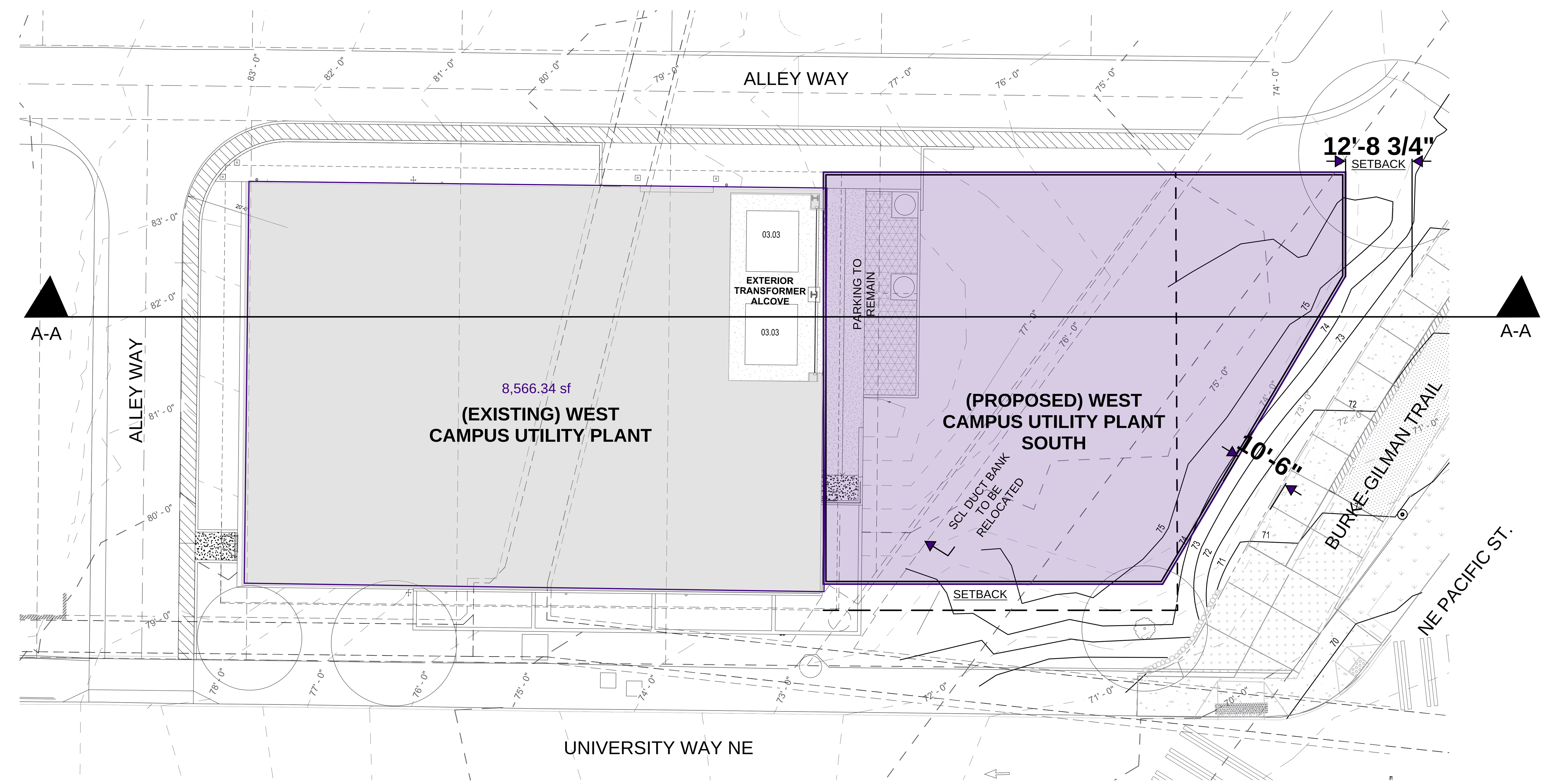
additional space within the building at the upper stories. Again, the scale of the façade so close to the trail appears feels overwhelming from the perspective of people on the trail.

Option 3

This option will require moving the electrical duct bank lines and encroach on some of the Burke-Gilman property, but it will not displace the trail. This option provides a stepped shape in plan to provide more amenity space around the trail and to break up the façade of the building. This option is more optimal from the perspective of the trail but makes sacrifices to an already tight mechanical space on the ground floor.



VICINITY SITE PLAN
SCALE: 1/64" = 1'-0"



SITE PLAN
SCALE: 1/16" = 1'-0"

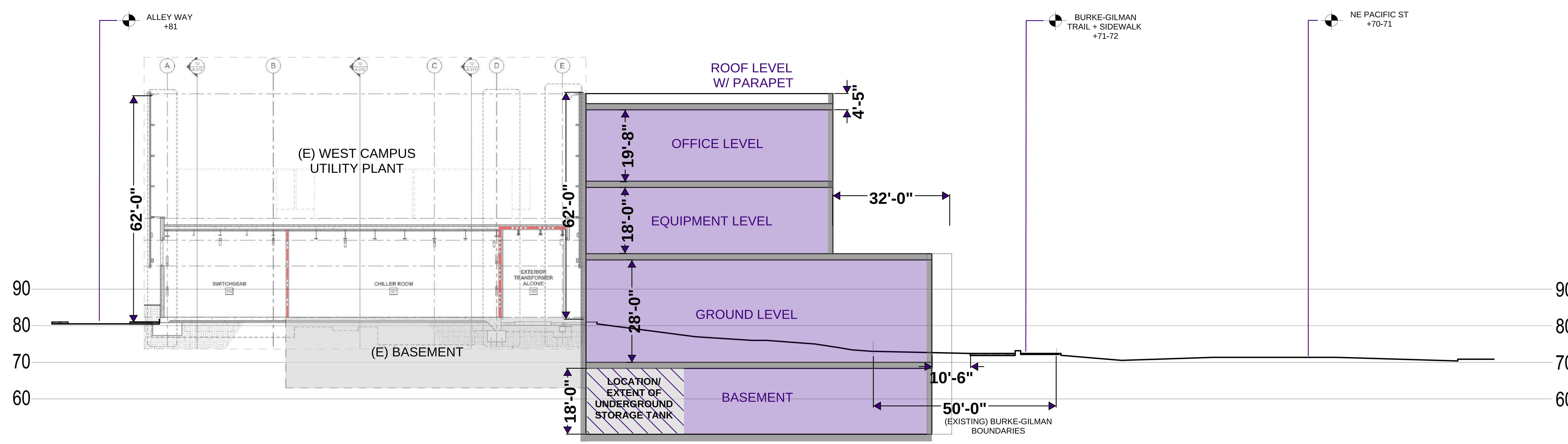
DRAWING REFERENCE ALL WCUP SHEETS:

BACKGROUNDS/ TOPOGRAPH LINES:
W27-SP+GD DWG.
2024-04-07 W27 DR16 GRADING PAVING PLAN

EXISTING WCUP:
SHEET A-212 WCUP BUILDING SECTION

FLOOR PLAN:
GENERATED/PROVIDED BY AEI

RENDERINGS PROGRAMS:
SKETCHUP / ENSCAPE



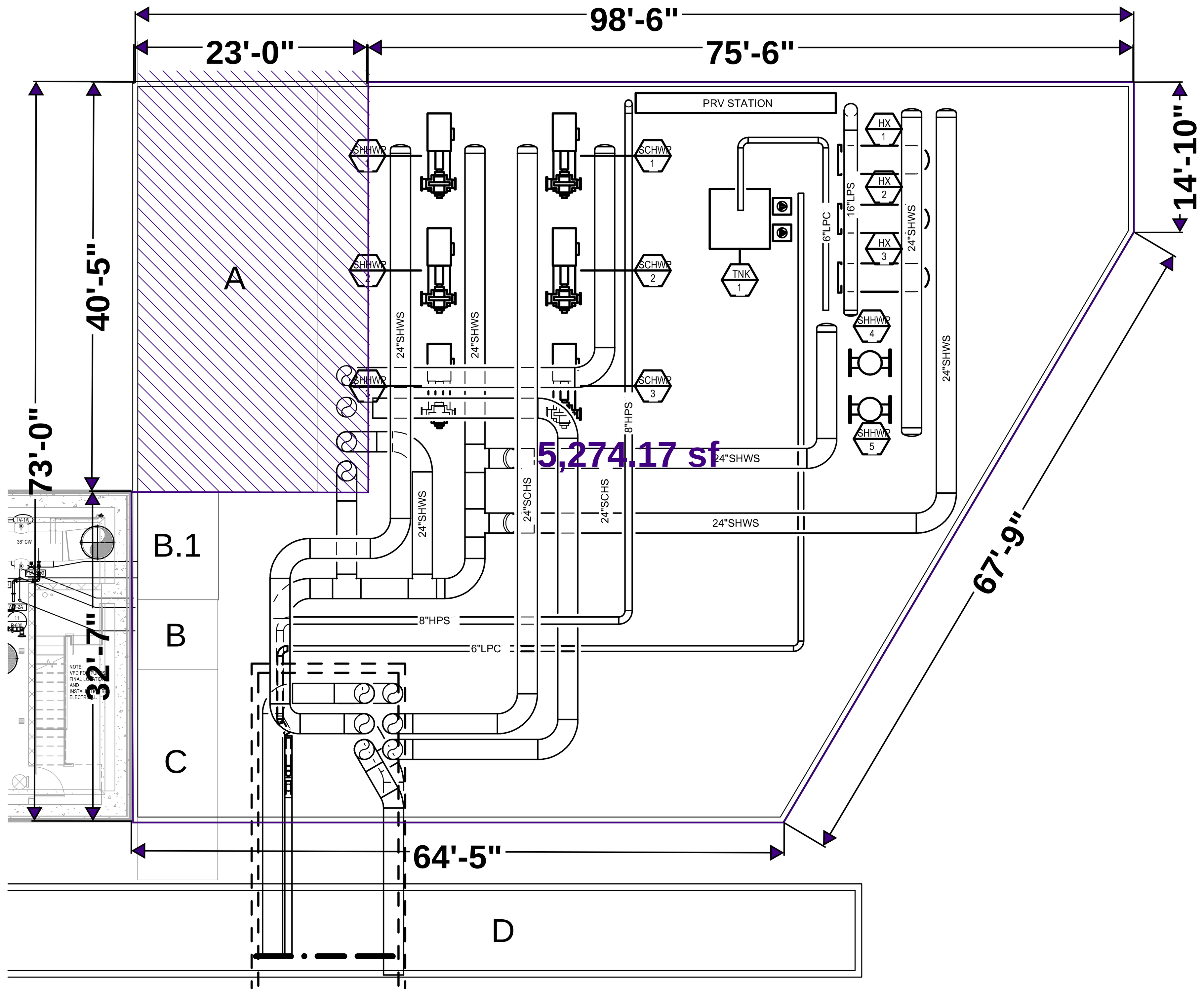
SITE SECTION A-A
SCALE: 1/16" = 1'-0"

WEST CAMPUS UTILITY PLANT:
SITE PLAN OPTION 1

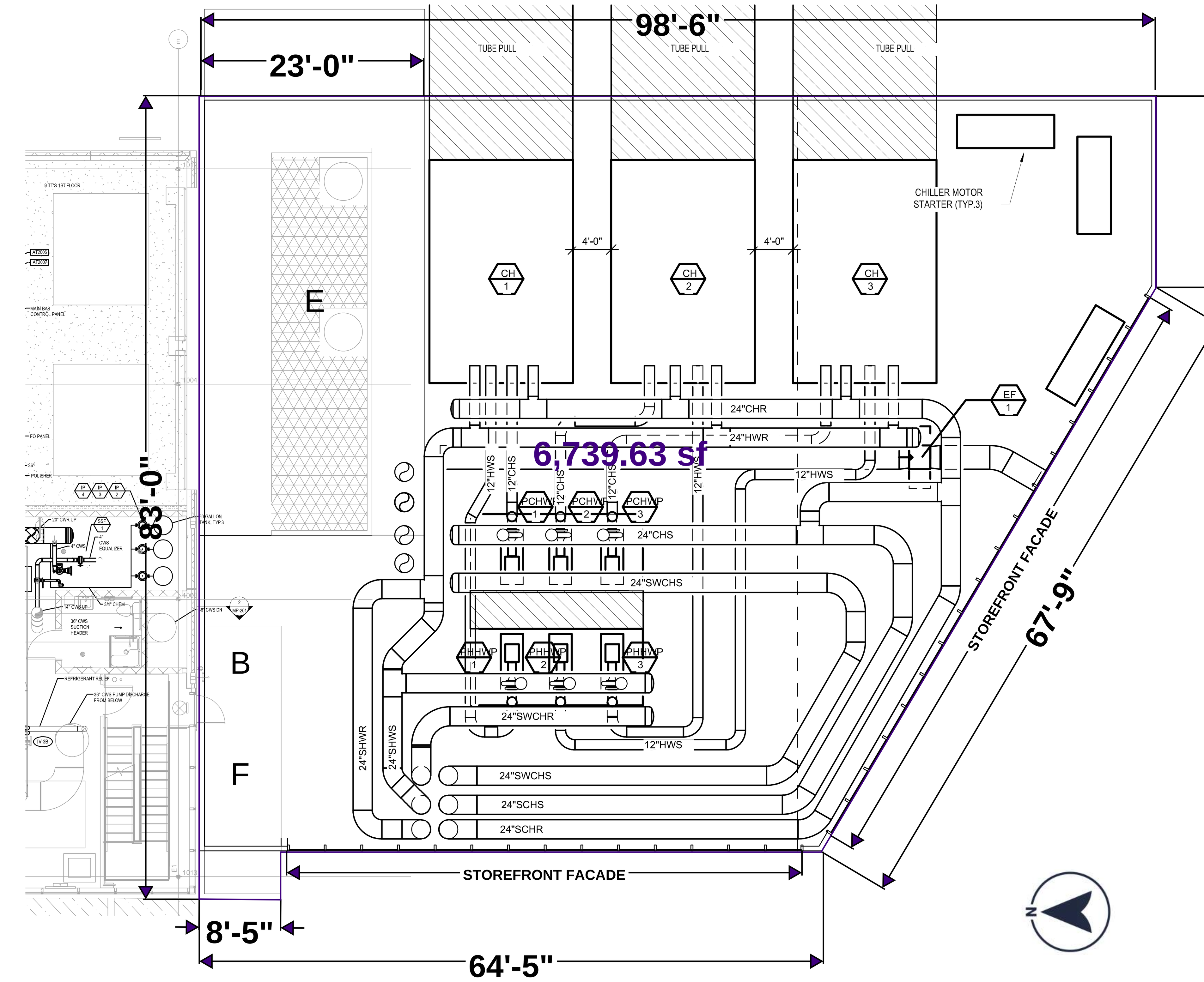
UNIVERSITY of WASHINGTON
ENERGY RENEWAL PROJECT

rolludaarchitects
architecture planning interior design

AEI Affiliated Engineers



BASEMENT LEVEL
SCALE: 3/32" = 1'-0"



GROUND LEVEL
SCALE: 3/32" = 1'-0"

PROPOSED SITE PROGRAMMING

A: EXISTING FUEL TANK STORAGE TO REMAIN

B: ELEVATOR
B1: ELEVATOR MACHINE ROOM

C: MAIN STAIRWELL

D: UNDERGROUND TUNNEL

E: EXISTING FUEL TANK PARKING TO REMAIN

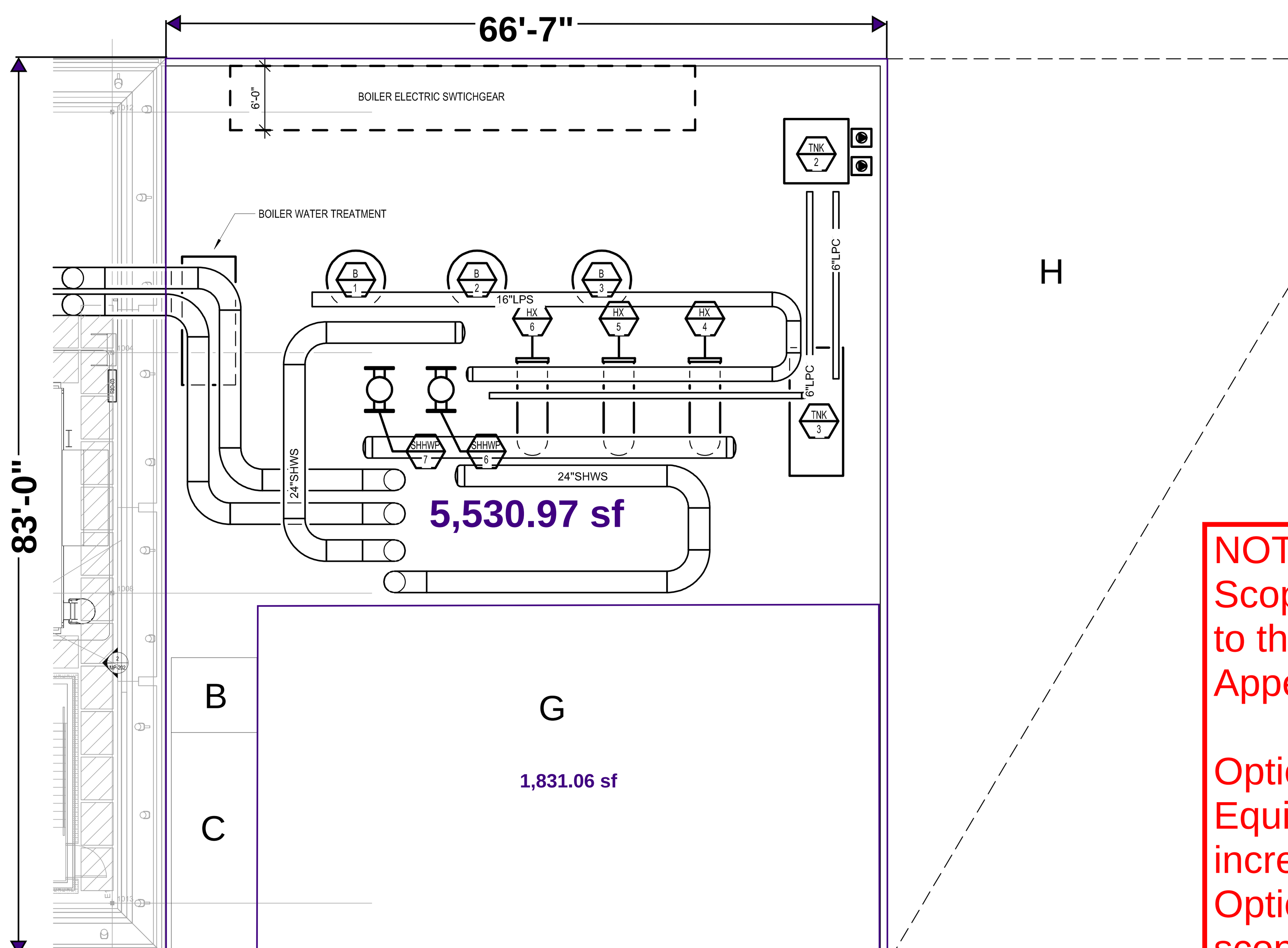
F: MAIN STAIRWELL/ ENTRANCE LOBBY

G: ELECTRICAL ROOM

H: EXTERIOR AREA

I: OFFICE WITH EXTRA SPACE FOR FUTURE GROWTH

J: ROOFTOP UNIT



EQUIPMENT LEVEL
SCALE: 3/32" = 1'-0"

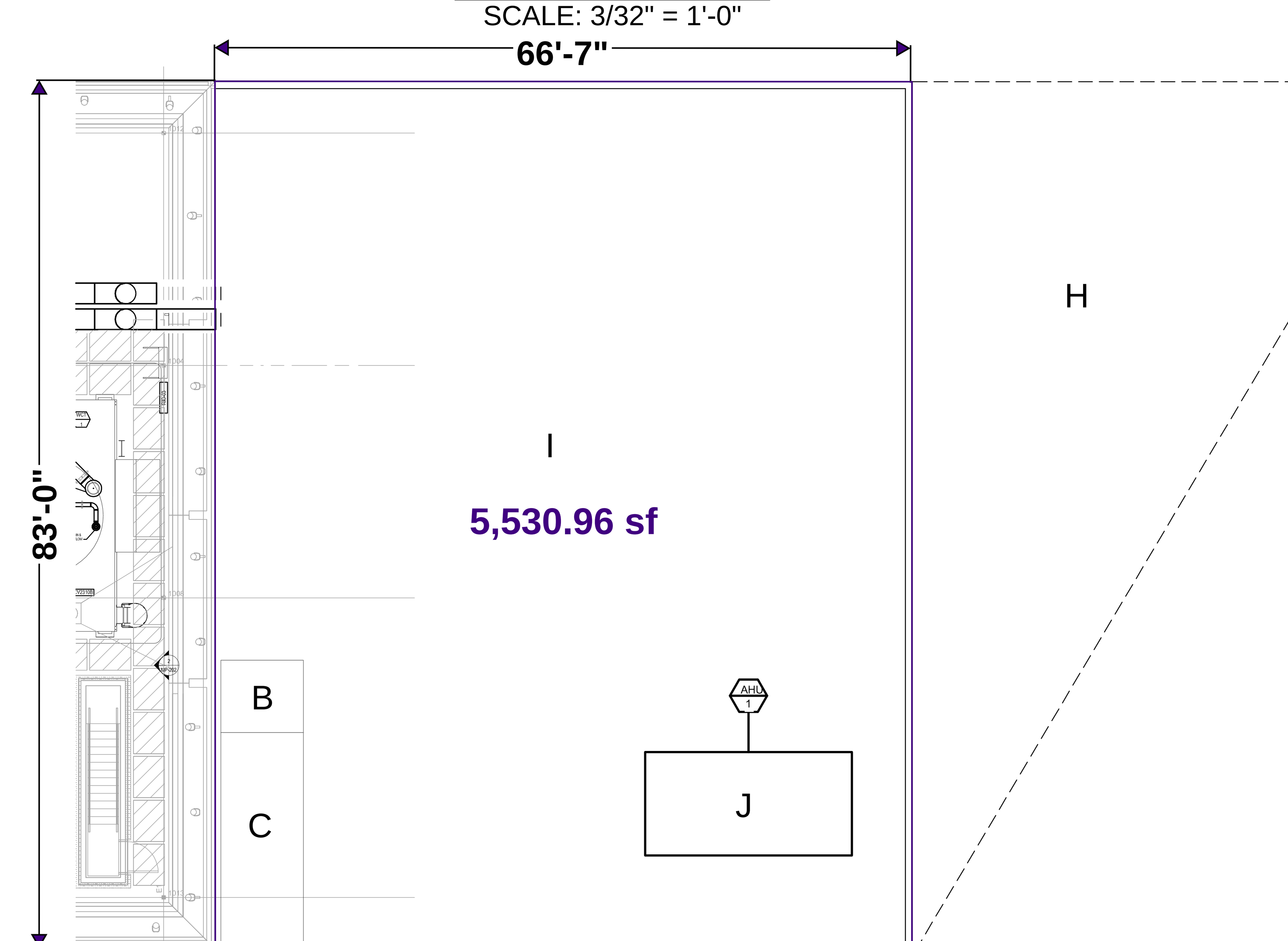
SQUARE FOOTAGE

BASEMENT LEVEL: **5,214 SQFT**
GROUND LEVEL: **6,739 SQFT**
EQUIPMENT LEVEL: **5,530 SQFT**
OFFICE LEVEL: **5,530 SQFT**

TOTAL SQUARE FOOTAGE OF BUILDING: 23,013 SQFT

NOTE: Refer to Appendix 9.13.2 for WCUP Scope of Work drawings which include revisions to the layouts of the floor plates shown in Appendix 9.7.

Option 1 will require additional floor area on the Equipment and Office levels to accommodate increased electrical room capacity. Refer to Option 2 for the new electrical room size. Final scope for WCUP Expansion will be between Options 1 & 2. Option 3 is unlikely to satisfy electrical requirements.



OFFICE LEVEL/ ROOF LEVEL
SCALE: 3/32" = 1'-0"

WEST CAMPUS UTILITY PLANT: FLOOR PLANS OPTION 1

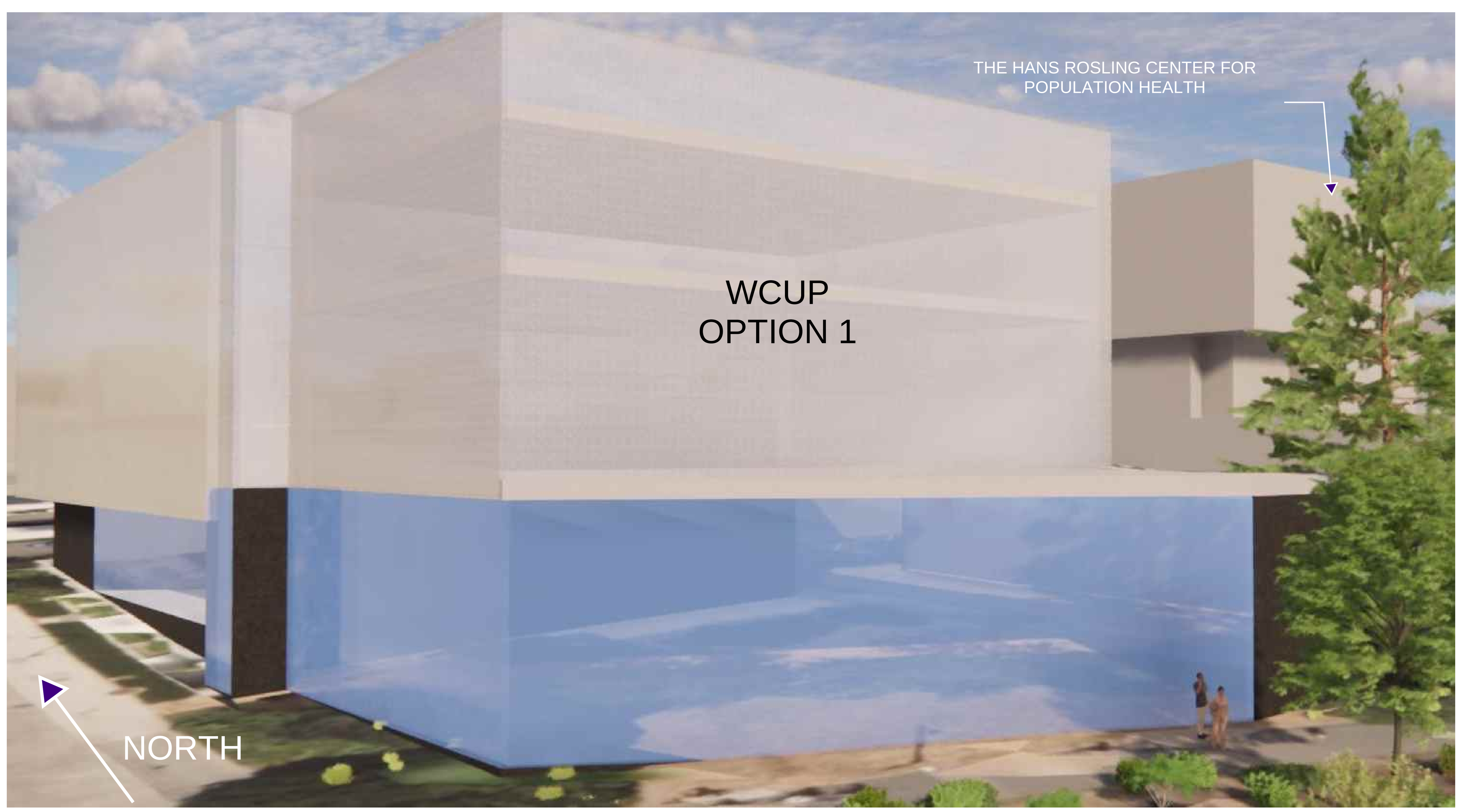
UNIVERSITY of WASHINGTON
ENERGY RENEWAL PROJECT

rolluda architects
architecture planning interior design

AEI Affiliated Engineers

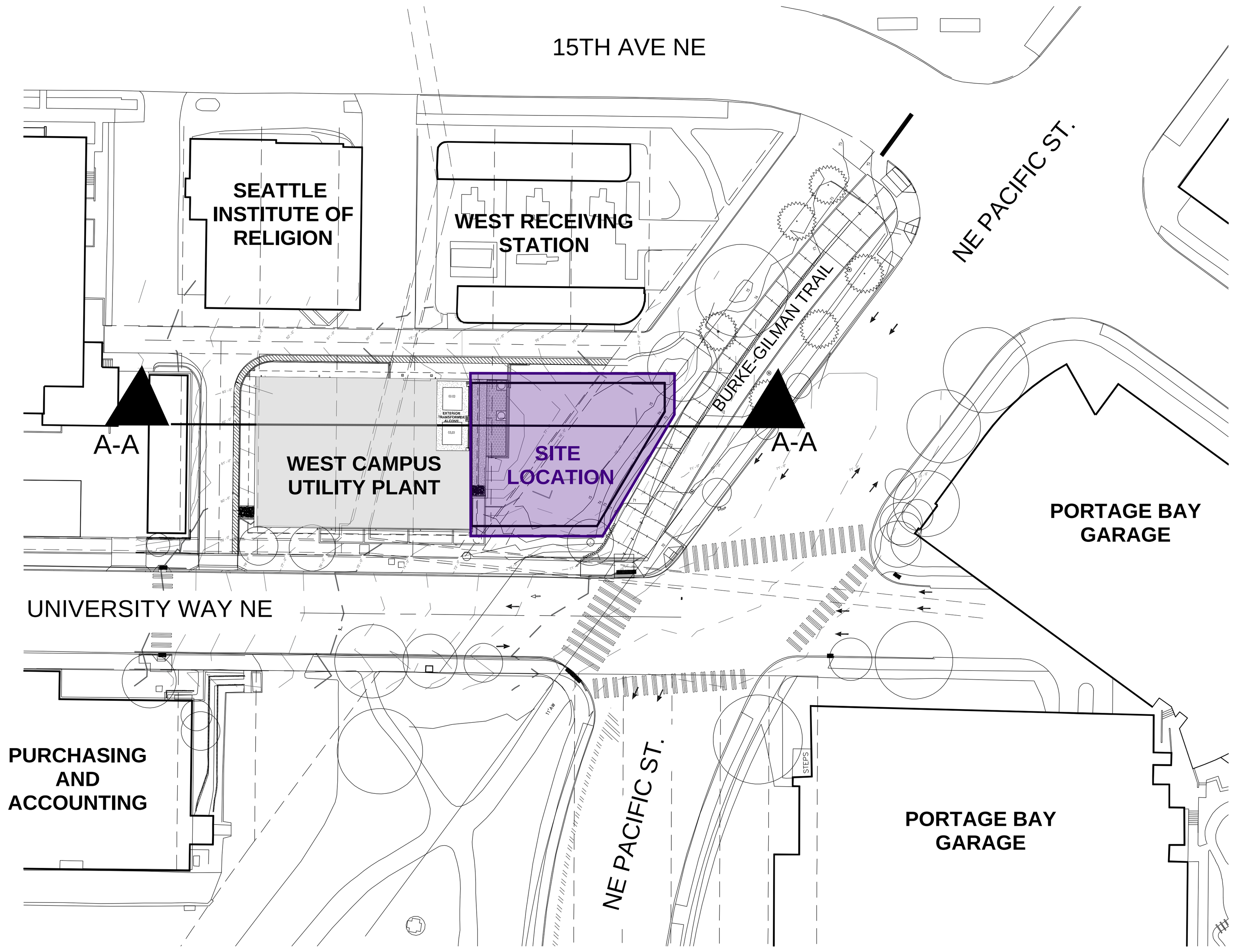
VIEW FROM WEST SIDE OF PACIFIC ST.

VIEW FROM BURKE-GILMAN TRAIL LOOKING WEST

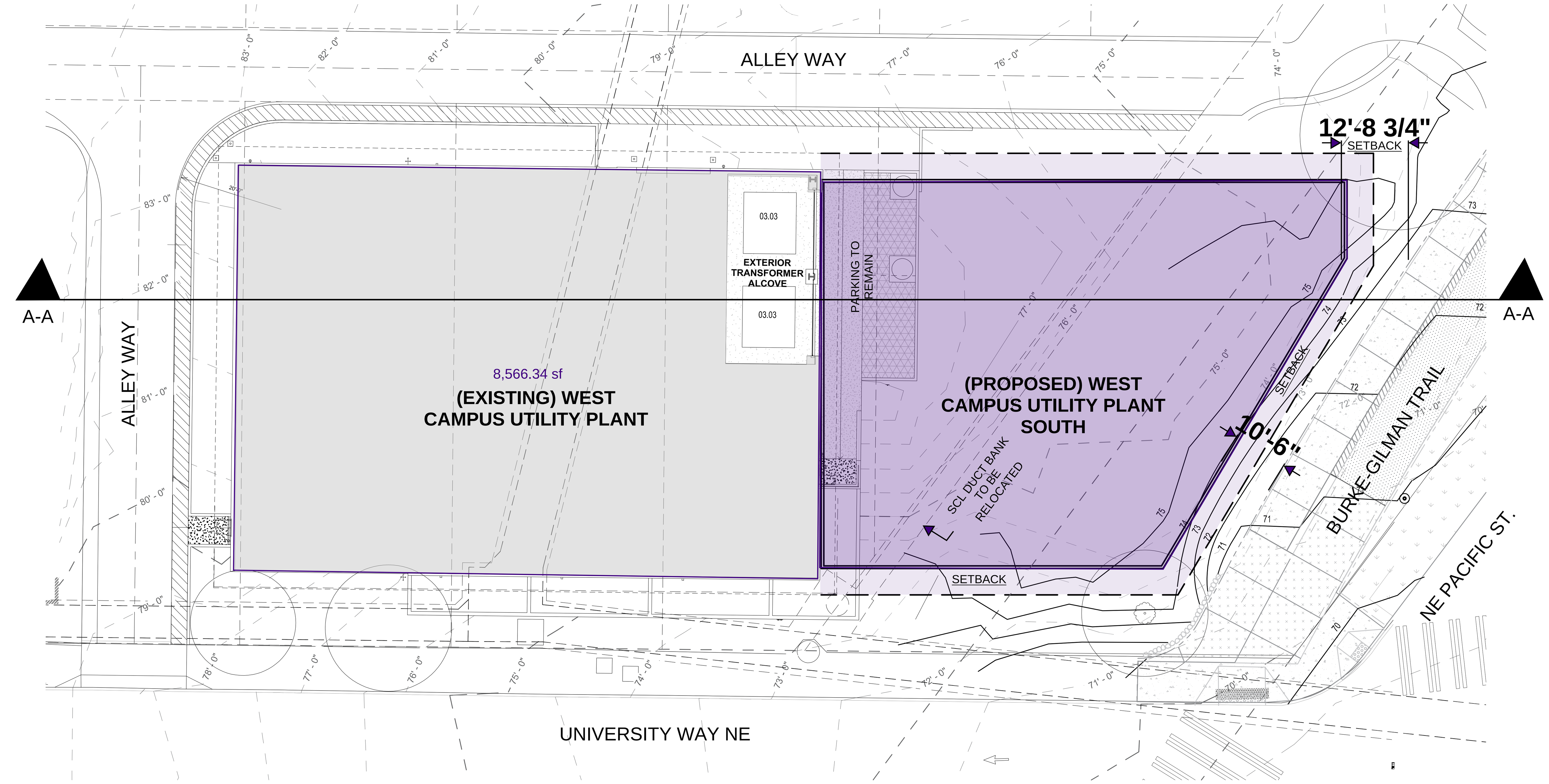


ARIEL VIEW FROM SOUTH SIDE OF PACIFIC ST.

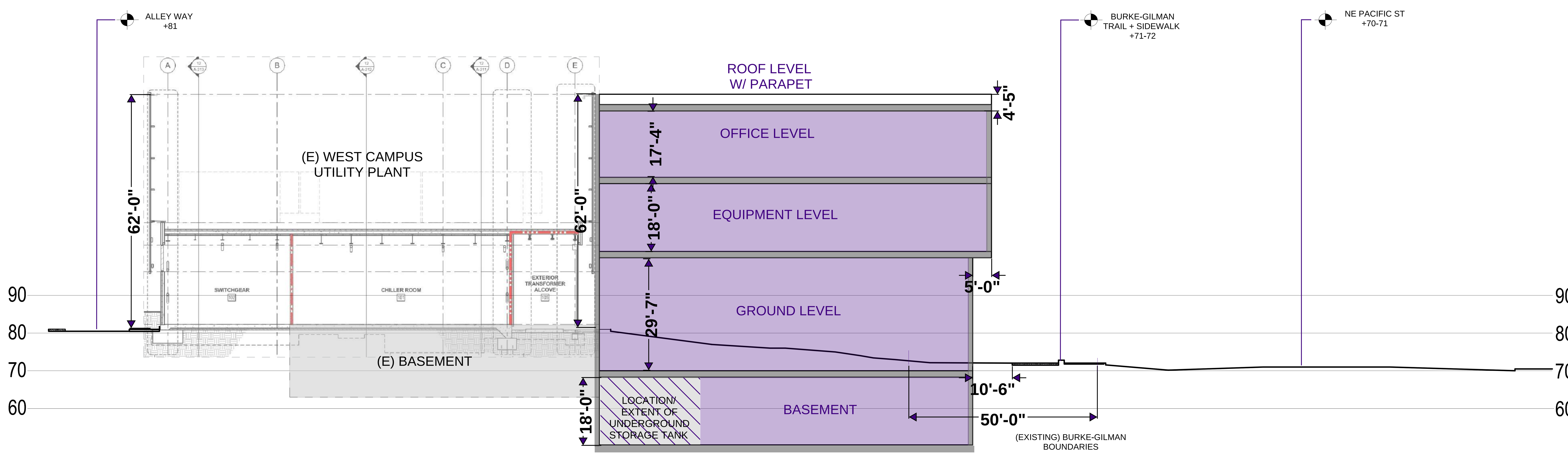
VIEW FROM WEST SIDE OF 15 AVE NE



VICINITY SITE PLAN
SCALE: 1/64" = 1'-0"



SITE PLAN
SCALE: 1/16" = 1'-0"



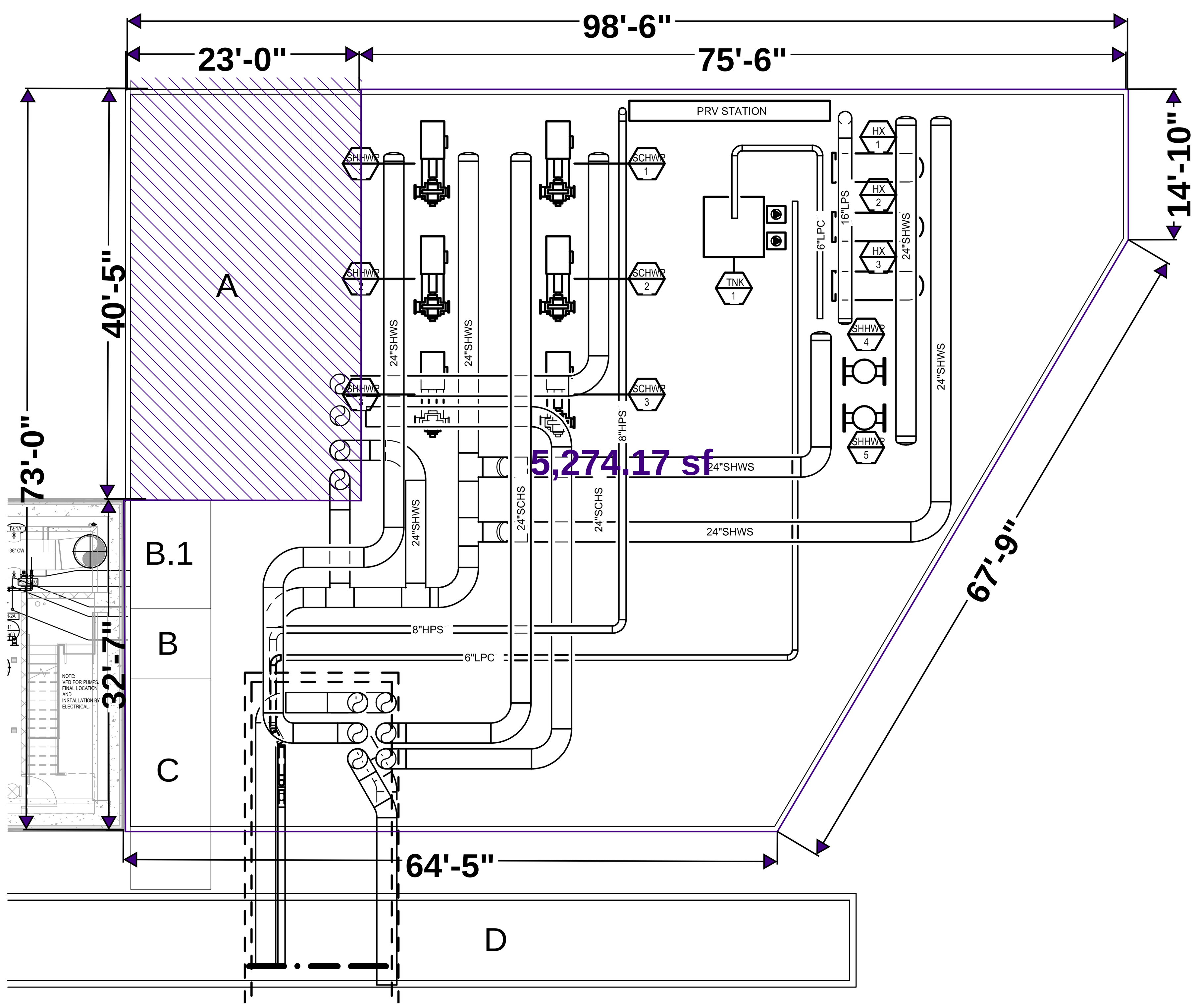
SITE SECTION A-A
SCALE: 1/16" = 1'-0"

WEST CAMPUS UTILITY PLANT:
SITE PLAN OPTION 2

UNIVERSITY of WASHINGTON
ENERGY RENEWAL PROJECT

rolluda architects
architecture planning interior design

Affiliated Engineers



BASEMENT LEVEL
SCALE: 3/32" = 1'-0"

PROPOSED SITE PROGRAMMING

A: EXISTING FUEL TANK STORAGE TO REMAIN

B: ELEVATOR
B1: ELEVATOR MACHINE ROOM

C: MAIN STAIRWELL

D: UNDERGROUND TUNNEL

E: EXISTING FUEL TANK PARKING TO REMAIN

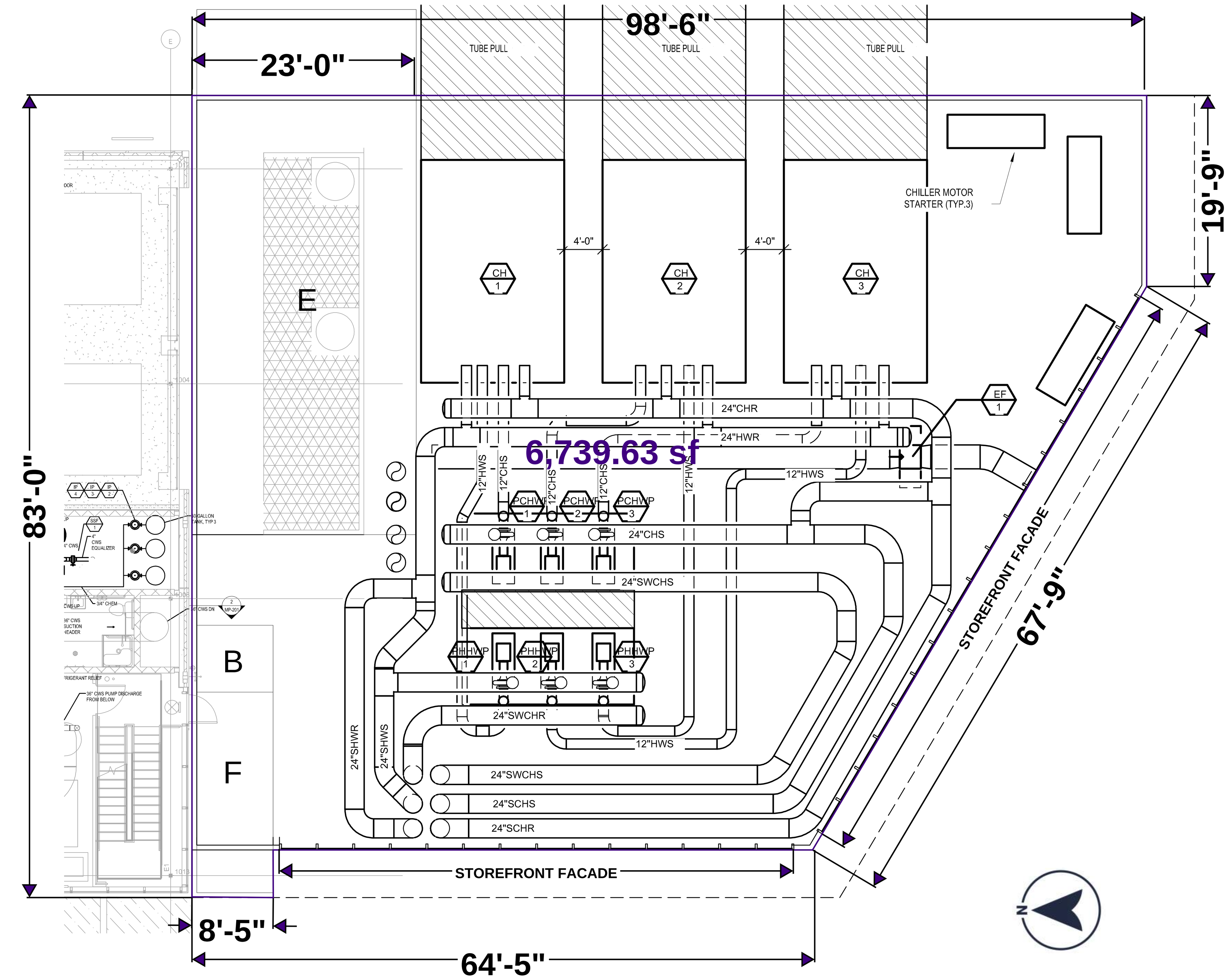
F: MAIN STAIRWELL/ ENTRANCE LOBBY

G: OPERATIONS CENTER

H: EXTRA SPACE FOR FUTURE GROWTH

I: OFFICE WITH EXTRA SPACE FOR FUTURE GROWTH

J: ROOFTOP UNIT

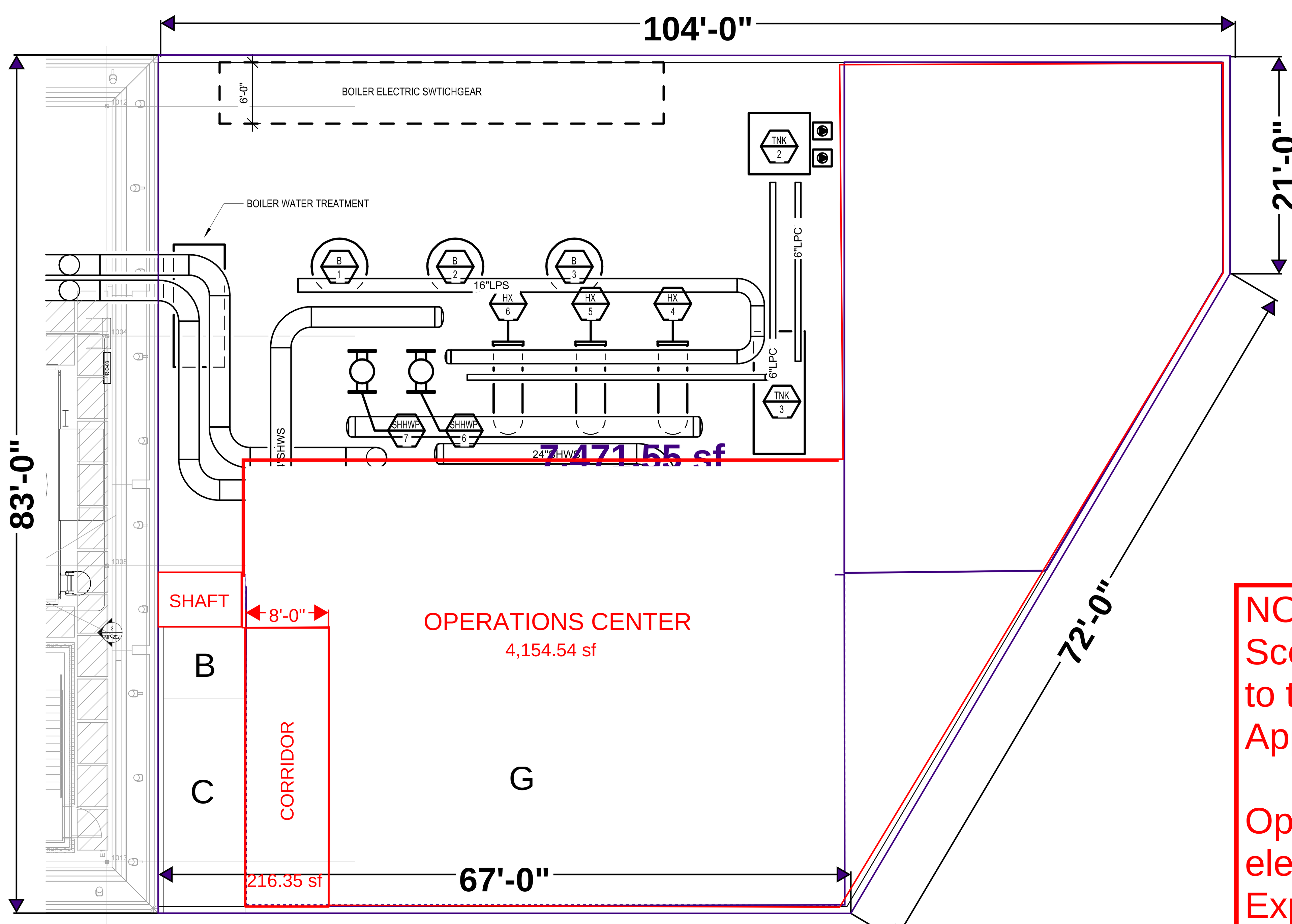


GROUND LEVEL
SCALE: 3/32" = 1'-0"

SQUARE FOOTAGE

BASEMENT LEVEL: **5,214 SQFT**
GROUND LEVEL: **6,739 SQFT**
EQUIPMENT LEVEL: **7,471 SQFT**
ELECTRICAL/OPS LEVEL: **7,471 SQFT**

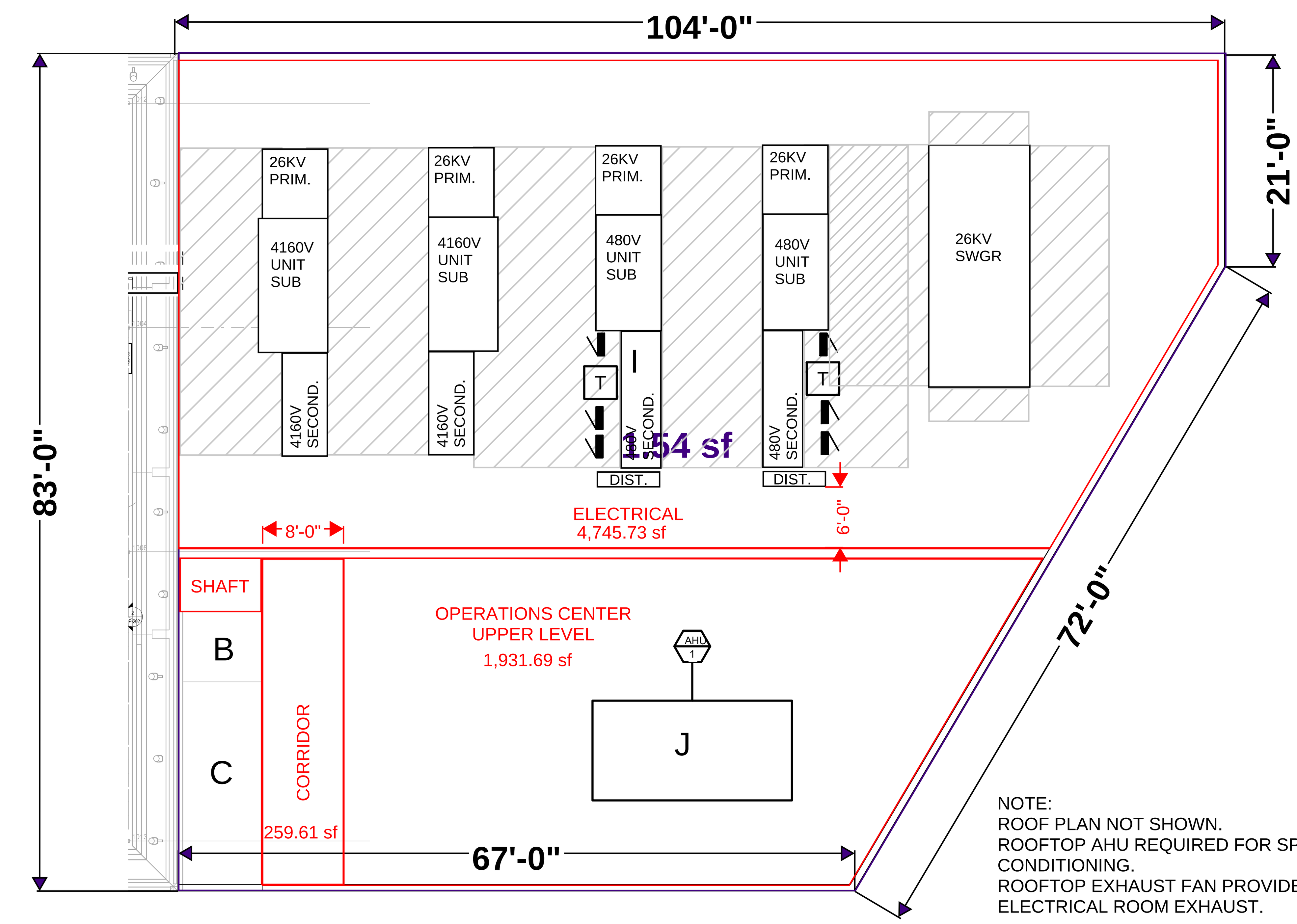
TOTAL SQUARE FOOTAGE OF BUILDING: **26,895 SQFT**



EQUIPMENT LEVEL
SCALE: 3/32" = 1'-0"

NOTE: Refer to Appendix 9.13.2 for WCUP Scope of Work drawings which include revisions to the layouts of the floor plates shown in Appendix 9.7.

Option 2 has been adjusted for the new electrical room size. Final scope for WCUP Expansion will be between Options 1 & 2. Option 3 is unlikely to satisfy electrical requirements.



NOTE:
ROOF PLAN NOT SHOWN.
ROOFTOP AHU REQUIRED FOR SPACE CONDITIONING.
ROOFTOP EXHAUST FAN PROVIDED FOR ELECTRICAL ROOM EXHAUST.

ELECTRICAL / OPS LEVEL & ROOF LEVEL
SCALE: 3/32" = 1'-0"

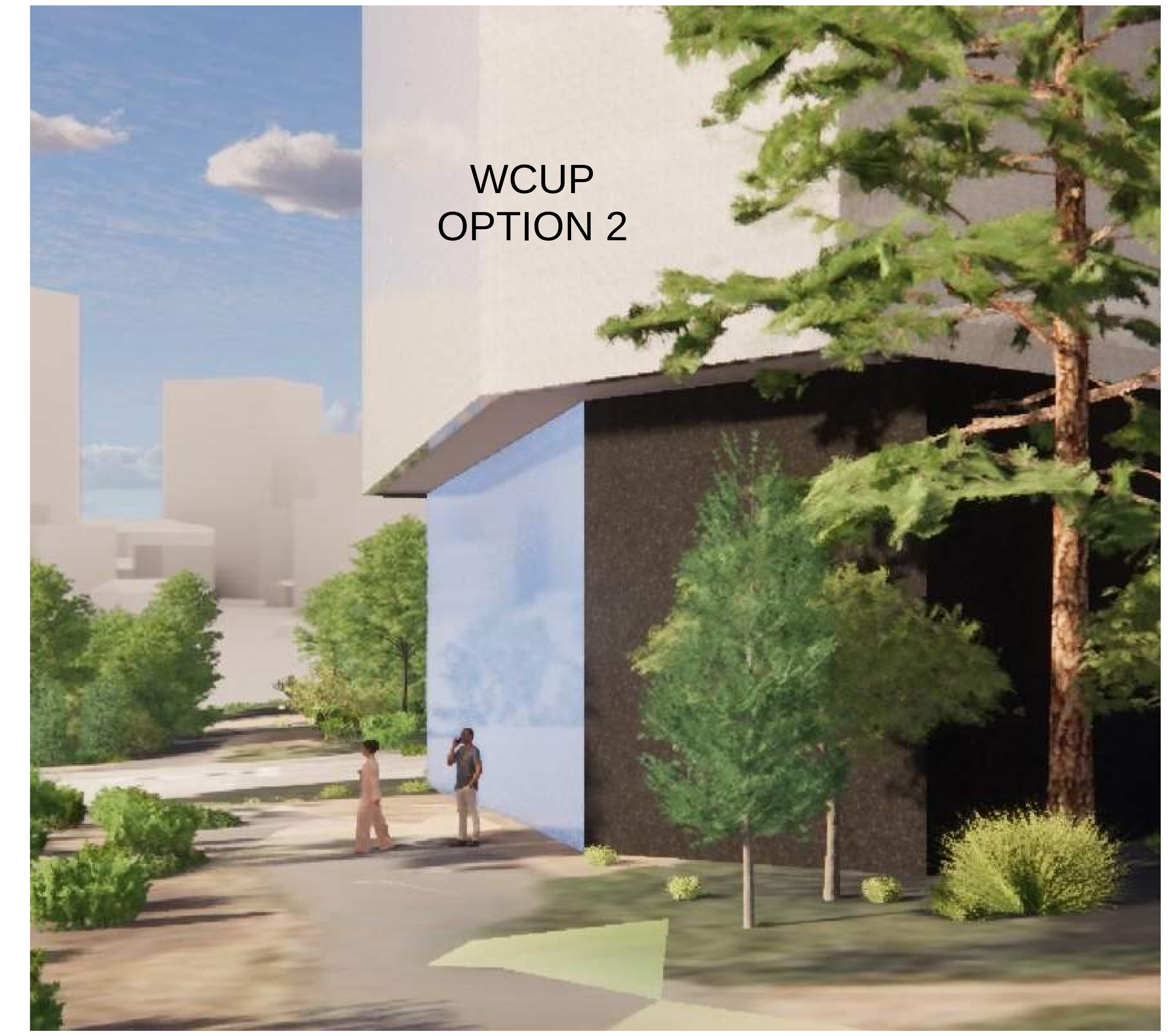
WEST CAMPUS UTILITY PLANT:
FLOOR PLANS OPTION 2

UNIVERSITY of WASHINGTON
ENERGY RENEWAL PROJECT

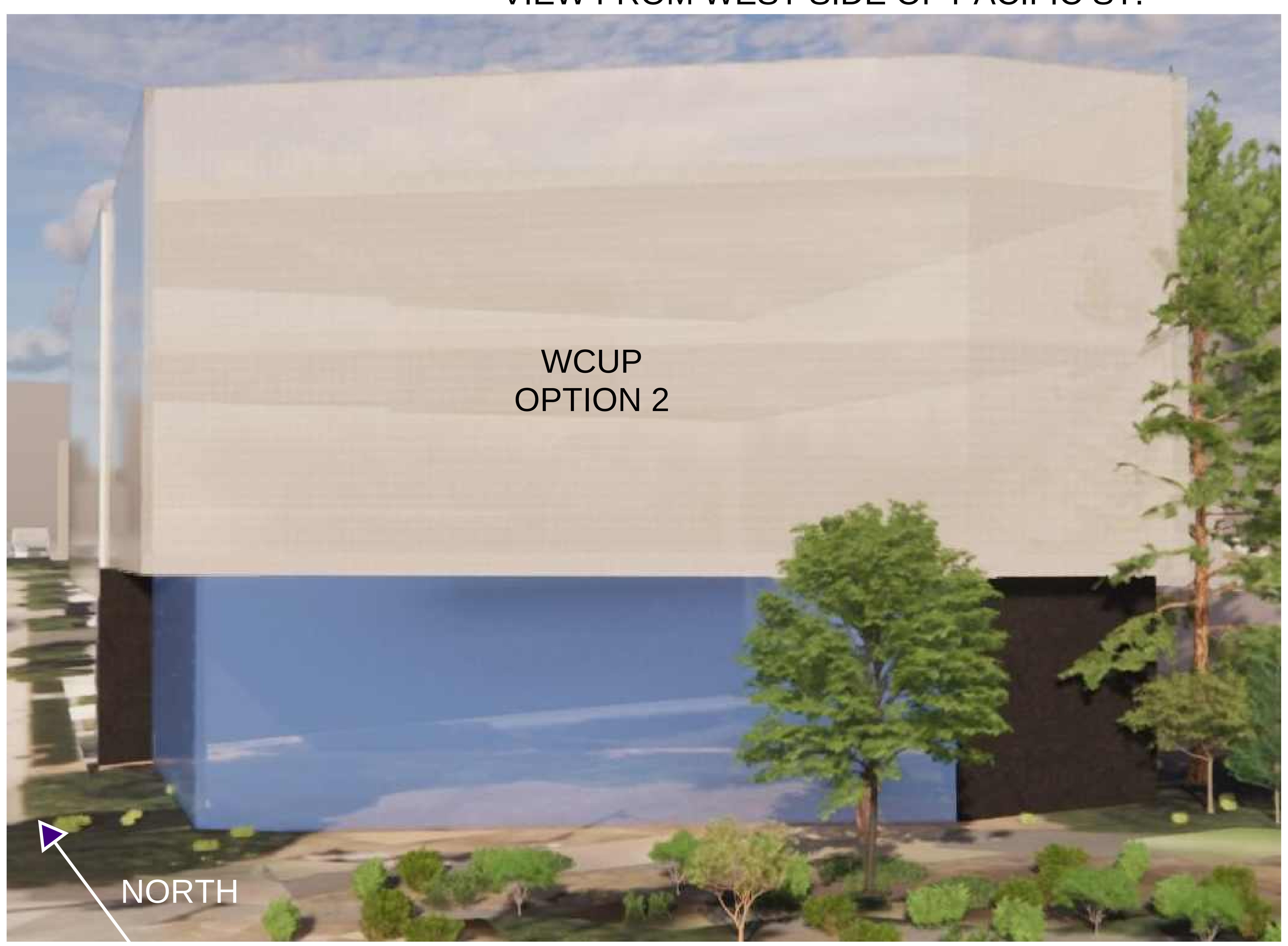
rolluda architects
architecture planning interior design

AEI Affiliated Engineers

VIEW FROM WEST SIDE OF PACIFIC ST.

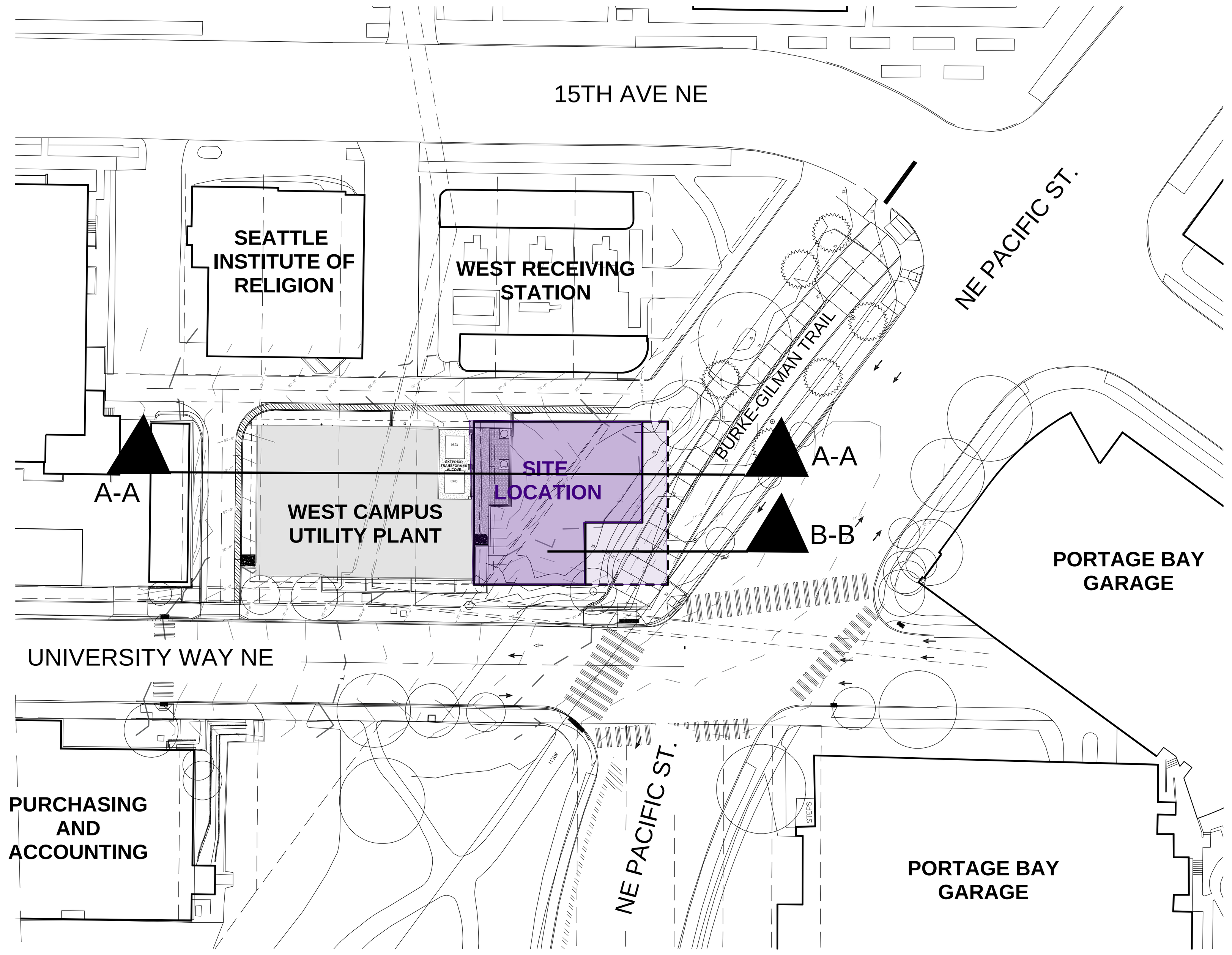


VIEW FROM BURKE-GILMAN TRAIL LOOKING WEST



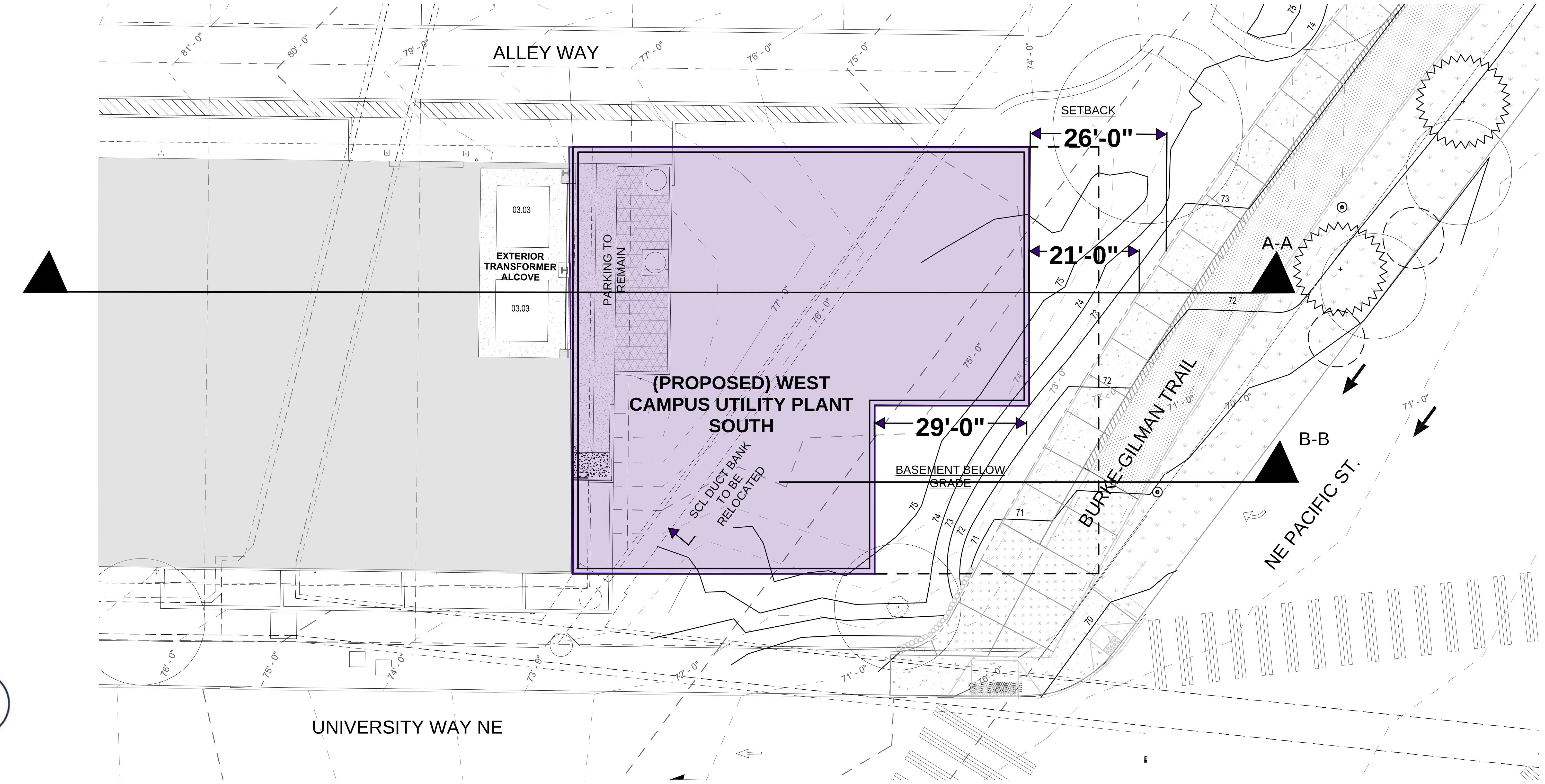
ARIEL VIEW FROM SOUTH SIDE OF PACIFIC ST.

VIEW FROM WEST SIDE OF 15 AVE NE



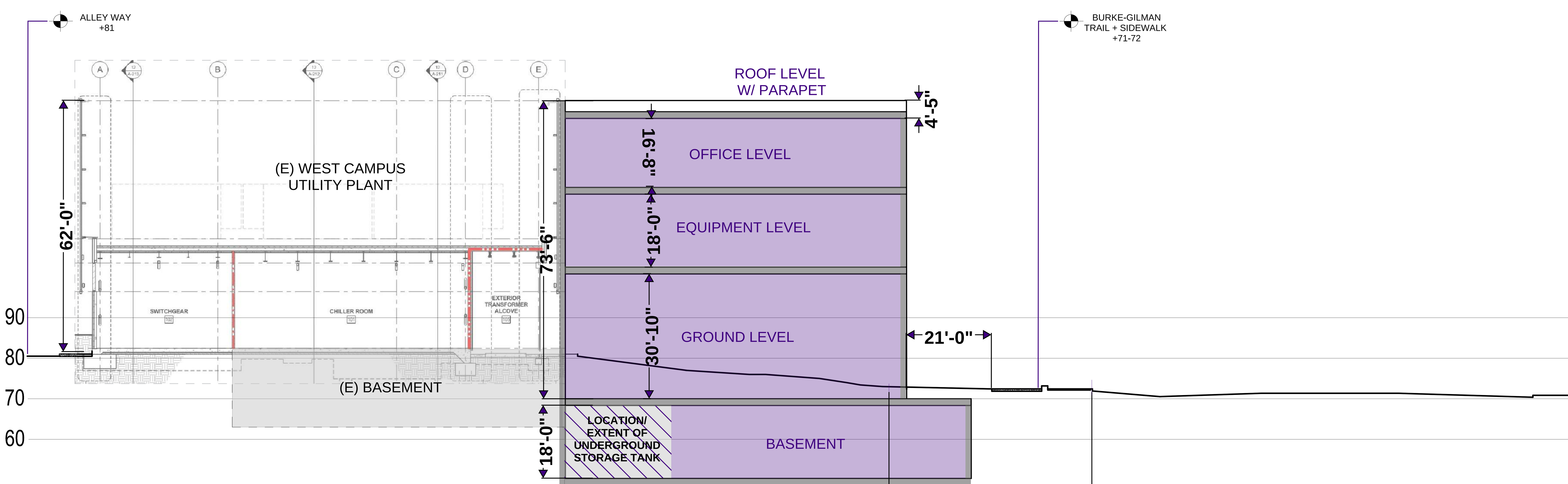
VICINITY SITE PLAN

SCALE: 1/64" = 1'-0"



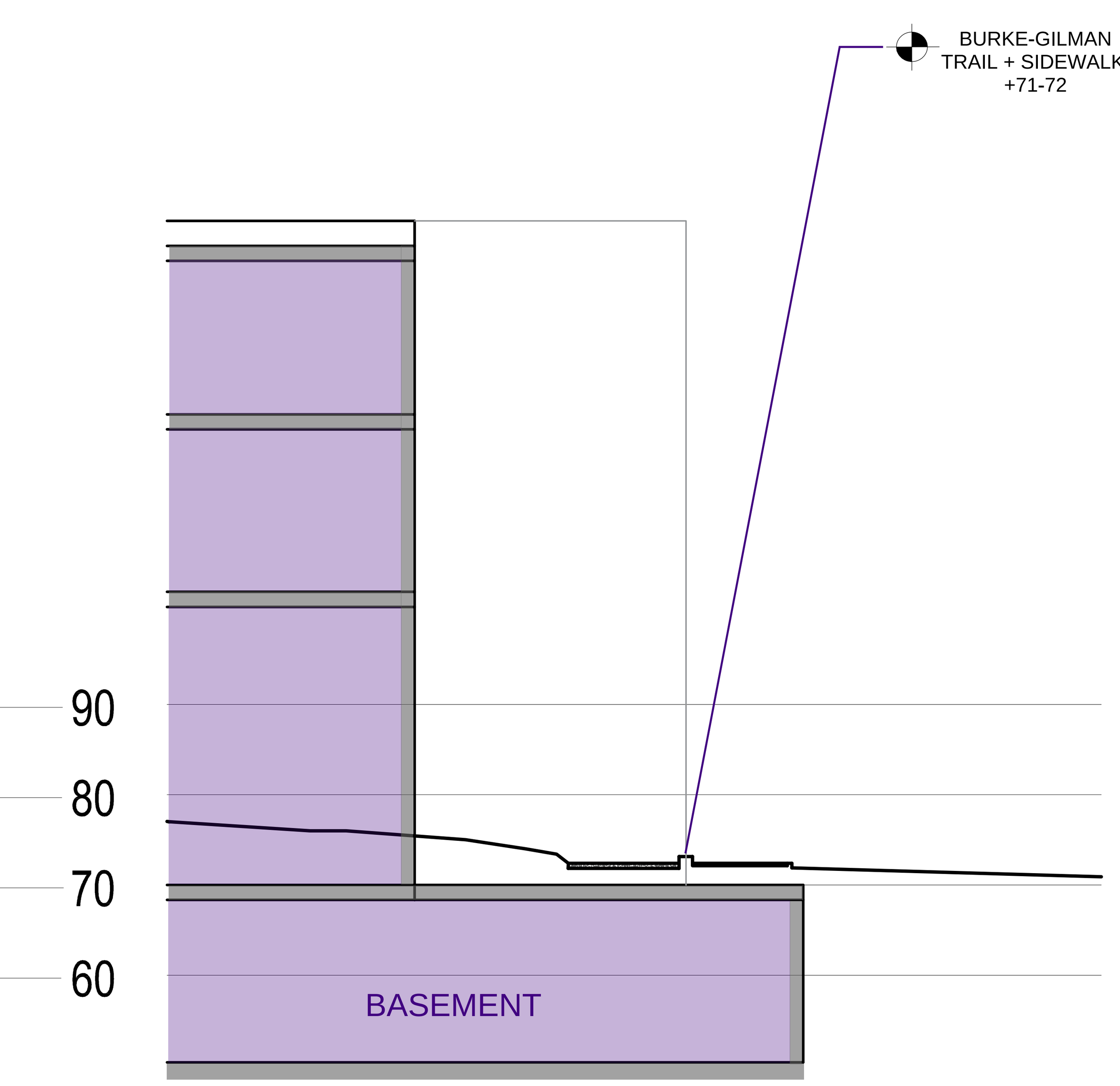
SITE PLAN

SCALE: 1/16" = 1'-0"



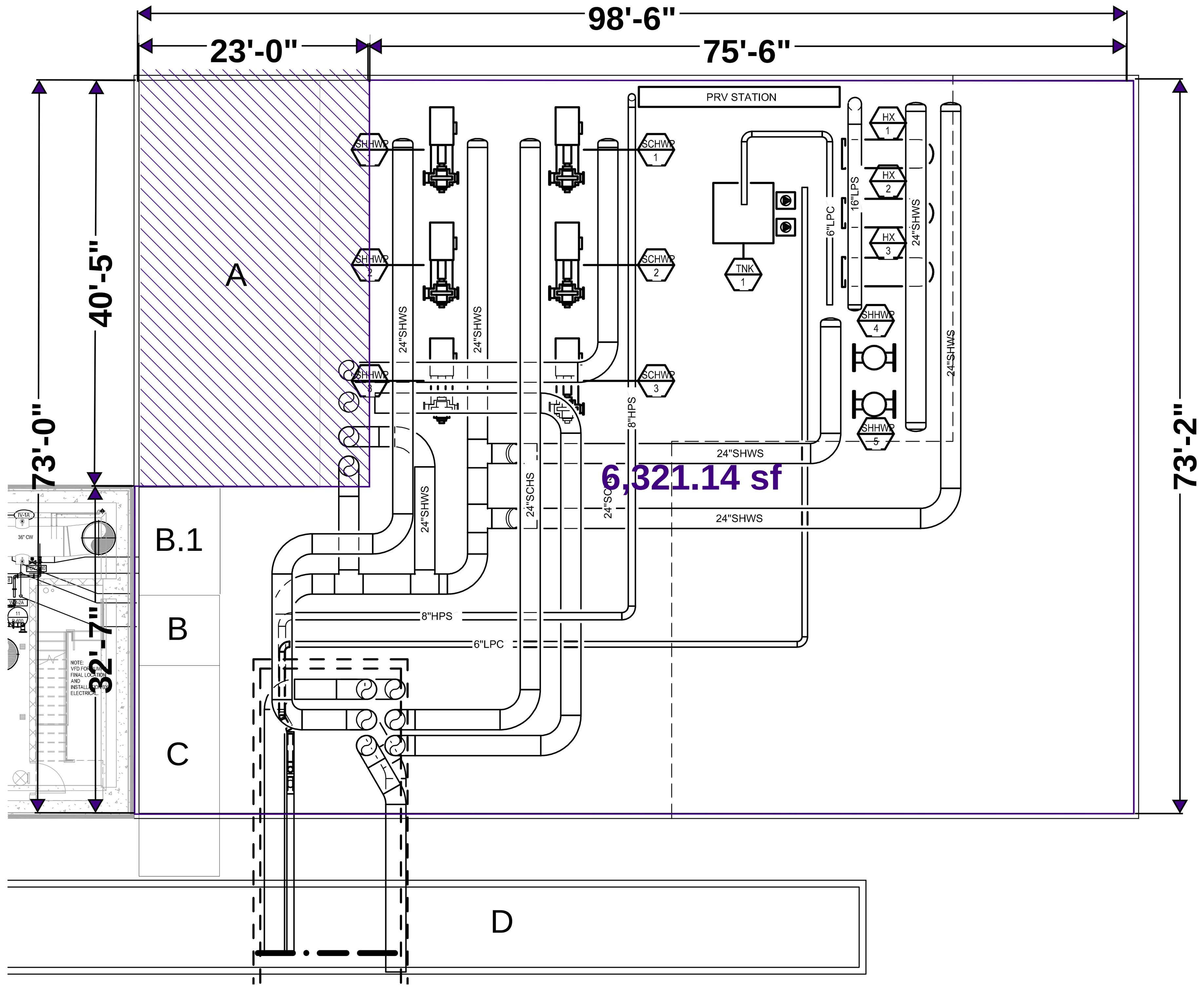
SITE SECTION A-A

SCALE: 1/16" = 1'-0"



SITE SECTION B-B

SCALE: 1/16" = 1'-0"



BASEMENT LEVEL
SCALE: 3/32" = 1'-0"

PROPOSED SITE PROGRAMMING

A: EXISTING FUEL TANK STORAGE TO REMAIN

B: ELEVATOR
B1: ELEVATOR MACHINE ROOM

C: MAIN STAIRWELL

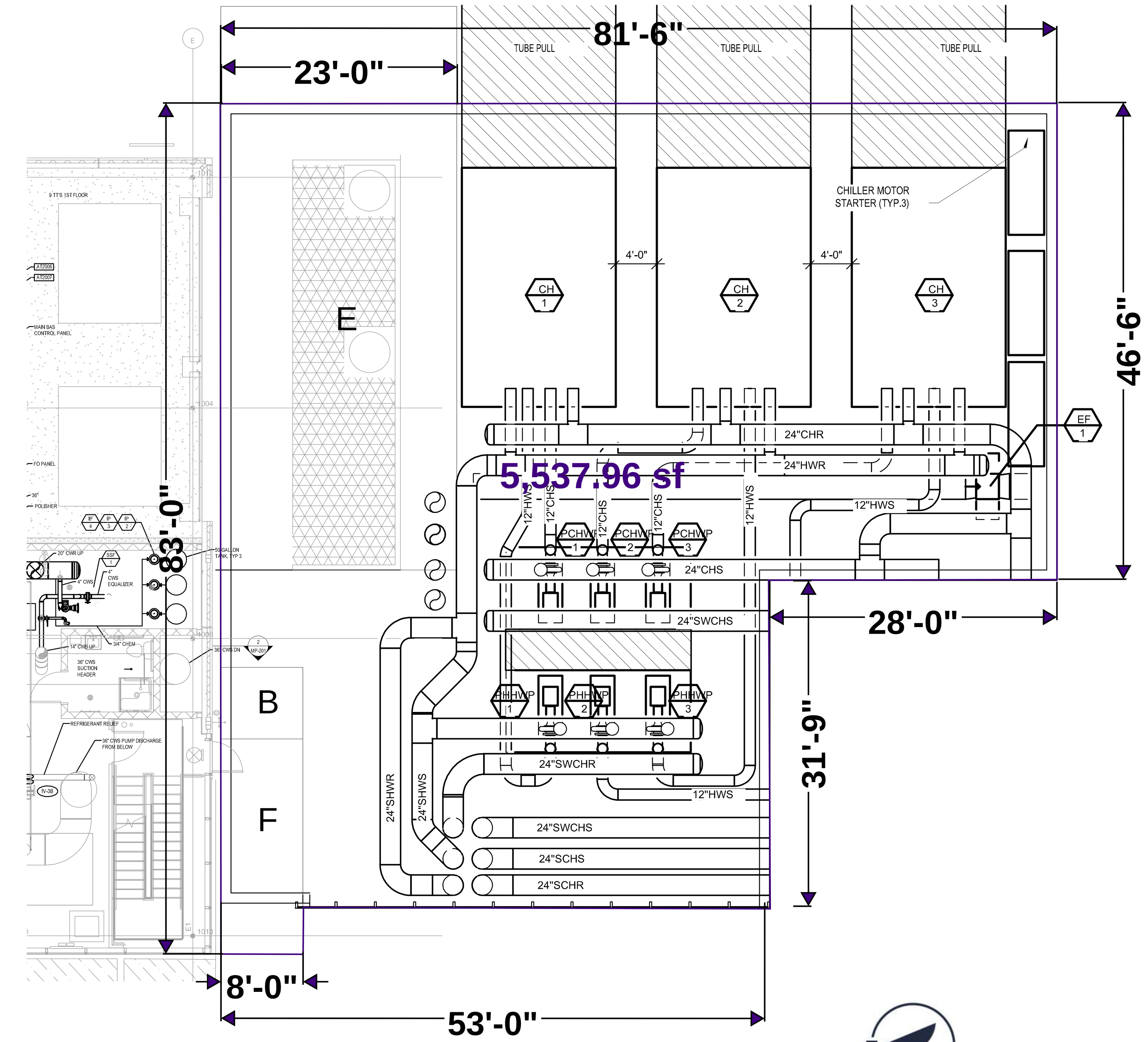
D: UNDERGROUND TUNNEL

E: EXISTING FUEL TANK PARKING TO REMAIN

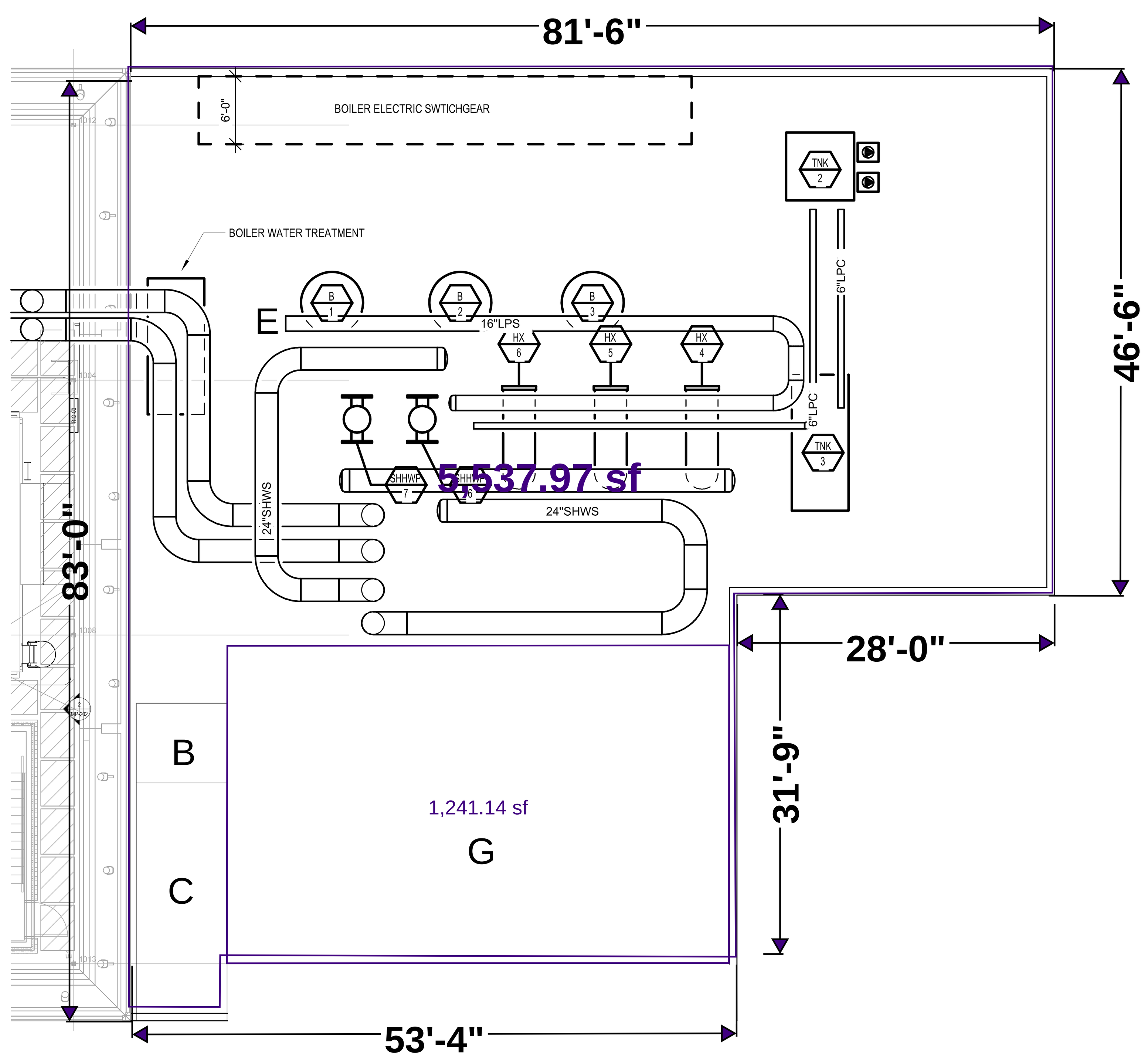
F: MAIN STAIRWELL/ ENTRANCE LOBBY

G: ELECTRICAL ROOM

H: OFFICE AREA/ SHOP/ STORAGE



GROUND LEVEL
SCALE: 3/32" = 1'-0"



EQUIPMENT LEVEL
SCALE: 3/32" = 1'-0"

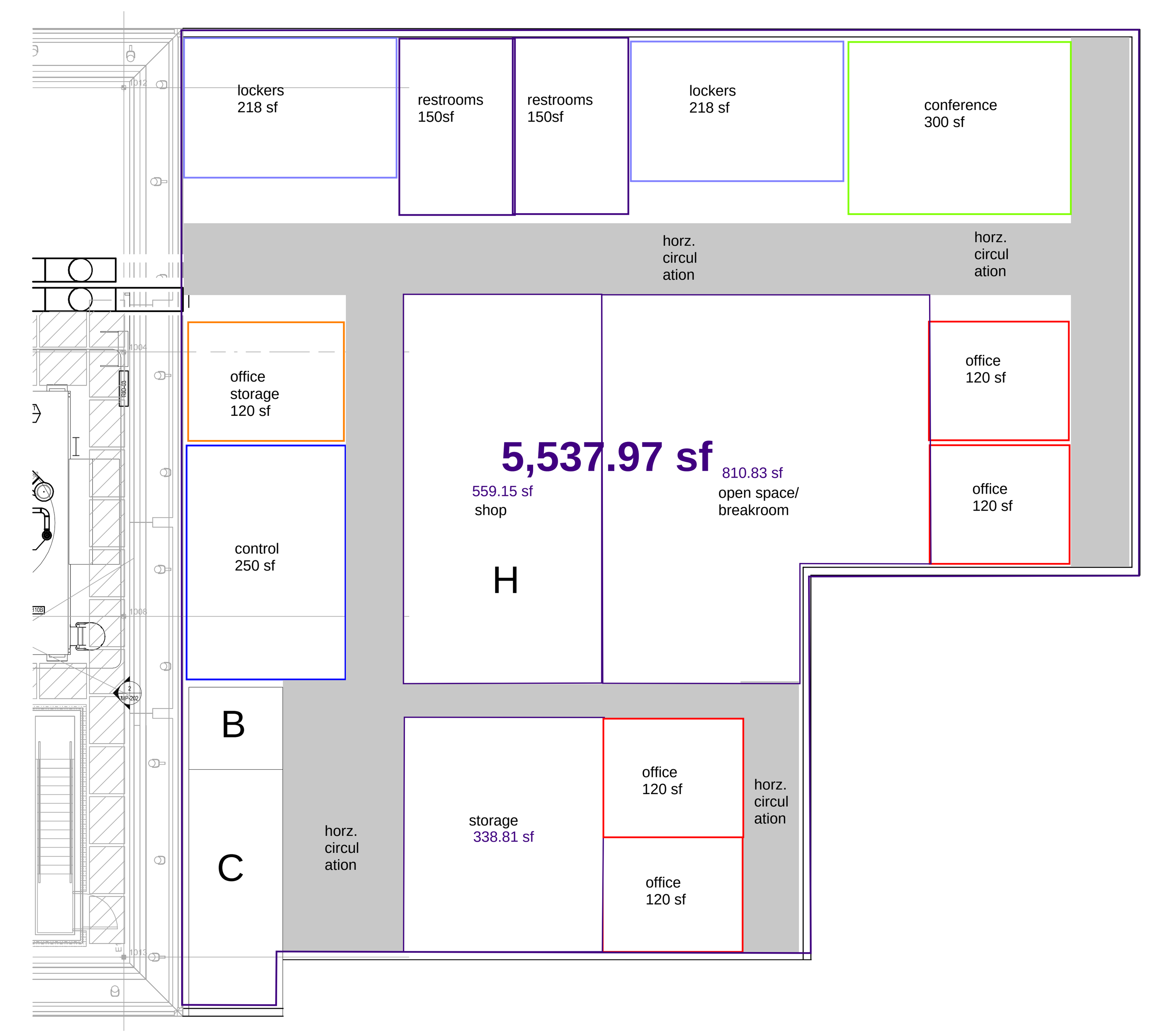
SQUARE FOOTAGE

BASEMENT LEVEL: **6,321 SQFT**
GROUND LEVEL: **5,537 SQFT**
EQUIPMENT LEVEL: **5,537 SQFT**
OFFICE LEVEL: **5,537 SQFT**

TOTAL SQUARE FOOTAGE OF BUILDING: **22,932 SQFT**

NOTE: Refer to Appendix 9.13.2 for WCUP Scope of Work drawings which include revisions to the layouts of the floor plates shown in Appendix 9.7.

Option 1 will require additional floor area on the Equipment and Office levels to accommodate increased electrical room capacity. Refer to Option 2 for the new electrical room size. Final scope for WCUP Expansion will be between Options 1 & 2. Option 3 is unlikely to satisfy electrical requirements.



OFFICE LEVEL/ ROOF LEVEL
SCALE: 3/32" = 1'-0"

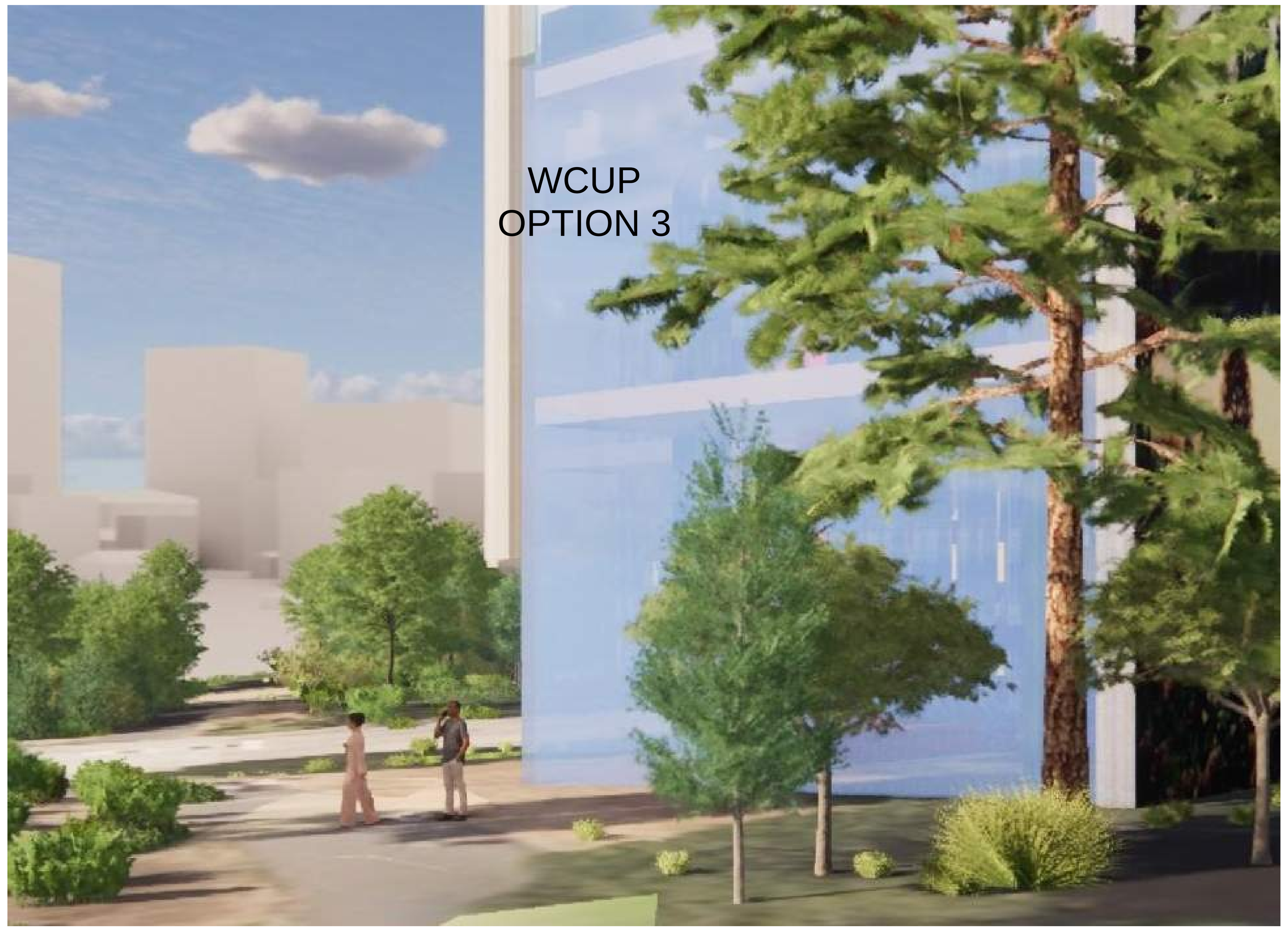
WEST CAMPUS UTILITY PLANT:
FLOOR PLANS OPTION 3

UNIVERSITY of WASHINGTON
ENERGY RENEWAL PROJECT

rolluda architects
architecture planning interior design

Affiliated Engineers

VIEW FROM WEST SIDE OF PACIFIC ST.



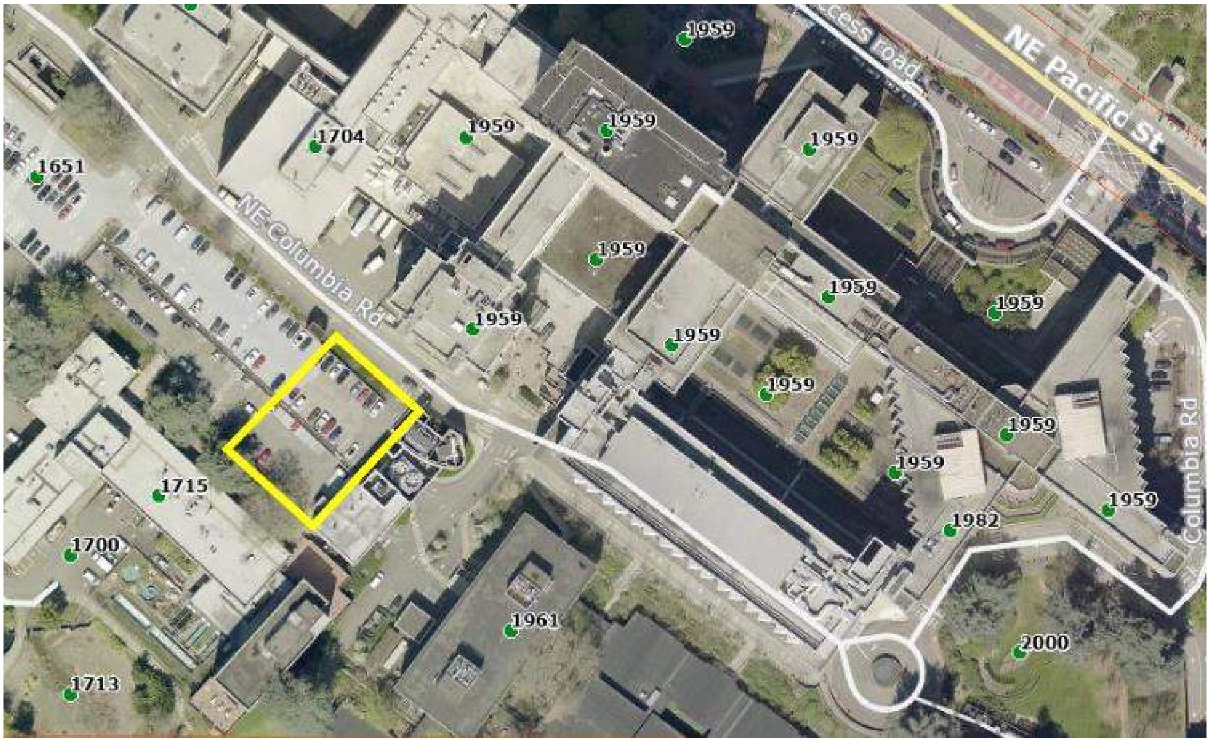
VIEW FROM BURKE-GILMAN TRAIL LOOKING WEST

ARIEL VIEW FROM SOUTH SIDE OF PACIFIC ST.

VIEW FROM WEST SIDE OF 15 AVE NE

South Plant Expansion Building

South Plant Expansion Site



Address: 15744 Ferry PL NE, 98105
Parcel Number(s): 1625049001-1651
Jurisdiction: Seattle

Property Legal Description: ENTIRE SEC LESS STS LESS GOV CANAL & LESS POR PLATTED TGW POR VAC ST ADJ & ABANDONED R/W OVER SECTION & TGW ALL BLK 6 IN LK WASHINGTON SHORE LANDS ADD & POR GL 2 (IN SEC 15-25-4) LY S OF 41ST ST & W OF W MGN OF SERBER DR TGW ALL BLK 18 A & POR VAC ST ADJ & ALL BLK 18 LK UNION SH LDS ADD TGW 15TH AVE NE PER SEATTLE VAC ORD #120249 REC # 20000825000511 LESS POR PER DEED REC #8611180561 & LESS POR DAF POR NE 1/4 OF NE 1/4 SD SEC 16 LY NE OF UNION PL NE AS ESTAB BY SEATTLE ORD #31996 NKA MARY GATES MEMORIAL DR NE & SLY OF NE 45TH ST AS ESTAB BY SEATTLE ORD #17947, Plat Block:, Plat Lot:

Zoning Area:	SMC 23.50A: MIO-105-LR3(M)
Building Height (MAX):	105 feet
Lot Size:	Approximately 7,082 square feet
Setbacks:	TBD
FAR:	TBD

South Plant Expansion Site

Current Site Use:	Parking Garage/ Area 51
Design Review Board Requirements:	○ Expansion of the plant by 4,000 square feet or more will require approval. At 14,163 square feet the expansion will require design review.

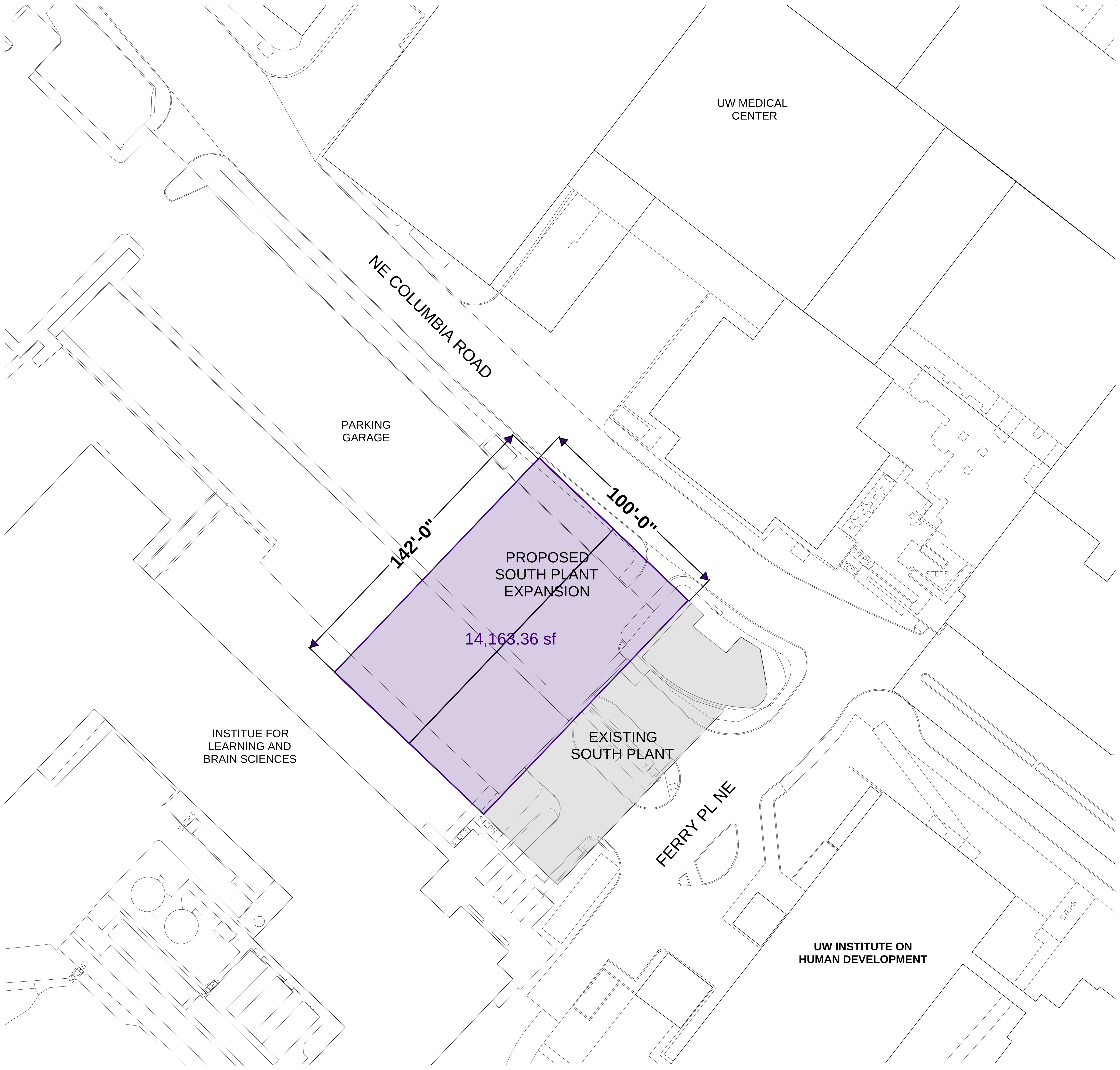
Design Considerations:	○ Impact on parking for the campus
	○ South-East end parking access would require a new location/ configuration
	○ South Plant expansion
	    ○ Demolish partial portion of parking garage
	    ○ Vacate and renovate a portion of the parking garage

Proposed Building Occupancy & Construction Type:	• Occupancy: F-2 w/ B Accessory • TYPE IIB – Fully Sprinklered – up to 4 Stories above grade

Site Narrative

To expand the South Plant, demolition, and reconfiguration of vehicular traffic access to the existing parking garage will be necessary. The parking garage, located to the north-west of the plant, will need to be demolished partially or in full to allow expansion.

This site is not part of any proposed work in the Energy Renewal Plan, however, it was studied due to the potential expansion of an existing University plant for future equipment.



DRAWING REFERENCE SOUTH PLANT SHEET:

BACKGROUNDS/ TOPOGRAPH LINES:
X_UWBLDGS_BACKGROUND 240417 ORIGINAL DWGS

SITE PLAN
SCALE: 1/32" = 1'-0"

Sewer Heat Recovery Plant Buildings

Sewer Heat Recovery Plant Site – Option 1

Address: 711 NE Northlake PL
Parcel Number(s): 4092302320
Jurisdiction: Seattle

Property Legal Description: LAKE VIEW ADD LESS ST; Plat Block: 14; Plat Lot: 4-5-6

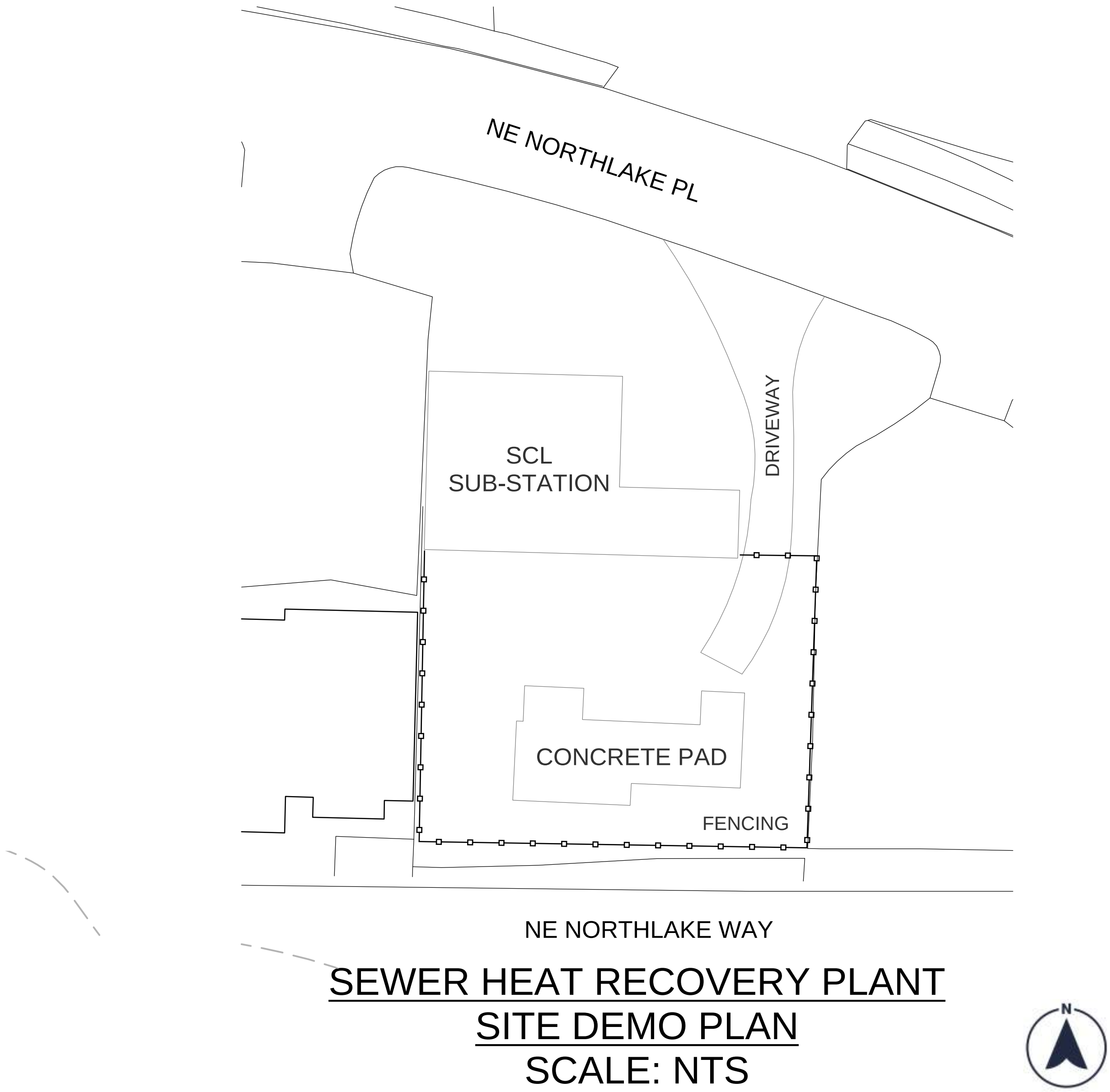
Zoning Area:	SMC 23.50A: IC-65 (M) / Shoreline Master Program Regulations
Building Height (MAX):	65 feet* *Exceptions for solar collector, and other rooftop features are permitted.
Lot Size:	6,900 square feet
Setbacks:	Seattle Municipal Code (SMC) 23.50A.180.B4: 5 foot deep landscaping strip between fence/ wall and street line or Artwork.
Floor Area Ration (FAR):	2.75 per SMC 23.50A.100, Table A
Landscaping Requirements:	SMC 23.50A.184: Landscaping and screening standards in the II and IC zones.

Sewer Heat Recovery Plant Site – Option 1

Current Site Use:	City Light Storage
Design Review Board Requirements:	• Project exceeds 12,000 square feet of nonresidential gross floor area. At 10,260 square feet this building will not require design review.
Design Considerations:	• Demolition of existing structures and cleanup of hazardous materials (brown site) • Parking Lot W40, to the East, may be utilized for additional area • Not currently owned by the University
Proposed Building Occupancy & Construction Type:	• Occupancy: F-2 w/ B Accessory • TYPE IIB – Fully Sprinklered – up to 4 Stories above grade

Site Narrative

The site for the new sewer heat recovery building will be located close to the new electrical substation site. The site's current use is Seattle City Light storage and will require purchase and cleanup due to hazardous materials on site. The advantage of this location is that it is closer to campus and thus the infrastructure for the plan as opposed to being further away from Option 2 site; nor will there be any adjacency to the Burke-Gilman trail.



SEWER HEAT RECOVERY PLANT
SITE DEMO PLAN
SCALE: NTS

SEWER HEAT RECOVERY PLANT
DEMO NOTES:

1. EXISTING SEATTLE CITY LIGHT SUB-STATION STORAGE BUILDING WILL BE REMOVE.

2. CONCRETE PAD, FENCING AND DRIVEWAY AND OTHER ITEMS WITHIN PROPERTY WILL BE DEMO AND REMOVED.

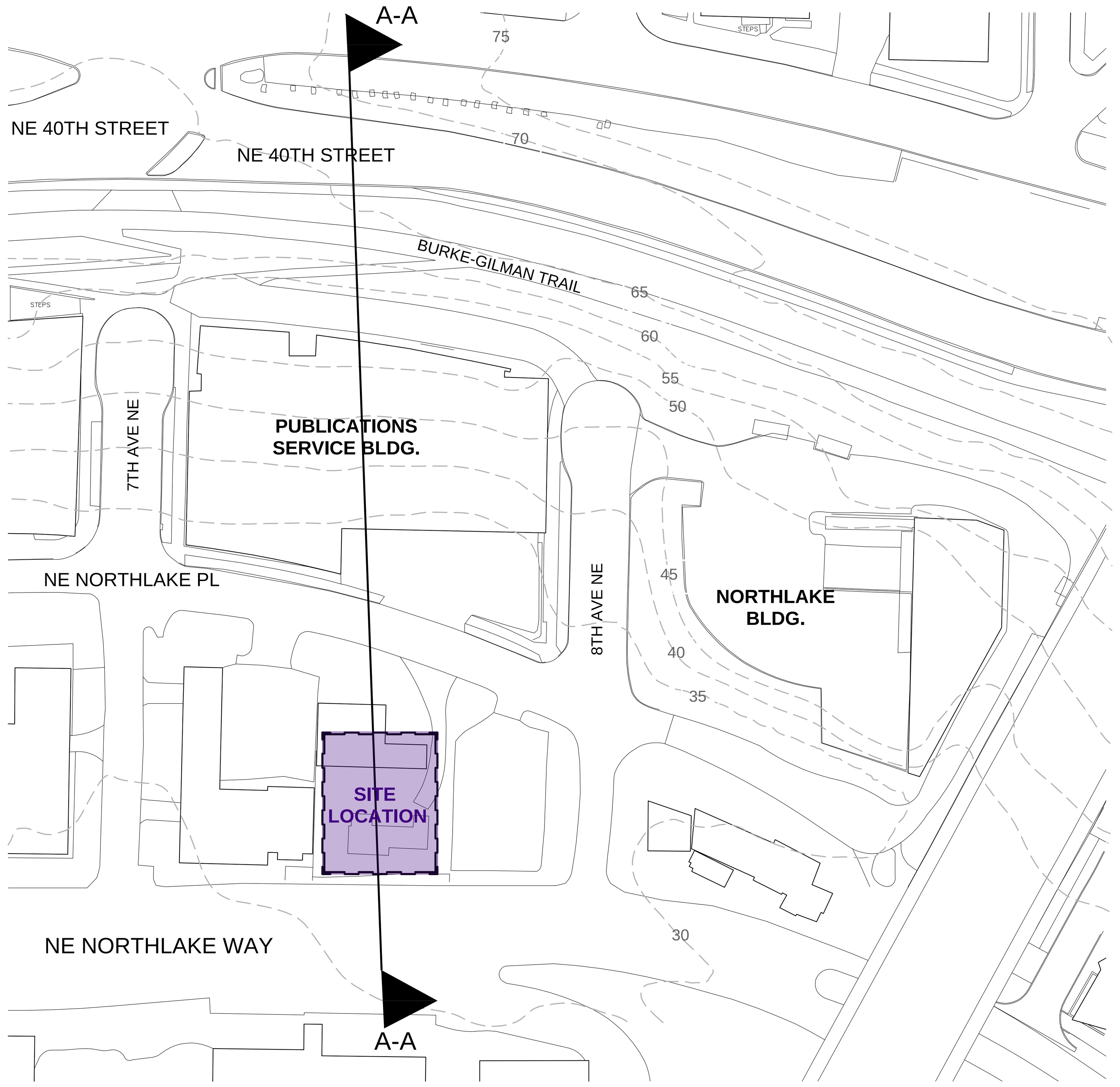
DRAWING REFERENCE ALL SEWER HEAT RECOVERY PLANT SHEETS:

BACKGROUNDS
X_UWBLDGS_BACKGROUND 240417 ORIGINAL DWGS

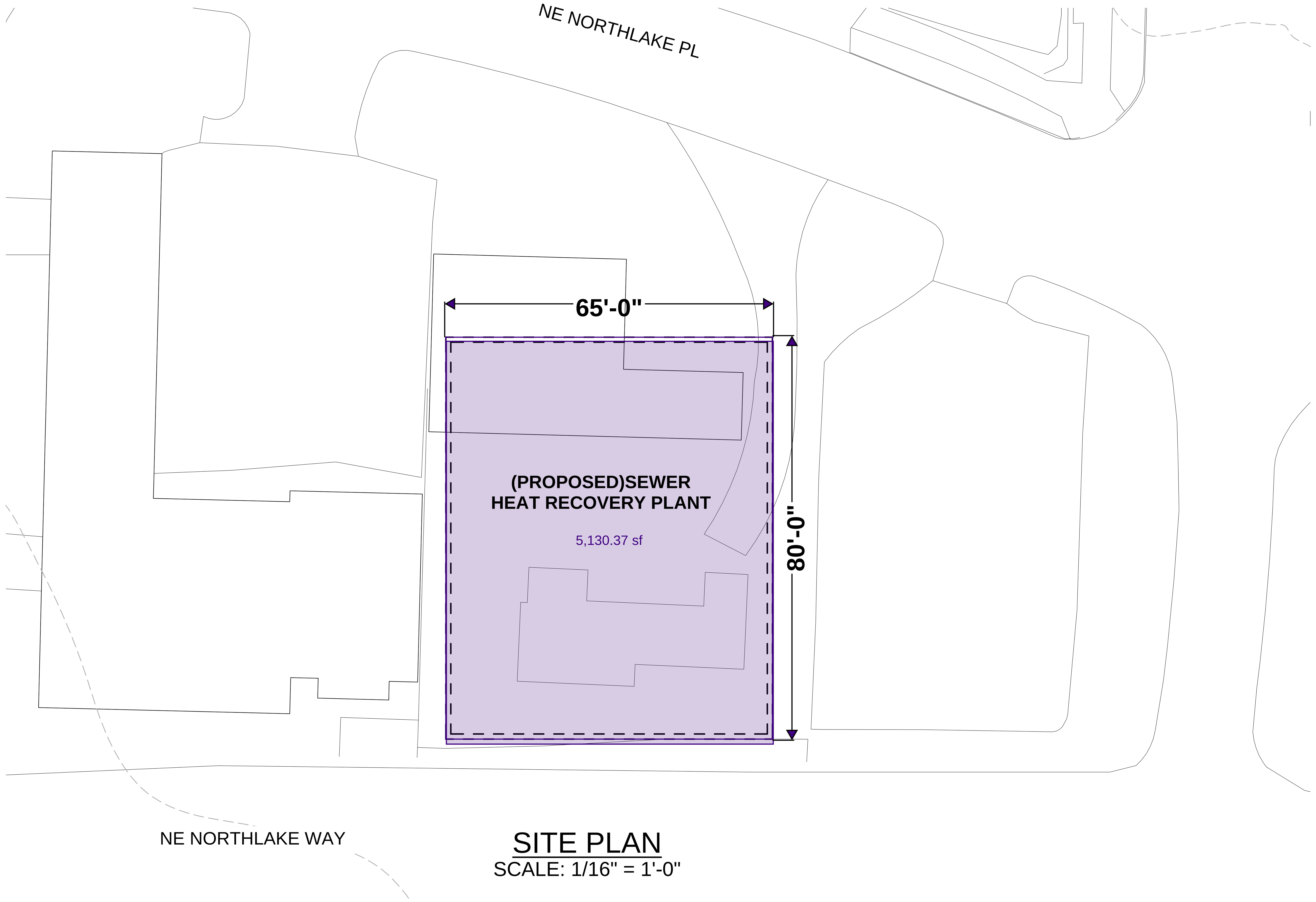
TOPOGRAPHIC LINES:
KING COUNTY iMAP WITH ELEVATION CONTOUR LINES
GOOGLE EARTH

FLOOR PLAN: EQUIPMENT LAYOUT
GENERATED/PROVIDED BY AEI

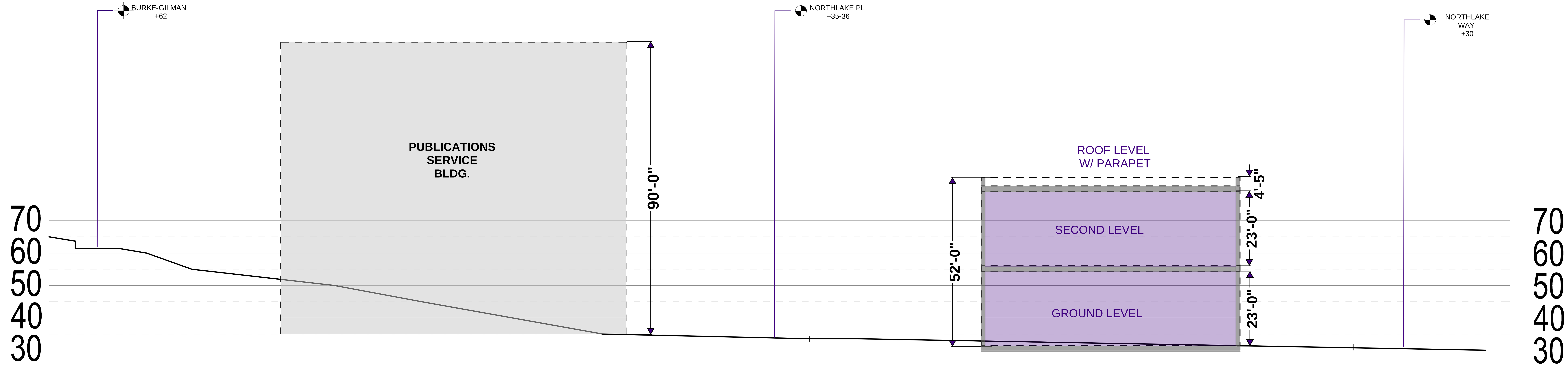
RENDERINGS PROGRAMS:
SKETCHUP / ENSCAPE



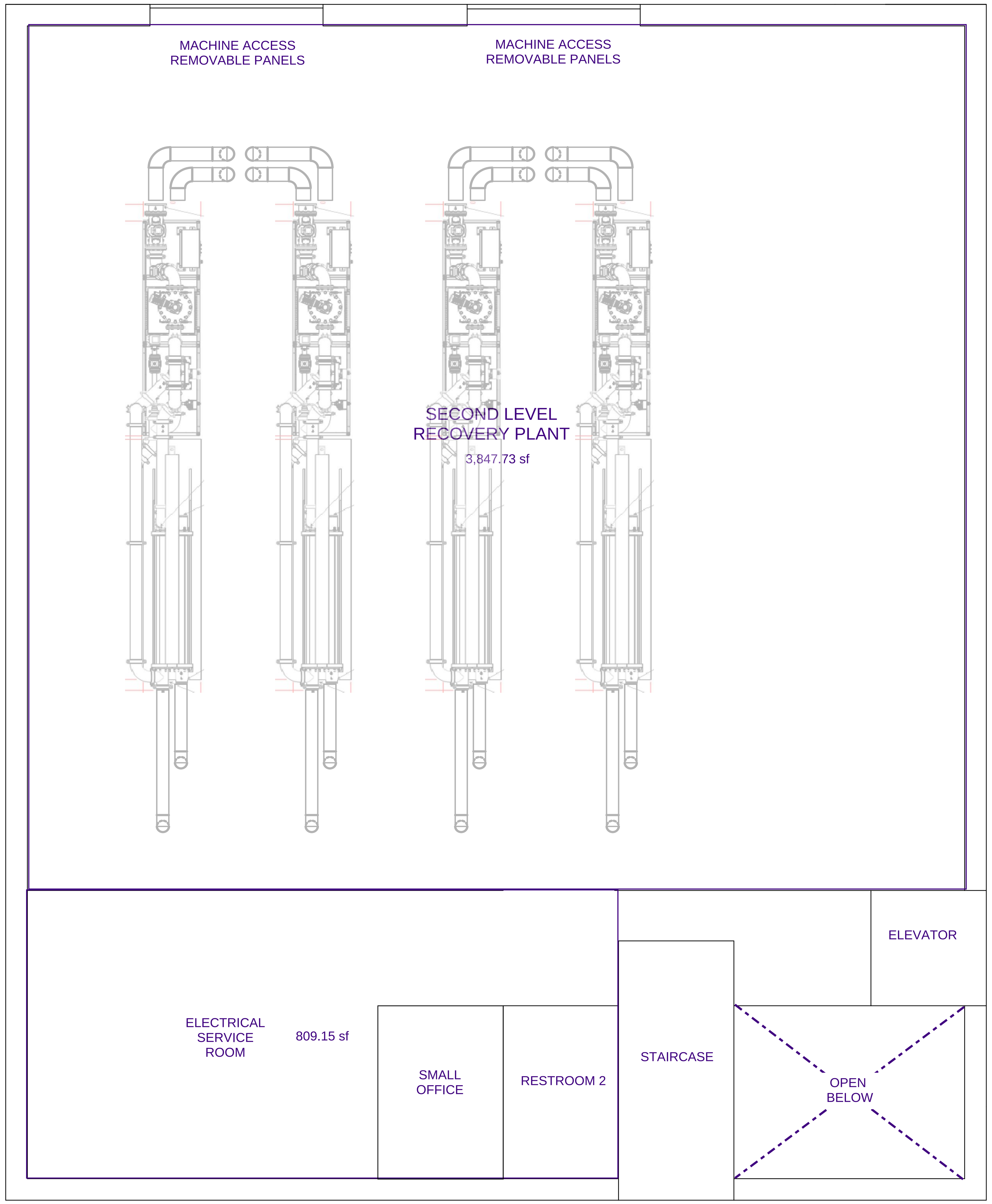
VICINITY SITE PLAN
SCALE: 1/64" = 1'-0"



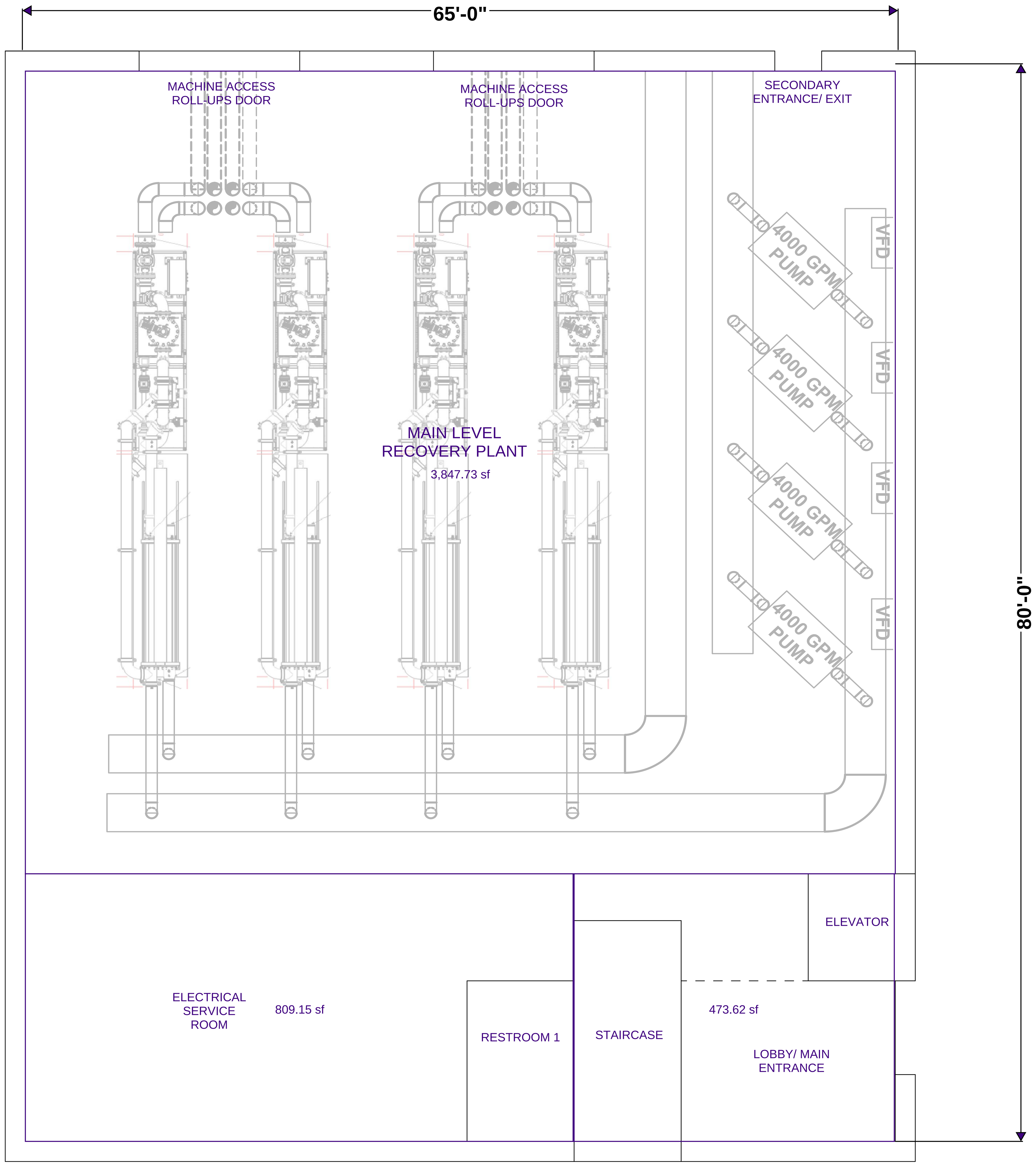
SITE PLAN
SCALE: 1/16" = 1'-0"



SITE SECTION A-A
SCALE: 1/16" = 1'-0"



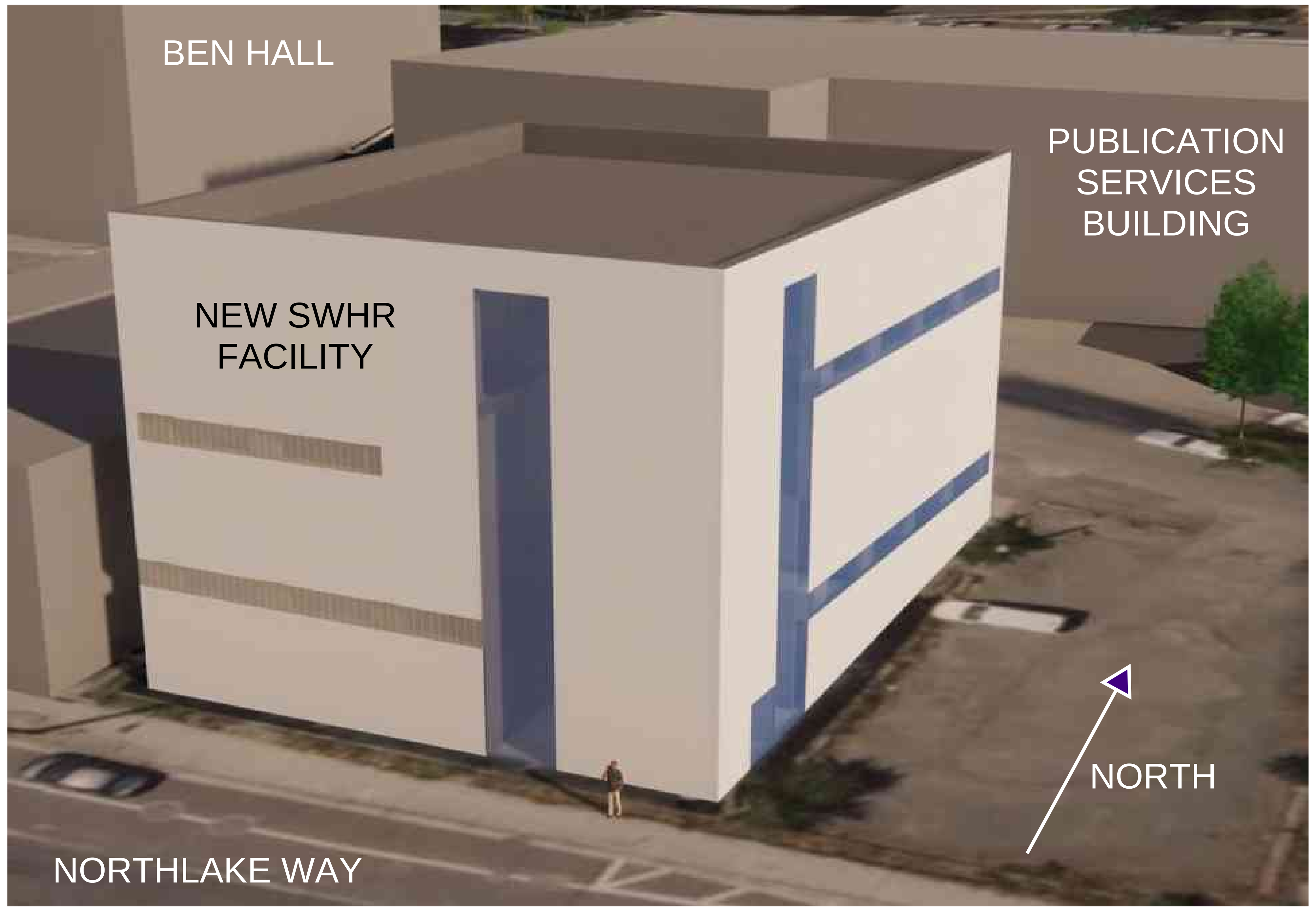
SECOND LEVEL
SCALE: 3/16" = 1'-0"



MAIN LEVEL
SCALE: 3/16" = 1'-0"

SQUARE FOOTAGE
MAIN LEVEL: **5,130 SQFT**
SECOND LEVEL: **5,130 SQFT**

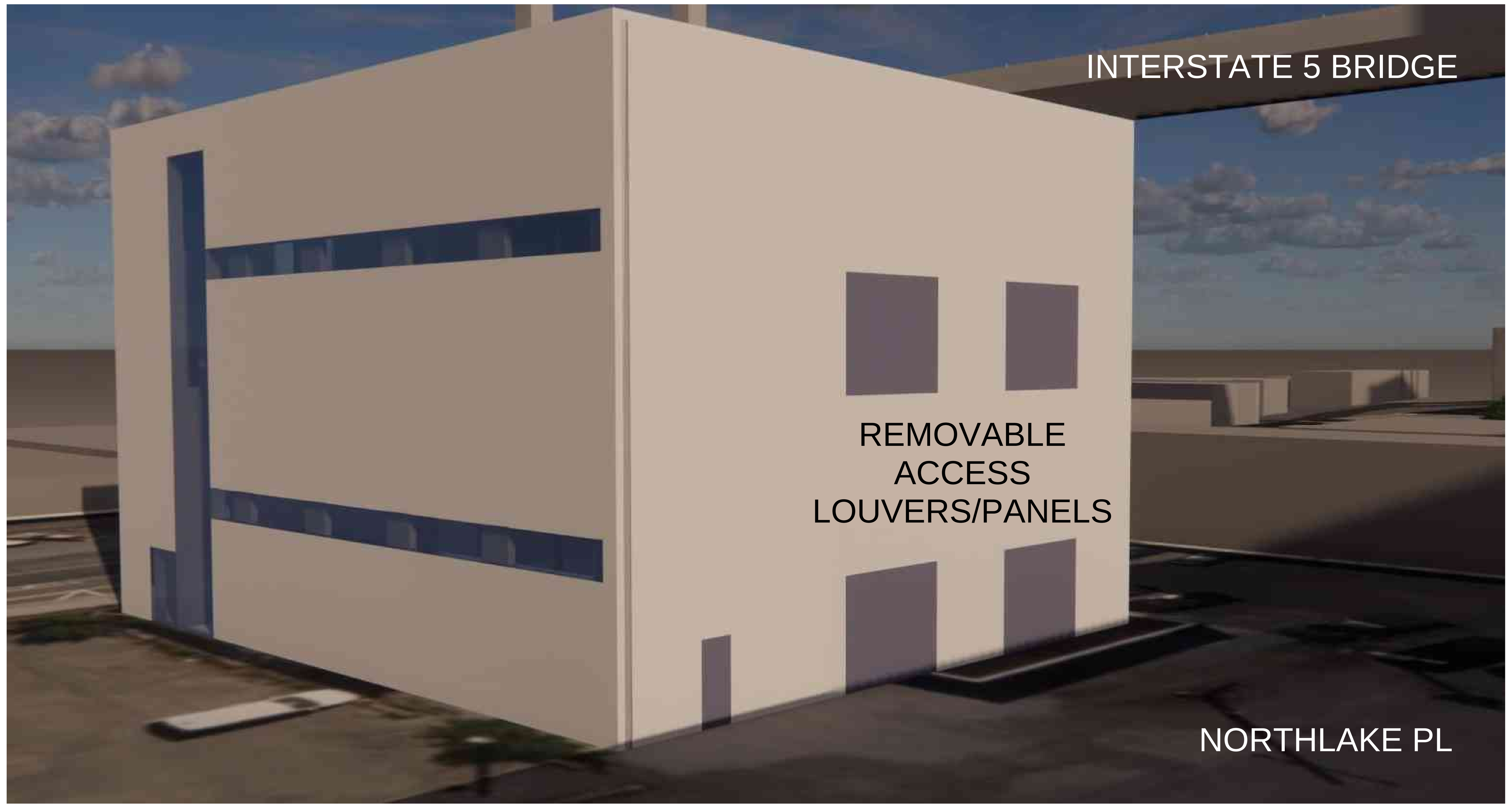
TOTAL SQUARE FOOTAGE OF BUILDING: **10,260 SQFT**



ARIEL VIEW FROM NE NORTHLAKE WAY LOOKING WEST

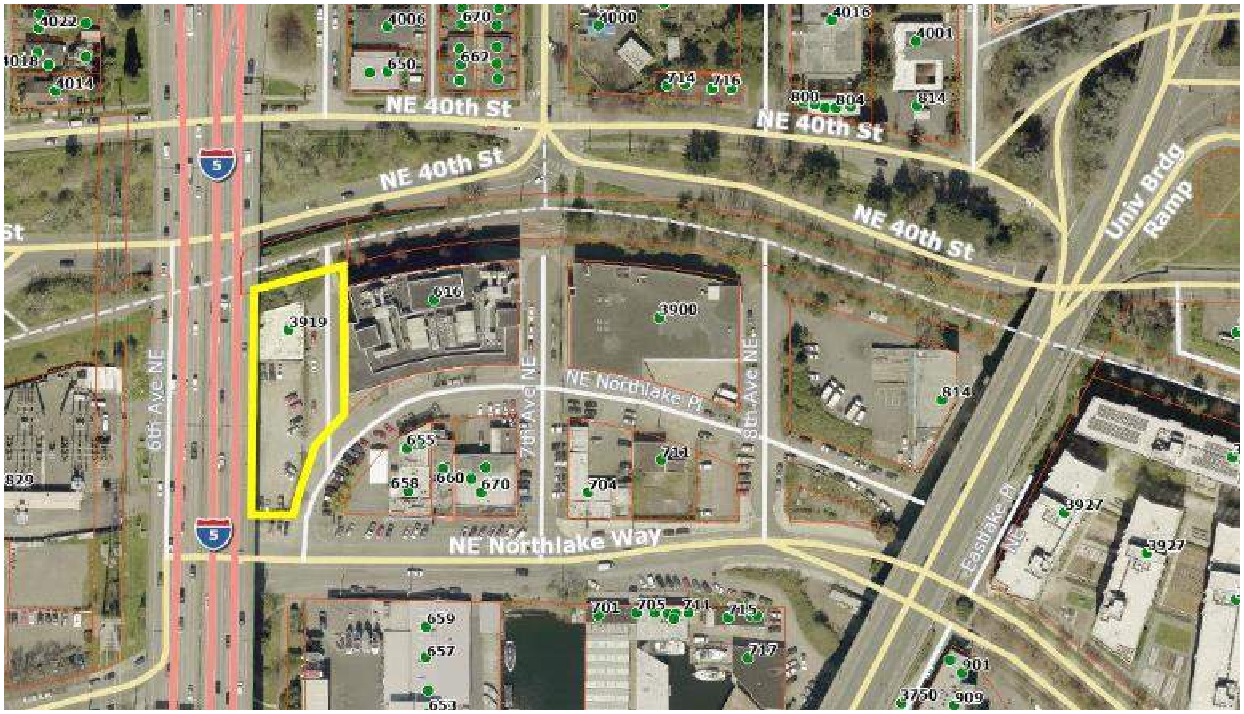
VIEW FROM SOUTH SIDE OF NE NORTHLAKE WAY

ARIEL VIEW FROM NE NORTHLAKE WAY LOOKING EAST



VIEW FROM NORTH OF NE NORTHLAKE PL

Sewer Heat Recovery Plant Site – Option 2



Address: 3919 Pasadena PL NE, 98105
Parcel Number(s): 4207401365
Jurisdiction: Seattle

Property Legal Description: King County Parcel Viewer shows only the street address number

Zoning Area:	SMC 23.50A: IC-65 (M)
Building Height (MAX):	65 feet* *Exceptions for solar collector, and other rooftop features are permitted.
Lot Size:	80 feet by 264 feet 21,120 square feet
Setbacks:	Seattle Municipal Code (SMC) 23.50A.180.4: 5 foot deep landscaping strip between fence/ wall and street line or Artwork.
Floor Area Ration (FAR):	2.75 per SMC 23.50A.100, Table A
Landscaping Requirements:	SMC 23.50A.184: Landscaping and screening standards in the II and IC zones.

Sewer Heat Recovery Plant Site – Option 2

Current Site Use:	WSDOT tow lot
Design Review Board Requirements:	• Project exceeds 12,000 square feet of nonresidential gross floor area. Assuming the building is equal to Option 1 in square footage, this building would not require design review at 10,260 square feet.
Design Considerations:	• Impact on restaurants, businesses and the Burke-Gilman trail located North of the property. • Adjacent to I-5 Highway bridge • The property isn't owned by the University and cannot be purchased from WSDOT
Burke-Gilman Trail:	Managed by City of Seattle, On-campus managed by UW
Proposed Building Occupancy & Construction Type:	• Occupancy: F-2 w/ B Accessory • TYPE IIB – Fully Sprinklered – up to 4 Stories above grade

Site Narrative

This option would be a similar layout to Option 1 but this site is adjacent to the Burke-Gilman trail and I-5 Highway bridge This site is farther away from the rest of the campus infrastructure, but is optimal from a location standpoint due to its proximity to sewer line. The main reason this site cannot be considered is due to WSDOT ownership and ability to not purchase the site.

Lake Water
Pump Equipment
House Station
Building

Lake Water Pump Equipment House Station Site

Address: Walla Walla RD, 98105 (Lot E-8)
Parcel Number(s): 1625049001-1651
Jurisdiction: Seattle

Property Legal Description: ENTIRE SEC LESS STS LESS GOV CANAL & LESS POR PLATTED TGW POR VAC ST ADJ & ABANDONED R/W OVER SECTION & TGW ALL BLK 6 IN LK WASHINGTON SHORE LANDS ADD & POR GL 2 (IN SEC 15-25-4) LY S OF 41ST ST & W OF W MGN OF SERBER DR TGW ALL BLK 18 A & POR VAC ST ADJ & ALL BLK 18 LK UNION SH LDS ADD TGW 15TH AVE NE PER SEATTLE VAC ORD #120249 REC # 20000825000511 LESS POR PER DEED REC #8611180561 & LESS POR DAF POR NE 1/4 OF NE 1/4 SD SEC 16 LY NE OF UNION PL NE AS ESTAB BY SEATTLE ORD #31996 NKA MARY GATES MEMORIAL DR NE & SLY OF NE 45TH ST AS ESTAB BY SEATTLE ORD #17947, Plat Block:, Plat Lot:

Zoning Area:	SMC 23.50A: MIO-37-LR1(M) / Shoreline Conservancy Management
Building Height (MAX):	37 feet
Lot Size:	TBD
Setbacks:	TBD
FAR:	TBD

Lake Water Pump Equipment House Station Site

Current Site Use:	Parking Lot E-8
Design Review Board Requirements:	• Non-Residential use over 4,000 square feet requires design review. At just 2,610 square feet this project will be exempt from design review.
Design Considerations:	o Impact on campus parking o Lake Washington Shoreline Conservancy Management requirements
Proposed Building Occupancy & Construction Type:	• Occupancy: F-2 w/ B Accessory • TYPE IIB – Fully Sprinklered – up to 4 Stories above grade

Site Narrative

The site for a future lake pumphouse makes sense to be located on the existing parking lot E-8 for proximity to the lake and the power plant directly to the west. The shell of this building will match the building language of the adjacent to the north.

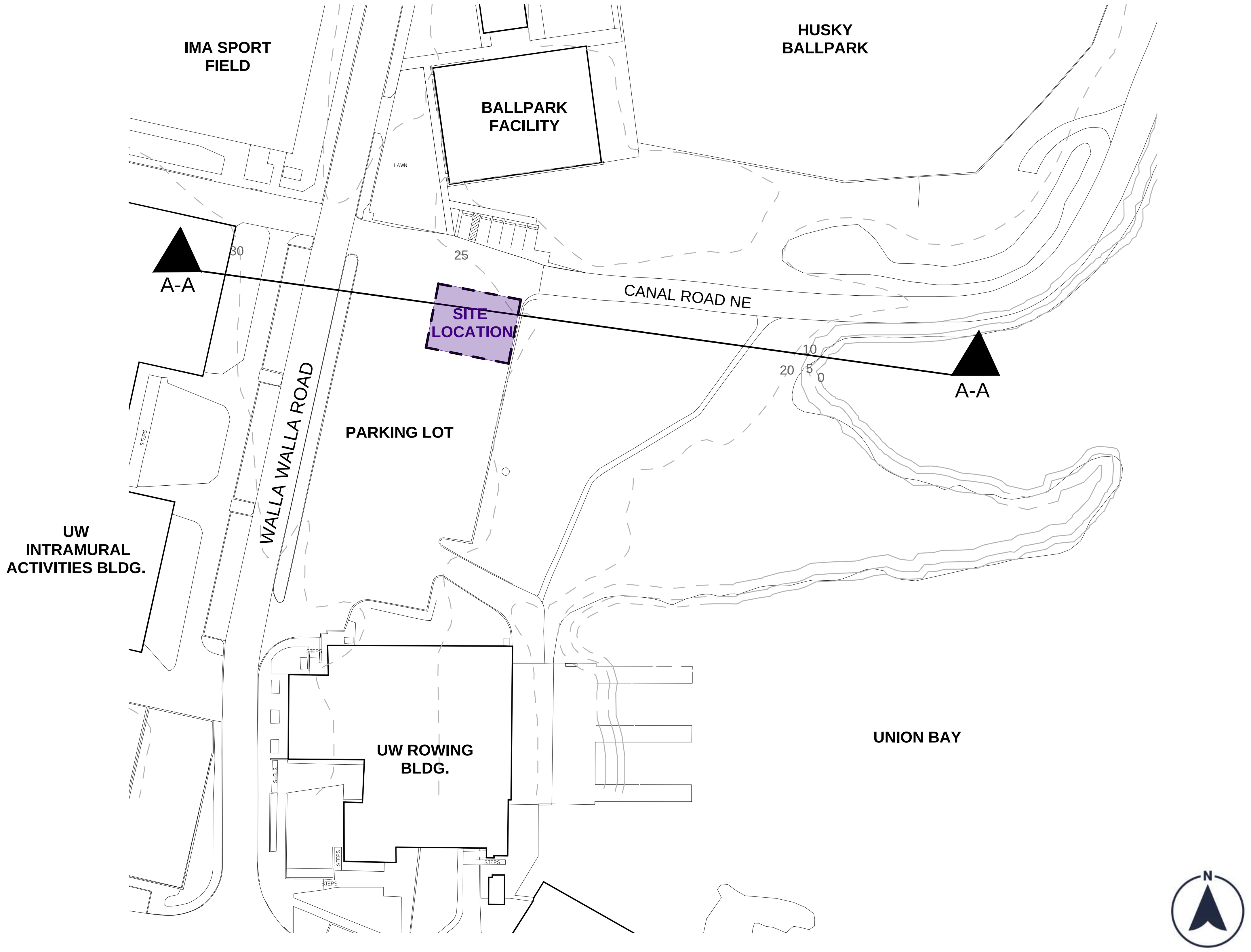
DRAWING REFERENCE ALL LAKE PUMP HOUSE SHEETS:

BACKGROUNDS
X_UWBLDGS_BACKGROUND 240417 ORIGINAL DWGS

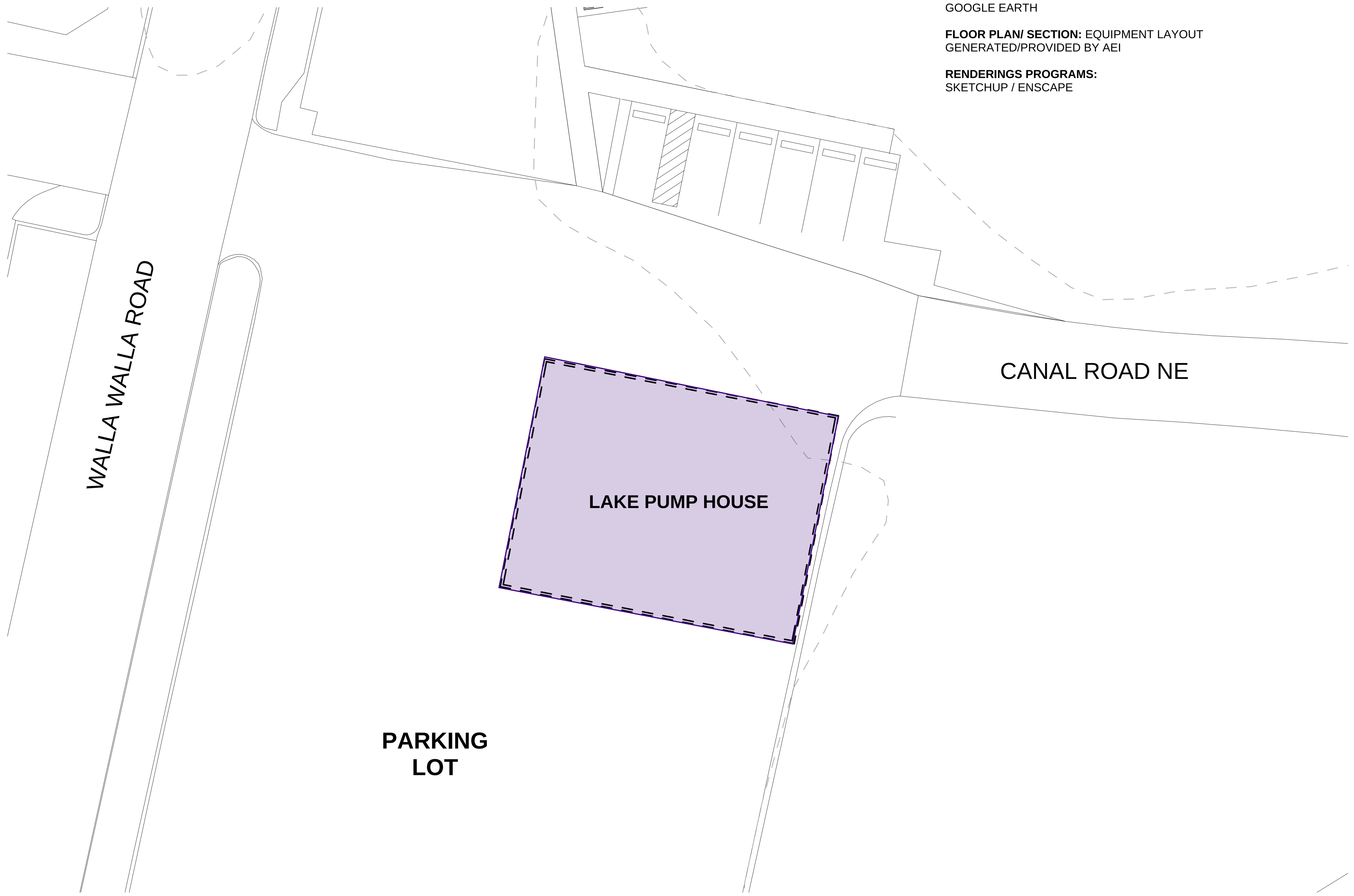
TOPOGRAPHIC LINES:
KING COUNTY IMAP WITH ELEVATION CONTOUR LINES
GOOGLE EARTH

FLOOR PLAN/ SECTION: EQUIPMENT LAYOUT GENERATED/PROVIDED BY AEI

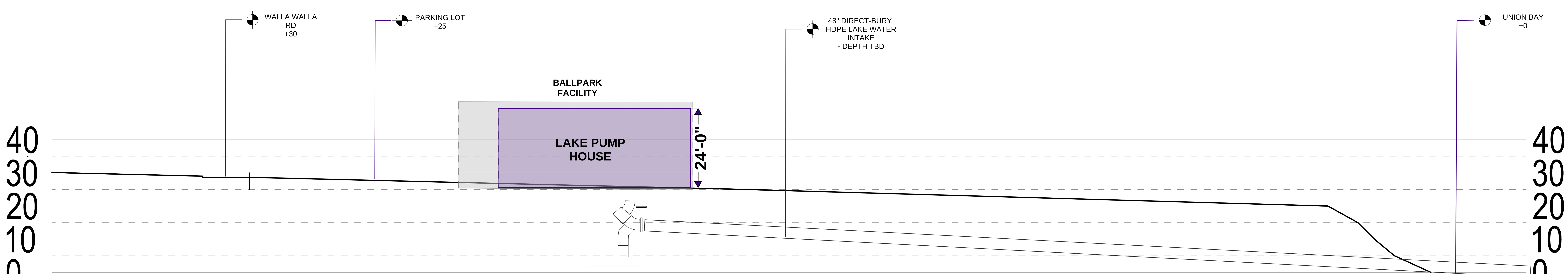
RENDERINGS PROGRAMS:
SKETCHUP / ENSCAPE

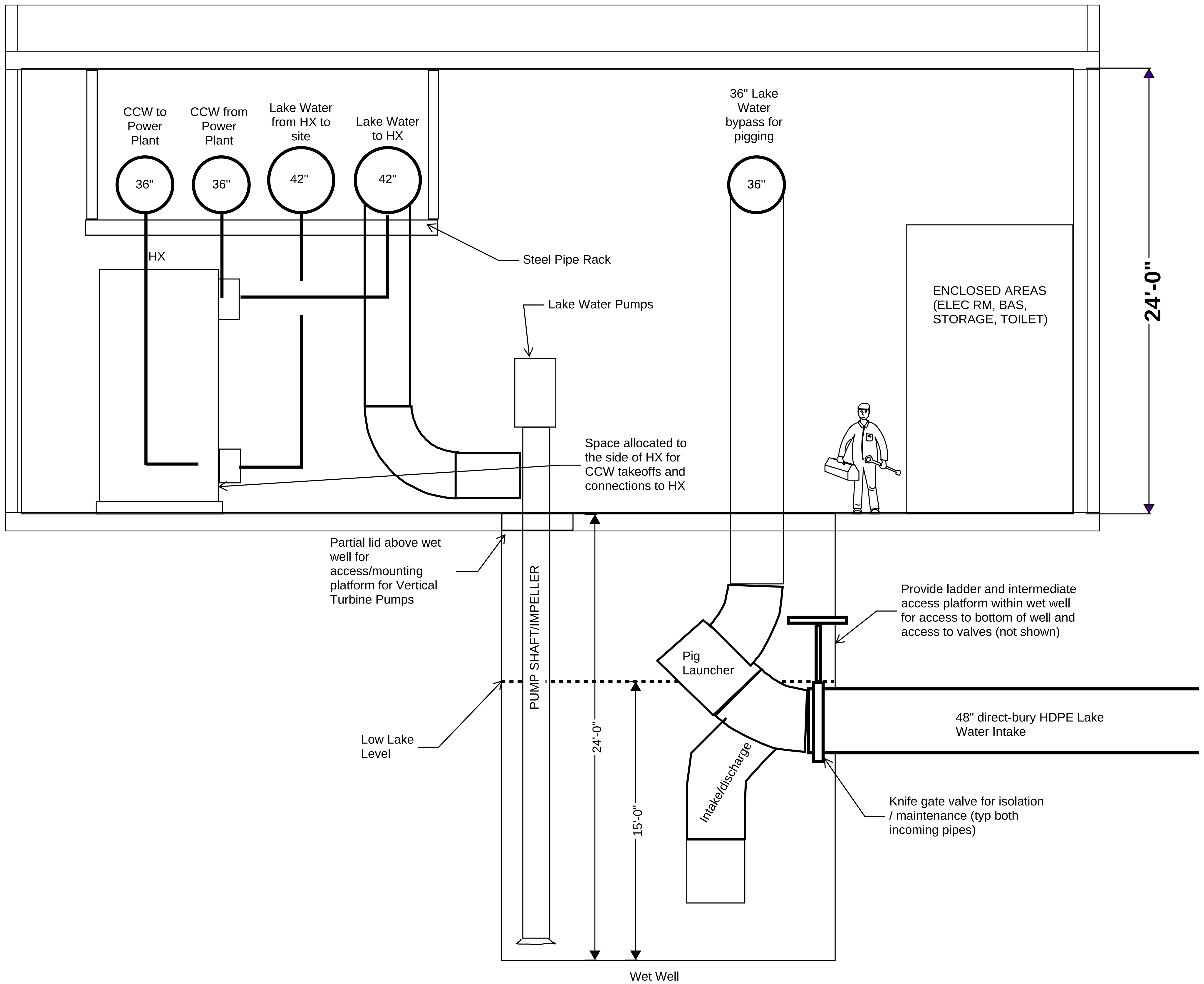


VICINITY SITE PLAN
SCALE: 1/64" = 1'-0"

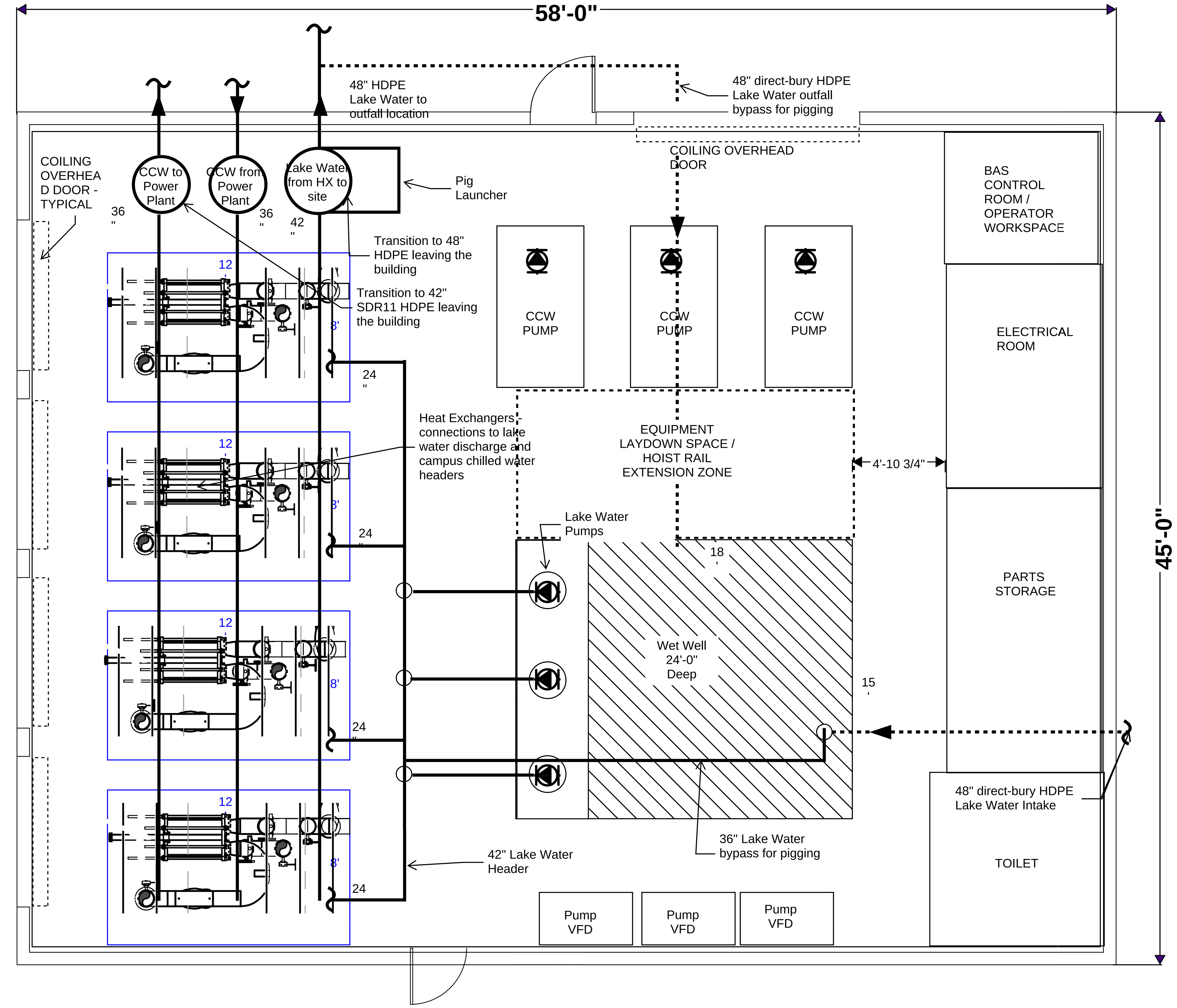


SITE PLAN
SCALE: 1/16" = 1'-0"





BUILDING SECTION
SCALE: 1/4" = 1'-0"

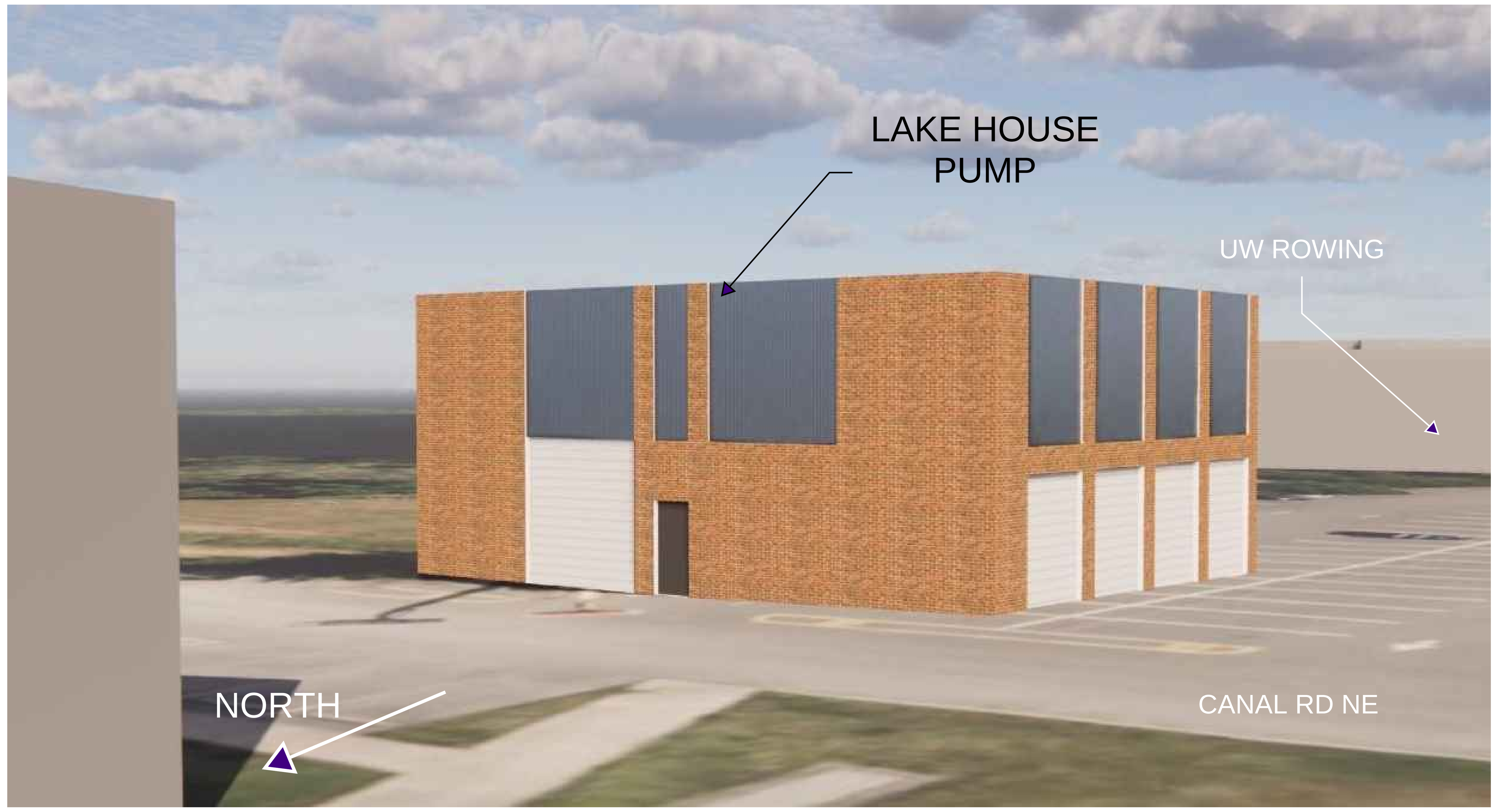


FLOOR PLAN
SCALE: 1/4" = 1'-0"

VIEW FROM NORTH SIDE OF CANAL RD NE

VIEW LOOKING NORTH FROM OF PARKING LOT E-8

VIEW FROM EAST SIDE OF CANAL RD NE



VIEW FROM NORTH SIDE OF CANAL RD NE

VIEW LOOKING NORTH FROM OF PARKING LOT E-8

VIEW FROM EAST SIDE OF CANAL RD NE

Electrical Receiving Station Site

Section redacted for security reasons.

9.8 Preliminary Tax Credit Analysis

9.8.1 General Notes / Considerations Regarding Potentially Applicable Tax Credits

Two-Tiered Credit Structure

The IRA retains the two-tiered credit amount structure from the Build Back Better Act (BBB) with a lower base credit and bonus credit rates up to 5 times the base credit rate. The increased rate can be achieved when projects meet prevailing wage and apprenticeship requirements (see further detail below). Additional bonus credit opportunities for Section 45 and Section 48 based on project location and domestic content requirements (see further detail below).

Prevailing Wage and Apprenticeship (PW&A)

As previously confirmed, UW has a clause in contracts that requires contractors to meet the Prevailing Wage and Apprenticeship (PW&A), thus it is expected that UW projects will qualify for the bonus credit allowable by meeting these requirements. For example, Sec. 48 base credit of 6% would go up to 30% if PW&A is met. It is important to note, that having the clause in the contract is not solely sufficient for bonus credit. IRA requires that detailed records be tracked and maintained for laborers that are involved in the construction. Notice 2022-61, Nov. 29, 2022 and Notice 2023-18514, Aug. 29, 2023: IRS/Treasury point to three tests: 1) Labor Hours Requirement, 2) Journeyworker to Apprentice Ratio Test, and 3) Participation Requirement. Certain penalties may be assessed if laborers are not paid prevailing wage or is apprenticeship ratio is not met, however cure provisions also in place.

Financing with Tax-Exempt Bonds

Please note that tax law under Sec.45(b)(3) requires that credit be reduced for tax exempt bonds, under the theory that entities utilizing tax-exempt debt on a project are already receiving a tax benefit through the tax exemption provided for the project financing. In such instances where a project is primarily financed through tax-exempt debt, the tax credit benefit is reduced by 15%. For example, a 30% credit would be reduced by 15% to avoid double tax benefit, resulting credit would be 25.5%.

Additional Bonuses

Tax credit eligible projects may be eligible for additional "bonuses": Additional 10% increase for domestic content and 10% for energy community. Applicability of such bonuses cannot be assessed at this stage of project development.

9.8.2 Tax Credit Eligibility by Project Type

UW Power Plant Infrastructure Renewal (Power Plant Phase 2 placed in service in 2023) – CHP Analysis

There is potential for UW's new turbine to qualify as well as direct costs and a portion of indirect costs under Sec. 48. However, further analysis is still required to better understand if and how items can be categorized as qualifying costs as WERP under Sec. 48.

- Current state of research has identified a similar waste energy recovery property (WERP) project that likely qualifies under Sec. 48. While the UW project is not identical to the researched project, the project properties are sufficiently alike that that certain costs may qualify under Sec. 48 as WERP
- Further analysis is still required to better understand if and how items can be categorized as qualifying costs as WERP under Sec. 48, and requires more insight from UW on underlying facts:
  - The **unit of property** and all functionally interdependent components of property.
  - The **building or equipment** – it is possible there may be several scenarios of what would constitute the "buildings or equipment" for the project such as campus overall or carve out.
  - The **primary purpose** – confirming and documenting that the primary purpose of such building or equipment is not the generation of electricity.

Plant

- Thermal energy storage tanks (TES) tanks are expected to quality under **Energy Storage Technology category of Sec. 48 or Section 48E**.
- **Sec. 48 Investment Tax Credit for Energy Property (ITC) (begin construction by 1/1/2025).** 6% base credit, up to 30% if meeting prevailing wage and apprenticeship requirements.

- **Sec. 48E Clean Electricity Investment Tax Credit (placed in service on after 12/31/24).** 6% base credit, up to 30% if meeting prevailing wage and apprenticeship requirements.

P-1	Convert CCW to Year-round Operation
P-2	Add CH-8 / CT-8 to Power Plant
P-3	WCUP CH5 & CT Installation
P-4	WCUP Annex
P-5	**CCW TES Tank**
P-6	**PHW TES Tank**
P-7	WCUP HRCs & Cooling Towers
P-8	Power Plant Heat Recovery Chiller and Cooling Towers
P-9	CCW Header and Secondary Pumping System
P-10	Power Plant PHW System
P-11	PP Electric Boilers + Emergency Gen Heat Recovery
P-12	WCUP Electric Boilers
P-13	WCUP Generators
P-14	PP PLC Controls Upgrade

Source

- Potential qualification of the Lake Interface System, more research is needed around argument to consider lake as ground water for qualification of the Lake projects under **Sec. 48** geothermal equipment.
- Sewer Heat Recovery Equipment may qualify under **Sec. 48E**; this matter is still being researched.

S-1	Lake Interface System
S-2	Sewer Heat Recovery Equipment

Solar

No specific SOWs or projects listed as part of the ERP. Nonetheless, depending on type of project relevant IRA sections are:

- **Sec. 45 Production Tax Credit for Electricity from Renewables (PTC)**.
- Electricity has to be produced and sold to an unrelated party. Base Credit Amount: $0.03/kW, increased 5 times if meeting prevailing wage and apprenticeship requirements. Credit is increased by 10% if meet domestic content and additional 10% if located in an energy community.
- **Sec. 48 Investment Tax Credit for Energy Property (ITC)**

- **Sec. 48E Clean Electricity Investment Tax Credit**

Buildings

Not expecting to have qualified projects within IRA scope.

B-1	Distributed Chiller Replacements
B-6	Comprehensive Metering and Data Analytics
B-7	Building Controls Upgrade
B-8,9,10	Building HHW Conversions
B-11	Local Steam Plants

Electrification

Not expecting to have qualified projects within IRA scope.

E-1	UW Substation
E-2	PP Ring Bus addition and New Express Feeders

Site Distribution

Not expecting to have qualified projects within IRA scope.

9.8.3 Preview of Phase III Funding and Financing Analysis

More detailed funding and financing analysis as well as guidance related to tax credits and incentives will be provided in Phase III. The analysis will include considerations for timing and bundling of projects to optimize the application for funding / reimbursement opportunities as well as a financial model that will provide scenarios and sensitivities relating to potential short-term and long-term financing options. The financial model will also consider the timing of applicable tax credits – whose proceeds will not be paid until after an eligible project has reached commercial operations and strategies to monetize such credits and help address up-front project funding sources and funding gaps. See Figure 9.8.3-1A for visual example of inputs and Figures 9.8.3-1B and 9.8.3-1C below for a visual example of outputs related to financial data to be analyzed and depicted.

Interest Rates

Short Term Debt Rate: 4.00%

Long Term Debt Rate: 4.00%

Phase wise- Sources and Uses of Funds

PHASE 1 (in Million $)

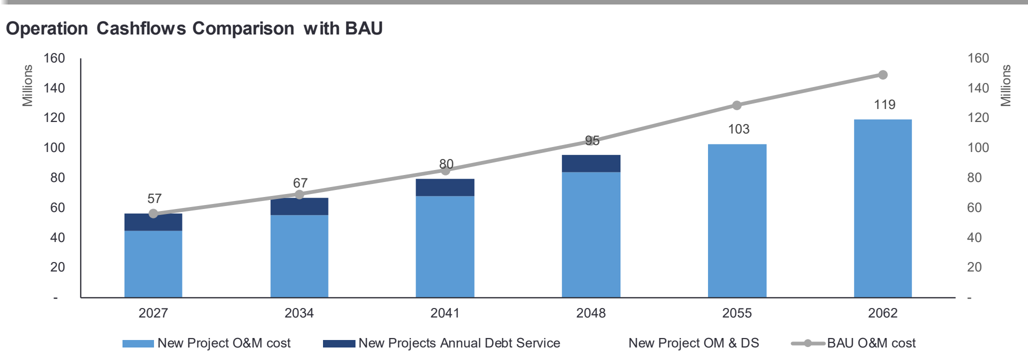
Phase 1 Sources	Total	2024	2025	2026	2027	2028	2029
Phase 1 State Direct Funding Disbursement	-	-	-	-	-	-	-
Phase 1 State Supported Debt Disbursement	-	-	-	-	-	-	-
Phase 1 Capex Financed by Tax Credits Receipts	-	-	-	-	-	-	-
Phase 1 Short Term Loan Disbursement	11.91	-	11.91	-	-	-	-
Phase 1 DOE Loan Disbursement	-	-	-	-	-	-	-
Phase 1 LT Debt Disbursement	200.39	-	74.99	86.89	38.51	-	-
Total Sources	**212.29**	**-**	**86.89**	**86.89**	**38.51**	**-**	**-**
Phase 1 Tax Credit Receipt END Balance	0.00	-	-	-	-	0.00	-

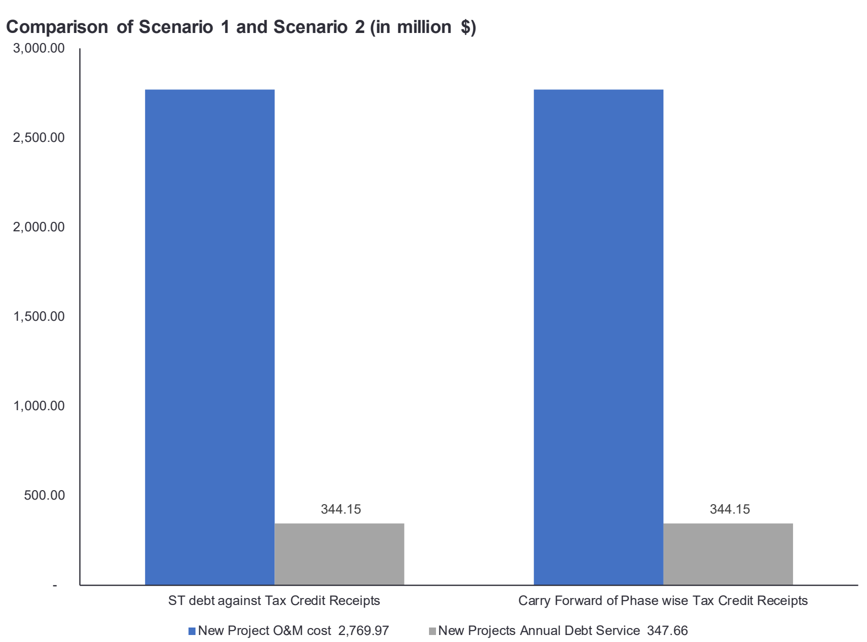
Phase 1 Uses	Total	2024	2025	2026	2027	2028	2029
Phase 1 CPAT#06: CHW Thermal Energy Storage Tank Total Cost	68.27	-	34.14	34.14	-	-	-
Phase 1 CPAT#07: Power Plant Boiler Removal Total Cost	1.84	-	0.92	0.92	-	-	-
Phase 1 CPAT#08: Micro District West Campus Total Cost	32.07	-	10.69	10.69	10.69	-	-
Phase 1 CPAT#09: Micro District South Pacific Total Cost	21.11	-	7.04	7.04	7.04	-	-
Phase 1 CPAT#10: Sewer Heat Recovery Site Piping Total Cost	20.71	-	6.90	6.90	6.90	-	-
Phase 1 CPAT#11: WCUP Heating System Improvements Total Cost	26.66	-	13.33	13.33	-	-	-
Phase 1 CPAT#12: Waste Receiving Station Electrical Upgrades Total Cost	29.97	-	9.99	9.99	9.99	-	-
Phase 1 CPAT#13: Chiller Installation Total Cost	11.66	-	3.89	3.89	3.89	-	-
Phase 1 Placeholder Spare 14 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 15 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 16 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 17 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 18 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 19 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 20 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 21 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 22 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 23 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 24 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 25 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 26 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 27 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 28 Total Cost	-	-	-	-	-	-	-
Phase 1 Placeholder Spare 29 Total Cost	-	-	-	-	-	-	-
Phase 1 Soft Cost Adder	-	-	-	-	-	-	-
Total Uses	**212.29**	**-**	**86.89**	**86.89**	**38.51**	**-**	**-**

Phase 1,2 TC Balance

9.8.3-1A: *Visual example of inputs for Phase III financial data analysis*

Details of Operational Expenses





9.8.3-1B and C: *Visual examples of outputs for Phase III financial data analysis*

9.9 Building Controls and Systems Analytics Assessment

University of Washington

UW Energy Renewal Plan

BUILDING CONTROLS AND SYSTEM ANALYTICS ASSESSMENT

October 25, 2024

Affiliated Engineers

Table of Contents

Glossary

- **BACnet:** A “Data Communication Protocol for Building Automation and Control Networks" developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
- **BAS:** Building Automation System.
- **Category:** PI System Explorer allows you to organize objects into categories. Categories are essentially object groups that you define yourself. Their purpose is to help you find objects more easily.
- **CCW:** Campus Cooling Water
- **CEUO:** Campus Energy, Utilities & Operations
- **DDC**: Direct digital control is the automated control of a condition or process by a digital device.
- **DHW**: Domestic Hot Water
- **Event frames:** Capturing important events in your process and collecting relevant data around those events can help analyze why they occurred.
- **FDD:** Fault Detection and Diagnostics
- **HHW:** Heating Hot Water
- **HVAC:** Heating, Ventilation, and Air Conditioning.
- **Modbus:** Modbus Protocol is a messaging structure developed by Modicon. It is used to establish client-server communication between intelligent devices.
- **NLB:** Network Load Balancer is a device that distributes network traffic across multiple servers, virtual machines, or WAN links to prevent a single host from becoming overloaded.
- **OPC:** OPC (Open Platform Communications) is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries.
- **PI Adapter**: PI Adapters enable new industrial IoT data patterns and are equipped to send data to an on-premises PI Server, up to OSIsoft Cloud Services, or through Edge Data Store. PI Adapters are supported on both Linux and Windows operating systems and can be deployed on rugged devices to monitor remote assets.
- **PI AF Model:** A PI AF model consists of connected elements that represent a logical model of your process. A model is itself an element, but with two additional element properties: layers and connections.

- **PI Archive:** The PI Archive "database" is a unique data storage tool that stores timestamps and values for process information. The PI "System" as it is often referred to at OSIsoft is the Asset Framework Database (AF). This is a database in the traditional sense stored and accessed using Microsoft SQL server.
- **PI Asset Framework (PI AF):** PI Asset Framework (PI AF) enables you to build a representation of your equipment and processes that can give you tremendous insight into your data.
- **PI Asset Model:** The PI AF representation of all your assets and processes together is called an asset model.
- **PI Asset:** In PI AF, the equipment, and processes that you want to monitor are called assets.
- **PI Attribute:** The associated data for an element is stored as attributes on the element. An attribute can alternatively reference a PI point, a formula, a value from a relational database, a file, a photograph, and more.
- **PI Connector**: PI Connectors similar to PI Interfaces, also collect data from sensors and control systems. They are designed to require minimal configuration and simplify the collection of data by intuitively scanning for a specific device protocol, collecting PI Points, and automatically creating a PI Asset Framework (AF) model for your asset.
- **PI Data Archive:** The OSIsoft product that stores time-series data from distributed data sources and serves this data to client applications in real-time. A major component of PI Server along with PI Asset Framework (AF).
- **PI DataLink:** PI DataLink is a Microsoft Excel add-in that enables you to retrieve information from your PI System directly into a spreadsheet.
- **PI Datalink:** PI Datalink support for event frames includes exploring and comparing hierarchical events. For more information, see Events in worksheets.
- **PI Element:** In the PI AF asset model, each piece of equipment is represented by an element.
- **PI Interface**: PI Interfaces collect data from external data sources using specific device protocols, providing real-time, fault-tolerant data to the PI System.
- **PI Point:** A single data stream stored by PI Data Archive. For example, a PI point might store the flow rate from a meter, a controller's mode of operation, the batch number of a product, text comments from an operator, or the results of a calculation.
- **PI System Explorer:** PI System Explorer provides a graphical user interface for creating, editing, and managing PI AF objects.

- **PI Tag (Input Tag and Output Tag):** The Tag attribute of a PI point is the name of the PI point. There is a one-to-one correspondence between the name of a point and the point itself. Because of this relationship, PI System documentation uses the terms "tag" and "point" interchangeably. Interfaces read values from a device and write these values to an input tag. Interfaces use an output tag to write a value to the device.
- **PI Vision:** AVEVA PI Vision enables you to view and analyze your PI System data during the time range of a particular event.
- **WCUP:** West Campus Utility Plant
- **Windows Failover Cluster:** A failover cluster is a group of independent computers that work together to increase the availability and scalability of clustered roles (formerly called clustered applications and services).

1.0 Data Collection and Reporting

The University of Washington (UW) employs the AVEVA PI System installed in 2021 for data visualization and historian. The PI System collects approximately 28,000 points at intervals ranging from 1 to 15 minutes, mainly through,

- HVAC equipment across 25 buildings.
- Meter points for CEUO-provided utilities such as steam, electricity, and CCW.
- Future expansions will include UW-owned natural gas and water/sewer meters.
- ABB historian in the Power Plant.
- FactoryTalk Historian in the WCUP.

Data collection utilizes protocols such as Modbus, BACnet, and OPC.

The following tools are utilized for data visualization.

- PI Vision
  - Meter rates
  - Meter consumption
- Tableau
  - Tracking outages
  - Rebilling
  - Monitoring energy performance
- Power BI
  - Validate meter performance
- Excel Connector
  - Ad hoc reports

The PI System is also used for managing,

- Utility data

Data is also being collected in SkySpark at WCUP for analytics and optimization.

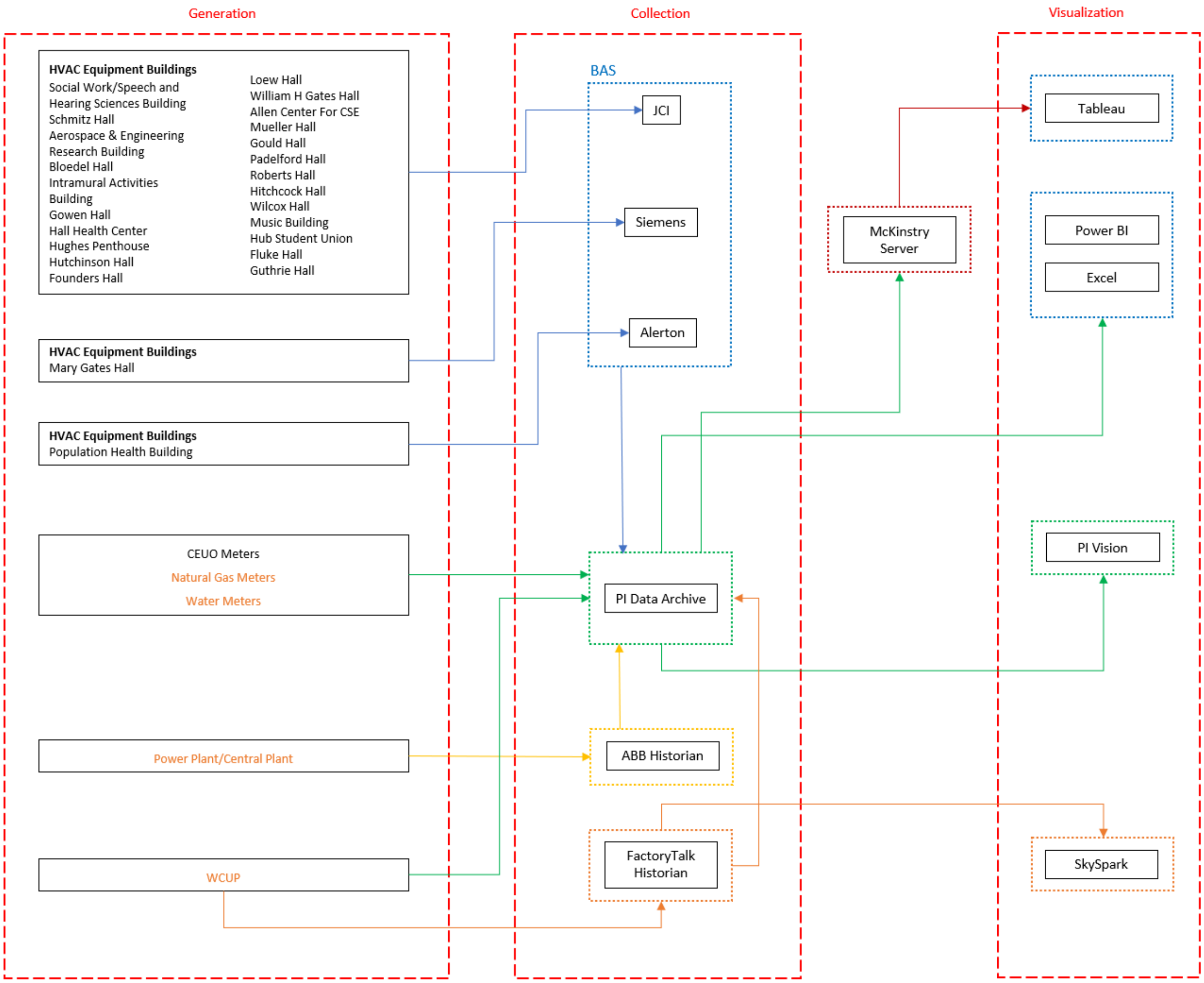


Figure 1: Existing Data Generation, Collection, and Visualization Map

Currently, the PI system collects data from the three Building Automation Systems (BAS), which in turn are polling data from 25 buildings, as illustrated in Figure 1. All major equipment points are included, along with zone-level controllers in some buildings. A sample of BAS points is provided in Table 1.

Table 1: UW BAS Sample Points

Bloedel Hall	Aerospace & Engineering Building	Hall Health Center
AHU	Heating Hot Water Pump	Terminal Unit
1132.BLD-.Rm14.ZnTmp 1132.BLD-.Rm10.ZnTmp 1132.BLD-.SF-P.PHTmp 1132.BLD-.SF-P.EFCmd 1132.BLD-.SF-P.EFSts	1131.AER-.HHW-PrH.HHWP07Cmd 1131.AER-.HHW-PrH.HHWP07Sts 1131.AER-.HHW-PrH.HHWP08Cmd 1131.AER-.HHW-PrH.HHWP08Sts	1203.TU-120.OccClgSp 1203.TU-123.InletAirVelPrs 1203.TU-123.EffClgSP 1203.TU-123.EffHtgSp 1203.TU-120.CCVlvCmd 1203.TU-120.SATmp 1203.TU-124.InletDmpCmd 1203.TU-120.EffOcc 1203.TU-120.HCVlvCmd

Table 2 provides the frequency of data collection for various PI Points.

Table 2: UW Data Collection Frequency

PI Points	Frequency
Electric Meter	1 minute
Chilled and Hot Water BTU Meter	15 minutes
Building DHW BTU Meter	15 minutes
HVAC Data from BAS	1 minute

2.0 Data Consistency and Standards

Standards and templates are established at the University of Washington for data collection within the PI System to ensure consistency and efficiency. These standards include a naming convention format: 'FacNum.Equipment.PointType'.

PI Tag Name examples:

- 1008.ECE.CCW.RetTemp
- 6524.HRC.ATS-B1-E01-1.KWH
- 1104.FTR.PLC-1122-1.M2-CR.Temp
- 1107.ALB.CCW.GPM
- 1279.CHL.CCW.DeltaT

To ensure data consistency across various protocols, a robust meter specification (Campus Energy, Utilities & Operations Standard) and a prescriptive specification with standard naming and documentation conventions are in place. Field support is provided both internally and through vendor contracts, such as with McKinstry, to ensure proper device configuration. Additionally, a DDC specification is being developed by UW in collaboration with its BAS consultant to maintain consistent naming conventions in BAS systems. Points integrated into the PI System are named in accordance with this standard.

The current object naming standard for BAS and metering is as follows:

<table>
<tr>
<td>Building_Equipment_Object
Building: Maximum of 4 characters
Equipment: Maximum of 10 characters
Object: Maximum of 29 characters
Object Examples:
BLDG_CHWP01_CHWSStrDifPrs (psi)
BLDG_CDWP01_CDWPmpCmd (Off/On)
ExhSys_EFRotCmd (Off/On)</td>
<td>Building_TYPEMeter_Object
Building: Maximum of 4 characters.
TYPE: Maximum of 2 characters.
Meter: Maximum of 8 characters.
Object: Maximum of 29 characters.
Object Examples:
BLDG_DWMain_VolTot (gal)
BLDG_NGMain_FlwRat (cfm)
BLDG_TECHW_CHWRTmp (^{0}F)
BLDG_ELMSB_Pwr (kW)</td>
</tr>
</table>

3.0 Data Analytics and Active Energy Management

[Refer to section **3.7 Building Controls & System Analytics** for standards and cost modeling.]

3.1 Data Repository

The University of Washington (UW) employs three building automation systems (BAS) including JCI, Alerton, and Siemens, and utilizes two additional data storage solutions in limited capabilities: an ABB data historian in the power plant and FactoryTalk Historian in the WCUP. Given the disparate nature of these systems, it is crucial to establish a unified and structured storage environment to prevent data silos.

To address this, the architecture depicted in Figure 2 is recommended. This architecture includes:

- A BAS-integrated enterprise SQL database for archiving BAS alarm and trend data. Although PI System has long term storage capabilities, it is recommended to have a database to keep the data in-house and for data portability.
- A BAS-integrated Data Historian platform (AVEVA PI) for archiving and visualizing BAS alarm and trend data.
- A BAS-integrated Data Analytics platform (SkySpark or a new FDD tool) for Fault Detection and Diagnostics (FDD).

In this approach, the standalone FDD tool focuses solely on identifying and diagnosing faults, while the data historian is used for broader data storage, management, and visualization purposes. This separation can streamline processes and optimize the strengths of each system.

Advantages of having a standalone FDD tool are as follow.

- FDD tools are specifically designed for fault detection and diagnostics, offering specialized algorithms and capabilities tailored to the systems they monitor.
- Provides the ability to create custom apps to integrate with your instance of SkySpark.
- SkySpark, for example provides the ability to write values to the BAS, generating the potential for automating functional performance tests in the commissioning process.

This integrated approach ensures a cohesive data management strategy, enhancing the efficiency and effectiveness of the campus's building automation systems.

It is essential to define project’s naming, tagging, and semantic requirements such as ASHRAE 223P, Project Haystack, Brick, and RealEstateCore schemas for data consistency across different systems.

When choosing an FDD vendor, there are several important factors to consider to ensure long-term cost efficiency and system performance. Some key points include:

- Vendors sell FDD software on either a points-based or subscription-based pricing model. Points-based pricing typically scales with the number of data points monitored, while subscription-based pricing involves ongoing service fees for continuous updates and use. It's crucial to perform a 5- to 10-year cost analysis to evaluate the total cost of ownership, including setup fees, hardware/software upgrades, and ongoing support for either pricing model.
- False alarms can lead to unnecessary costs and wasted time. Investigate how vendors handle false faults, including the accuracy of their diagnostic algorithms and the ability to adjust fault sensitivity thresholds to minimize false positives. Ensure the vendor provides strong support for resolving false alarms and works closely with your team to fine-tune the system for your specific building needs.
- For buildings with limited monitoring points, consider how the vendor helps optimize point usage by focusing on critical systems, using advanced analytics, and allowing dynamic point reassignment as priorities shift.
- The scalability of the system should be considered, ensuring it can grow with future expansions or equipment additions without requiring a costly overhaul.
- Look into the vendor's update cycle, frequency of software patches, and long-term innovation plans. Future-proofing the system is vital, especially regarding emerging technologies like AI and IoT advancements.
- Vendor training and support are essential. Ensure there are comprehensive training programs for your team, as well as responsive technical support, ideally with short resolution times for critical issues.

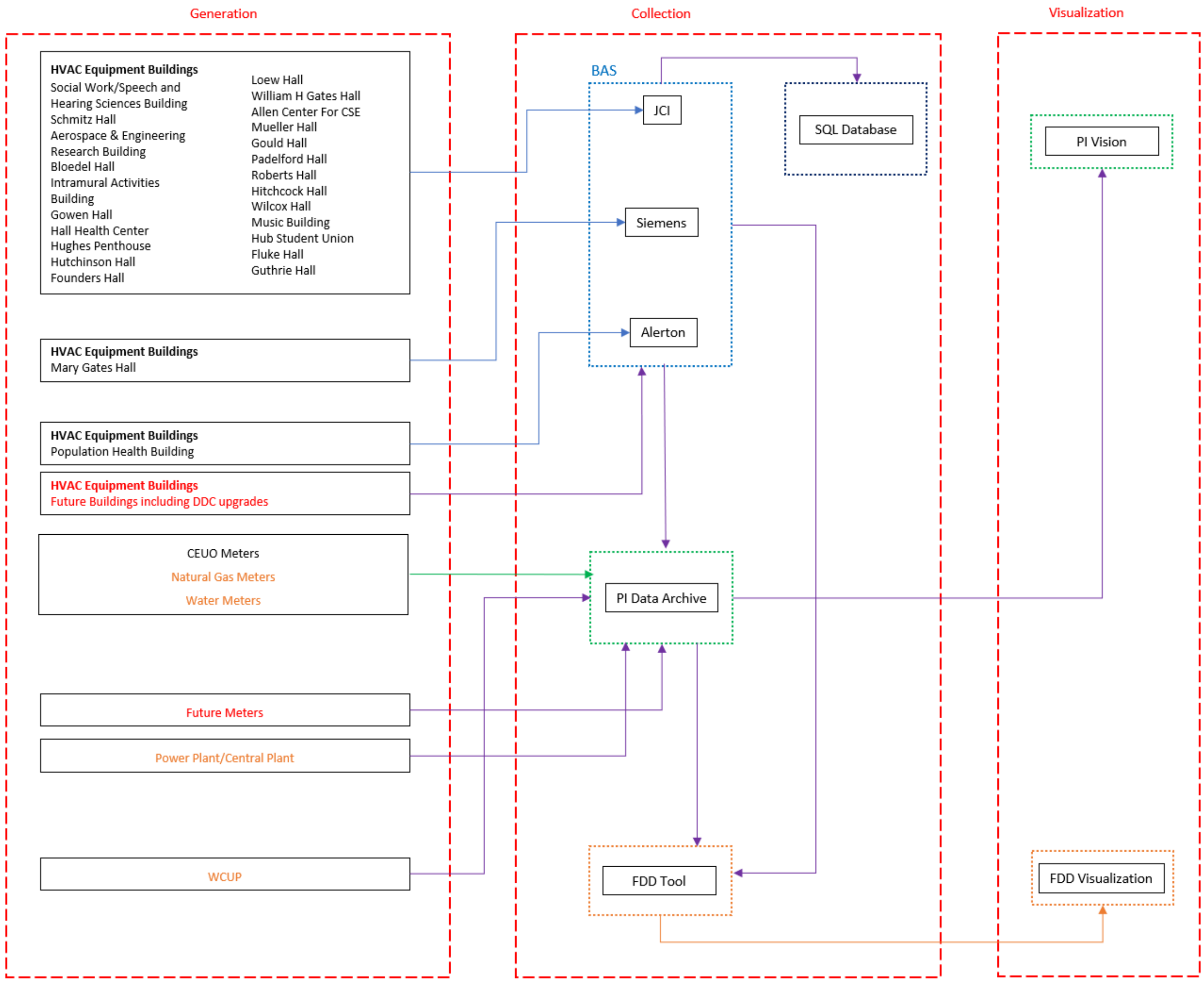


Figure 2: No ABB Historian + Standalone FDD Tool + PI Historian

An additional architecture where PI System is used for FDD is shown in Figure 3. The PI System inherently includes capabilities for various calculations, setting boundaries, and generating warnings at no additional cost. FDD leverages the Asset Framework component of the PI System for FDD. While the capabilities are present, implementing each use case solution requires knowledge, practice, or assistance from a Systems Integrator.

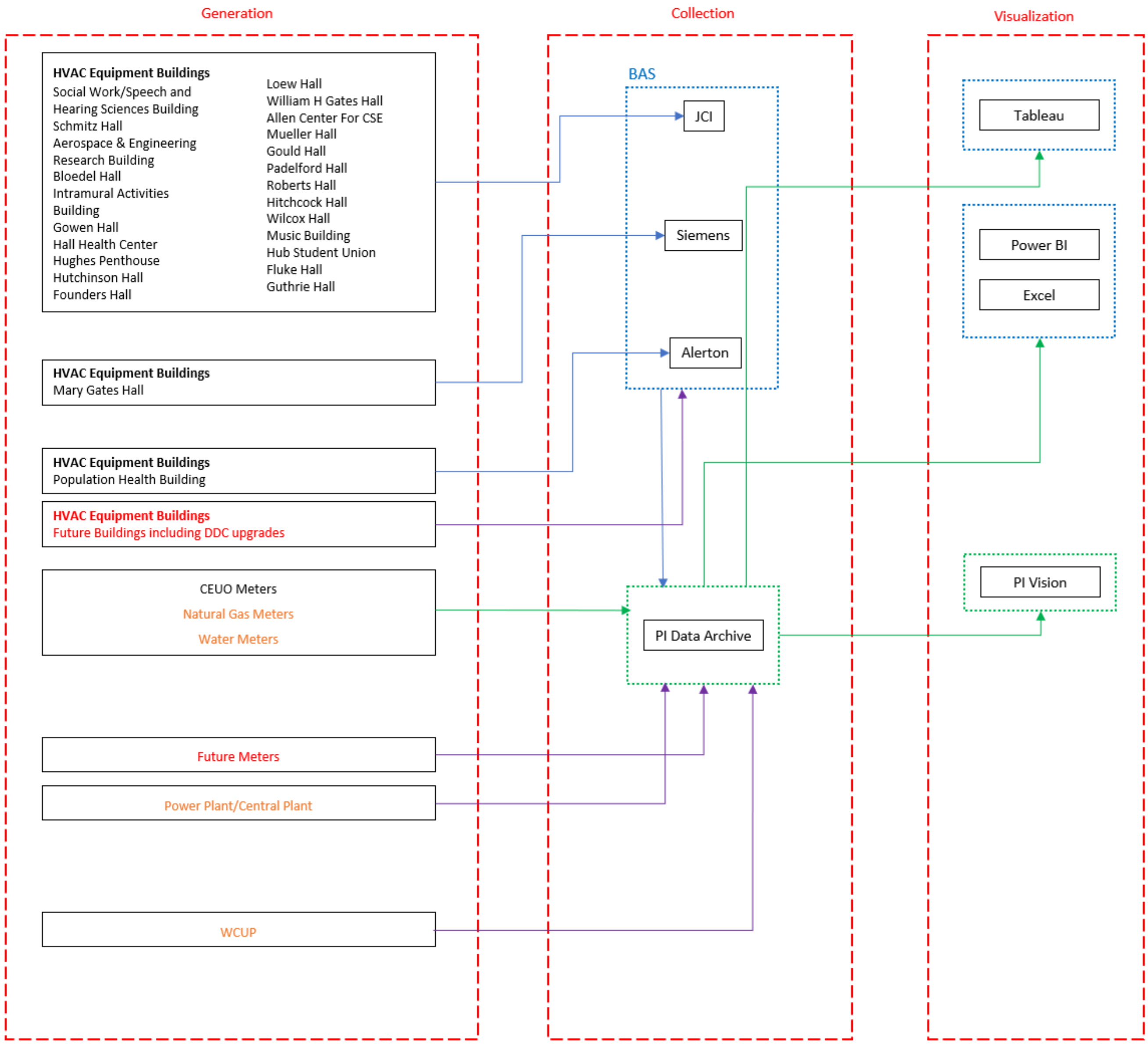


Figure 3: No ABB Historian + No FactoryTalk Historian + PI System for FDD

4.0 Best Practices and Recommendations

4.1 High Availability

A highly available PI System ensures uninterrupted access to data during both planned and unplanned outages. Planned outages involve scheduled maintenance of software or hardware, while unplanned outages result from unforeseen issues like power interruptions, network failures, hardware malfunctions, and software errors. In disaster scenarios, extensive system failures may occur. Essentially, the high availability feature of the PI System offer redundancy to prevent disruptions, whether they are planned or unexpected.

A typical AVEVA High Availability architecture is shown in Figure 4. This configuration is based on the following technologies:

- Windows Failover Clusters for an Always On availability group
- Network load balancing, to distribute PI AF client-to-PI AF application service communication

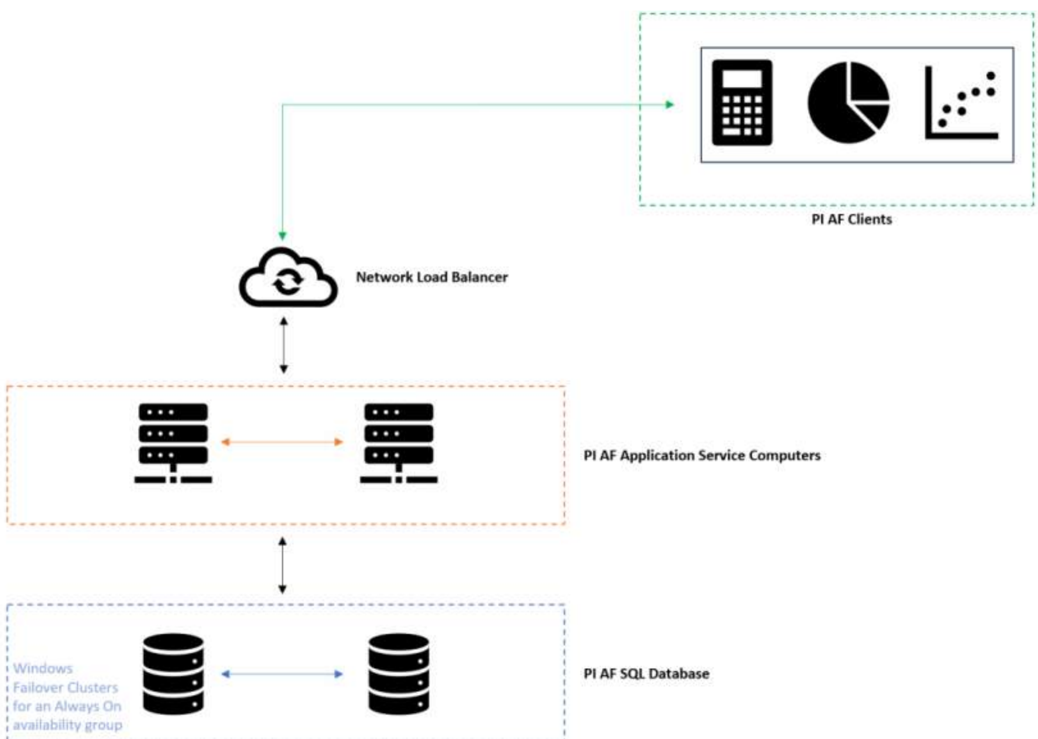


Figure 4: Typical AVEVA High Availability Architecture

4.2 Dedicated High Frequency Data Storage

The PI System is designed to capture real-time events in a snapshot table and store compressed data in the PI Data Archive. This data architecture is optimized for short-term event data and long-term data storage. However, the current setup at UW lacks the capabilities to store and analyze high frequency data. Modern low latency time series databases can fill this gap. By integrating a dedicated high-frequency data storage, fast processes such as electric demand response can be analyzed in parallel with the existing data infrastructure. A typical architecture of a snapshot DB is shown in Figure 5.

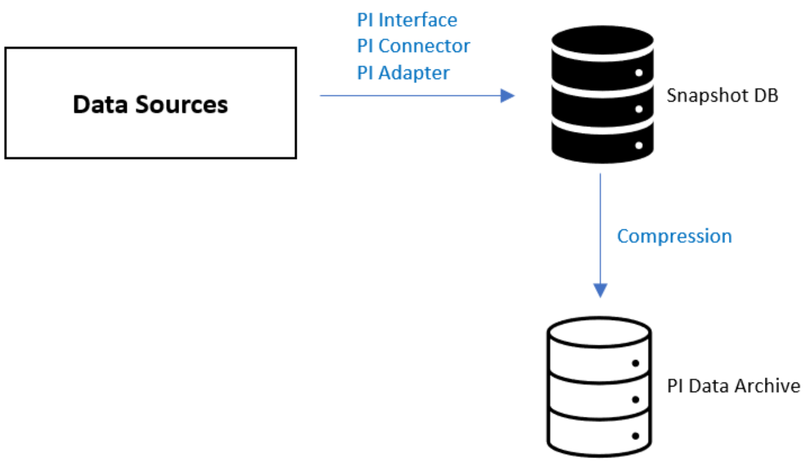
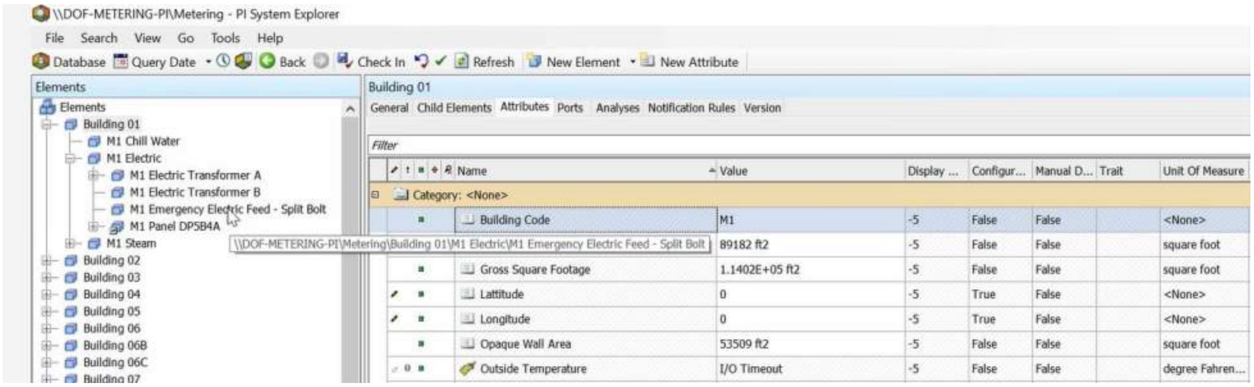


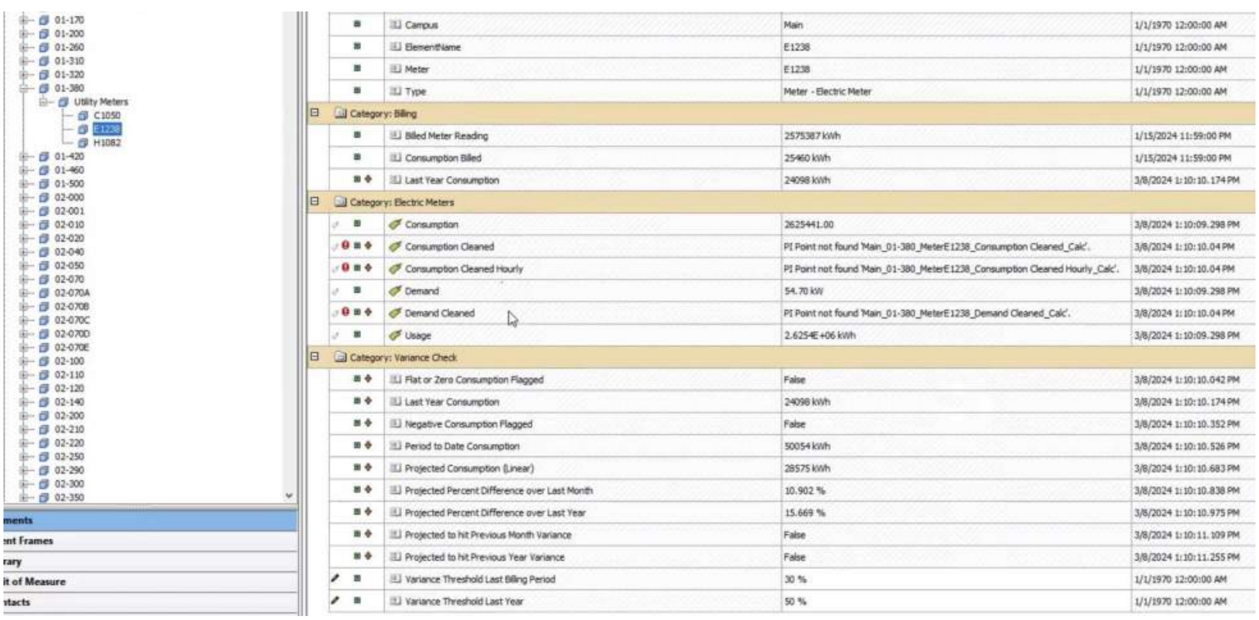
Figure 5: Typical Snapshot DB Architecture

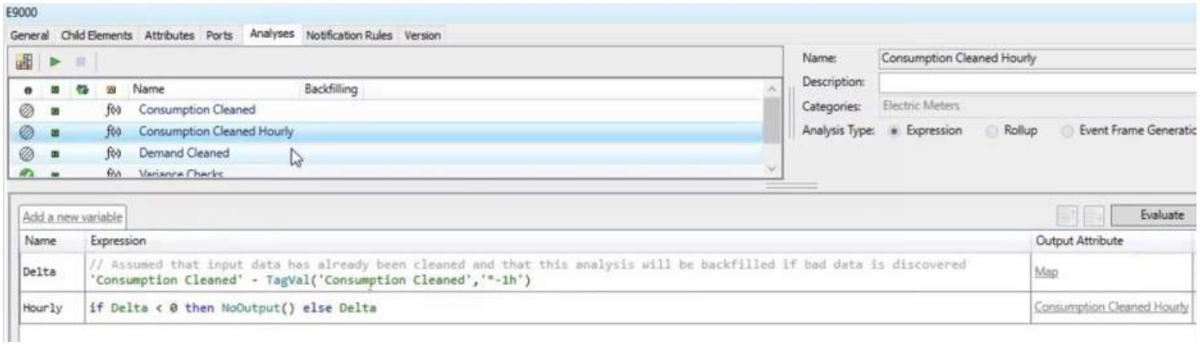
4.3 PI System Explorer

- Custom metering scripts for specific equipment under the building meter to get additional useful data. Furthermore, pinned shortcuts for quick navigation.

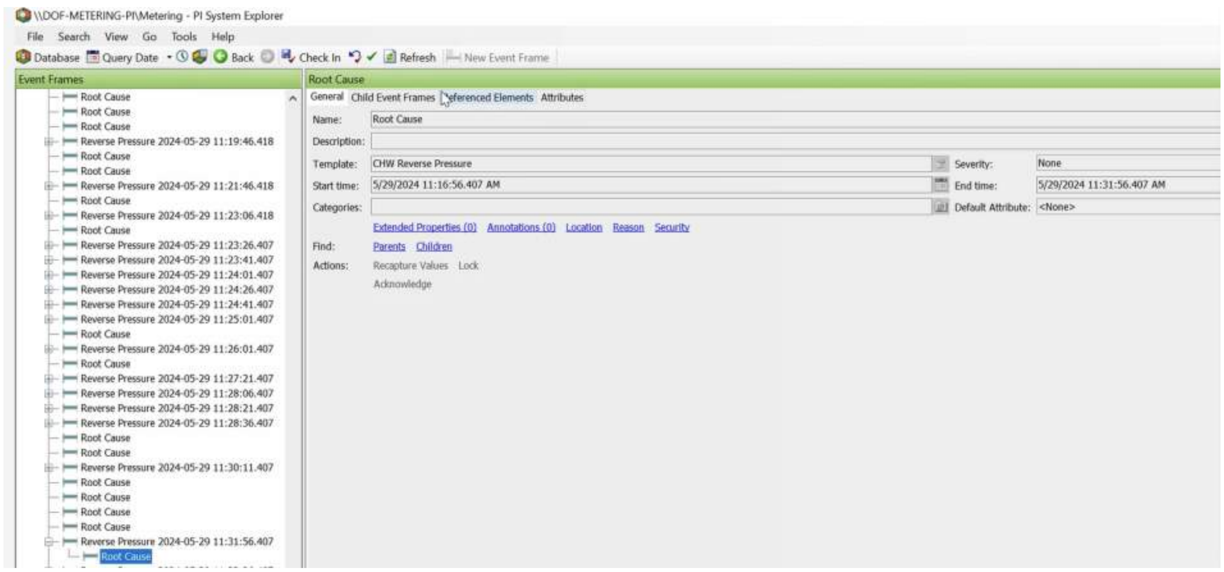


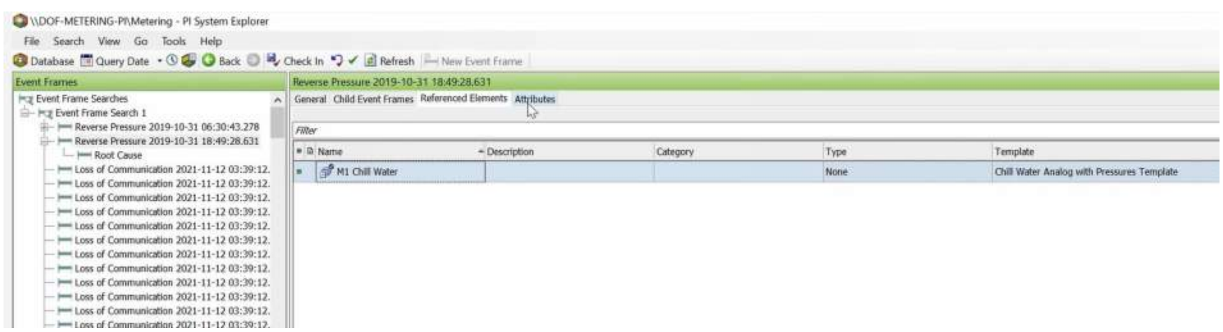
- PI Vision can replace Tableau using an Event Frame (Event frames in PI AF) to trigger PI Visualization.
- PI System Explorer allows to organize objects into categories. Categories are essentially object groups that are defined. Their purpose is to help find objects more easily. When searched for an object, one can use the category as a filter to reduce the list of results. Objects can belong to multiple categories.
- Custom scripts can be used to develop Variance Checks for electric meters. For example, Flat or Zero Consumption Flagged, Negative Consumption Flagged, etc.





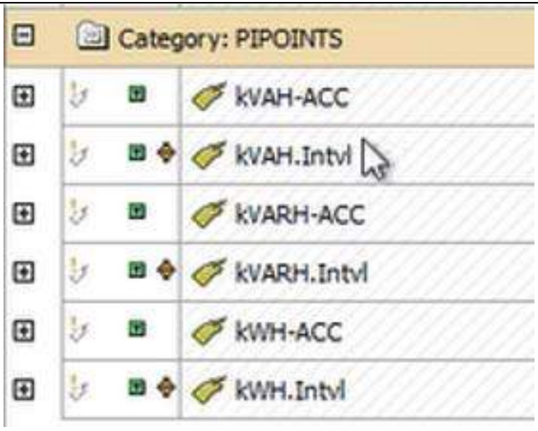
- Event Frame can be used for root cause analysis.





- Name the category names per electrical naming conventions, not the units. Additionally, conduct analysis such as Power Factor to understand how much of the incoming current is performing useful work. This can help reduce overall system demand, increase efficiency, and lessen the strain on the electrical grid.

UW


Category: PIPOINTS
kVAH-ACC
kVAH.Intvl
kVARH-ACC
kVARH.Intvl
kWH-ACC
kWH.Intvl

Others


Category: Power
Apparent Power
Reactive Power
Real Power
Total Power Used
Category: Power Factor
Power Factor
Power Factor Lead/Lag
Power Factor Raw
Category: Status
Bad Quality
Stale Data
Category: Totalizer
Total Power Used

5.0 References

AVEVA Documentation

AVEVA PI System

AVEVA Success Stories

9.10 Detailed Cost Estimates

The following cost estimates were developed during Phase II of the ERP process. These represent the cost estimates at the Phase II milestone; however, the final estimates are included in the Phase III report.

The Whiting-Turner Contracting Company
5285 Meadows Road, Suite #280
Lake Oswego, OR 97035
503-265-2000
www.whiting-turner.com

Project Name:	University of Washington - Energy Renewal Plan (ERP)
Type of Estimate:	Initial Concept Budget - Phase II
Estimate Date:	August 16, 2024
Project Location:	Seattle, WA
Client:	AEI
Client Contact:	Robby Oylear
Architect/Engineer:	AEI
Whiting-Turner Contact:	Steve Thomas / Adam Smith / Patrick Kantor / Kodiak Waldal
Document Set:	Phase II Documents (33 project SOW documents, dates vary)
Project Description:	Phase II of the University of Washington Energy Renewal Program includes 33 different projects aimed at decarbonizing UW Energy Systems. Projects are broken down into five core components: Building, Electrification, Plant, Site Distribution, and Source.

University of Washington - Energy Renewal Plan (ERP)
Initial Concept Budget - Phase II
August 16, 2024

EXECUTIVE COST SUMMARY

PRELIMINARY CONCEPTUAL ESTIMATES

BUILDINGS	Component ($)
B-1 Chiller Replacements	$20,573,390
B-6 Metering Program	$6,729,745
B-7 Controls Upgrades	$180,922,993
B-8,9,10 HHW Conversions	$260,097,167
B-11 Local Satellite Steam Plants	$60,469,792
ELECTRIFICATION (All Projects Combined)	$183,466,137
PLANT (All Projects Combined)	$382,932,123
SITE DISTRIBUTION (All Projects Combined)	$489,260,859
SOURCE (All Projects Combined)	$182,953,233
Energy Renewal Plan TOTAL	**$1,767,405,441**

Building HHW Conversion Category Average		
Low	Medium	High
$692,785	$2,037,014	$4,055,220

Note: Building HHW conversion costs based on completing conversion of five (5) buildings at a time.

General Notes:
1. See attached breakdown summaries for B-1, B-6, B-7, B-8 & B-11 .
2. Building HHW conversion costs based on completing conversion of five (5) buildings at a time.
3. Cost estimates are in 2024 dollars and do not include escalation beyond 2024.
4. Cost estimates do not include Builder's Risk, we have assumed this to be by UW.
5. Cost estimates do not include lane use/closure permits and fees, we have assumed this to be by UW.

9.11 Project Preliminary Milestone Schedules

This report is superseded and removed to reduce file size - please see final report in Phase 3

9.12 Constructability Commentary

UW ENERGY RENEWAL PLAN
CONSTRUCTABILITY COMMENTARY

The following section represents high level constructability commentary regarding the currently proposed projects aimed at decarbonizing University of Washington's district energy system. Constructability commentary has been broken down by project type (i.e. Buildings, Electrification, Plant, Site Distribution and Source). While comments are generally high level at this point, we expect as projects go through the design phases a number of these concerns can be made known and impacts assessed.

BUILDINGS

- It is recommended that building level modifications be completed in conjunction with site distribution projects to maximize the use of temporary, regional boilers. This will streamline coordination between the sequencing of existing steam demolition, new PHW installation and mechanical room modifications.
- Performing construction activities in occupied buildings will necessitate significant field investigation and coordination to verify existing MEP systems and prevent inadvertent impacts to building systems, occupants, and building function.
- Wherever possible, it is recommended that existing storage rooms and/or underutilized spaces be considered for conversion to new mechanical rooms to accommodate PHW equipment. This will facilitate the entire buildout of the mechanical room prior to disrupting existing steam services and mitigate the usage of temporary steam services. The original mechanical rooms may be converted to other use upon completion if possible.

ELECTRIFICATION

- General Note: Routing of new duct banks across active campus will require extensive coordination, scheduling and communication in order to perform work while keeping pedestrians safe and minimizing traffic flow disruptions.
- E-1 New UW Substation and Connection to Existing WRS
  - Ongoing coordination with SCL, TBD requirements, and systems impact study to be issued by SCL.
  - SCL Transformer lead for private development is 6-8 years out from release. Assuming UW and SCL will be able to mitigate.

PLANT

- General Note: Procurement times for equipment of the sizes contemplated for these projects continue to be long lead items and ultimately vary depending on manufacturer (if multiple acceptable per design) and will potentially remain in constant flux until fully released.
- General Note: Restrictions on access required to maneuver new and old equipment, piping, and other support components in and out of the existing facilities. May require removal and reinstallation of existing systems to remain in order to complete work and will not likely be known until further into design process.
- General Note: Commissioning time required for project as equipment, piping, controls components will be intensive with several operation modes and sequences required to be tested out.
- General Note: Identifying and addressing hazardous materials such as contaminated soils, lead and asbestos insulation, mastics, paint, etc., PCBs, etc.
- P-1 Convert CCW system to year-round operation:
  - Unknown of exact and specific control system programming changes required to fully implement.
  - Exposing unforeseen conditions and issues with existing systems, valves, components, etc.

throughout implementation.

- P-4 WCUP Annex project:
  - Coordination of shutdown impacts for switch over of SCL and UW duct banks under existing footprint.
  - Proper support and protection required of existing WCUP fuel tank immediately adjacent to the WCUP Annex expansion.
  - Coordination and timing of adjacent tunnel and W27 project construction timelines.
- P-5 CCW TES Tank:
  - Existing structure capacity to support new piping on roof and within coal storage areas of the Power Plant.
- P-6 PHW TES Tank:
  - Existing structure capacity to support new piping on roof and within coal storage areas of the Power Plant.
- P-14 Power Plant Controls Upgrade:
  - Unknown of exact and specific control system programming changes required and/or hardware upgrades required to fully implement.

SITE DISTRIBUTION

- Reuse of existing tunnels will trigger confined space requirements and limit trade partner productivity. Demolished materials and new materials must be hoisted into and out of existing vaults and carted to a given work area. Ultimately, materials will need to be moved inside of existing tunnels in an assembly line fashion as the tunnels are too narrow to allow for carts to pass by one another. Furthermore, in cases in which existing vaults are over 200 LF from a work area, productivity will be especially reduced.
- Due to limited space in existing tunnels, steam will need to be demolished in short sequences to limit the effected buildings. Use of regional steam plants noted under the Building conversions will greatly improve the overall construction efficiency and schedule duration of existing tunnel work as well as minimize the amount of coordination required.
- Due to utilization of steam tunnels, PHW will need to be installed very linearly. This will limit how many buildings can go online over time.
- In cases where steam demolition and PHW install are sequenced to maintain a steam loop and heating services to other buildings, steam valves and PHW valves must be installed at building lateral locations. Although this solution will mitigate the need for temporary steam boilers to keep existing buildings online, the project team will run into inefficiencies associated with flushing as PHW piping will be flushed in suboptimal distances.
- It is inevitable that temporary steam boilers will be required to maintain heating services to existing buildings. As a result, significant field investigation will be necessary at the design phase to understand each building's mechanical room, MEP systems and connections to existing tunnels. It is recommended that regional boilers be considered to temporarily feed multiple buildings at a time and allow for several crews to work within existing tunnels to demolish existing steam piping and install new PHW piping.
- Several schematic tunnel sections show cases in which existing pipe shown to be demolished is currently installed in close proximity to existing pipe that is shown to remain. It is recommended that existing pipes be abandoned to reduce costs and mitigate potential for inadvertent impacts to existing, live systems.
- Given the significant quantity of pipe required for the Energy Renewal Plan, it is recommended that offsite lots be made available to the General Contractor for equipment staging, jobsite trailers and material laydown. This will facilitate pipe deliveries to a location that is near the work area and pipe can then be quickly transported as needed. Ultimately, it would be extremely inefficient to deliver materials directly to

the work area due to site space constraints. Whether the project involves a new, direct-bury trench in the ROW or reuse of existing tunnels in the heart of the campus, it is unlikely that there will be necessary room to store large quantities of pipe.

- Installation of new tunnels will lead to significant impacts on surrounding vehicle and pedestrian traffic. Discussions with UW Metro and SDOT should be started far before construction to coordinate traffic control measures. Furthermore, it is recommended that night work be considered when major streets such as Pacific St. must be shut down.

SOURCE

- S-2 Sewer Heat Recovery Project – SHARC heat exchangers of the size being contemplated are under development and will not be available until mid/late 2026 at the earliest.
- S-2 Sewer Heat Recovery Project – Through conversations with various trade partners, it assumed that installing new sewer water intake piping and pumped sewer water return pipe in such close proximity to existing larger water mains and Benjamin Hall Interdisciplinary Research Building and Publications Services Building would be infeasible. As a result, the alternate Pasadena Place connection point is strongly recommended and is the basis of the attached estimate.

9.13 Scope of Work Documents

9.13.1 Scope of Work Narratives

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-1

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Replace distributed chillers by connecting to CCW system

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*

Remove building chillers and cooling towers (where applicable) and provide CCW service to provide cooling from the Campus Utility Plants. **Itemize cost per building.**

SEQUENCE: *(1-2 sentences)*

This work would beneficially occur alongside the PHW conversions described in SOW-B-8, 9, and 10. Building CCW conversions would be assessed as they are constructed to verify that the capacity of the Campus Utility Plants aligns with the increased centralized load. Capacity increases are described in SOW-P-2, 3, 7, and 8.

1.0 Detailed Work Description

A key part of the UW's Energy Strategy is to consolidate chillers located at buildings around campus by removing them and serving the buildings with centralized equipment at the Campus Utility Plants. The centralized equipment will be better maintained and generally start at a higher efficiency than the building-level equipment.

Removal of building-level distributed chillers and integration with the campus system will include:

- Extending CCW service to buildings without a current CCW connection.
- Demolition of existing building-level equipment
- Replacement of building chilled water pumps
- Addition of a heat exchanger or pressure reducing valve to isolate the buildings from the campus system from a water chemistry and/or hydraulic standpoint
- Building Automation System control upgrades

1.1 Demolition of Existing Chillers

Demolish equipment as indicated in the Building Conversion Summary_CCW attachment including:

- Water-cooled chillers, associated cooling towers, chilled water pumps, and condenser water pumps and appurtenances
- Air-cooled chillers
- Heat-recovery chillers

Provide BAS programming changes to integrate the sequence of operations of existing exhaust air heat recovery coils connected to the CCW system and allow for plant-level control of these exhaust air heat recovery coils. This occurs at the following buildings:

FACNUM – Building Name
- 1254 - UWMC EA Wing
- 6105 - Molecular Engineering & Sciences Building
- 6403 - Animal Research and Care Facility
- 6428 - Nanoengineering & Sciences Building
- 6524 - Hans Rosling Center for Population Health

1.2 Buildings with new CCW HX and Pumps

Buildings indicated to be provided with a new CCW heat exchanger and pump set shall be provided at the capacities indicated in the Building Conversion Summary_CCW attachment. Heat exchangers shall be plate & frame heat gasketed exchangers and sized for a 2°F approach temperature between the source water supply (42°F) and building water supply (44°F). New pumps shall be centrifugal end suction or horizontal split-case type with vibration isolation base. Pumps shall be provided with a variable speed drive per pump and new electrical connection.

Pumps shall be arranged in a decoupled manner with a decoupler pipe between the supply and return from the campus CCW system and the building pumps located on the building side of the decoupler. The return water control valve shall be located on the campus CCW return line.

1.3 Buildings with New Pressure Reducing Valve and Pumps

Some buildings currently connected to the CCW system require isolation from the campus CCW system due to their relative height above the proposed height of the CCW Thermal Energy Storage (TES) tank. These buildings require the addition of a pressure sustaining valve and new building-level distribution pumps.

Buildings indicated to be provided with a new Pressure Reducing Valve and pump set shall be provided at the capacities indicated in the Building Conversion Summary_CCW attachment. New pumps shall be centrifugal end suction or horizontal split-case type with vibration isolation base. Pumps shall be provided with a variable speed drive per pump and new electrical connection.

Pumps shall be arranged in a decoupled manner with a decoupler pipe between the supply and return from the campus CCW system and the building pumps located on the building side of the decoupler. The return water control valve shall be located on the campus CCW return line.

A pressure sustaining valve is provided on the return line back to campus. This allows the building side pumps to provide the necessary pressure to supply a building with piping and coils above the fill pressure of the system. When the water returns from the building loads, the pressure sustaining valve reduces the pressure to maintain a limit on the return pressure exerted on the system. This allows for a system fill pressure to be set low enough to satisfy the requirements of an atmospheric TES tank located at a lower elevation than the buildings served. Refer to Figure 1.3.1.

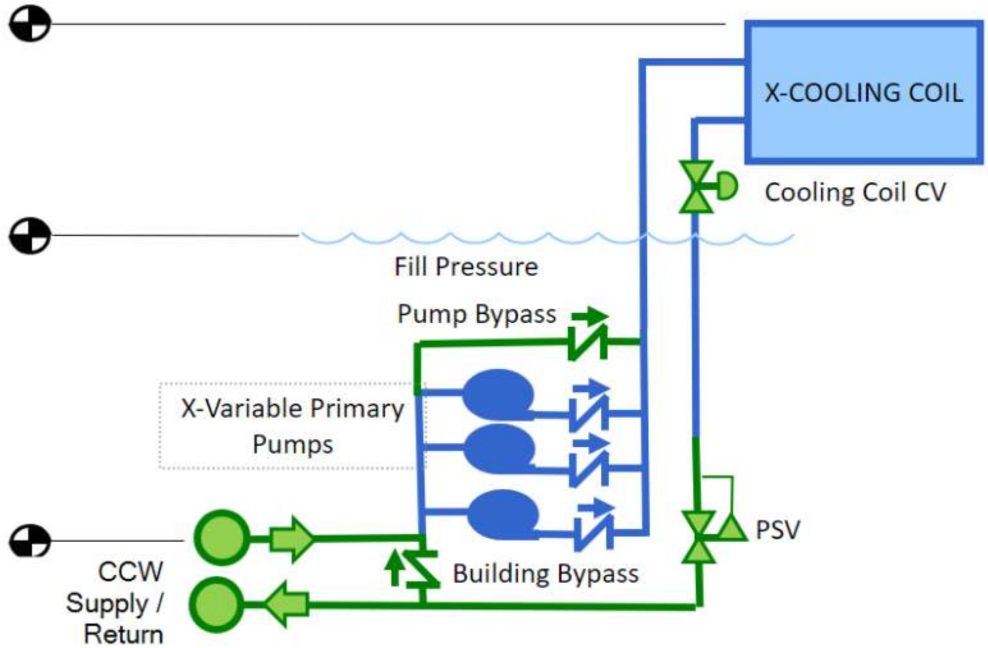


Figure 1.3.1 Diagram showing a building with cooling coils located above the system fill pressure.

1.4 Building Automation System Controls

Provide new BAS instrumentation and corresponding manual gauges and valving as follows for CCW connection to buildings including:

- Campus differential pressure transmitter
- CCW supply and return temperatures
- CCW flow meter
- CCW return control valve (high-performance butterfly valve)

2.0 Precedent / Following Activities

This work would beneficially occur alongside the PHW conversions described in SOW-B-8, 9, and 10. Building CCW conversions would be assessed as they are constructed to verify that the capacity of the Campus Utility Plants aligns with the increased centralized load. Capacity increases are described in SOW-P-2, 3, 7, and 8.

3.0 Attachments

Building Conversion Summary Table – CCW provides a table of buildings and defines the following scopes:

- Buildings being provided with a new connection to the CCW system where one did not previously exist
- Current connection to CCW system (no scope, reference only)
- Existing distributed chiller to be removed
- Existing heat recovery chillers to be removed
- New heat exchangers and pumps provided and size
- New CCW pipe size
- Distributed chiller cooling capacity (reference only)
- Location of existing chiller for estimating the length of new CCW pipe to chiller
- Valves and tees for future CCW conversions
- New Pressure reducing valves and pumps required.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-6

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Metering and Data Analytics Program

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Scope of work involves the installation of new electric, chilled water, and steam flow meters and integrating them with the PI System for enhanced data collection, monitoring, and analysis.

SEQUENCE: *(1-2 sentences)*
This work is independent of the other activities in the UW ERP.

1.0 Detailed Work Description

- Procure and install electric, chilled water, and steam flow meters. Refer to the Building Metering Table for detailed counts of metering scope by building.
- Provide the necessary PI Connectors and PI Interface for BACnet or Modbus to integrate with the PI System.
- Provide separate pricing by meter type (Electrical, Steam, CCW).
- Meters for new connections to the PHW and CCW systems are assumed to be included in the costs provided for that new work, under separate SOW documents.

1.1 Electric Meters

The following needs to be provided for the installation of new electric meters:

- Electric meter suitable for the expected load.
- Enclosure or cabinet to securely house the electric meter, unless installed integrally into a panelboard by the vendor.
- Provide current transformer (CT), wiring, conduit CT shorting block, and disconnect with fusing.
- Provide Modbus or Ethernet modules for communications link.

- Provide 1-inch metal conduit for the communication wiring.
- Except as otherwise indicated, provide the manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by the manufacturer, and as required for the application indicated.
- PI Connectors and/or PI Interfaces specific for protocols like Modbus to collect data from the meters.

1.2 Chilled Water and Steam Flow Meters

The following needs to be provided for the installation of new chilled water and steam flow meters:

- Provide a suitable flow meter (such as electromagnetic) and temperature sensor for a complete hydronic energy measurement system.
- IP or RS485 interface connection for communication with BACnet MS/TP or Modbus RTU directly to the BAS.
- Provide a class II power supply.
- Active analog and digital outputs.
- Remote wall mount aluminum cast if using a meter with NEMA 4 touch screen display.
- NEMA 4 Transmitter Enclosure and NEMA 6 Wetted Sensor Enclosure.
- Optional 0.5-inch FNPT waterproof conduit connectors.
- Except as otherwise indicated, provide the manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by the manufacturer, and as required for the application indicated.
- Provide required wiring, cables, and conduits
- PI Connectors and/or PI Interfaces specific for protocols like BACnet or Modbus to collect data from the meters.

2.0 Precedent / Following Activities

N/A

3.0 Attachments

Refer to the Building Metering Table for detailed counts of metering scope by building.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-7

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Building Controls Upgrades

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
The scope of work involves upgrading existing pneumatic control systems to Direct Digital Control (DDC), converting partial controls to full controls, and integrating them with the PI System for enhanced data collection, monitoring, and analysis.

SEQUENCE: *(1-2 sentences)*
This work is not directly dependent of the other activities in the UW ERP. This work would beneficially occur at the same time as building conversion work under SOW-B-8, 9, and 10.

1.0 Detailed Work Description

- Demolish the existing pneumatic controls and upgrade to DDC.
- Convert the building's partial controls to full controls.
- Provide the necessary PI Connectors and/or PI Interface for BACnet or Modbus to integrate with the PI System.

1.1 Pneumatic to DDC Upgrades

Below is the list of buildings with pneumatic controls recommended for an upgrade to DDC:

FAC NUM	GROSS AREA (SF)	BUILDING
1101	5,459	Transportation Services Building
1129	16,946	Ceramic and Metal Arts Building
1143	288,352	McMahon Hall

FAC NUM	GROSS AREA (SF)	BUILDING
1147	206,114	Haggett Hall
1155	10,831	Staff Human Resources Building
1156	43,099	Mackenzie Hall
1172	1,920	Urban Horticulture Field House
1177	23,220	Lewis Hall
1183	5,104	Cunningham Hall
1185	1,871	Aerodynamics Laboratory
1186	22,933	Harris Hydraulics Laboratory
1196	27,045	Pavilion Pool
1199	9,131	Plant Operations Building
1219	70,345	Center on Human Development and Disability Clinic
1220	12,378	Center on Human Development and Disability South
1221	53,201	Magnuson Health Sciences Center A
1224	48,288	Magnuson Health Sciences Center C
1277	76,271	Benson Hall
1348	6,914	North Physics Laboratory Cyclotron Shop
1349	2,147	Theodor Jacobsen Observatory

FAC NUM	GROSS AREA (SF)	BUILDING
1352	25,066	Oceanography Building
1740	15818	Alumni House

To convert from pneumatic to Direct Digital Control (DDC), the following components are required:

- Furnish and install DDC control units. Provide controllers including standalone control for HVAC equipment and terminal unit controllers for controlling dampers, if required.
- The new building automation system (BAS) shall utilize electronic sensing, microprocessor-based digital control, and electronic actuation of dampers and valves (except where noted otherwise) to perform control sequences and functions specified.
- Provide control products and systems that completely integrate and operate from the existing mechanical equipment currently in operation.
- Contractor shall furnish and install any power supply surge protection, filters, etc. as necessary for proper operation and the protection of controllers, operator interfaces, printers, routers, gateways, and other hardware and interface devices. All equipment shall be capable of handling voltage variations 10 percent above or below the measured nominal value (TBD), with no effect on hardware, software, communications, and data storage.
- Provider shall extend all power source wiring required for operation of all equipment and devices provided.
- All control power for a given standalone controller and all associated controls for this standalone controller shall originate from the same circuit.
- All mechanical equipment which is supplied with emergency power shall have the DDC controller supplied with emergency power.
- Provide an uninterruptible power supply (UPS) if required or as necessary. UPS shall protect against blackouts, brownouts, surges, and noise. UPS shall include LAN port and modem line surge protection.
- Provide a Maintenance Bypass Switch that allows input voltage to bypass the UPS and directly power the connected equipment if an abnormal condition prevents the UPS from supporting the load, or if the UPS is required to be taken out of service. Provide all software, cables, peripherals, etc. for a complete system.

- Control wiring between field-installed controls, indicating devices, and unit control panels.
- Interlock wiring between electrically interlocked devices, sensors, and between a hand or auto position of motor starters as indicated for all mechanical and controls.
- Wiring associated with annunciator and alarm panels (remote alarm panels) and connections to their associated field devices.
- All other necessary wiring for a fully complete and functional control system as specified.
- Provide electronic and electric control products in sizes and capacities indicated, consisting of valves, dampers, controllers, sensors, and other components as required for complete installation. Except as otherwise indicated, provide the manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by the manufacturer, and as required for the application indicated.
- Communication Wiring and BAS low voltage wiring/cables: All wiring shall be in accordance with the latest edition of the National Electrical Code.
- Contractor shall supply all communication wiring between controllers, routers, gateways, local and remote peripherals, local supervisory LAN, and secondary controller LAN.
- Provide signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, etc., and low voltage control wiring with appropriate sizes.
- Provide control panels with suitable brackets for wall mounting, unless noted otherwise, for each control system and UL-listed cabinets for use with line voltage devices.
- Provide control valves, if required, that shall be pressure independent type, unless otherwise noted for chilled water and heating hot water coils. Control valves shall be equipped with heavy-duty actuators and pilot positioners with proper close-off rating and capability for each individual application. Pressure independent control valves shall be provided with actuators manufactured and warranted by the valve manufacturer.
- Provide factory-fabricated automatic control dampers if required of sizes, velocity, and pressure classes as required for smooth, stable, and controllable airflow.
- Provide field devices for input and output of digital (binary) and analog signals into controllers. Provide signal conditioning for all field devices as recommended by field device manufacturers and as required for proper operation in the system.
- Field devices specified herein are generally ‘two-wire’ type transmitters, with power for the device to be supplied from the respective controller. If the controller provided is not equipped to provide this power, is not designed to work with ‘two-wire’ type transmitters, if the field device is to serve as input to more than one controller, or where the length of wire to the controller will unacceptably affect the accuracy, the Contractor

shall provide 'four-wire' type equal transmitter and necessary regulated DC power supply or 120 VAC power supply, as required.

- For field devices specified hereinafter that require signal conditioners, signal boosters, signal repeaters, or other devices for proper interface to controllers, Contractor shall furnish and install the proper device, including 120V power as required. Such devices shall have accuracy and repeatability equal to, or better than, the accuracy and repeatability listed for respective field devices.
- Provide temperature sensors where necessary. Standard Control and Monitoring sensors shall be utilized for all other sensors not identified as Certified Control and Monitoring sensors. A combination of temperature and humidity sensors may be used for zone-level monitoring.
- Provide differential pressure transmitters, valve bypass for differential pressure sensors, differential pressure switches, pressure switches, current switches, current transformers, CO2 sensors/transmitters, electric control components (limit switches, freezestat, firestat, thermostat, etc.), control relays, control transformers, time delay relays, electric push button switch, pilot light, alarm horn, and electric selector switch, where necessary and if required.
- Provide engraved phenolic or micarta nameplates for all equipment, components, and field devices furnished.

1.2 Complete Controls Integration

Below is the list of buildings with partial controls recommended for conversion to full controls. The comments column indicates the spaces with existing control systems.

FAC NUM	GROSS AREA (SF)	BUILDING	COMMENTS
1119	27317	John M. Wallace Hall	Mechanical Room with Johnson Controls.
1124	132856	Condon Hall	Mechanical Room with Johnson Controls.
1126	154893	Meany Hall	Mechanical Room with Johnson Controls.

FAC NUM	GROSS AREA (SF)	BUILDING	COMMENTS
1127	107532	Schmitz Hall	Mechanical Room with Johnson Controls.
1136	139308	Padelford Hall	Mechanical Room with Johnson Controls.
1141	53521	Oceanography Teaching Building	Mechanical Room with Johnson Controls.
1148	146576	Plant Services Building	Training Center with Johnson Controls.
1154	107895	Henderson Hall	Mechanical Room with Johnson Controls.
1168	479989	Magnuson Health Sciences Center T	Mechanical Room with Johnson Controls.
1174	180246	Magnuson Health Sciences Center J	Two Floors and Mechanical Room with Johnson Controls
1192	73176	Miller Hall	Fourth Floor with Johnson Controls.
1193	333022	Suzzallo Library	Buildings 1925 and 1935 with Alerton Controls.
1201	69226	Gowen Hall	Mechanical Room with Johnson Controls.
1204	159160	Hansee Hall	Mechanical Room with Johnson Controls.

FAC NUM	GROSS AREA (SF)	BUILDING	COMMENTS
1223	240467	Magnuson Health Sciences Center BB	Floor 17th and Mechanical Room with Johnson Controls
1225	60533	Magnuson Health Sciences Center E	Mechanical Room with Johnson Controls.
1275	32417	Graves Annex Building	Mechanical Room with Johnson Controls.
1279	39730	Chemistry Library Building	Basement Labs with Johnson Controls.
1294	77771	Atmospheric Sciences-Geophysics Building	Mechanical Room with Johnson Controls.
1300	150951	Magnuson Health Sciences Center I	Basement Mechanical Room with Johnson Controls.
1304	116200	Magnuson Health Sciences Center B	Mechanical Room with Johnson Controls.
1308	74847	South Campus Center	Mechanical Room with Johnson Controls.
1325	39936	Engineering Library	Mechanical Room with Johnson Controls.
6138	123298	Poplar Hall	KMC with Other Controls (Unknown).
6514	19320	Life Sciences Greenhouse	HAVC Side with Siemens Controls excluding the Greenhouse System

The following is required for conversion to full controls:

- The requirement mentioned in 'Section 1.1 Pneumatic to DDC Upgrades' applies to this section as well.
- Provide required components, all interface devices and software where required and necessary to provide an integrated system connecting controllers, gateways, routers, etc. to the BAS.

1.3 PI System Integration

To integrate the points from the controllers to the PI System, the following needs to be provided:

- PI Connectors and/or PI Interfaces specific for protocols like BACnet or Modbus to collect data from the meters.

2.0 Precedent / Following Activities

N/A

3.0 Attachments

N/A

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-8

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Conversion of Low Difficulty Existing Buildings from Steam to Heating Water

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Scope of work will include extension of piping from connection of utility tunnel to building or direct-bury. Low difficulty buildings have existing hot water distribution systems with no steam distributed through the building. Work will be limited to the mechanical room space and extension of new hot water from tunnel/site.

SEQUENCE: *(1-2 sentences)*
Building conversion scope will be tied directly to the schedule for distribution piping within tunnels. As buildings would be cut off from the steam source by distribution work within the tunnels, building conversions would need to be planned and executed ahead of that implementation. This work will follow along with the site distribution replacement schedule.

1.0 Detailed Work Description

High-level summary scope of work for building conversions:

- Extension from the primary heating water distribution system (located at the tunnel connection to the building or direct-bury) point of connection to building mechanical room.
- Installation of new water-to-water plate and frame heat exchangers (HX)
- Installation of DHW and LHW system components (HX + Storage tanks or Electric stand-alone)

Scheduling concerns: ideally this work would occur in shoulder or summer season to minimize the impact of the heating service interruption window to occupied building activities.

1.1 Demolition Scope

Demolition of existing steam and condensate piping, steam-to-water shell & tube HX, and pneumatic controls associated with existing space heating and domestic/lab water heating systems. All steam and condensate piping, as well as steam appurtenances (condensate receivers / pumps, steam or condensate meters), shall be demolished.

1.2 Primary Heating Water Distribution to Building Mechanical Room

It should be assumed that mechanical rooms are not immediately adjacent to the tunnel. Extension from the tunnel pipe can be assumed to already have been provided with isolation valves. Assume a 50 ft distance from the tunnel connection to the building and the mechanical room (100 ft of piping with supply/return) as an average representative length of pipe routed through the building. Assume that piping is routed through areas with ceilings which must be removed and repaired to install piping in a concealed space.

Pipe sizes to each mechanical room are provided in the Building Conversion Summary Table.

Primary heating water supply and return piping will be SCH 40 carbon steel piping with 2" fiberglass insulation and all-service jacket. Supports, guides, and anchors shall be provided.

1.3 Space Heating Heat Exchangers and Pumps

Building heating water systems are currently heated by steam-to-water shell and tube HXs, which will be replaced with new plate & frame heat gasketed exchangers. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (162°F) and the building hot water supply (160°F). Existing hot water pumps shall remain.

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and pumps. Heat exchangers are listed by MBH capacity. Pumps are listed by motor horsepower, where they are expected to be replaced. New pumps shall be centrifugal end suction or horizontal split-case type with vibration isolation base.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, and pumps. For Low Difficulty buildings, the pumps, coils, and piping downstream of the HX shall be existing to remain.

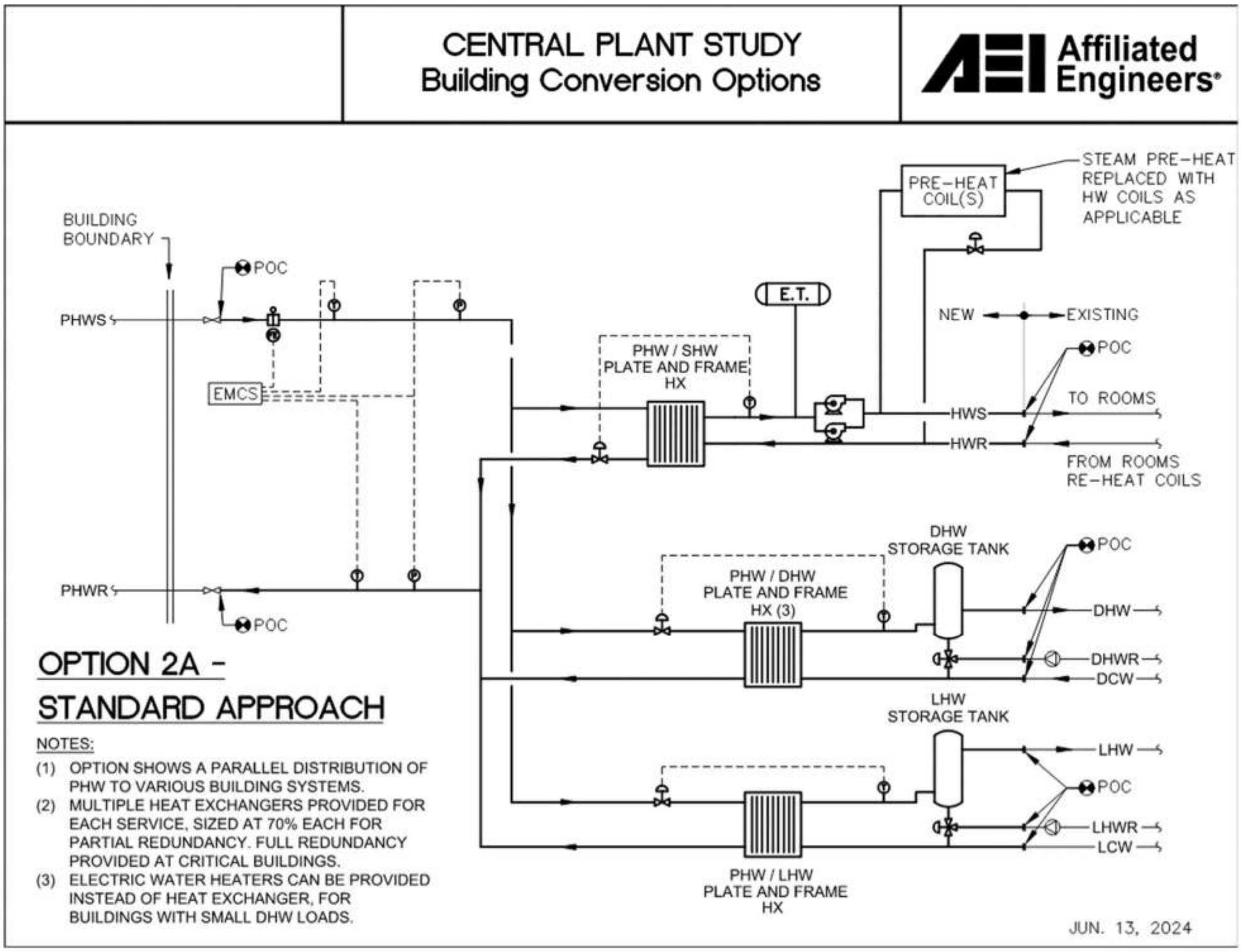


Figure 1.3.1 Building Hot Water Conversion Diagram

1.4 Domestic Hot Water / Lab Hot Water System

Domestic and Lab Hot Water systems are currently fed by steam-to-water shell and tube HXs, which will be replaced with new double-wall plate & frame heat gasketed exchangers. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (142°F) and the domestic / lab hot water supply (140°F). The source water supply temperature for the domestic / lab water systems is lower due to anticipated shoulder-season supply temperature reset sequences.

1.4.1 HEAT EXCHANGERS AND STORAGE TANKS

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and storage tanks. Heat exchangers are listed by MBH capacity. Storage tanks are listed in gallons. Storage tanks shall be vertical type with a minimum of 2" insulation.

Low difficulty buildings require a new storage tank on DHW and LHW systems.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, pumps, and storage tanks.

1.4.2 ELECTRIC WATER HEATERS

Refer to the Building Conversion Summary Table for the building DHW/LHW demand (MBH) and DHW System Type (Redundant, 70% Redundant, or Electric) to determine the size and quantity of HXs for the building conversion. The same table includes information on the requirement for hot water storage tanks.

Where buildings are noted as Electric, a HX is not required due to the system size not justifying a hydronic connection. Electric systems are typically limited to 24 kW or less per Energy Code requirements.

1.5 Building Controls

New DDC building automation system components will be provided for control and monitoring. BAS shall communicate to the facility network for remote monitoring and response by the district energy control system.

1.6 Temporary Heating Systems

All lab and hospital buildings shall be provided with temporary heating service to maintain continuous service for building operations. Any non-lab/hospital buildings deemed to require a shutdown of more than one week shall include a temporary heating service, which may include trailer-mounted hot water boilers with connections to existing systems. The requirement for temporary systems is left to the discretion of the estimating team based on the estimated construction schedule and projected service interruptions.

2.0 Precedent / Following Activities

Building conversion work can occur ahead of the piping distribution work within the tunnels, provided that there is adequate space within existing mechanical rooms or adjacent spaces converted for that purpose, to allow for installation of new water-to-water heat exchangers in parallel with existing.

Building conversion work done ahead of time in this way would greatly reduce interruption of building heat, domestic water, and lab hot water during the switch over from steam-source to water-source.

There are no following activities to the building conversion work, however, the Building Chiller replacement work is likely to be scheduled at the same time for construction scheduling efficiency.

3.0 Attachments

Refer to the Building Conversion Summary Table for detailed information on the scope of work within individual buildings.

Refer to the site piping distribution plans provided under the SOW-D-X files for the central piping system.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-9

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Conversion of Moderate Difficulty Existing Buildings from Steam to Heating Water

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Scope of work will include extension of piping from connection of utility tunnel to building or direct-bury. Moderate difficulty buildings have existing hot water distribution systems to room/zone-level terminal units and steam distribution to AHU coils or steam process loads. Work will extend beyond the mechanical room to each AHU steam coil being replaced.

SEQUENCE: *(1-2 sentences)*
Building conversion scope will be tied directly to the schedule for distribution piping within tunnels. As buildings would be cut off from the steam source by distribution work within the tunnels, building conversions would need to be planned and executed ahead of that implementation. This work will follow along with the site distribution replacement schedule.

1.0 Detailed Work Description

High-level summary scope of work for building conversions:

- Extension from the primary heating water distribution system (located at the tunnel connection to the building or direct-bury) point of connection to building mechanical room.
- Installation of new water-to-water plate and frame heat exchangers (HX)
- Replace existing air handling unit (AHU) steam coils with hot water coils. New building HW piping riser from the mechanical room (typically located in the basement) to the building AHUs (located in the basement or on the roof). Coils shall be installed within the existing AHU casing. It is anticipated that no modifications will be required to the unit

casing or supply fans since the coils should be a similar pressure drop to the previous installation.

- The replacement of existing building HW pumps to meet increased flow requirement to serve building AHU coils. Provide new Variable Frequency Drives for each pump.
- Installation of DHW and LHW system components (HX + Storage tanks or Electric stand-alone)
- Point-of-use steam generators will be provided for steam processes and humidification requirements.
- Electrical power distribution, panels, and disconnects as required for new hot water pumps, coil pumps, and electric steam generators.

Scheduling concerns: ideally this work would occur in shoulder or summer season to minimize the impact of the heating service interruption window to occupied building activities.

1.1 Demolition Scope

Demolition of existing steam and condensate piping, steam-to-water shell & tube HX, steam coils in AHUs, and pneumatic controls associated with existing space heating and domestic/lab water heating systems. All steam and condensate piping as well as steam appurtenances (condensate receivers / pumps, steam, or condensate meters) shall be demolished.

1.2 Primary Heating Water Distribution to Building Mechanical Room

It should be assumed that mechanical rooms are not immediately adjacent to the tunnel. Extension from the tunnel pipe can be assumed to already have been provided with isolation valves. Assume a 50 ft distance from the tunnel connection to the building and the mechanical room (100 ft of piping with supply/return) as an average representative length of pipe routed through the building. Assume that piping is routed through areas with ceilings which must be removed and repaired to install piping in a concealed space.

Pipe sizes to each mechanical room are provided in the Building Conversion Summary Table.

Primary heating water supply and return piping will be SCH 40 carbon steel piping with 2” fiberglass insulation and an all-service jacket. Supports, guides, and anchors shall be provided.

1.3 Space Heating Heat Exchangers and Pumps

Building heating water systems are currently heated by steam-to-water shell and tube HXs, which will be replaced with new plate & frame heat gasketed exchangers. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (162°F) and the building hot water supply (160°F). Existing hot water pumps shall remain.

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and pumps. Heat exchangers are listed by MBH capacity. Pumps are listed by motor horsepower, where they are expected to be replaced. New pumps shall be centrifugal end suction or horizontal split-case type with vibration isolation base.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, and pumps. For Moderate Difficulty buildings, the zone terminal coils, and piping downstream of the HX shall be existing to remain.

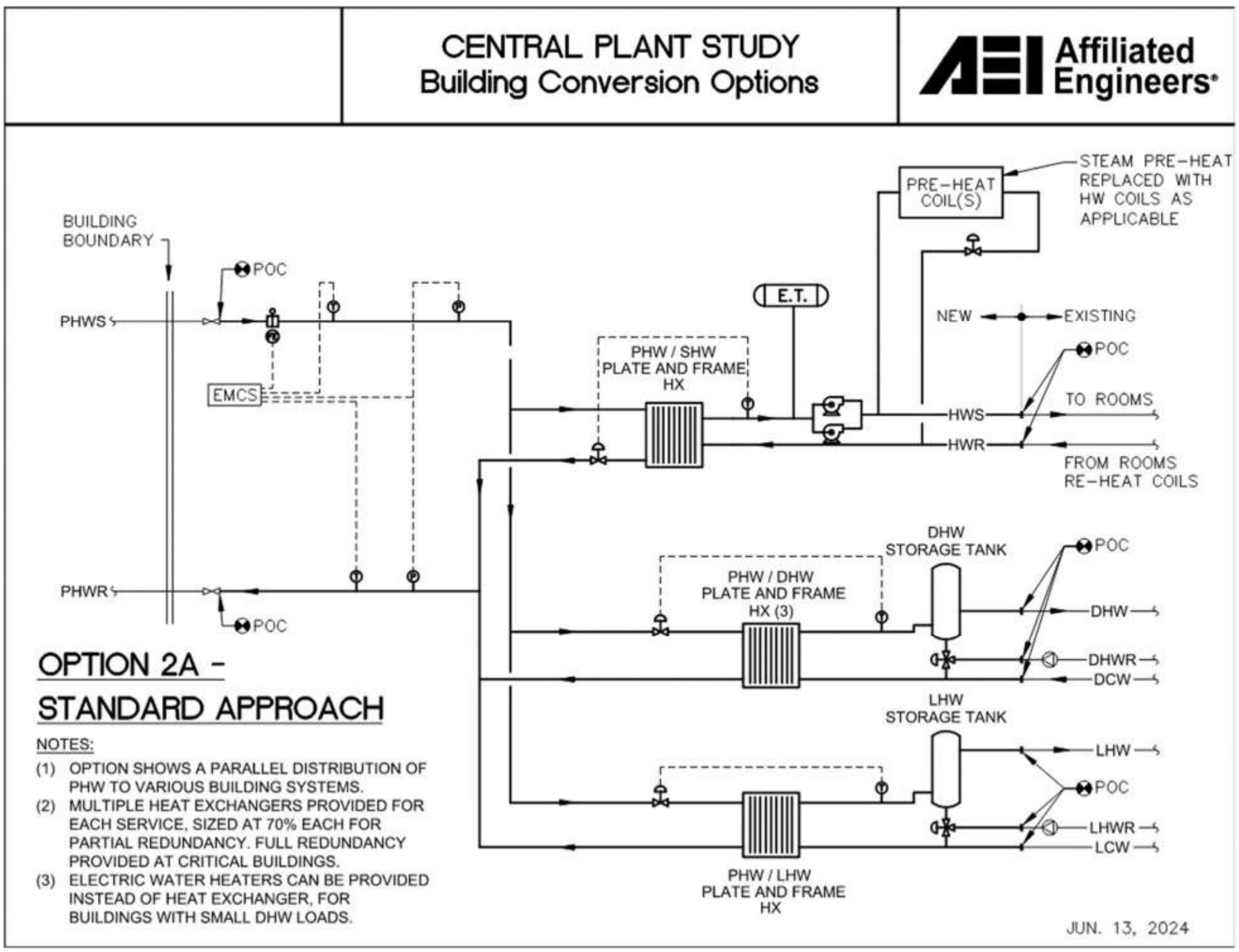


Figure 1.3.1 Building Hot Water Conversion Diagram

1.4 Air Handling Unit Steam-to-HW Coil Replacement

New piping shall be provided from the existing building mechanical room to all existing AHUs with steam coils. This will require piping through the existing building to each AHU. Steam coils will be replaced with new heating water coils. These coils shall be sized for a maximum 118°F entering water temperature and a 20°F temperature difference, following current best practices for heat pump systems.

Coils shall be provided with a circulator pump sized for the design flow of the coil for freeze protection. In this way, the flow through the coil is constant.

As noted in section 1.3, existing building hot water pumps will be replaced with new to provide the increased flow and pressure associated with the AHU heating water coils.

1.5 Domestic Hot Water / Lab Hot Water System

Domestic and Lab Hot Water systems are currently fed by steam-to-water shell and tube HXs, which will be replaced with new double-wall plate & frame heat gasketed exchangers. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (142°F) and the domestic / lab hot water supply (140°F). The source water supply temperature for the domestic / lab water systems is lower due to anticipated shoulder-season supply temperature reset sequences.

1.5.1 HEAT EXCHANGERS AND STORAGE TANKS

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and storage tanks. Heat exchangers are listed by MBH capacity. Storage tanks are listed in gallons. Storage tanks shall be vertical type with a minimum of 2” insulation.

Moderate difficulty buildings require a new storage tank on DHW and LHW systems.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, pumps, and storage tanks.

1.5.2 ELECTRIC WATER HEATERS

Refer to the Building Conversion Summary Table for the building for the size and quantity of HXs for the building conversion. The same table includes information on the requirement for hot water storage tanks.

Where buildings are noted as Electric, a HX is not required due to the system size not justifying a hydronic connection. Electric systems are typically limited to 24 kW or less per Energy Code requirements.

1.5.3 ELECTRIC POINT-OF-USE STEAM GENERATORS

Some buildings with small to moderate quantities of steam used for process uses (sterilization for example) or humidification will require electric point-of-use steam generators to be provided. Refer to the Building Conversion Summary Table for Steam Generator requirements.

Where new electric point-of-use steam generators are required, assume a 300 lb/hr capacity electric resistance steam generator. The new steam generator system shall be provided with supply water service and electrical service. Electric steam generator shall be provided with 480V and 110 kW electrical connection.

1.6 Building Controls

New DDC building automation system components will be provided for control and monitoring. BAS shall communicate to the facility network for remote monitoring and response by the district energy control system.

1.7 Temporary Heating Systems

All lab and hospital buildings shall be provided with temporary heating service to maintain continuous service for building operations. Any non-lab/hospital buildings deemed to require a shutdown of more than one week shall include a temporary heating service, which may include trailer-mounted hot water boilers with connections to existing systems. The requirement for temporary systems is left to the discretion of the estimating team based on the estimated construction schedule and projected service interruptions.

2.0 Precedent / Following Activities

Building conversion work can occur ahead of the piping distribution work within the tunnels, provided that there is adequate space within existing mechanical rooms or adjacent spaces converted for that purpose, to allow for installation of new water-to-water heat exchangers in parallel with existing.

Building conversion work done ahead of time in this way would greatly reduce interruption of building heat, domestic water, and lab hot water during the switch over from steam-source to water-source.

There are no following activities to the building conversion work, however, the Building Chiller replacement work is likely to be scheduled at the same time for construction scheduling efficiency.

3.0 Attachments

Refer to the Building Conversion Summary Table for detailed information on the scope of work within individual buildings.

Refer to the site piping distribution plans provided under the SOW-D-X files for the central piping system.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

B-10

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Conversion of High Difficulty Existing Buildings from Steam to Heating Water

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Scope of work will include extension of piping from connection of utility tunnel to building or direct-bury. High difficulty buildings have existing steam distribution systems to room/zone-level terminal units and steam distribution to AHU coils. Additionally, steam process loads may exist and require replacement. New heating water systems where none previously existed will be installed. Expansion of existing mechanical room space or new mechanical rooms converted from storage or other unused space will be required. Work will extend beyond the mechanical room to each AHU steam coil being replaced and to every room level steam device.

SEQUENCE: *(1-2 sentences)*
Building conversion scope will be tied directly to the schedule for distribution piping within tunnels. As buildings would be cut off from the steam source by distribution work within the tunnels, building conversions would need to be planned and executed ahead of that implementation. This work will follow along with the site distribution replacement schedule.

1.0 Detailed Work Description

High-level summary scope of work for building conversions:

- Extension from the primary heating water distribution system (located at the tunnel connection to the building or direct-bury) point of connection to building mechanical room.
- New room-level hot water radiators shall be provided in each room previously provided with steam radiators.

- New heating water systems where none previously existed will be installed in buildings with steam radiators. Expansion of existing mechanical room space or new mechanical rooms converted from storage or other unused space will be required. Work will extend beyond the mechanical room to each AHU steam coil being replaced and to every room-level steam device.
    - Installation of new water-to-water plate and frame heat exchangers (HX)
    - The replacement of existing building HW pumps to meet increased flow requirement to serve building AHU coils. Provide new Variable Frequency Drives for each pump.
    - Replace existing AHU steam coils with hot water coils. A new building HW piping system shall be provided to all new zone-level terminal equipment and central AHUs.
    - Coils shall be installed within the existing AHU casing. It is anticipated that no modifications will be required to the unit casing or supply fans since the coils should be a similar pressure drop to the previous installation.
- Provide glycol feeder system to new building HW loops.
- Installation of DHW and LHW system components (HX + Storage tanks or Electric stand-alone)
- Point-of-use steam generators will be provided for steam processes and humidification requirements. For certain facilities, a new central steam generation plant may be provided and distributed throughout the campus where significant quantities of steam process loads exist. Refer to other Scope of Work documents for details on those systems.
- Electrical power distribution, panels, and disconnects as required for new hot water pumps, coil pumps, and electric steam generators.

Scheduling concerns: ideally this work would occur in shoulder or summer season to minimize the impact of the heating service interruption window to occupied building activities.

1.1 Demolition Scope

Demolition of existing steam and condensate piping, steam-to-water shell & tube HX, steam coils in AHUs, and pneumatic controls associated with existing space heating and domestic/lab water heating systems. All steam and condensate piping, as well as steam appurtenances (ie. condensate receivers / pumps, steam, or condensate meters), shall be demolished. Existing steam distributed throughout the building shall be demolished.

1.2 Primary Heating Water Distribution to Building Mechanical Room

It should be assumed that mechanical rooms are not immediately adjacent to the tunnel. Extension from the tunnel pipe can be assumed to already have been provided with isolation valves. Assume a 50 ft distance from the tunnel connection to the building and the mechanical room (100 ft of piping with supply/return) as an average representative length of pipe routed through the building. Assume that piping is routed through areas with ceilings which must be removed and repaired to install piping in a concealed space.

Pipe sizes to each mechanical room are provided in the Building Conversion Summary Table.

Primary heating water supply and return piping will be SCH 40 carbon steel piping with 2" fiberglass insulation and an all-service jacket. Supports, guides, and anchors shall be provided.

1.3 Space Heating Heat Exchangers and Pumps

Building heating water systems are currently heated by direct-use steam coils and radiators, which will be replaced with a new building-level hydronic heating water system. Plate & frame heat gasketed exchangers shall be provided between the campus primary heating water system and the building heating water system. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (162°F) and the building hot water supply (160°F). Existing hot water pumps shall remain.

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and pumps and the requirement for the replacement of Steam Radiators. Heat exchangers are listed by MBH capacity. Pumps are listed by motor horsepower, where they are expected to be replaced. New pumps shall be centrifugal end suction or horizontal split-case type with vibration isolation base.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, and pumps. For High Difficulty buildings with existing hydronic heating systems, the zone terminal coils and piping downstream of the HX shall be existing to remain. For High Difficulty buildings with steam radiators, no components or piping of the existing heating system shall remain.

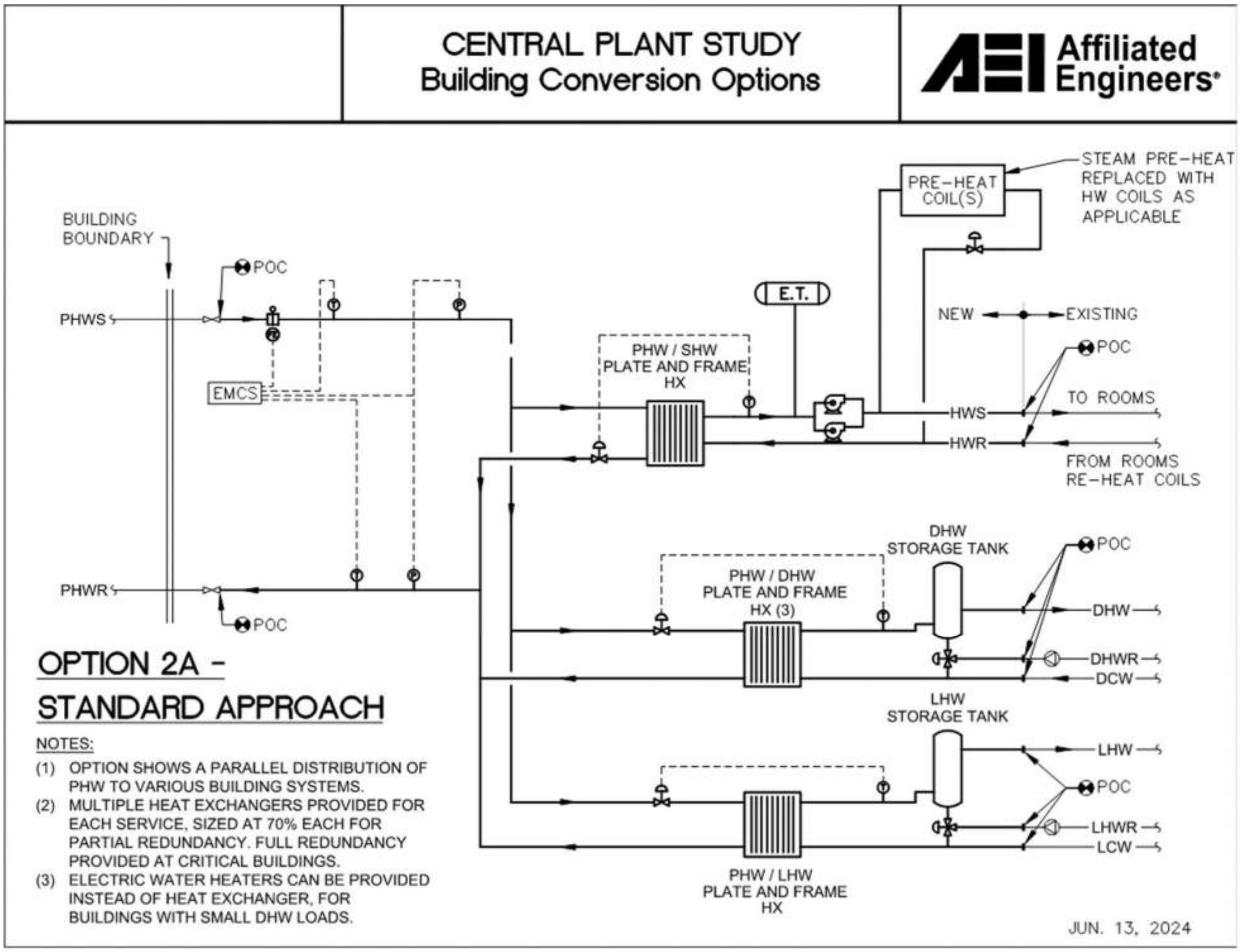


Figure 1.3.1 Building Hot Water Conversion Diagram.

1.4 Air Handling Unit Steam-to-HW Coil Replacement

New piping shall be provided from the existing building mechanical room to all existing AHUs with steam coils. This will require piping through the existing building to each AHU. Steam coils will be replaced with new heating water coils. These coils shall be sized for a maximum 118°F entering water temperature and a 20°F temperature difference, following current best practices for heat pump systems.

Coils shall be provided with a circulator pump sized for the design flow of the coil for freeze protection. In this way, the flow through the coil is constant.

1.5 Domestic Hot Water / Lab Hot Water System

Domestic and Lab Hot Water systems are currently fed by steam-to-water shell and tube HXs, which will be replaced with new double-wall plate & frame heat gasketed exchangers. Heat exchangers shall be sized for a 2°F approach temperature between the source water supply (142°F) and the domestic / lab hot water supply (140°F). The source water supply temperature for the domestic / lab water systems is lower due to anticipated shoulder-season supply temperature reset sequences.

1.5.1 HEAT EXCHANGERS AND STORAGE TANKS

Refer to the Building Conversion Summary Table for the size and quantity of building heating water heat exchangers and storage tanks. Heat exchangers are listed by MBH capacity. Storage tanks are listed in gallons. Storage tanks shall be vertical type with a minimum of 2" insulation.

Moderate difficulty buildings require a new storage tank on DHW and LHW systems.

Refer to Figure 1.3.1 for additional details on piping system configuration, control valves, instrumentation, pumps, and storage tanks.

1.5.2 ELECTRIC WATER HEATERS

Refer to the Building Conversion Summary Table for the building for the size and quantity of HXs for the building conversion. The same table includes information on the requirement for hot water storage tanks.

Where buildings are noted as Electric, a HX is not required due to the system size not justifying a hydronic connection. Electric systems are typically limited to 24 kW or less per Energy Code requirements.

1.5.3 ELECTRIC POINT-OF-USE STEAM GENERATORS

Some buildings with small to moderate quantities of steam used for process uses (sterilization for example) or humidification will require electric point-of-use steam generators to be provided. Refer to the Building Conversion Summary Table for Steam Generator requirements.

Where new electric point-of-use steam generators are required, assume a 300 lb/hr capacity electric resistance steam generator. The new steam generator system shall be provided with supply water service and electrical service. Electric steam generator shall be provided with 480V and 110 kW electrical connection.

For certain facilities, a new central steam generation plant may be provided and distributed throughout the campus where significant quantities of steam process loads exist. Refer to SOW-B-11 Local Satellite Steam Plants for Process Load documents for details on those systems.

1.6 Building Controls

New DDC building automation system components will be provided for control and monitoring. BAS shall communicate to the facility network for remote monitoring and response by the district energy control system.

1.7 Temporary Heating Systems

All lab and hospital buildings shall be provided with temporary heating service to maintain continuous service for building operations. Any non-lab/hospital buildings deemed to require a shutdown of more than one week shall include a temporary heating service, which may include trailer-mounted hot water boilers with connections to existing systems. The requirement for temporary systems is left to the discretion of the estimating team based on the estimated construction schedule and projected service interruptions.

2.0 Precedent / Following Activities

Building conversion work can occur ahead of the piping distribution work within the tunnels, provided that there is adequate space within existing mechanical rooms or adjacent spaces converted for that purpose, to allow for installation of new water-to-water heat exchangers in parallel with existing.

If the building conversion work was done ahead of time it would greatly reduce interruption of building heat, domestic water, and lab hot water during the switchover from steam-source to water-source.

There are no following activities to the building conversion work, however, the Building Chiller replacement work is likely to be scheduled at the same time for construction scheduling efficiency.

3.0 Attachments

Refer to the Building Conversion Summary Table for detailed information on the scope of work within individual buildings.

Refer to the site piping distribution plans provided under the SOW-D-X files for the central piping system.

Scope of Work Description

PROJECT NUMBER:

B-11

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Local (Satellite) Steam Plants for Process Loads – ARCF, MSHC and Medical Center

SUMMARY DESCRIPTION:

This project includes scope descriptions for construction of new satellite 185psi steam plants and distribution piping to connect to steam process loads. These new steam plants will serve existing process (non-heating) loads that need to remain on steam after the campus steam service is decommissioned. These are three separate, individual projects that should be priced separately.

SEQUENCE: *(1-2 sentences)*

Several research facilities require steam for critical day-to-day functions and cannot tolerate any shutdowns. These facilities must be supplied with steam from satellite plants (or temporary services) before the connection to the existing campus steam system is disconnected. The existing branch steam piping infrastructure serving the end-use devices may want to remain intact for reuse, as it is likely installed throughout multiple levels of occupied spaces (especially in MHSC). Connections of new satellite steam plants to the existing steam piping system may want to occur near the mains in the tunnels or buildings' basements. In addition, in many cases the steam piping serving this equipment today must be removed before new PHW piping can be installed in many of the tunnels; proper phasing for this transformation is critical, and temporary services may need to be provided to maintain system operation.

1.0 Detailed Work Description

What follows is a description of the installation of three separate satellite steam plants for the process loads in the South of Pacific Campus; ARCF/Foege Satellite Steam Plant, MHSC Satellite Steam Plant, and Medical Center Satellite Steam Plant. A simple schedule of the plants is provided in Table 1.0.1.

TABLE 1.0.1. SATELLITE STEAM PLANT SCHEDULE

Satellite Steam Plant Schedule										
Plant Number	Service	Sum of Peaks (Lb/Hr)	Approx Total Lb/Hr Required w/ 30% Diversity	Aprox Total Boiler HP	Total # Boilers	Skid Size w/ Feedwater System and Boilers	Boiler Room Sq Ft.	Approx. Skid Operating Weight (lbs)	Notes	Basis of Design
SSP-1	ARCF/Foege	15,000	10,500	313	3	564" x 120" x 160"H	1175	65,800	Includes Feedwater Skid	Fulton VMP
SSP-2	Central MHSC	10,000	7,000	209	3	486" x 120" x 180"H	1020	65,800	Includes Feedwater Skid	Fulton VMP
SSP-3	UW Med Center	6,000	4,200	125	3	402" x 100" x 150"H	850	27,700	Includes Feedwater Skid	Fulton VSRT/VMP

1.1 Satellite Steam Plant SSP-1: Serves ARCF/Foege Bioengineering and Genome

In order to serve large process loads at ARCF and Foege Genome/Bioengineering, a satellite steam plant is to be installed in the vicinity of those buildings. Refer to Fig B-11-1, below. The exact location of the new boiler plant is to be determined, but for the purposes of this estimate, the boiler/feedwater skid location will be the existing chiller room in the basement of Foege Hall. The chillers located in the basement are proposed to be phased out and removed as part of the WCUP CCW expansion plan. Removal of these chillers would create space for the new steam boilers and the accompanying feedwater skid. See Fig B-11-2, below. The new boiler system shall be provided with natural gas service, supply water service, electrical service, combustion air service, flue gas service, and relief valves service. Combustion exhaust flue and relief vents will require complex routing up Foege to the roof.

Routing between Foege and ARCF would take place direct bury, or run in the tunnel, if space is available. Cost shall include the most expensive of these two options. Distance between ARCF mechanical room and Foege mechanical room is ~350' of horizontal piping, including some vertical transitions, and two building entrances. Routing the steam line at least partially through the J/K Loading Dock is also an option. See Fig B-11-3, below.

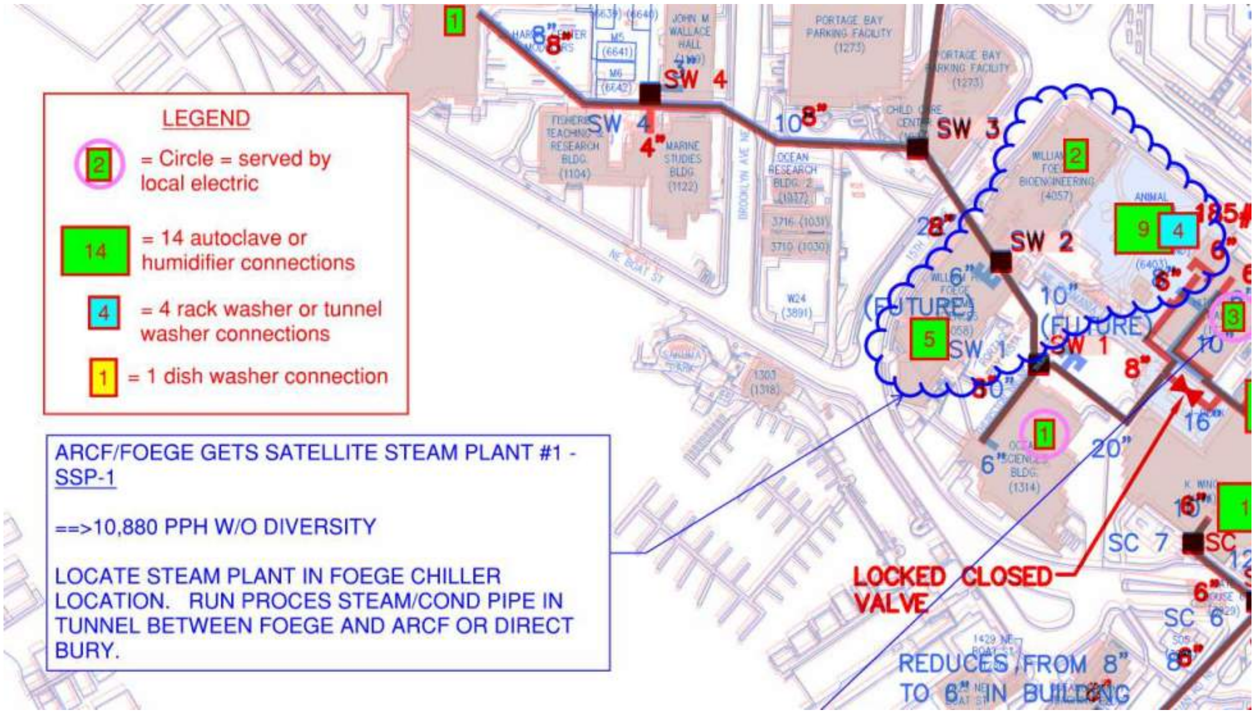


Fig B-11-1: Vicinity Map of SSP-1

In order to get a new process steam service in place in the ARCF/Foege Neighborhood, these steps need to occur:

1. Replace the chiller capacity in Foege basement with CCW capacity from the WCUP plant. Remove chillers. (This is part of the building conversions package)
2. Provide and install gas-fired steam boiler package in Foege basement, 2x150 Boiler HP steam boilers. (This scope of work)
3. Connect new steam boiler supply and condensate return to existing process steam load piping in Foege and ARCF. Piping to ARCF is either in the tunnel or direct bury. (This scope of work)
4. With process loads now covered with the new boiler system, steam piping to/from Foege can be taken down and replaced by PHW. (This is part of the distribution package.)
5. Ideally, steam piping can be routed to the source connections in Foege and ARCF, such that no piping modifications need to happen inside the building.

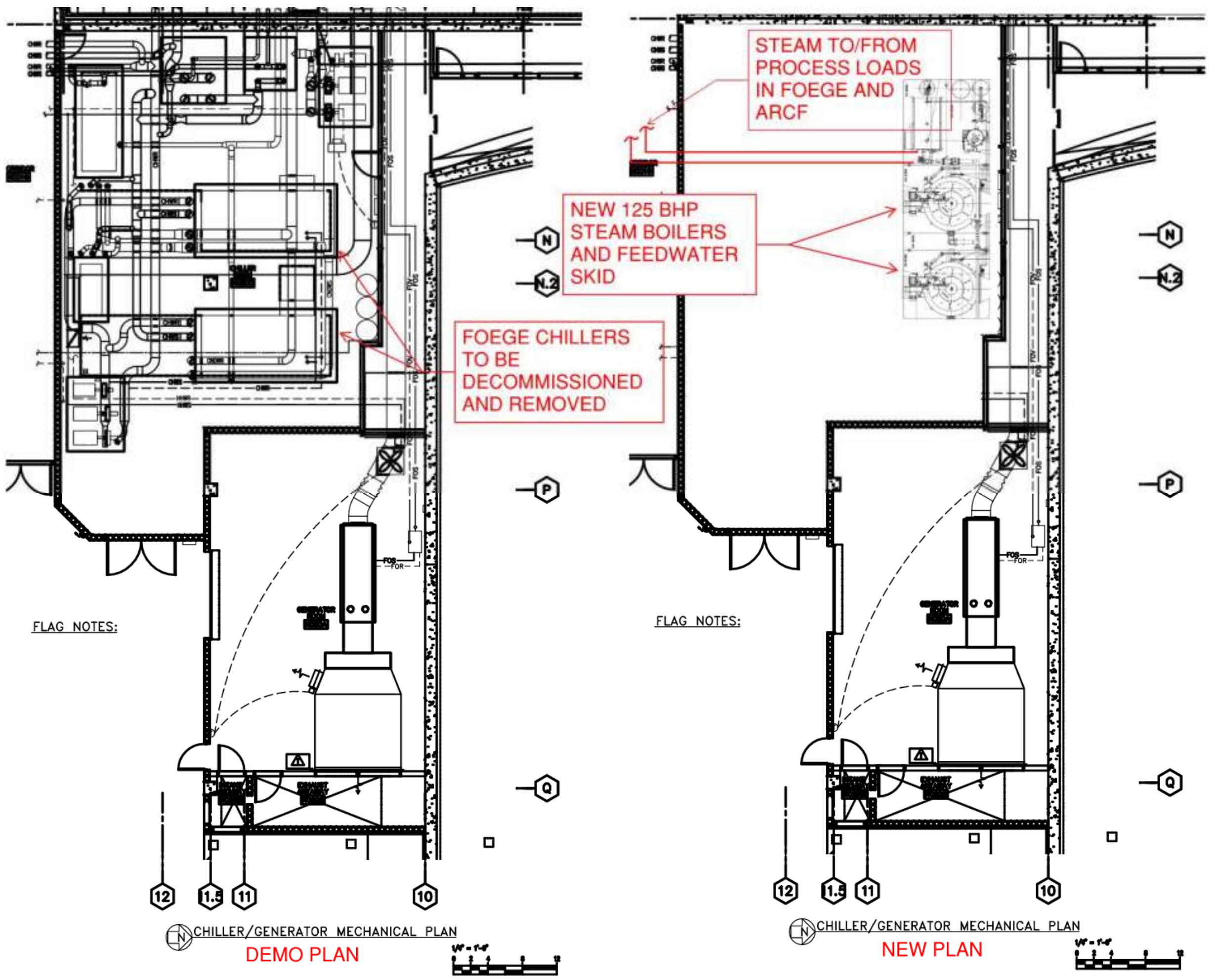


Fig B-11-2: Foege Basement Chiller Room Floor Plans

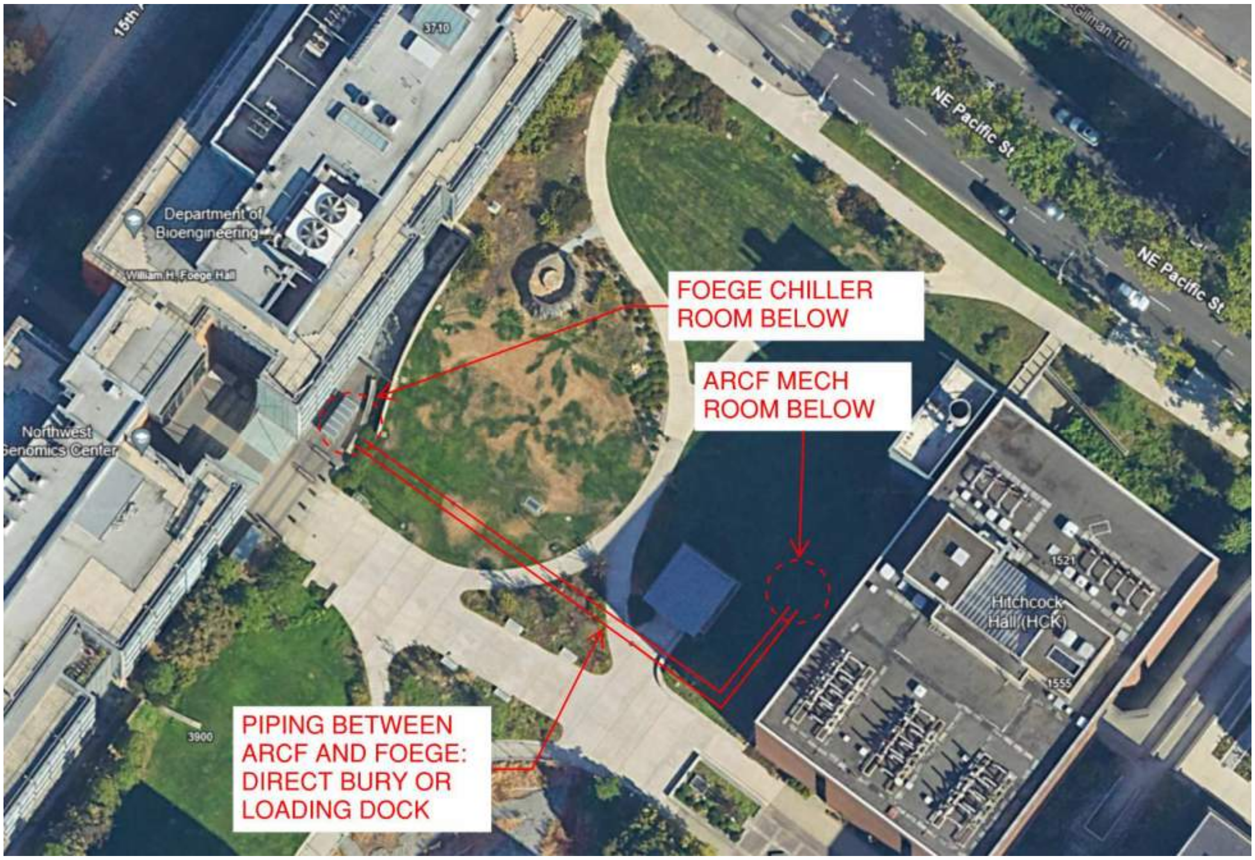


Fig B-11-3: ARCF-to-Foege Piping Concept

1.2 Satellite Steam Plant <u>SSP-2:</u> Serves Central Health Sciences Buildings, G/H/I/J/K/T Wings

In order to serve existing process loads in Magnussen Health Sciences Center, a satellite steam plant is installed in the vicinity of those buildings. The exact location of the new boiler plant is to be determined, but a central location taking advantage of future building development in I-Wing or H-Wing could yield potential opportunities. Refer to Fig B-11-4, below. The new boiler system shall be provided with natural gas service, supply water service, electrical service, combustion air service, flue gas service, and relief valves service.

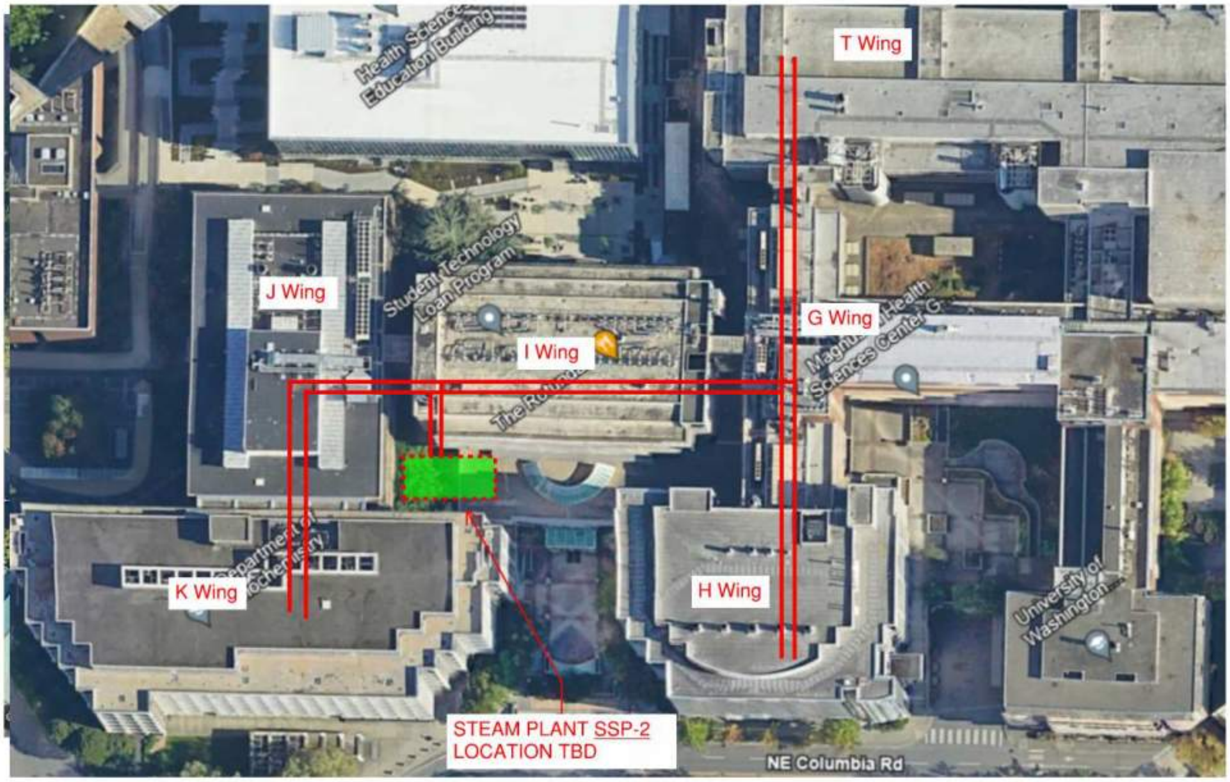


Fig B-11-4: MHSC Process Steam Piping Concept

The points of use of the steam in these wings are in different locations, and the risers in each wing are not necessarily adjacent to each other. As such, some horizontal steam piping will be required to connect each of the building risers. The exact routing of the piping will require detailed coordination around existing infrastructure and utilities (see Fig B-11-5, below), but for the purposes of this estimate, a total of 1200 linear feet of steam and 1200 linear feet of condensate piping shall be assumed for the horizontal connections to the risers. Assume a challenging route through occupied building space. A condensate receiver shall be assumed to be needed for each wing, and approximately 600′ of parallel 1″ steam condensate drip lines should be assumed to be required. Although it might be possible to reuse some of the existing steam piping in the tunnel system, it should be assumed that all the horizontal piping to connect to the (6) individual building risers shall be new pipes.

Fig B-11-5: I-Wing(left) and J-Wing(right) Utility Tunnel/Corridors

1.3 Satellite Steam Plant SSP-3: Serves University of Washington Medical Center

In order to serve ~30 existing process loads in the University of Washington Medical Center, a satellite steam plant is installed in the vicinity of that facility. The exact location of the new boiler plant is to be determined, but a location near the S-1 Parking Garage/Chiller Plant will be assumed for this scoping exercise. Refer to Fig B-11-5, below. The new boiler system shall be provided with natural gas service, supply water service, electrical service, combustion air service, flue gas service, and relief valves service.

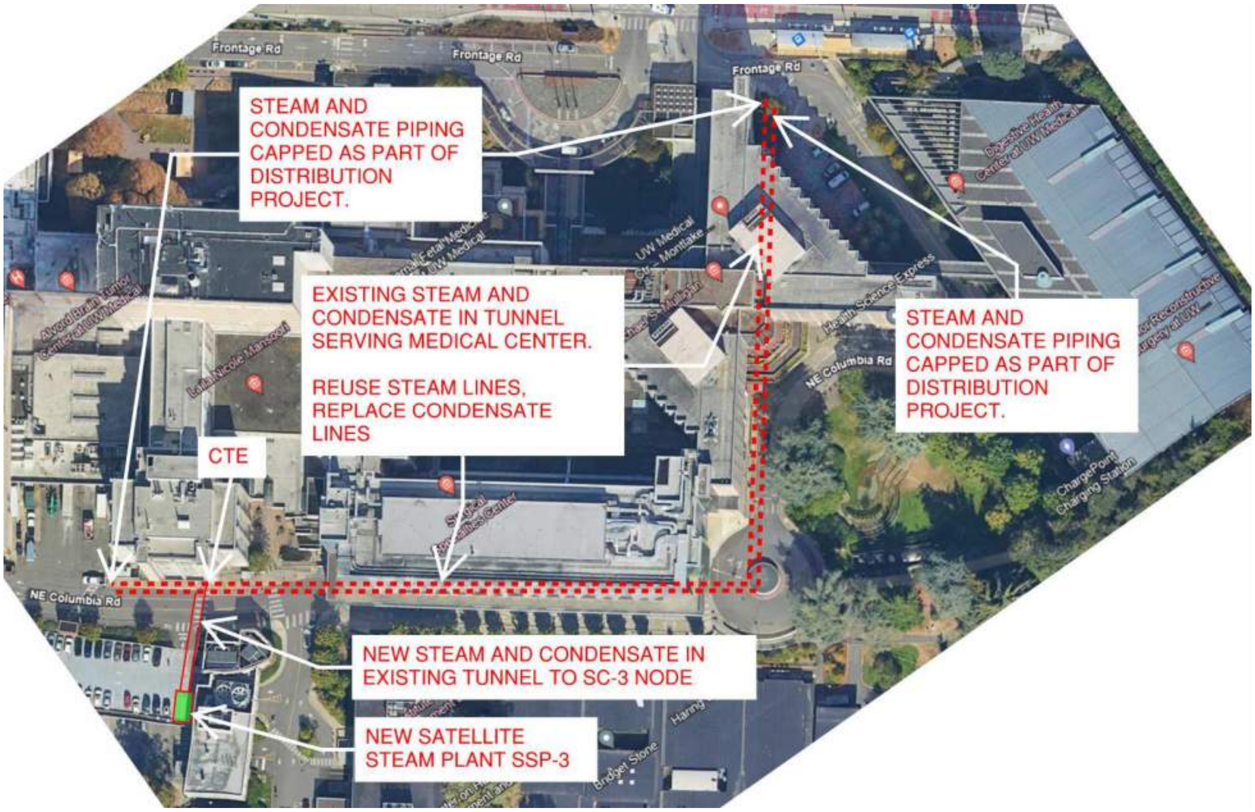


Fig B-11-6: Medical Center Process Steam Piping Concept

The existing medical center has approximately 30 points of use of process steam, serviced by four injection points from the tunnel. Since revising the distribution throughout the Medical Center would be disruptive, reconnecting to the steam takeoffs in the tunnel system would be preferred. With a new satellite plant located near the S-1 chiller plant, new steam service lines could be routed to the existing tunnel system to tie into the existing steam distribution system. The exact routing of the piping will require detailed coordination around existing infrastructure and but for the purposes of this estimate, a total of 300 linear feet of steam and 1000 linear feet of condensate piping shall be assumed for the horizontal connections to tunnel mains. Assume a challenging route through occupied building space. A condensate receiver shall be assumed to be needed for each of the 4 injection points.

2.0 Precedent / Following Activities

The installation/reuse of the steam lines must be coordinated with the installation of new PHW system being installed as part of the distribution scope.

The installation of the new Satellite Steam Plants must be sequenced appropriately based on the areas they are being installed in. SSP-1 must be sequenced with the connection of Foege to the CCW system to allow for removal of the existing chillers, freeing up space for the steam equipment.

3.0 Attachments

None.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-1

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Convert CCW System to Year-round Operation.

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
The project discontinues the seasonal operation of the Power Plant CCW system (and use of the CCW loop as a source-sink loop in winter). Re-programming will be required at buildings that currently use CCW as a source or sink in winter. Addition of a wide array of additional metering /monitoring coupled with retro-Cx is recommended to daylight any potential hydraulic issues that may result. Some campus buildings are put into "winter" mode which partially opens the CCW valves to protect the coils from freezing. Another method of protection will be required.

SEQUENCE: *(1-2 sentences)*
Perform retro-commissioning exercises. Execute control sequence changes at buildings to prevent use of CCW as a source-sink loop. Execute any recommendations generated during the retro-Cx exercise. Enable permanent year-round inter-operation of Power Plant CCW with WCUP.

1.0 Detailed Work Description

The hardware to enable a basic conversion to year-round CCW system operation is largely in place. The conversion to year-round operation is expected to be primarily a retro-commissioning exercise, coupled with changes in software that will inhibit the use of the CCW loop as a source-sink loop in winter. Since the Power Plant chillers and WCUP chillers have not often been run in parallel (particularly at peak periods) retro-Cx is intended to expose unforeseen hydraulic issues that arise as the two plants operate together.

As the second phase of conversion, the Power Plant chilled water pumps should be converted from their current manually operated state to primary-secondary operation with fully automated variable speed capability in the secondary side. This scope of work is described in SOW-P-9 CCW Header and Secondary Pumping System.

1.1 Background

The CCW system was originally considered a comfort cooling system, with a defined period of operation from approximately mid to late May to mid-October (this operating schedule has gradually expanded due to warmer weather). The system has been operated as a source-sink (heat recovery) loop during the months outside the cooling window, with some select 100% outside air buildings drawing heat from the loop to preheat outside air, and other buildings discharging heat from process cooling loads into the loop. The power plant also rejects machinery heat into the CCW system instead of using the cooling towers during the winter months. The heat balance has been maintained over the years by adding heating or cooling loads to the loop as new buildings and systems were designed-- adding heat sources if the loop was not warming or adding heat sinks if the loop temperature was rising too high. AEI's understanding is that the temperature of this loop rises to 70 deg F at its peak periods.

1.2 Evolution of CCW System and WCUP

More and more critical buildings and loads have been added to the CCW system over the years and as the CCW system and its distribution network became more and more taxed as the campus grew, critical buildings, in particular, were encouraged to install their own local chillers, so that critical loads could be met and so that shoulder season temperature excursions could be managed locally by activating the local chillers based on outside air temperature (OAT) rather than a date on a calendar. The William H Foege Building is a prime example; the Foege Building not only has its own water-cooled chilled water plant, but also emergency backup air-cooled chillers to back up critical process cooling loads, plus redundant air-cooled chillers dedicated to a vivarium in the basement of the Bio-Engineering (north) end of the building.

The WCUP was proposed and built in 2014-2015 as a result of the Power Plant approaching the limits of its capacity to house chillers, the limits of the distribution system to deliver water to the southwest areas of campus, and as a means to prevent the ongoing need to provide local cooling at new critical buildings (particularly those remote from the PP). WCUP was intended from the beginning to operate whenever OAT required it, due to the critical loads within its operating area. The WCUP absorbed the southwestern-most extents of the CCW distribution and upsized some of the local distribution system to reflect the presence of a new local cooling source. This helped unload the PP chillers and relieve bottlenecks in the distribution system. Shutoff valves were added at the boundaries of the newly created WCUP distribution system so that it operates normally to serve just those buildings that its current capacity can support. The valves can be opened and have occasionally been opened, primarily during shoulder seasons, to allow the WCUP to address loads across campus. The intent is to expand the operating range of the WCUP as its installed capacity increases by adding valves at further reaches from WCUP and use of those to isolate a broader distribution network.

1.3 Changes Required at Building Level

Buildings with process cooling loads are typically configured as shown below:

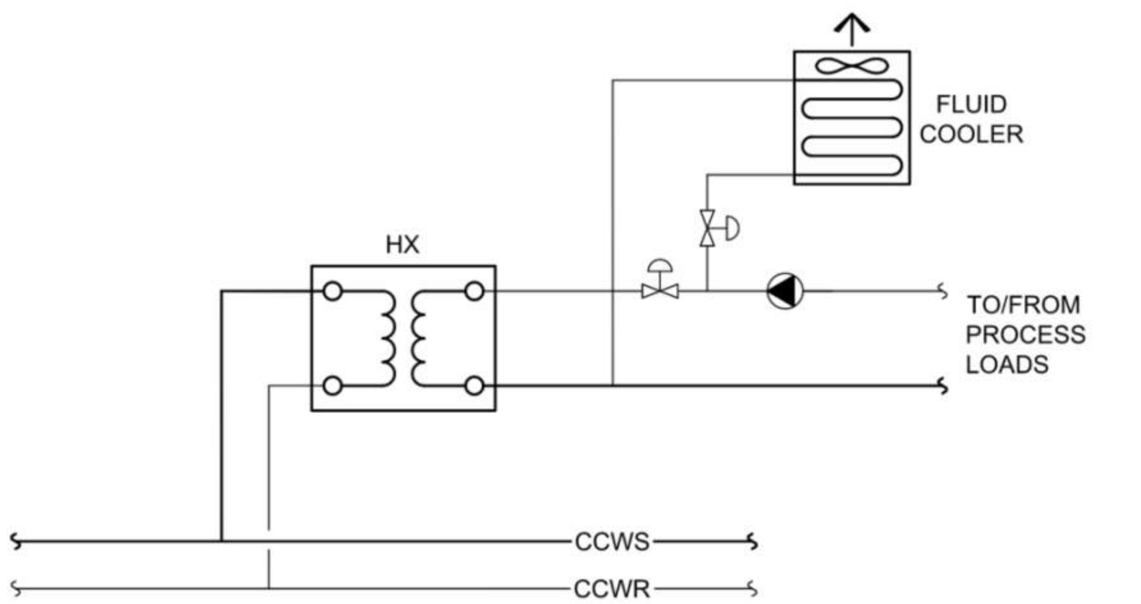


Figure 1.3.1 Buildings Using CCW as Heat Sink in Winter (Current and Future)

We recommend that these buildings remain largely unchanged but be re-programmed to use CCW as the sink when heat addition is beneficial to the system (e.g. when campus heat loads exceed campus cooling loads).

Buildings using the CCW loop as a winter heat source are typically configured as shown below:

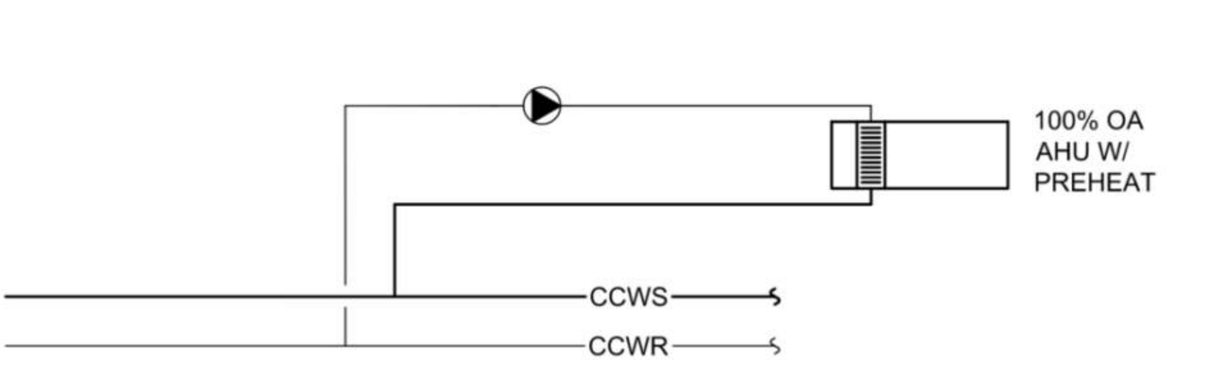
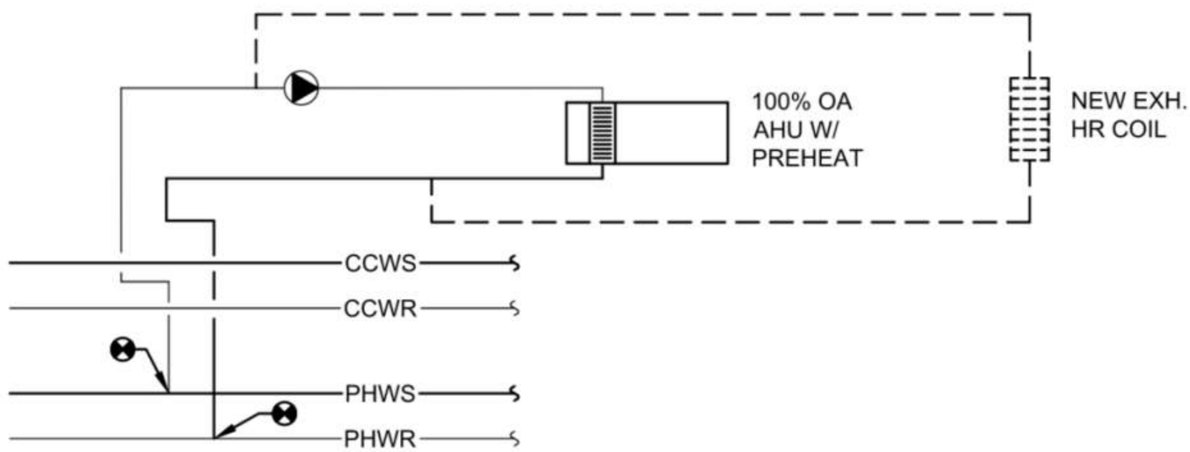


Figure 1.3.2 Buildings Using CCW as Heat Source in Winter (Current)

If the building already includes hot water heating coils, these coils can optionally be de-commissioned and removed (to reduce pressure drop) as the base recommendation. If the building requires a new primary hot water heating (PHW) coil (i.e., it uses steam preheat now), the OA preheat coil should be evaluated for use as the new PHW coil.

As an efficiency improvement, we recommend that the outside air preheat coils be incorporated into a building runaround heat recovery loop if a heating water coil already exists, and the exhaust side of the building can accommodate a coil. This should be evaluated for feasibility on a building-by-building basis in the future – the basis of the current estimate should be de-commissioning and removal of the coils, or re-use as PHW where no central heating water coil currently exists.

For the purposes of this estimate, it is assumed that all coils can be decommissioned without the need for any new piping or coils within the AHU. Other options for consideration by the design team for that project work are shown in Figure 1.3.3.



OPTION 1: FOR BUILDINGS W/O HOT WATER HEATING COIL. RECONNECT PREHEAT COIL TO NEW PHW SYSTEM.

OPTION 2: RECONFIGURE AS PART OF A NEW RUN AROUND HEAT RECOVERY SYSTEM.

OPTION 3: DEMO COIL AND PUMP, DISCONNECT FROM CCW.

Figure 1.3.3 Buildings Using CCW as Heat Source in Winter (Recommended Conversion)

2.0 Precedent / Following Activities

2.1 Precedent #1: Install new Pressure Sensors

Installation of these sensors will provide additional information during the retro-Cx process. We recommend that several differential pressure (DP) sensors be installed at remote locations in the north and southeast (UWMC) distribution areas (currently served by the Power Plant). We also recommend low point and high point pressure sensors be installed so that absolute system pressures can be monitored during the interconnection process (and these will be very valuable for conversion of the Power Plant CCW system to primary secondary operation (refer to SOW memo P-9) and for the addition of the CCW TES tank (refer to SOW memo P-5).

The proposed locations are indicated in the attachment CCW Diagram - New Instrumentation.

2.2 Precedent #2 : Retro-Cx

We recommend a retro Cx activity to daylight any hydraulic issues that may result from permanent year-round interconnection. The testing would include multiple stages:

1) Pretest work – Verify existing differential pressure sensor locations and operation. Install new static pressure sensors across the hydraulic network. See attachment CCW Diagram - New Instrumentation for proposed locations.
2) Shoulder Season – April-May 2025.
    a. Interconnect the plants (using valves indicated in the attachment CCW Diagram - New Instrumentation). Valve off the expansion tank at the Power Plant. Observe operation, trend log system pressures and note any hydraulic issues, alarms, or unusual events.
    b. Isolate the WCUP expansion tank and open valves at the PP expansion tank. Observe operation, trend log system pressures and note any hydraulic issues, alarms, or unusual events.
3) Peak Season (July – August 2025)
    a. Interconnect the plants (using valves indicated in the attachment CCW Diagram - New Instrumentation). Valve off the expansion tank at the Power Plant. Observe operation, trend log system pressures and note any hydraulic issues, alarms, or unusual events.
    b. Isolate the WCUP expansion tank and open valves at the PP expansion tank. Observe operation, trend log system pressures and note any hydraulic issues, alarms, or unusual events.

2.3 Precedent #3: Elimination of CCW Winter Operation Sequences

Many buildings on campus use the CCW loop as a heat sink in winter, but all of the buildings have alternate heat rejection methods, typically closed-loop fluid coolers, which were used as the summer heat rejection mechanism. The system should be reprogrammed to allow the CCW system to act as a sink for the process heat whenever the system benefits from heat addition (e.g. campus heating loads match or exceed cooling loads). Fluid coolers should be retained and used as heat rejection mechanisms when the campus is in a cooling-dominated mode, thereby reducing the burden on the CCW system. As such, these systems will act in a similar manner to their operation; the BAS should be re-programmed to switch from CCW to fluid coolers as the heat rejection mechanism based on the current campus heating and cooling load profile, rather than the date of campus switchover to CCW system heat sink mode (as is done currently). Over time, as these fluid coolers reach the end of their useful life, Facilities Engineering could determine that they are no longer needed and the load could be served year-round by the CCW system, as a way of reducing maintenance costs.

Many other buildings use the CCW loop in winter as a heat source, primarily 100% OA buildings that use CCW in a heat recovery (preheat) coil. These coils should be physically disconnected and removed (to reduce pressure drop). At a minimum, they need to be disconnected and drained. The heat recovery coils need to be de-commissioned and the building automation systems (BAS's) need to be reprogrammed to discontinue use of coils.

A few unique situations exist, for example, at Population Health and Husky Union Building, the buildings' HVAC systems are built around CCW as a heat source for heat recovery chillers in winter, but both buildings have steam and CCW connections that can be used to allow heating or cooling by the central systems.

Some campus buildings are put into "winter" mode which partially opens the CCW valves to protect the coils from freezing. Another method of protection will be required.

2.3 Following #1: WCUP Becomes Lead Plant for Trim Capacity

At initial conversion, since the WCUP includes full automation, we recommend that it be used to trim capacity, with the PP used to stage production capacity up or down (typically in 2000 ton increments), e.g. if the WCUP chillers currently in operation are approaching 90% of their output capability, a new 2000 ton chiller at PP should be staged on. This would be done manually by Plant Operators, until such time that the PP has sufficient automation.

3.0 Attachments

CCW Diagram - New Instrumentation - Map of existing DP sensors and BTU meters and proposed new pressure, temperature and DP sensors and BTU meters.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-2

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Add CH-8 and associated tower CT-14.

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
The project will add CH-8 in the planned expansion space adjacent to existing CH-7, and add the associated cooling tower cells above, adjacent to CT-13 (serving CH-7), and CCW pump and condenser water pumps in the mezzanine level between chillers and towers.

SEQUENCE: *(1-2 sentences)*
Work should be planned for late fall through early spring to minimize impacts on the campus cooling water supply.

1.0 Background Information

Space was allocated in the existing CH-7 enclosure to house a future CH-8 and its associated primary pump, condenser water pump, and cooling towers, during the initial 1997 buildout. CH-7 is a 2300V chiller, and the electrical infrastructure is set up to support CH-8 at 2300V. When CH-7 was installed, VFDs were uncommon on chillers of this scale (2000 tons), so space was allocated for a starter. 2300V VFDs are now much more affordable than they were in 1997, so it is assumed that CH-8's design will be based around a 2000 ton, 2300V machine with a VFD. The VFD is much larger than a starter, but there appears to be space to allow for the installation of the VFD. Selections were made for 2000 ton and 3000 ton machines using R-513a, as a space fit exercise. Anything larger than 2000 tons will be a challenge to fit in the space.

1.1 Detailed Work Description - Mechanical

This project will install a 2,000-ton chiller, pumps, and associated cooling tower. The 2000 ton machine and its associated VFD are shown below.

Design Note (for reference only): These machines can also be provided with R-1234ze, with a 25% derating – so a 1500 ton machine using R-1234ze would fit in the space as shown below. The footprint of a 3000 ton R-513a machine and VFD are outlined in blue.

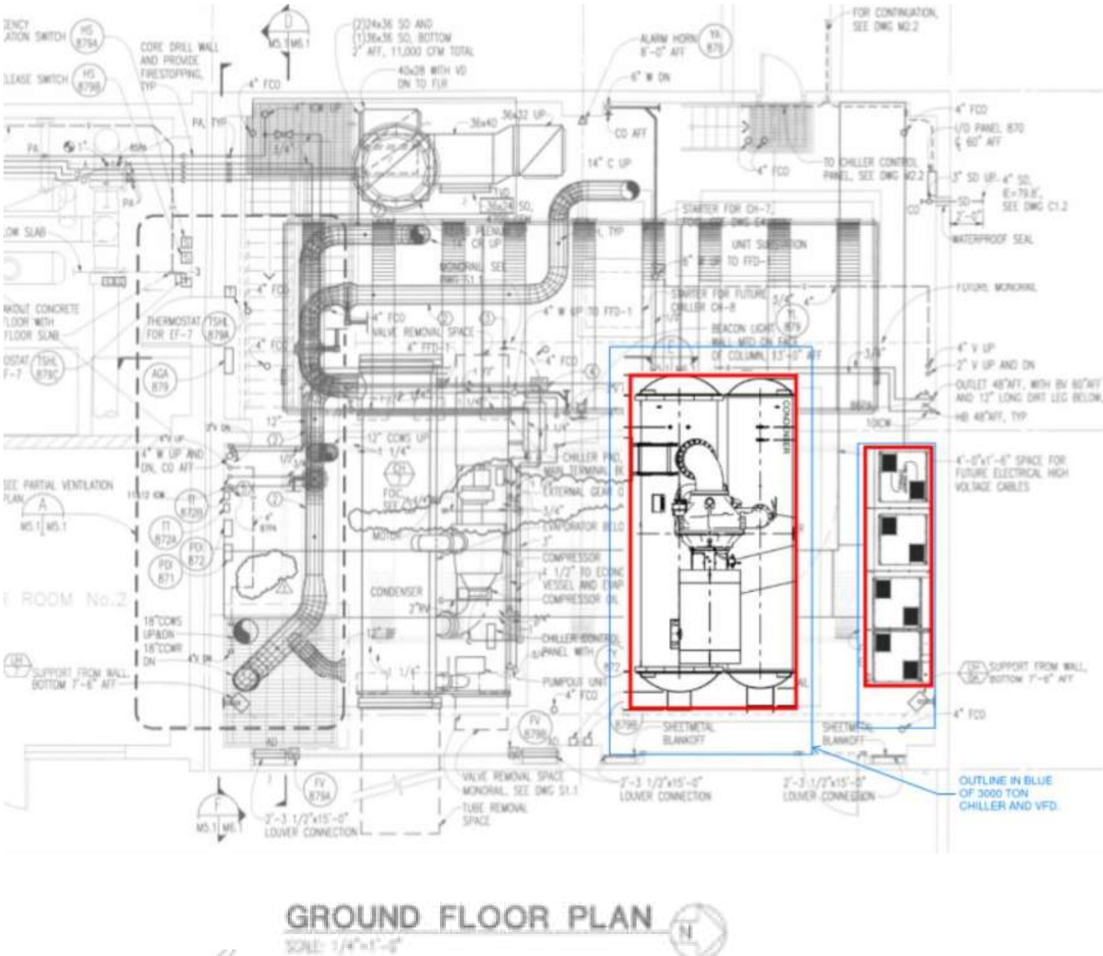


Figure 1.1.1. CH-8 plan

When CH-7 was initially installed, it was served by a pair of forced draft cooling towers. The original plan was to arrange CH-8's forced draft towers back-to-back with the CH-7 towers (since forced draft towers typically draw from one side only). CH-7's towers were replaced in 2013 with induced draft counterflow towers with footprints very similar to the original forced draft (and much more efficient). The new CH-8 cooling towers have been selected to match the new induced draft towers serving CH-7 and to work with them from an airflow perspective.

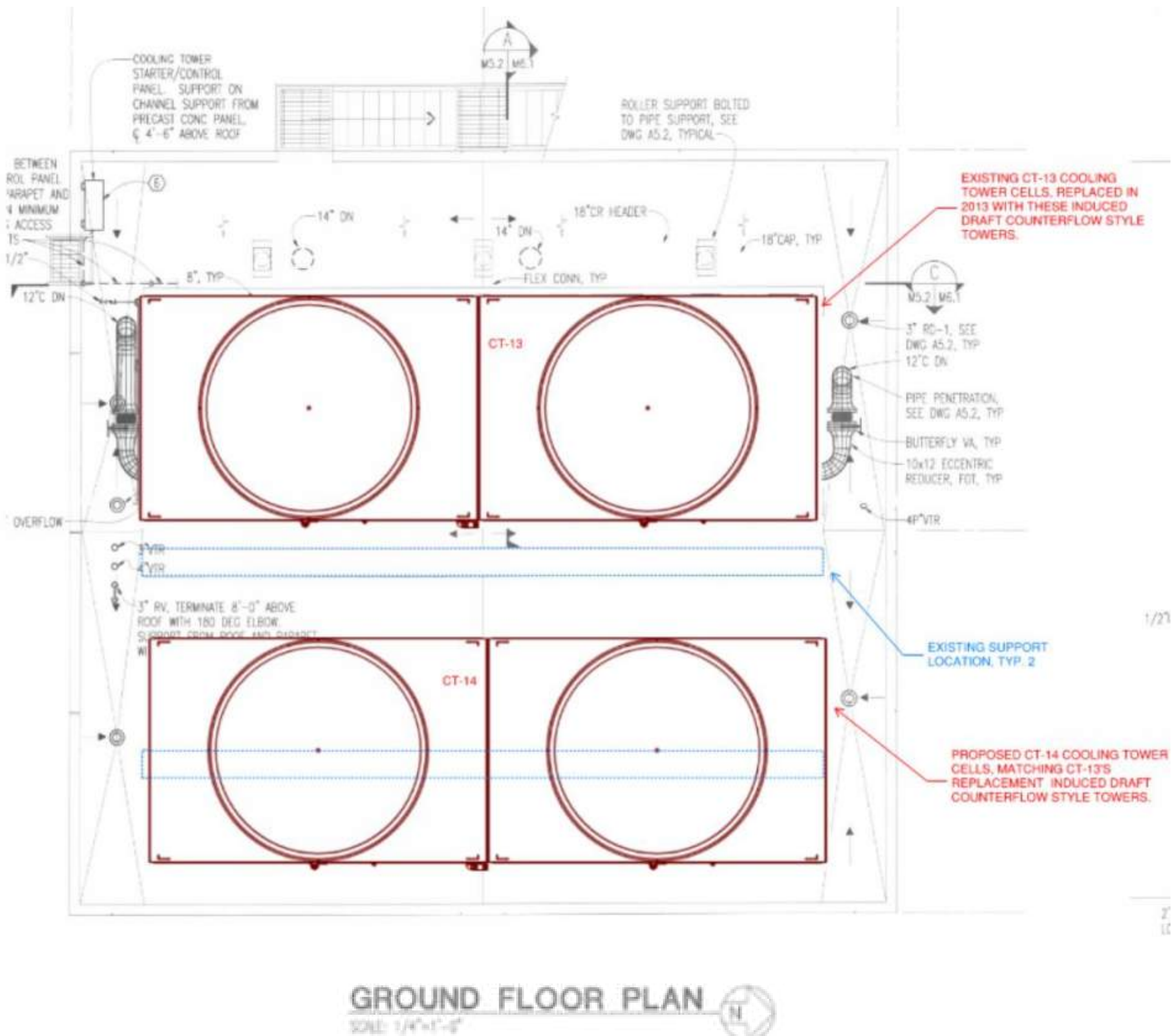


Figure 1.1.2. CT-14 (serving CH-8) Plan

The existing building includes a pump mezzanine between the chillers (below) and towers (above). As part of the CH-8 addition, new CCW primary and condenser water pumps will be located in spaces previously allocated. Pumps will be similar to:

- Chilled Water - B&G e-HSC 8x10x17, 300 HP, 1800 RPM, 2300V with variable frequency drive
- Condenser Water – B&G e-HSC 10x12x15.5, 75 HP, 1200 RPM, 480V.

In addition to the major equipment noted above, the following items should be included in pricing for this work scope:

1) Upgrade of the existing refrigerant monitoring system (RMS) to accommodate the new refrigerant (assumed to be R-513a for this exercise). The entire RMS is likely to require replacement if it does not match the current UW standard – the Honeywell 301 EM.
2) Interconnecting CCW and CW pipe from the new chiller and tower assemblies to the existing headers (all CCW and CW piping at 12").
3) Interconnection of towers via large (24") equalizing pipe.
4) Structural review of roof to analyze weight of new CCW and CW pipe.

1.2 DETAILED WORK DESCRIPTION – ELECTRICAL

Provide electrical power to serve new chillers, cooling towers, and pumps.

Mechanical equipment loads:

- Chiller 8 – 2300V 383 MCA
- Cooling Tower 8 – 100 HP
- Chilled Water pump – 300 HP
- Condenser Water pump – 75 HP

For Chiller 8, expand 2400 VAC Bus F in the East Receiving Station to provide new circuit breaker. Provide 2.4 kV, 3Ph, 3W, 500 KCMIL armored cable from E2 to the chiller VFD. Provide VFD-rated, 2.4 kV, 3Ph, 3W, 500 KCMIL armored cable from VFD to Chiller 8.

For Cooling Tower 8, provide 480V, 3ph connection from existing MCC6 or equivalent. Provide 480V, 3Ph, 3W, 3"C - 3#350KCMIL + 1#4G connection.

For the Chilled Water Pump, provide a 2.4 KV connection from the nearest switchgear. Provide 100A circuit breaker and feeder to new VFD and water pump. Provide 2.4 kV, 3Ph, 3W, #1 AWG armored cable from switchgear to VFD. Provide VFD-rated, 2.4 kV, 3Ph, 3W, #1 AWG armored cable from VFD to pump.

For the Condenser Water Pump, Provide 480V, 3ph connection from existing MCC6 or equivalent. Provide 480V, 3Ph, 3W, 3"C - 3#250KCMIL + 1#4G connection.

2.0 Precedent / Following Activities

Since CH-7's replacement induced draft style towers appear to have been located on the previously existing supports for the original forced draft towers, they are not located optimally for co-location with new induced draft counterflow cells to serve CH-8. CH-8's tower supports will need to be located east of the supports for the originally envisioned forced draft towers intended for CT-14, as outlined in Figure 1.1.1.2 above. A structural engineer should review this shift and make recommendations for any supplemental structural steel, as well as recommend a roof dunnage system to support the new towers. If these towers will be cross-connected with CH-7’s towers (CT-13), the basins must be at exactly the same elevation and a large equalizing pipe (i.e. 24” to 30”) is also likely to be necessary.

Full Cx should be completed and include the interaction of CH-8 with the existing CCW system, as well as the ability of CT-13 and CT-14 to interoperate.

3.0 Attachments

1. Original CH-7 addition design documents
2. Equipment Selections and vendor ROM pricing for CH-8 and CT-14

Affiliated Engineers

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-3

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

WCUP Chiller 5 Installation

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Install owner furnished chiller WCH5 in the WCUP. Provide associated Cooling Tower and set of two primary pumps.

SEQUENCE: *(1-2 sentences)*
This work should occur before UW SOW-P-7 WCUP HRCs and Cooling Towers, but not directly tied to that project.

1.0 Detailed Work Description

Summary scope of work for WCUP Chiller (WCH5) and Cooling Tower (WCH5) installation.

Note: This work has already been estimated as part of the CPAT request. The only items that are different from the previous pricing exercise are emphasized in **bold text**.

- Install Chiller WCH5 (owner furnished, contractor installed) in the existing WCUP facility. Provide a new housekeeping pad.
    - Provide new piping to/from WCH5 to the existing CCW supply and return headers. Connecting to existing valved tees. Refer to the attachments for details.
- Install 1750-ton cross-flow cooling tower Cooling Tower WCT5 on the roof. Provide a new support structure. Provide a Variable Frequency Drive.
    - Provide new piping to/from WCT5 to the condenser water supply and return headers. Refer to the attachments for details.

- **Extend the length of the existing 36" condenser water supply and return headers and provide future taps for connection to future cooling towers provided under SOW-P-7 WCUP HRCs and Cooling Towers**
- **Extend the length of the existing 20" CT equalizing line and provide future taps for connection to future cooling towers provided under SOW-P-7 WCUP HRCs and Cooling Towers**
- New 400 HP primary chilled water pump with VFD
- New 200 HP cooling tower pump with VFD
- Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.
- New electrical feeder, relay, meter, and feeders to new chiller, pumps, and cooling tower.
- Electrical infrastructure scope:
    - Chiller #5 (1500 tons): Install new 480V, 2000A, 3Ph feeder from existing switchboard E to chiller. Utilize existing space in SUB_C. Provide new 2000A SEL relay and meter.
    - Cooling Tower (100HP): Provide new 300A, 480V, 3 Ph feeder from existing SUB_B to CT-5. Replace the existing 800A spare circuit breaker with a new 300A circuit breaker. Provide connection to 12 FLA, 480v basin heater.
    - PCWP (400HP VFD): Provide 600A, 480V, 3P breaker and 600A feeder from SUB_C. Provide new 600A, 480V, 3 Ph feeder. Replace the existing 800A spare circuit breaker with a new 600A circuit breaker.
    - CT Water Pump (200HP): Provide 500A, 480V, 3P breaker and 500A feeder from SUB_A. Provide new 500A, 480V, 3 Ph feeder. Replace the existing 800A spare circuit breaker with a new 500A circuit breaker.

1.1 Photos

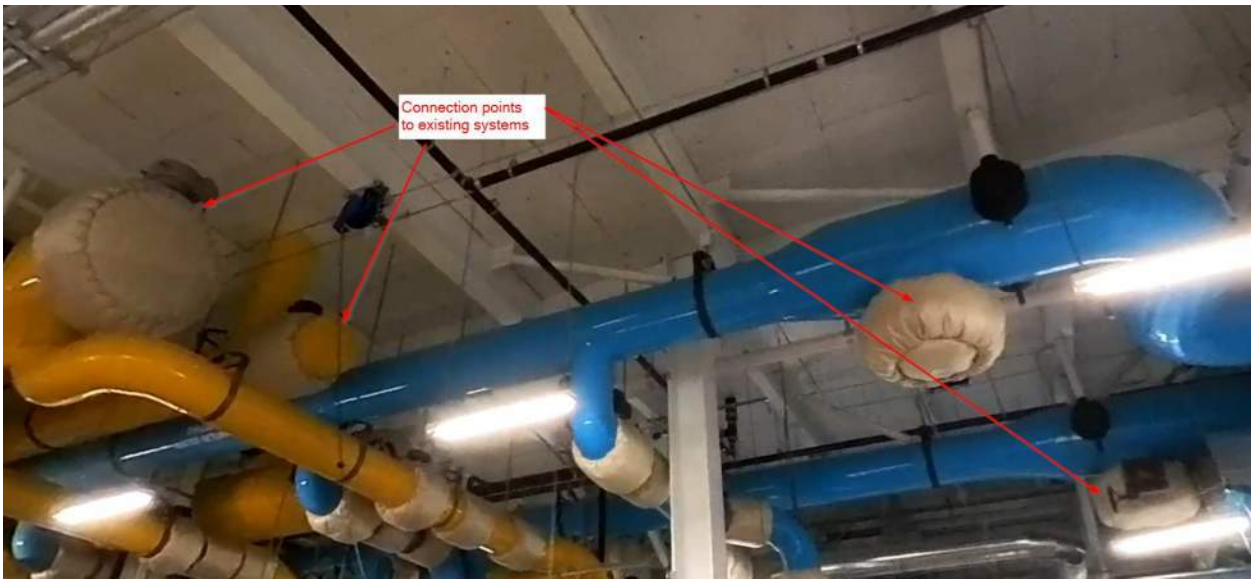


Figure 1.1.1 Photo from Chiller floor level showing connection points for extension of existing systems to WCH5 and WCT5, as well as the extension of the header with future valves provided for WCH6 and future WCUP annex connections.

Figure 1.1.2 Photo from cooling tower arrangement with elevated support structure and access platforms.

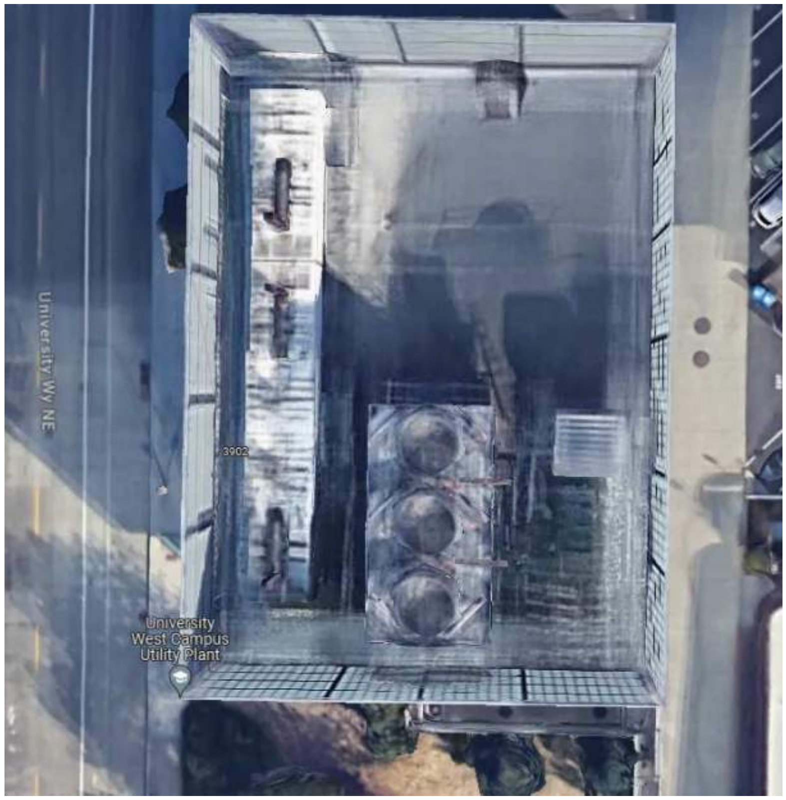


Figure 1.1.3 Satellite image of existing WCUP roof condition. WCT5 will be installed adjacent to the existing cooling tower array.

2.0 Precedent / Following Activities

This work should occur before UW SOW-P-7 WCUP HRCs and Cooling Towers, but not directly tied to that project.

See also these scope of work documents:

- SOW-P-4 WCUP Annex
- SOW-P-7 WCUP HRCs and Cooling Towers
- SOW-P-12 WCUP Electric Boilers
- SOW-P-13 WCUP Generators

3.0 Attachments

Refer to the attached WCUP and Annex Project Scope of Work Drawings which note the scope for each of the projects within the WCUP.

Affiliated Engineers

Scope of Work Description

PROJECT NUMBER:

P-4

STATUS:

COMPLETE

TITLE:

Addition of new WCUP Annex Building with associated Steam-to-hot water heating system

SUMMARY DESCRIPTION:

Construction of a 23,600 SF extension of the existing WCUP to the south of the existing building. The extension consists of a basement, ground level, and two additional stories above grade.

SEQUENCE:

Construction of this building and supporting mechanical systems in this package will provide heat for the first step in the PHW buildout via Power Plant-generated steam. Work related to the new utility tunnel running through the W27 project will impact this project, as this section of the tunnel will be mined and may require staging in the area that will be the WCUP Annex Basement. This tunnel scope is covered under distribution scope documents (SOW-D-W-1 West Campus Piping). Seattle City Light and UW duct banks run diagonally through the area of the WCUP Annex. Those will require relocation as part of this scope of work.

1.0 Base Building Description

WCUP Annex Building Description (refer to WCUP Scope of Work Drawings and Equipment Schedule, attached):

The building has four levels; basement (below grade), ground floor, first floor, and second floor. The floor plates do not align with the existing WCUP facility to provide additional floor-to-floor height and align the basement floor to an elevation compatible for interface with the new tunnel serving West Campus.

Building construction type and outward appearance to match existing WCUP, complying with existing Building Codes and best practices.

Shell and Core components of the WCUP Annex shall be included in this project. Portions of mechanical electrical scope will be excluded from this project and included in separate projects.

Office and Plant Operations buildout shall be included in this project.

The Annex footprint currently sits over SCL and UW electrical duct banks. These duct banks shall be relocated as part of this project. This effort shall be sequenced and coordinated with the work for the UW Substation. Refer to SOW-E-1 UW Substation.

The Annex shall be constructed around the existing underground fuel oil tank. The area above the fuel oil tank serves as a parking area and transformer removal path. This tank, parking area, and removal path shall remain and be incorporated into the Annex construction such that the existing access path is maintained and no part of the fuel oil tank is impacted. The fuel oil tank is direct buried and will require support and shoring to remain in place.

Coordination with the utility tunnel interface where large pipes enter the building could include phasing or spatial challenges. There are several large bore pipes, both new and existing that are entering and existing the plant. A high level of coordination and sequencing challenges are anticipated.

1.1 Mechanical Scope Included in Project

As the first step in the PHW buildout, this project will include a steam-to-hot water heat exchange system and distribution pumping system, including:

- Steam and condensate piping from the tunnel connection into the building
- Steam-to-HW heat exchanger and steam/condensate piping, condensate return system to send condensate back to the power plant via the existing condensate piping system.
- Primary pumping/piping system for Steam-to-HW converter loop.
- Secondary (campus distribution) pumps, VFDs, and electrical components
- Hot water distribution piping throughout the plant and to the tunnel.
- Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.
- Building HVAC to maintain a maximum of 85°F in mechanical/electrical spaces and typical comfort cooling design conditions for the office and storage level.
- Electrical room exhaust system rated for smoke control. Qty. 2 Greenheck CUBE-480 exhaust fans with Variable Frequency Drives (21,000 CFM / 0.75" ESP).

1.2 Electrical Scope Included in Project

Provide electrical infrastructure to support the new Annex building and mechanical equipment listed above. Provide lighting fixtures and lighting controls. Install one section of 26Kv switchboard further described in P-7. One of the three 26 kV feeders will be installed as part of this project, fed through the ductbank pathway provided in E-1. The additional two feeders will be provided in P-7. Install 3MVA unit substation with 4000A, 480V, 3 Ph, 4W, distribution board. Provide 300 KVA 480/208v transformer with 800A, 208V, 3Ph, 4W distribution board. Provide 208v branch panelboards for maintenance receptacles, controls, and support loads. WCUP Annex project should provide space for future electrical gear and distribution to equipment provided under SOW-P-7 WCUP HRCs and Cooling Towers SOW-P-12 WCUP Electric Boilers. Provide space for 26 kV Switchgear. The actual electrical infrastructure for those projects should be included within those project's scope.

2.0 Precedent / Following Activities

See also these scope of work documents:

- SOW-P-3 WCUP WCH5 & WCT5
- SOW-P-7 WCUP HRCs and Cooling Towers
- SOW-P-12 WCUP Electric Boilers
- SOW-P-13 WCUP Generators

3.0 Attachments

Refer to the attached WCUP and Annex Project Scope of Work Drawings which note the scope for each of the projects within the WCUP.

4.0 Constructability Commentary

Items to consider for estimates:

- Complications due to construction next to the existing building and fuel oil tank.
- Relocation of electrical duct banks.
- Coordination with adjacent tunnel and W27 project. Use of Annex basement construction pit as receiving area for mined tunnel.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-5

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Provide new Thermal Energy Storage (chilled water) tank and future location for a second (hot water)

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Provide new Thermal Energy Storage system and Facilities Services building to the north of the existing Power Plant facility. Provide new diesel engine generators to supply TES pumps.

SEQUENCE: *(1-2 sentences)*
This work is intended to occur in the 2025-2027 first biennium of the Energy Renewal Program. Work must coincide or occur after the work described in SOW-P-9 CCW Header and Secondary Pumping System.

1.0 Detailed Work Description

High-level summary scope of work for Campus Cooling Water (CCW) Thermal Energy Storage (TES) Tank:

- Demolish existing Plant Operations Annex Buildings and Groundskeeping facilities.
- Excavate the existing site area down to the current elevation of Mason Road. Provide a retaining wall.
- Provide a new CCW TES tank, mechanical equipment building, and a future location for a Primary Heating Water (PHW) TES tank.
  - Route piping from CCW TES tanks to primary/secondary pump header within the existing Power Plant.
  - Provide a structural foundation for TES tanks as required for complete seismic anchorage.
- Provide a new three-story Facilities Services building to replace the previous function of the Shop 43, Plant Operations Annex Buildings, and Groundskeeping buildings.

- Provide a new central chemical water treatment system sized for the significant water volume added to the system by the TES tank.
- Install two 2 MW 4,160V, 3P, 3W diesel engine generators within a 2-hr rated indoor generator room on the second story of the new Facilities Services building, at grade with existing Annex buildings (~95’ ASL) for equipment access.
- Provide new 4MW unit substation with 13.8kV primary and 4160V secondary.
- Provide new 5kV electrical paralleling switchgear rated for 4,160V with 1,200A bussing to feed double-ended switchgear described in E-2 and P-9. Generators will be provided with a sub-base UL2085 fuel oil tank.
- Provide remote radiator, exterior louvers, and generator exhaust up to the roof of the new Facilities Services building.
- Provide a new fuel oil pump supply and return system from the existing fuel oil system located south of the Power Plant. Assume 1,500 ft total piping of 2” steel piping routed from the Power Plant to the new generator room.

1.1 Site Enabling Work

Existing site houses two buildings (Plant Operations Annex 4 & 6) as well as three shed structures used for storage of outdoor equipment. Refer to Figure 1.1.1 for the existing site plan.

Figure 1.1.1 Existing Site Plan

Provide surface improvements, parking, site lighting, and storm drainage as required.

1.1.1 Demolition and Excavation

Demolish existing Plant Operations Annex Buildings 2, 3, 4, 6, and Storage Shed. Refer to Figure 1.1.1. Remove existing electrical power, steam, condensate, water, sewer, and IT utilities and terminate at the existing main infrastructure.

Excavate the existing site and provide a retaining wall along the west and south perimeter as shown in Figure 1.1.1.1 and in the attached Thermal Energy Storage site plan.

Figure 1.1.1.1 Existing Site Plan

1.2 Thermal Energy Storage Tank

Provide 90′ diameter x 100′ tall steel atmospheric above-ground site-built thermal energy storage tank. Basis of Design: Chicago Bridge & Iron (CBI). Tanks shall be constructed of welded steel and provided with an anti-corrosion liner. Top and bottom diffusers. Tank is to be sized to provide 4.2 million gallons of usable stored water with a slosh zone for seismic events.

Tank shall be provided with temperature sensors mounted along its height at 2′ intervals. Tank shall be provided with access stair around the perimeter of the tank providing access for maintenance to the top of the tank and all instrumentation along the sides of the tank.

Tank shall be field insulated and jacketed. Polyisocyanurate or polyurethane insulation shall be a minimum of 4″ thick along the entire surface of the tank shell. Cladding system shall be steel, bonded to the outer layer of insulation.

Tanks shall be field painted in a color chosen by Architect.

1.2.1 THERMAL ENERGY STORAGE TANK FOUNDATION

Provide a structural foundation for TES tanks as required for complete seismic anchorage. Provide a foundation for an additional Primary Hot Water (PHW) TES tank to be provided under SOW-P-6 PHW TES Tank.

1.3 Hydronic System Components

CCW Thermal Energy Storage system requires a new chemical water treatment system sized for the capacity of the TES tank volume plus the existing system volume (~1.5 million gallons). This system shall be located in the Mechanical building adjacent to the TES tanks.

Supply and return piping (42″) from the Thermal Energy Storage tanks shall route from the CCW TES tank to the new CCW piping supply header provided under SOW-P-9 CCW Header and Secondary Pumping System. Approximately 115′ of direct-bury supply and return piping (230′ total supply and return) and 230′ of piping run across the roof of the plant (460′ total supply and return). Pipe material between the TES tank and the CCW header shall be as follows:

- Above-ground: welded carbon steel piping, 2″ insulation with jacket, mounted on rollers. Aluminum jacket where located outdoors.
- Direct bury: HDPE SDR 11, rated for 200psi in cold water applications, 1.5″ insulation with jacket. With leak detection.

Provide insulation and jacketing of all piping systems. Provide supports, guides, and anchors of all piping systems.

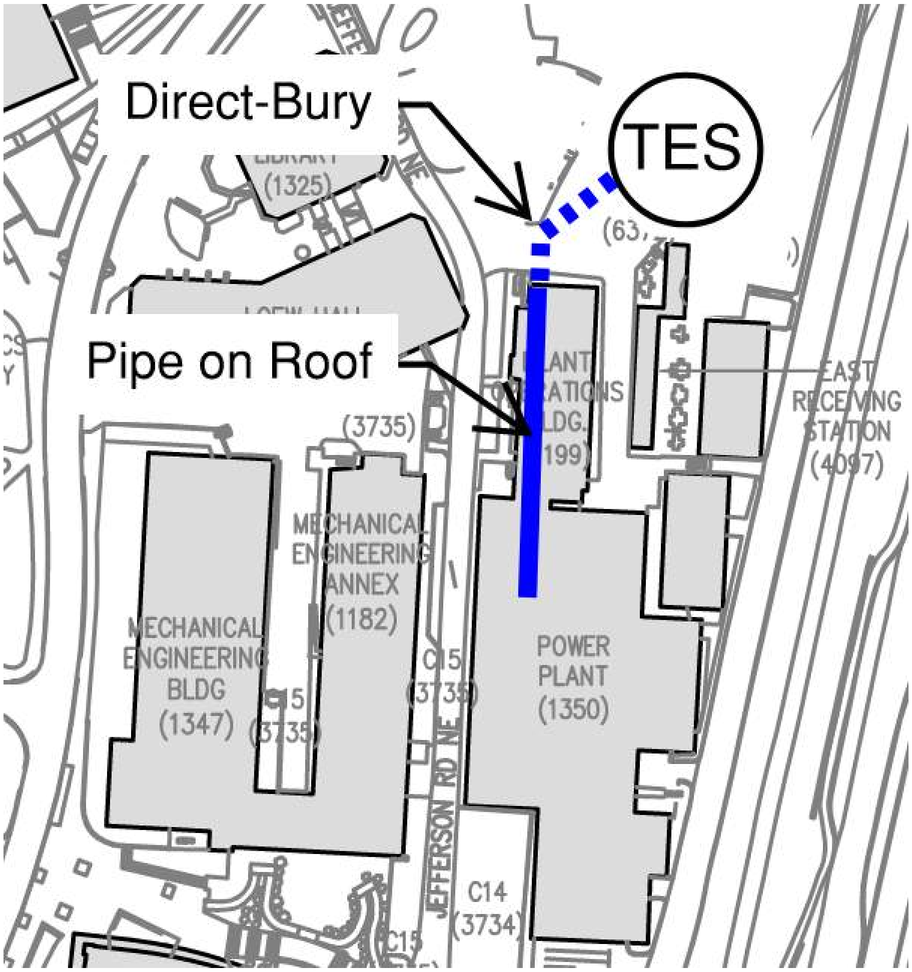


Figure 1.3.1. Sketch showing route of CCW piping from TES tanks to primary/secondary pump header in the Power Plant.

1.4 Facilities Services and Mechanical Building

Provide two new structures on site in addition to the Thermal Energy Storage tank.

Three-story facilities 5,000 sq ft floor plate and 15,000 gross square foot services building shall be provided as shown in the Thermal Energy Storage site plan. The ground floor shall include equipment storage area for groundskeeping staff. Upper floors shall be offices and a generator room. Provide diesel engine generators and appurtenances as noted in section 1.0.

A single-story 1,000 sq ft Mechanical building shall be provided. This building will house water treatment system for TES tank system.

2.0 Precedent / Following Activities

CCW TES tank project shall be completed at the same time or after SOW-P-9 CCW Header and Secondary Pumping System.

Building conversions of existing buildings noted in the Building Conversions Summary Table to require new Pressure Reducing Valve & Pumps shall be completed prior to the construction of the CCW TES tank.

3.0 Attachments

Refer to the attached Thermal Energy Storage site plan for details on the site, excavation, Thermal Energy Storage tank, and Facilities Services Building.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-6

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Provide new Thermal Energy Storage (hot water) tank adjacent to existing chilled water Thermal Energy Storage tank

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Provide new Primary Hot Water (PHW) Thermal Energy Storage tank on the existing foundation provided for this purpose as part of SOW-P-5.

SEQUENCE: *(1-2 sentences)*
This work is intended to occur after SOW-P-5 CCW TES Tank. Work must coincide with or occur after the work described in SOW-P-10 Power Plant PHW System.

1.0 Detailed Work Description

High-level summary scope of work for Campus Cooling Water (CCW) Thermal Energy Storage (TES) Tank:

- Provide a new PHW TES tank in the location provided for this purpose under SOW-P-5.
    - Route piping from PHW TES tanks to primary/secondary pump header within existing Power Plant.
- Provide a new central chemical water treatment system sized for the TES tank plus an additional 1 million gallons for the distribution system.
- Provide a nitrogen generator and nitrogen tank storage system for maintaining a nitrogen blanket at the top of the PHW tank.

1.1 Thermal Energy Storage Tank

Provide 60′ diameter x 75′ tall steel atmospheric above-ground site-built thermal energy storage tank. Basis of Design: Chicago Bridge & Iron (CBI). Tanks shall be constructed of welded steel and provided with an anti-corrosion liner. Top and bottom diffusers. Tank is sized to provide 1.3 million gallons of usable stored water with a slosh zone for seismic events.

Tank shall be provided with temperature sensors mounted along its height at 2′ intervals. Tank shall be provided with access stair around the perimeter of the tank providing access for maintenance to the top of the tank and all instrumentation along the sides of the tank.

Tank shall be field insulated and jacketed. Polyisocyanurate or polyurethane insulation shall be a minimum of 4″ thick along the entire surface of the tank shell. Cladding system shall be steel, bonded to the outer layer of insulation.

Tanks shall be field painted in a color chosen by Architect.

1.1.1 THERMAL ENERGY STORAGE TANK FOUNDATION

Seismically anchor the TES tank to the existing foundation slab provided under SOW-P-5 CCW TES Tank.

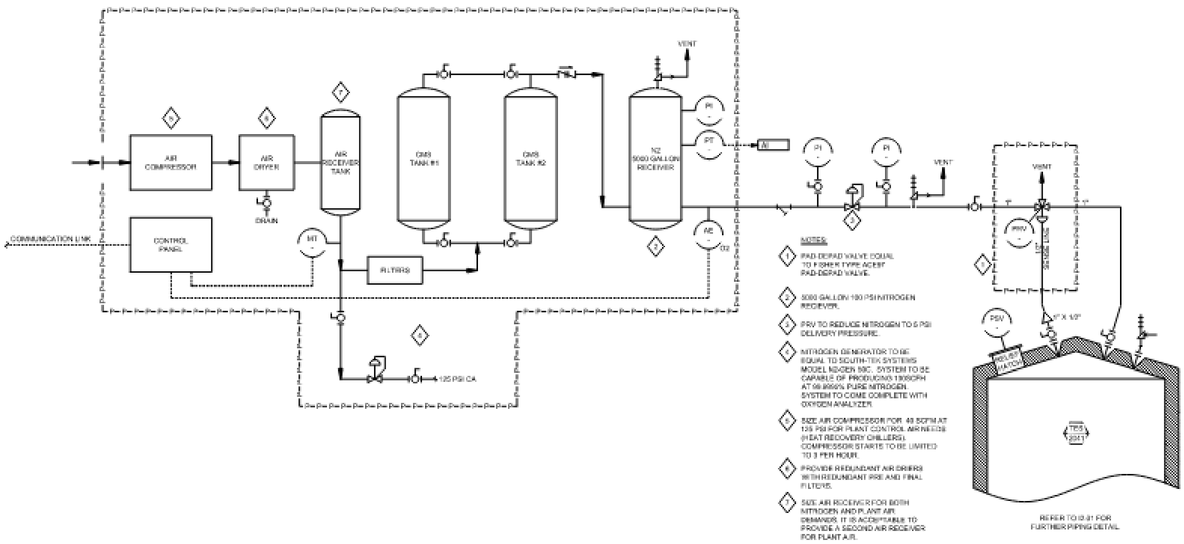
1.2 Hydronic System Components

PHW Thermal Energy Storage system requires a new chemical water treatment system sized for the capacity of the TES tank volume plus the system volume (~1 million gallons). This system shall be located in the Mechanical building adjacent to the TES tanks.

Due to the material used in the PHW distribution system (thin-wall steel piping), the PHW system is at a higher risk of corrosion. To prevent this from becoming an issue, instead of the PHW tank being open to the atmosphere, which would allow the water to constantly be in contact with air and entrain oxygen, the system is provided with a nitrogen generator and storage tank which will maintain the tank at a pressure near atmospheric pressure with a blanket of nitrogen.

Nitrogen system includes:

- STS model N2 GEN -50 PSA (Nitrogen Generator)
- 5000-gallon N2 storage tank
- STS Model 7100 O2 analyzer
- Rotary screw type feed air compressor with 70-gallon storage tank.



1 NITROGEN BLANKET SYSTEM
SCALE: NOT TO SCALE

Supply and return piping (30”) from the Thermal Energy Storage tanks shall route from the PHW TES tank to the new PHW piping supply header provided under SOW-P-10 Power Plant PHW System. Approximately 165 of direct-bury supply and return piping (330’ total supply and return) and 230’ of piping run across the roof of the plant (460’ total supply and return). Pipe material between the TES tank and the PHW header shall be as follows:

- Above-ground: welded carbon steel piping, 2” insulation with jacket, mounted on rollers. Aluminum jacket where located outdoors.
- Direct bury: EN253 pre-insulated steel piping, 2” insulation with jacket. With leak detection.

Provide insulation and jacketing of all piping systems. Provide supports, guides, and anchors of all piping systems.

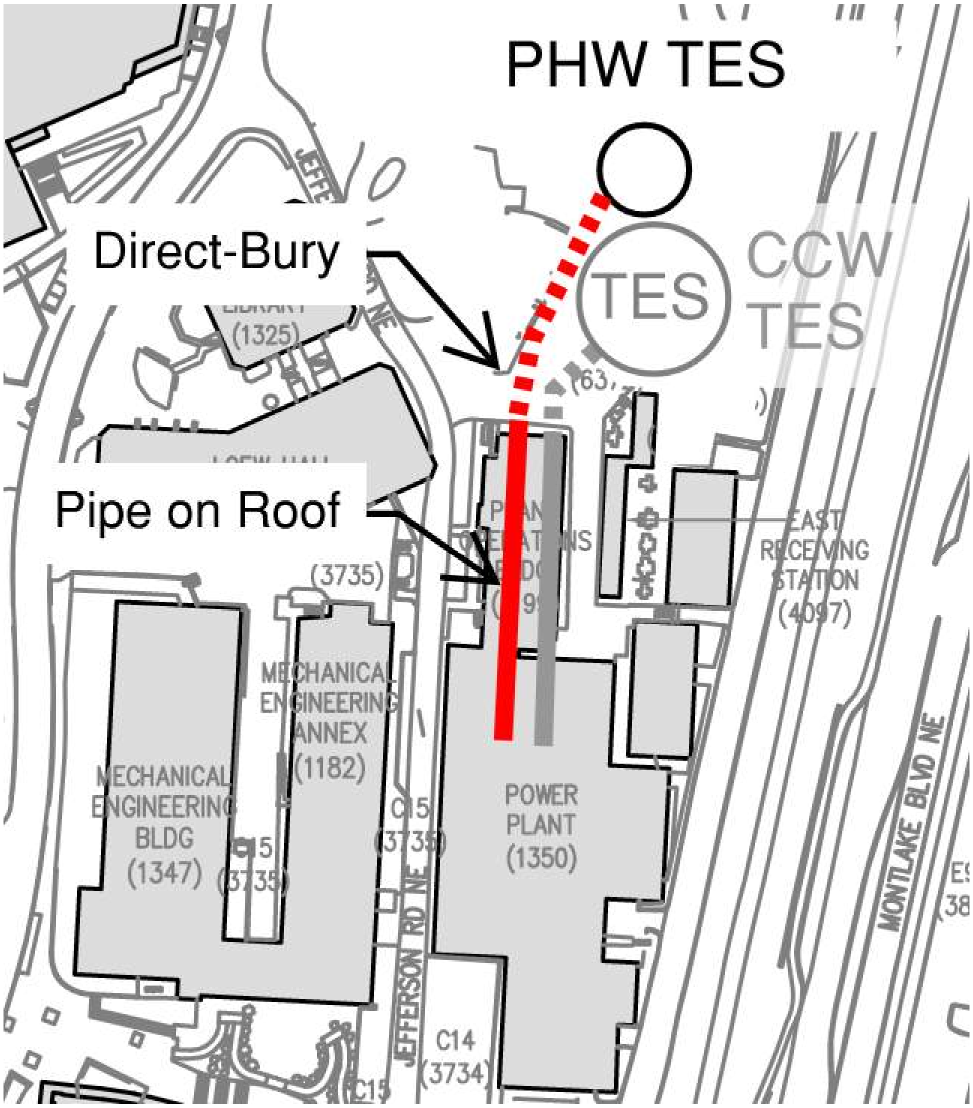


Figure 1.2.1. Sketch showing route of CCW piping from TES tanks to primary/secondary pump header in the Power Plant.

2.0 Precedent / Following Activities

This work is intended to occur after SOW-P-5 CCW TES Tank. PHW TES tank project shall be completed at the same time or after SOW-P-10 Power Plant PHW System.

3.0 Attachments

Refer to the attached Thermal Energy Storage site plan for details on the site, excavation, Thermal Energy Storage tank, and Facilities Services Building.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-7

STATUS:

COMPLETE

TITLE:

Install Heat Recovery Chillers and Cooling Towers at WCUP

SUMMARY DESCRIPTION:

This project includes (3) nominal 1500-ton heat recovery chillers and (2) nominal 1750-ton cooling towers at the WCUP. The heat recovery chillers are located in the new WCUP Annex, and the cooling towers are located on the roof of the existing WCUP. Project also includes associated piping, pumping, controls, and electrical infrastructure. Refer to attached WCUP Scope of Work Drawings and Equipment Schedule.

SEQUENCE:

This work is likely to be completed after the WCUP Annex is built, however, this project could take place in concert with the WCUP Annex project. The cooling towers can be installed on the roof of the existing WCUP at any time. Ideally, the sewer water heat recovery piping is in place before this heat recovery chiller plant is brought online.

1.1 Heat Recovery Chiller Scope

Heat recovery chiller portion of the project comprises:

- (3) 1500-ton heat recovery chillers (HRCs), basis of design is York CYK
- (1) Primary pump and VFDs on both hot water and chilled water side of each HRC. (6) Primary pumps total
- Primary piping, valving, and controls for PHW and CCW in the plant. Refer to piping diagram for approximate valve count and system configuration
- Secondary pumps and VFDs on CCW system
- All piping from tunnel entry, through the heat recovery system, and back to the tunnel, including CCW, PHW, and SWHR (Sewer Water Heat Recovery)
- Condenser water and CCW pipe connections as required between the WCUP Annex and the existing WCUP

1.2 Cooling Tower Scope

Cooling Tower portion of the project comprises:

- (2) 1750-ton crossflow cooling towers. Marley NC is basis of design.
- (2) 200 HP condenser water pumps and VFDs
- All piping from cooling towers to/from existing tower water header.
- Cooling tower makeup water piping
- All valving and controls

1.3 Heat Exchanger Scope

Provide (2) heat exchangers connecting cooling towers to sewer water heat recovery loop, sized in an N+1 arrangement for full capacity through three operating heat exchangers. Each heat exchanger shall have the following characteristics:

- Material 304 SS
- Plate and frame gasketed cross-flow
- 3,600 GPM
- 4°F approach temp
- Provide 10% extra plates for fouling

Each heat exchanger shall be provided with automated high-performance butterfly control valves for flow modulation and automatic isolation.

1.4 Building Automation System Scope

Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.

1.5 Electrical Scope

Provide:

- Medium voltage service from UW Substation to WCUP Annex will be provided by three 26.4kV feeders serving 26MVA of the connected load. Feeders will route below grade in new duct systems utilizing surface street utility right-of-way construction from UWS to WRS. The duct banks for these feeders are installed in SOW E-1, one feeder is pulled in P-4 and two feeders are pulled in this SOW, P-7. 26.4kV feeders will route to and rise to level 3 in the WCUP Annex to terminate in 35kV class switchgear (WA, WB, and WC Busses) 26kV feeders will extend from the switchgear to new unit subs and future boilers (SOW-P-12).
- Medium voltage switchgear will provide main sections for each incoming feeder and tie breaker sections supporting switching configurations similar to primary selective operation. Medium voltage distribution will serve (2) unit substations with 4,160V secondaries to feed (3) heat recovery chillers. Provisions for future (3) 26.4 kV electric boilers will be made and installation deferred until work under P-12. Distribution will be conduit and wire overhead.
- Low voltage cooling and ancillary mechanical equipment operating at 480V will be served from two unit substations rated 3000kVA and serving Main-Tie-Main switchgear. Low voltage distribution will be conduit and wire overhead.

2.0 Precedent / Following Activities

This project is the foundation of the west campus heat recovery plant. It can be built in concert with the WCUP Annex project. Ideally, the sewer water heat recovery loop will be available for use by the completion of this project.

See also these scope of work documents:

- SOW-P-3 WCUP WCH5 & WCT5
- SOW-P-4 WCUP Annex
- SOW-P-12 WCUP Electric Boilers
- SOW-P-13 WCUP Generators

3.0 Attachments

Refer to the attached WCUP and Annex Project Scope of Work Drawings which note the scope for each of the projects within the WCUP.

4.0 Constructability Commentary

This project is piping/valving/controls intensive, with several different modes of operation and options for heat recovery chiller operation, as compared to a standard chilled water central plant.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-8

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Install Heat Recovery Chillers, Cooling Tower, and Heat Exchangers at Power Plant

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*

This project includes (4) nominal 2000-ton heat recovery chillers and (2) nominal 2000-ton cooling towers at the Power Plant. The heat recovery chillers are located in former boiler 3 and 5 areas and the cooling towers are located on the roof above. Project also includes associated piping, pumping, controls, and electrical infrastructure. Refer to the attached PP Scope of Work Drawings and Equipment Schedule.

SEQUENCE: *(1-2 sentences)*
This project must follow the reconfiguration of the CCW header (P-9), installation of the PHW systems (P-10), and Electrical Power Plant Upgrades (E-2).

1.1 Demolition Scope

This project will include the demolition of Boiler 3 & 5 within the existing power plant.

1.2 Heat Recovery Chiller Scope

Heat recovery chiller portion of the project comprises:

- (4) 2000-ton heat recovery chillers (HRCs), the basis of design is York CYK
- (1) Primary pump and VFDs on both hot water and chilled water side of each HRC. (8) Primary pumps total
- Primary piping, valving, and controls for PHW and CCW in the plant. Refer to the piping diagram for approximate valve count and system configuration
- All piping from heat recovery chillers to CCW header (refer to SOW-P-9), primary HW piping (refer to P-10 for secondary hot water piping)

1.3 Cooling Tower Scope

Cooling Tower portion of the project comprises:

- (2) 2000-ton crossflow cooling towers. Marley NC is basis of design.
- (2) 250 HP condenser water pumps and VFDs
- All piping from cooling towers to/from heat recovery chillers
- Cooling tower makeup water piping
- All valving and controls

1.4 Electrical Scope

Electrical scope described within this scope package is supported from electrical infrastructure described in SOW E-2 PP Ring Bus addition and New Express Feeders. Infrastructure under P-9 describes medium voltage equipment and distribution provisions for this work scope.

Electrical portion of this project includes:

- Medium voltage 15kV class metal-clad circuit breakers to be utilized in space provisioned within gear described under SOW E-2. Circuit breaker will serve:
    - Medium voltage unit substations having 4160v secondaries will serve four heat recovery chillers. One 3750kVA unit substation is associated with each heat recovery chiller.
    - Medium voltage unit substations having 480V secondaries serving approximately 1MVA of connected ancillary mechanical system associated with heat recovery chiller operation. (work under E-2)
- 5kV Distribution will be conduit and wire overhead from the unit substation to medium voltage equipment.
- Medium voltage unit substations rated 2000kVA and having 480v secondaries will be provided to serve approximately 1.5MVA of connected mechanical load. Secondaries will terminate at double-ended switchgear operating in a Main-Tie-Main configuration. Mechanical equipment supported will include (7) 100hp and (5) 150hp motors.
- VFD motor control and harmonic mitigation provided for each pump.
- Low voltage Distribution will be conduit and wire overhead.

Mechanical equipment loads:

- Qty 4 Heat Recovery Chillers – 4160V MCA 3422 kW each
- (2) Cooling Towers – 100 HP each
- HRC primary pumps 4 x 100 HP, 4 x 150 HP

1.5 Structural Scope

Heat Recovery Chillers and Cooling Towers will require structural support framing built within the shell of the existing building that exists independent of the existing structure. Provide new foundation, footings, and columns to support new mechanical equipment platforms at the Operator Level of the plant.

Cooling towers must be provided with support that does not rely on the existing roof or beams. Structural support shall span across the existing structure as necessary to attach to columns which will be reinforced as part of this project.

2.0 Cooling Tower Portion Precedent / Following Activities

This project must follow the demolition of B-3 and B-5 and the reconfiguration and extension of the CCW header in the Power Plant.

3.0 Attachments

Power Plant Floor Plans and Sections.

Power Plant Equipment Schedule

4.0 Constructability Commentary

This project is piping/valving/controls intensive, with several different modes of operation and options for heat recovery chiller operation, as compared to a standard chilled water central plant.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-9

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Power Plant Upgrade - CCW Header and Secondary Pumping System

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
This project reconfigures the CCW header to segregate loads from generation equipment, relocates all loads to the distribution side of new secondary pumps.

SEQUENCE: *(1-2 sentences)*
This project shall take place before either SOW P-5, P-8, and P-10.

1.0 Background Information

The CCW header at the Power Plant suffers a number of hydraulic issues that are only likely to become worse as the plant is expanded. The manually operated primary-only pumping system is also inconsistent with the WCUP configuration and less compatible with the future heat recovery chiller plant.

The existing Power Plant (PP) campus cooling water (CCW) system is a manually operated, primary pumping only system, with dedicated pumps per chiller. The existing CCW header is unconventional in that it interconnects plants and loads in a way that only makes sense historically and geographically (i.e. location of multiple plants and tunnel connections). The result is a series of three CCW plant areas within the Power Plant pumping into a circuitous header in three locations with distribution takeoff points to loads occurring at various points along this header. This creates hydraulic issues that are currently addressed by operating pumps not associated with operative chillers at certain times of year as a means to get water to flow in appropriate directions (resulting in degradation of chilled water supply temperature).

The PP CCW system is also currently designed as a primary only supply system, which makes the chiller flowrates dependent on the system flow rate, and vice versa. Primary-secondary pumping offers more flexibility, particularly when heat recovery chillers are added to the system. Primary-secondary systems offer greater flexibility to preferentially loaded heat recovery chillers (when beneficial) and more easily accommodate thermal energy storage tanks. As a result, it is recommended to convert the PP CCW system to primary-secondary operation.

1.1 Detailed Work Description

The scope of work for this project includes:

- Creation of a true common header that interconnects all of the three existing sub-plant areas within the PP (the CH-1 thru 4 area, the CH-5/6 area, and the CH-7/future CH-8 area), providing each chiller equal access to each load.
- Creation of a primary-secondary bridge, normally incorporating the cold TES tank as the bridge (but also with conventional decoupler capability).
- Addition of secondary pumps that will distribute CCW to loads equally.
- Disconnection of main distribution piping connections from the current circuitous header, and reconnection of main distribution piping to the secondary pumps' distribution header.
- Connection of the cold thermal energy storage (CTES) tank in two ways; the tank will have connections to the load side of the secondary distribution system for charging as well as to the primary-secondary bridge (effectively making it part of the bridge) for discharging.

1.2 Common Primary Header Creation

As noted above, the existing "header" interconnects three distinct chiller plant areas with loads interspersed between plants. The creation of the common header will involve a new 42" supply and return primary CCW headers routed in the upper coal bin area from the three existing chiller plants south to both the proposed location of new heat recovery chillers in the area occupied by boilers 3 &5 (to be demolished, see SOW P-8) and the proposed location of new secondary CCW pumps in the Shop 43 area. The location of the secondary pumps in Shop 43 will also require (1) additional 42" secondary CCWS line to be routed through the coal bin from the secondary pumps back to the main points of distribution near existing CH-5 and 6.

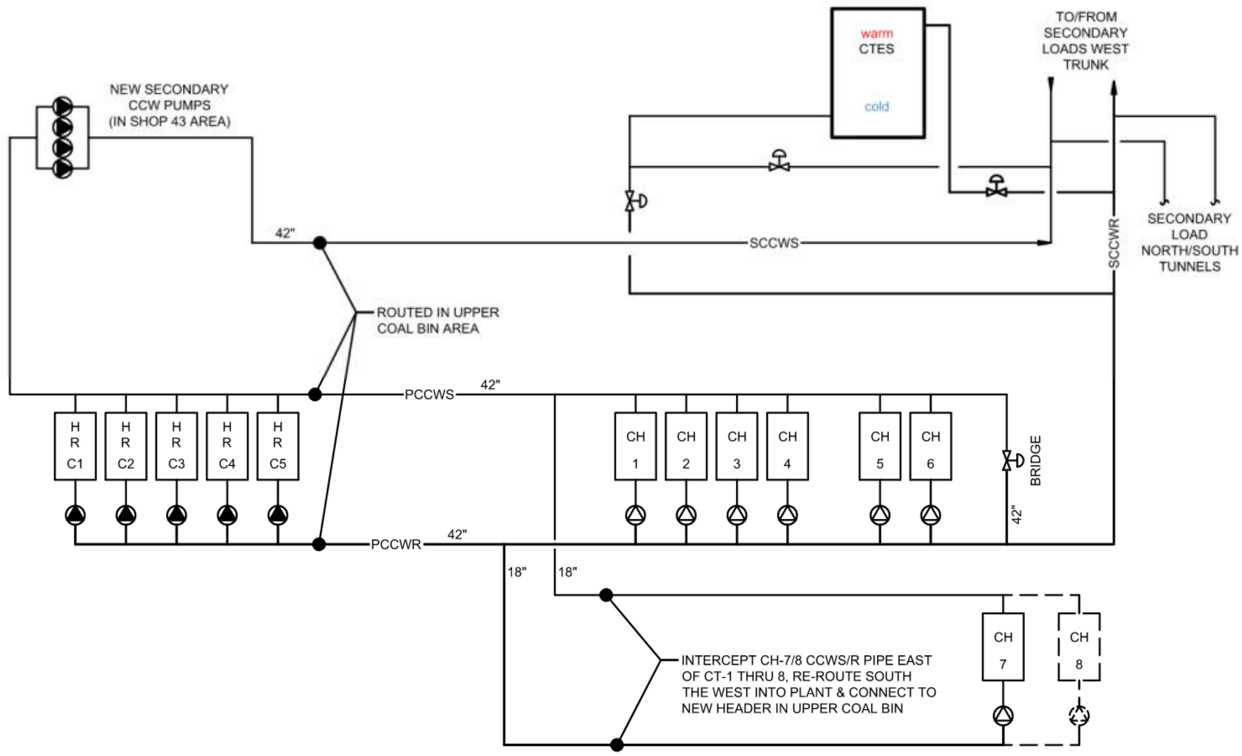


Figure 1.2.1. Power Plant CCW System Reconfiguration Schematic

1.3 Secondary Pump Installation

Secondary pumps facilitate a number of functions necessary for the operation of a heat recovery chiller plant with thermal storage. Primary-secondary chilled water pumping allows preferential loading of heat recovery chillers and as proposed, the new secondary pumps also act as pumps for charging or discharging the CTES tank.

The proposed new secondary pumps are intended to be located in the Shop 43 area. Pumps are N+1, (5) pumps at 9000 GPM, each with a 700 HP motor.

Secondary pumps are currently envisioned in the Shop 43 area, due to space constraints elsewhere, but the location of the pumps near the Chiller 5/6 area would significantly streamline the logical flow of CCW. We recommend the issue of secondary pump location be re-visited in the next iteration of this design.

1.4 Electrical Scope

Electrical work described under this scope package will extend from the infrastructure installed in E-2.

- Medium voltage 5kV metal clad switchgear, close coupled to 4160v unit substations installed under SOW E-2, will serve approximately 3.5MVA of Secondary CCW pumps. The Switchgear line-up serving these pumps will operate in a M-T-M configuration and a distribution section with motor protection and control will be provide for each of the five 700hp Secondary CCW pumps (work under P-9).
- VFD motor control and harmonic mitigation provided for each pump.
- 5kV Distribution will be conduit and wire overhead from the unit substation to medium voltage equipment.

1.5 Structural Scope

New piping distribution systems within the Power Plant associated with this project and SOW-P-10 will require significant consideration for structural support within the shell of the existing building. There are sections of the plant previously designed for storage, processing, and distribution of coal that are thought to have robust structures that may be able to support the new piping systems. Structural analysis has not been performed to validate this.

1.6 CTES Tank Integration

The CTES tank will be integrated into the new header system in a way that allows multi-modal operation. In charge mode, the tank will be connected to the secondary side of the distribution system, allowing either plant to charge the tank. In discharge mode, the tank will be located in the classic location, within the primary-secondary bridge. This allows the tank to act as a chiller or as a load, without the need for additional dedicated tank pumps.

1.7 Construction Sequencing

Install new runs of piping first, terminating in the vicinity of points of connection to existing systems. Install new secondary pumps. Demo piping to be permanently removed during winter, make final connections to new pipe header configuration. Enable and test the new system.

2.0 Precedent / Following Activities

The header concept addresses the addition of heat recovery chillers as described in SOW P-8 and the CTES tank integration into the header system as described in SOW P-5. This project shall take place before either SOW P-5 or P-8.

3.0 Attachments

Power Plant Floor Plans and Sections.

Power Plant Equipment Summary

4.0 Constructability Commentary

Routing of the (3) 42” primary and secondary supply and return headers need field verification.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-10

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Power Plant Upgrade – Steam-to-water converters, hot water pumps, and hot water header installation

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*

The project adds steam-to-hot water converters to the Power Plant to provide hot water to the new distribution network as the first stage of hot water system conversion. The project includes the secondary hot water distribution piping and pumps.

SEQUENCE: *(1-2 sentences)*

Installation required prior to heat recovery chiller and electric boiler installation in early phases of conversion.

1.1 Demolition Scope

This project will include the demolition of Boiler 5 within the existing power plant.

1.2 Steam-to-Hot Water Converter Scope

Steam-to-Hot Water Convertors will be installed in the boiler plant:

- (4) 95,000 pph steam-to-hot water converters
- Sidecar pumps/piping interconnecting heat exchangers to secondary hot water piping loop
- Pumps, (3) @ 9,500 GPM, 125 HP.
- All piping, valving, and controls from steam header to converters and converter to secondary hot water loop

1.3 Hot Water Pump and Piping Scope

Primary Hot Water Piping and Pumping portion of the project comprises:

- (4) 6,300 GPM secondary hot water pumps B&G HSC 8x10x17 is basis of design. 600 HP with VFD supplied from generatorbacked power systems.

- 30" secondary hot water supply and return headers
- All valving and controls

1.4 Electrical Scope

Electrical scope described within this scope package is supported from electrical infrastructure described under E-2. Infrastructure under E-2 describes medium voltage equipment and distribution provisions for service to this work scope.

Electrical portion of this project includes:

- Medium voltage 15kV class metal-clad circuit breakers to be utilized in space provisioned within gear described under E-2 and P-5 (ATP with normal source and generator source feeding MTM switchgear). Circuit breaker will serve:
- Medium voltage unit substations rated 3000kVA and having 4160v secondaries will be provided to serve approximately 3.0MVA of connected mechanical load. Secondaries will terminate at double-ended switchgear operating in a Main-Tie-Main configuration. Mechanical equipment supported will include (4) 600hp motors.
- Medium voltage 5kV metal clad switchgear, close coupled to 4160v unit substations, will serve secondary hot water pumps. The Switchgear line-up serving these pumps will operate in an M-T-M configuration and a distribution section with motor protection and control will be provided for each of the four 600hp pumps.
- VFD motor control and harmonic mitigation are provided for each pump.
- 5kV Distribution will be conduit and wire overhead from the unit substation to medium voltage equipment.

2.0 Precedent / Following Activities

This project precedes the installation of the heat recovery chillers at the Power Plant (P-8) and the PHW TES tank (P-6).

3.0 Attachments

Power Plant Floor Plans and Sections.

Power Plant Equipment Schedule

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-11

STATUS:

WORK IN PROGRESS

TITLE: *(Short and descriptive name for the project)*

Power Plant Upgrade – Add Electric Boilers and Emergency Generator Heat Capture

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Project includes the installation of (3) 6-MW electrode boilers and associated equipment; including electrical feeders and panels, feedwater skids and steam-to-water heat exchangers; and plate and frame heat exchangers at each of (5) diesel gensets.

SEQUENCE: *(1-2 sentences)*
This project would occur after P-8 and P-10.

1.0 Detailed Work Description

Electrode boilers located in the former Boiler 3 & 5 area provide trim heat for the new PHW system above and beyond what the heat recovery chillers can provide. Electrode boilers create steam using high-voltage electricity and heating hot water is created with steam-to-hot water heat exchangers. These heat exchangers are tied into the primary heating water system with a sidecar piping/pumping system. The electrode boiler system requires a feedwater system to supply hot water to the boilers, this can be a skid-mounted system provided by the electrode boiler manufacturer.

In addition, heat exchangers will be provided to extract heat from the engine jacket water at the (5) 2 MW diesel generator sets at the Power Plant. Heat exchangers will be valved in parallel with existing remote radiators with water redirected to new heat exchangers when generators are operating, and heat is required for campus operation. Each generator rejects approximately 750 kW to jacket water.

1.1 Electric Boiler Scope

- (3) 6-MW electrode boilers, basis of design is Precision HVJ-128, 13.2 kV.

  - o Provided in a redundant arrangement. Only two boilers are intended to operate under peak load scenario.
- Packaged feedwater skid for boilers, provided by the boiler manufacturer
- Steam-to-water heat exchangers at each boiler
- Water-to-water plate and frame heat exchangers at each genset.
- Genset heat capture pumps. 5 x 200 GPM @ 10 HP.
- Sidecar pumps and VFDs on the PHW system serving each system. 3 x 1400 GPM @ 75 HP.
- Piping, valving, and controls for each sidecar loop on the PHW system in the plant

1.2 Electrical Scope Included in Project

Electrical scope described within this scope package is supported from electrical infrastructure described in SOW E-2. Infrastructure under E-2 describes medium voltage equipment and distribution provisions for service to this work scope.

Electrical portion of this project includes:

- Medium voltage 15kV class metal-clad circuit breakers to be utilized in space provisioned within gear described under SOW E-2. Circuit breaker will serve:
  - o Medium voltage Electrode Boilers. Three boilers, 6MW each, will be served directly from the switchgear.
- 15kV Distribution will be conduit and wire overhead from the unit substation to medium voltage equipment.
- Ancillary mechanical loads at 480v will be served from space provisions in low-voltage switchgear provided under SOW P-8. Mechanical equipment supported will include (8) motor loads at or below 75hp.
- VFD motor control and harmonic mitigation provided for each pump.
- Low voltage Distribution will be conduit and wire overhead.

Mechanical equipment loads:

- Qty 3 Electrode Boilers – 13.2kV 6 MW each (max 2 simultaneous operation)
- Qty 3 Electrode Boiler Circ/Feedwater Pumps – 75 HP each (max 2 simultaneous operation)
- Qty 3 Electrode Boiler PHW sidecar pumps – 75 HP each (max 2 simultaneous operation)
- Qty 5 Genset heat capture pumps - 10 HP.
- Qty 2 Drups heat capture pumps - 10 HP.

1.3 Controls

Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.

2.0 Precedent / Following Activities

This project would occur after P-8 and P-10.

3.0 Attachments

Power Plant Floor Plans and Sections.

Power Plant Equipment Schedule

4.0 Constructability Commentary

Electrode boilers are very tall and will require a high floor-to-floor height. Access platforms and ladders may be required.

Scope of Work Description

PROJECT NUMBER:

P-12

STATUS:

WORK IN PROGRESS

TITLE:

WCUP Upgrade – Add Electric Boilers

SUMMARY DESCRIPTION:
Project includes the installation of (3) 6-MW electrode boilers and associated equipment; including electrical feeders and panels, feedwater skids, and steam-to-water heat exchangers.

SEQUENCE:
Project will occur after the WCUP Annex project and not part of that building's construction sequence.

1.0 Detailed Work Description

Electrode boilers located on Level 1 of the WCUP Annex provide trim heat for the new PHW system above and beyond what the heat recovery chillers can provide. Electrode boilers create steam using high-voltage electricity, and heating hot water is created with steam-to-hot water heat exchangers. These heat exchangers are tied into the primary heating water system with a sidecar piping/pumping system. The electrode boiler system requires a feedwater system to supply hot water to the boilers, this can be a skid-mounted system provided by the electrode boiler manufacturer.

1.1 Electric Boiler Scope

- (3) 6-MW electrode boilers, basis of design is Aerco Sequoia, 26 kV.
    - Provided in a redundant arrangement. Only two boilers are intended to operate under peak load scenario.
- Packaged feedwater skid for boilers, provided by the boiler manufacturer
- Steam-to-water heat exchangers at each boiler
- Sidecar pumps and VFDs on the PHW system serving each system. 3 x 1400 GPM @ 75 HP.
- Piping, valving, and controls for this sidecar loop on the PHW system in the plant

1.2 Electrical Scope Included in Project

Provide electrical infrastructure to support the mechanical equipment listed above. Electrical infrastructure is described in SOW P-7. Provide 26kV distribution to the boilers via conduit and wire overhead from the 26kW switchgear to medium voltage equipment.

Provide distribution beakers in the switchboard described in P-4 and P-7 to serve three PHW sidecar pumps.

Mechanical equipment loads:

- Qty 3 Electrode Boilers – 26kV, 6 MW each (max 2 simultaneous operation)
- Qty 3 Electrode Boiler PHW sidecar pumps – 75 HP each (max 2 simultaneous operation)

1.3 Controls

Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.

2.0 Precedent / Following Activities

This project will be completed after the WCUP Annex project.

See also these scope of work documents:

- SOW-P-3 WCUP WCH5 & WCT5
- SOW-P-4 WCUP Annex
- SOW-P-7 WCUP HRCs and Cooling Towers
- SOW-P-13 WCUP Generators

3.0 Attachments

Refer to the attached WCUP and Annex Project Scope of Work Drawings which note the scope for each of the projects within the WCUP.

4.0 Constructability Commentary

Electrode boilers are ~16′ tall and will require a high floor-to-floor height. Access platforms and ladders may be required.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-13

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

WCUP Upgrade – Add Remaining Standby Power Generators

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Install two 2 MW diesel engine generator with weather protective enclosure and sub-base UL2085 fuel tank located on the existing WCUP roof.

SEQUENCE: *(1-2 sentences)*
This project can be completed out of sequence with other WCUP related work.

1.0 Detailed Work Description

Install two diesel engine generators on the existing WCUP roof. Provide all appurtenances and integrate with existing building standby power systems.

1.1.1 ELECTRICAL SCOPE OF WORK

Install two 2 MW 4,160V, 3P, 3W diesel engine generator with weather protective enclosure and sub-base UL2085 fuel tank located on the existing WCUP roof. Packaged generator enclosure shall include an external muffler, extensions for combustion exhaust, and radiator air intake and exhaust. Match installation of the existing generators.

Provide new feeder from new generators to existing electrical switchgear in existing WCUP electrical room. Feeder shall be 5kv rated, armored multicore copper, (3)500 KCMIL, 1#1 GND.

Provide a new roof curb for each generator. Repair existing roof as required with penetrations from new generators down through the building.

Figure 1.1.1.1 Photo of existing rooftop generator.

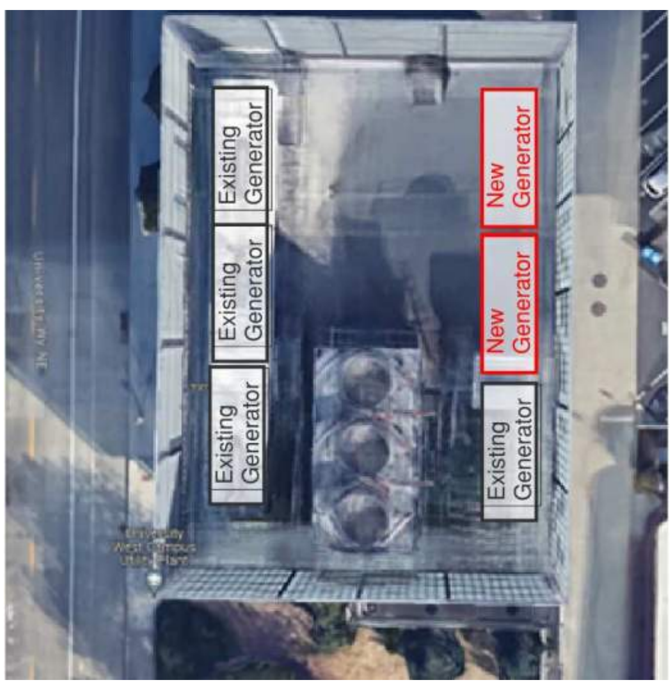


Figure 1.1.1.2 Satellite image of existing WCUP roof condition. New generators will be installed along eastern roof edge.

1.1.2 MECHANICAL SCOPE OF WORK

The existing fuel oil system was designed for these future generators. Extend fuel oil piping from the Ground Level mechanical room up to the roof. Refer to Figure 1.1.2.1.

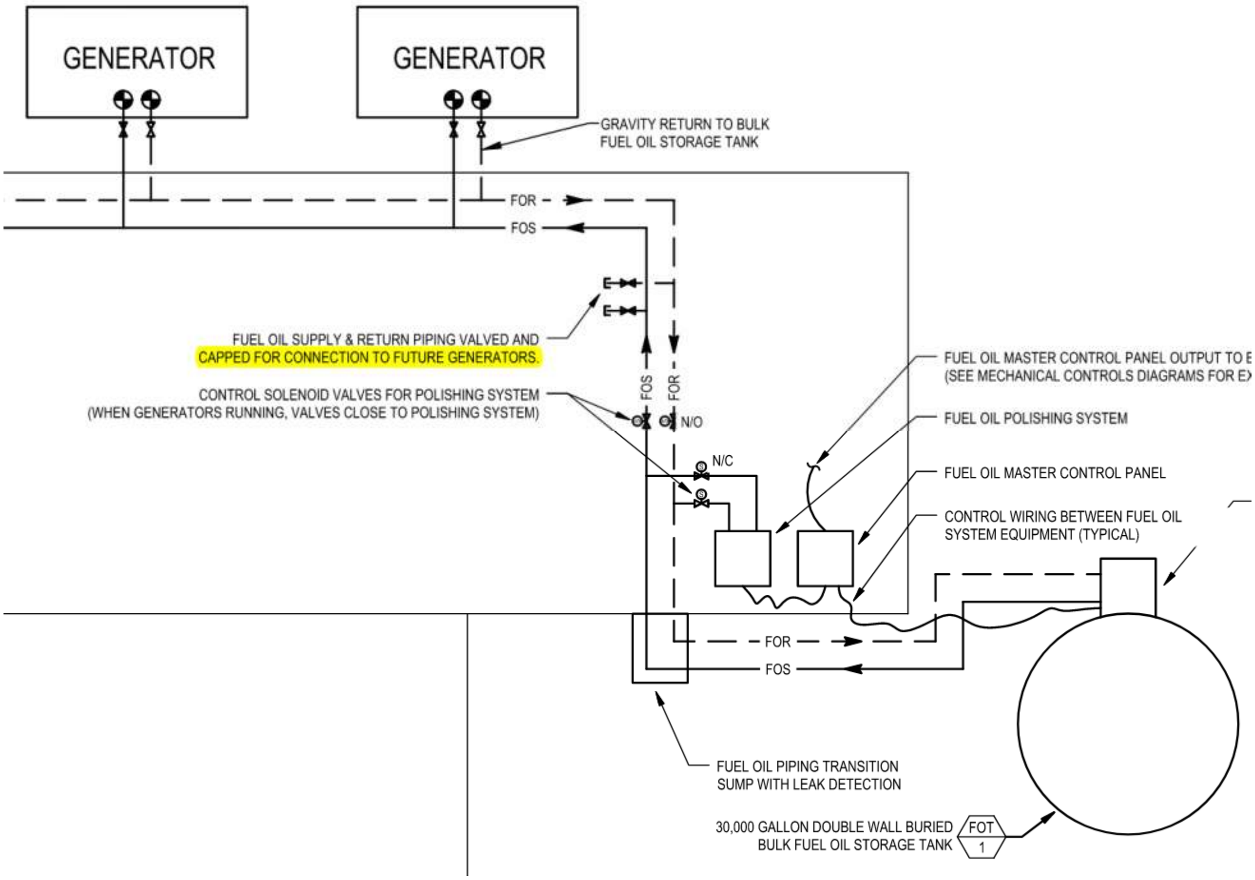


Figure 1.1.2.1 Record drawing Fuel Oil diagram.

1.1.3 CONTROLS SCOPE OF WORK

Integrate new controls with the existing system as required for a fully operational system. The existing system is PLC.

2.0 Precedent / Following Activities

This project can be completed out of sequence with other WCUP related work.

See also these scope of work documents:

- SOW-P-3 WCUP WCH5 & WCT5
- SOW-P-4 WCUP Annex
- SOW-P-7 WCUP HRCs and Cooling Towers
- SOW-P-12 WCUP Electric Boilers

3.0 Attachments

Refer to the attached WCUP and Annex Project Scope of Work Drawings which note the scope for each of the projects within the WCUP.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

P-14

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Power Plant Controls Upgrade.

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
The project will upgrade the PLC-based control system serving the Power Plant (PP) to provide full automation of existing equipment and to fully automate future equipment anticipated.

SEQUENCE: *(1-2 sentences)*
The control system upgrade is intended to be one of the first projects in the ERP.

1.0 Detailed Work Description

The project will consist of the following – upgrade the Power Plant PLC-based control system to perform the following functions:

1) Automate control of primary CCW pumps, chillers, and cooling towers. Add VFDs to pumps where not currently present for added flexibility. Cooling tower fans all include VFDs (installed in 2012/2013 upgrades).
    a. Address existing chillers, pumps, and towers
    b. Include integration and automation of new CH-8 and CT-14 controls.
2) Automate sequencing of chillers and future heat recovery chillers for both CCW and PHW production.
    a. Automate lake water pumping as a heat source to support heat recovery chiller heating mode. Automate switchover to backup cooling tower use for heat recovery chillers when cooling dominates campus loads (and conventional chillers are insufficient to meet load).
    b. Automate sequencing of backup heating (whether from steam-to-hot water converters, from future electric boilers, or from generator radiators when in use).

1.1 Automation of Current CCW System (pumps, chillers, and towers)

Automation of the CCW system should include the addition of VFDs to pumps to allow fine-tuning of flow control and to minimize energy use. New differential pressure sensors have already been defined in scope memo P-1 and will be necessary for automated control of chilled water pumping; pumps will control to maintain minimum delta-P at the worst-case point in the system currently being served.

Chillers should be staged automatically based on a combination of chiller leaving water temperature feedback, system delta-P feedback, and feedback from flow meters (primarily the three existing "controlotron" BTU meters). Loss of leaving water temperature control should be the primary means of staging on a new chiller, but the system should also monitor the system's ability to meet differential pressure requirements at all monitoring points being serving and at the system's current delta-t/flow characteristics.

Cooling tower fan VFDs are currently manually enabled, but once enabled, the existing PLC system controls fan speed to maintain condenser water supply temperature. The PLC system also monitors minimum flow switches at individual tower cells and vibration switches at fans. Similar to the chillers, enable and disable signals to tower fan VFDs should be automated, and tied to the quantity and location of operating chillers.

1.2 Automation of future systems (Heat Recovery Chillers, Steam-to-hot water converters, Boilers)

As additional equipment is installed at the Power Plant, a robust automation system will be required to properly stage heat recovery chillers, supplemental heat sources from which the HRCs can draw heat, and supplemental heat generation devices.

The automation system will require big-picture knowledge of the current campus heating and cooling loads. Since both the WCUP and the PP will include heat recovery chillers and will operate in tandem, one of the PLC systems serving the two plants will act as the executive system, determining which chillers and heat recovery chillers in each plant will operate. The decision on the quantity of chillers and heat recovery chillers required to operate will be based on the current measured flow/BTU metering of CCW and PHW and the height of the thermocline within the thermal energy storage (TES) tanks.

2.0 Precedent / Following Activities

N/A

3.0 Attachments

N/A

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

S-1

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Lake Interface System

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Scope of work includes construction of the pump/HX facility, on-shore and off-shore piping, and CHW piping to/from the Power Plant.

SEQUENCE: *(1-2 sentences)*
This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

1.0 Detailed Work Description

The Lake Interface System provides heating and cooling energy to the Power Plant via heating or cooling the Campus Cooling Water which will connect the Power Plant to the Lake Interface Equipment Building.

High-level summary scope of work for the Lake Interface System:

- Site enabling and excavation work associated with the new Lake Interface Equipment building.
- Construct the new Lake Interface Equipment building in UW Parking Lot E-8.
- The building is constructed in the area of UW's East Campus which requires piles for structural foundation.
- Building houses lake water interface pumps and heat exchangers.
- Provide new water, sewer, and storm utility service connections.
- Electrical power to be fed from the East Receiving Station at the Power Plant. Provide electrical switchgear, panels, and distribution. Provide metering integrated with UW's existing metering network.

- Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85 deg F.
- Off-shore piping and intake structure including direct-bury pipe between building and shoreline and trenched installation method across Union Bay to the intake located at Lake Washington.
- Direct-bury outfall piping between the Lake Interface Equipment building and the outfall location in Portage Bay. Pipe diffuser located along the shore of Portage Bay.
- Surface level improvements to trail along Montlake Cut to Portage Bay as part of the installation of direct-bury piping between the Lake Interface Equipment building and outfall.
- Direct-bury CCW piping between the Lake Interface Equipment building and the Power Plant.

1.1 Cost Estimate by Others

Makai Ocean Engineering has provided a cost estimate of the system. The Whiting-Turner team will need to provide a revised estimate for the Lake Equipment Interface Building and the "Distribution Network" which includes all of the on-shore direct-bury piping. The Makai Estimate should be used for the Shore Crossing, Pre-Engineering, and Offshore Lake Water Pipes.

1.2 Lake Interface System Piping

1.2.1 GENERAL

Piping installations shall be assumed to be configured as follows:

- Lake Interface System Discharge/Intake Piping:
  - Direct bury: 48" HDPE SDR 11, rated for 200psi in cold water applications, 1.5" insulation with jacket. With leak detection.
  - Above-ground: welded carbon steel piping, 2" insulation with jacket, mounted on rollers.

1.2.2 ON-SHORE PIPING (DISCHARGE)

On-shore lake interface system piping is routed from the discharge side of the Lake Interface Equipment building along the shore of Union Bay and the Montlake Cut, to a discharge location as shown on the Site Distribution Maps – CCW drawing. Piping shall be buried with a minimum 3’ of cover with appropriate backfill materials.

Surface improvements along the route of the discharge pipe between the Canoe House (1187) on the southeastern edge of the shore and the outfall/diffuser location shall include restoration of the trail.

At the outlet of the discharge piping provide a pipe diffuser as shown in Figure 1.2.2.1. Four 24” discharge branches will be provided, with a length of 25 ft each and 6 diffuser ports angled into the water.

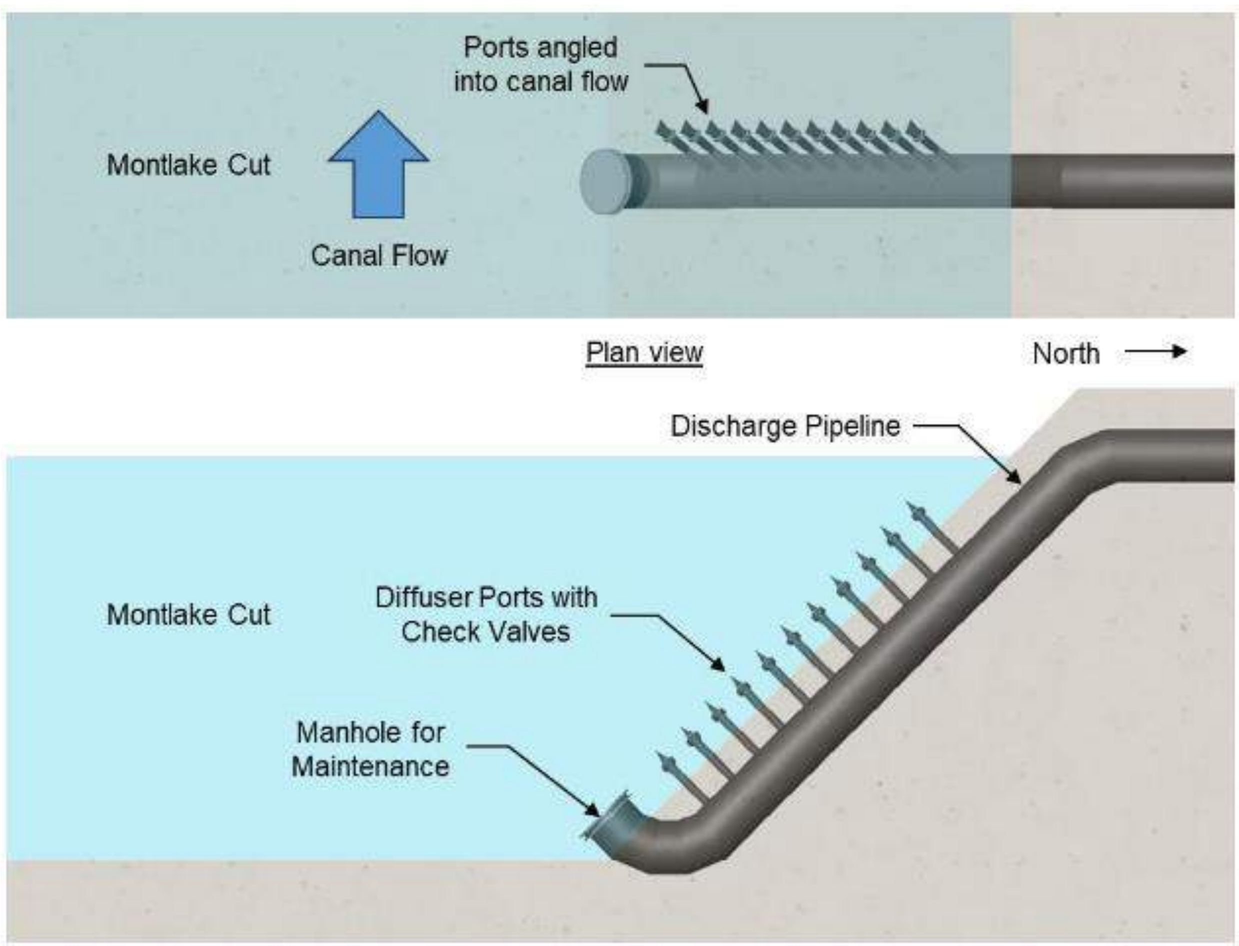


Figure 1.2.2.1. Example diffuser configuration.

1.2.3 OFF-SHORE PIPING (INTAKE)

Off-shore lake interface system piping is covered by Makai Ocean Engineering's cost estimate, using Config 2b Discharge to Cut-Trench. Refer to Makai Ocean Engineering's cost estimate in the attachments.

1.3 Lake Interface Equipment Building

1.3.1 SITE ENABLING WORK

Prepare the site for the new structure and buried utilities. Provide new water, sewer, and storm utility service connections. Electrical power to be fed from East Receiving Station at Power Plant.

1.3.2 BUILDING STRUCTURE AND SUPPORTING INFRASTRUCTURE

Construct new Lake Interface Equipment building in UW Parking Lot E-8. Building is constructed in in the area of UW's East Campus that requires piles for structural foundation. Building structure shall be insulated per the current Seattle Energy Code as a fully conditioned building. Comply with existing Building Codes and best practices.

Provide 15 kV rated three phase loop feeder from Power Plant / East Receiving Station (ERS) to Lake Equipment Building. Provide double ended unit subs with 4160V secondary at pump house rated for 1MW. Provide MV distribution cabling to pump motor VFD's and pumps. Provide metering integrated with UW's existing metering network.

Provide 480V transformer for support loads in Lake Equipment Building including ventilation, freeze protection, and lighting.

Provide 208V system for support loads within Lake Equipment Building including controls, maintenance receptacles, and support loads.

Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85F.

Provide interior and exterior lighting systems.

Provide security and IT systems.

1.3.3 Lake Water Pump System

Provide three vertical turbine pumps, sized in an N+1 arrangement for full capacity delivered with only two operating pumps. Pumps shall be mounted above the wet well. Pump suction is mounted in the wet well. Pump discharge is routed to a header which distributes individually to each heat exchanger. From the heat exchangers, the pipes collect in another header which routes out of the building and is continued on the site. Refer to the Lake Interface Pump Bldg Concept Plan for further details.

Each pump shall have the following characteristics:

- 11,000 GPM @ 50 ft head – 200 motor HP
- Pump suction extension as required for depth of the wet well
- Variable speed drive
- Basis of Design: Sulzer JT. Contact HD Fowler Co.

1.3.4 Wet Well and Lake Water Piping Intake

The wet well shall be constructed to the dimensions shown on the Lake Interface Pump Bldg Concept Plan. The wet well shall be constructed as a water-tight concrete basin.

Provide ladder and intermediate access platform grating within the wet well for access to the bottom of the well and valves.

Lake intake pipe is routed direct-bury from the on-shore landing point into the wet well. The pipe is located such that it is below the low lake level and thus lake water drains into the wet well by gravity. The lake intake piping transitions from HDPE underground to carbon steel once it enters the building. Provide necessary valves and fittings for isolation of the intake pipe and launching of "pigs" for pipe cleaning. A second buried pipe enters the wet well which connects to the discharge/outfall piping and acts as a bypass for pigging operations, allowing the system to reverse flow.

1.3.5 Heat Exchangers

Provide four heat exchangers, sized in an N+1 arrangement for full capacity through three operating heat exchangers. Each heat exchanger shall have the following characteristics:

- Material 304 SS

- Plate and frame gasketed cross-flow
- Total system flow on both the hot side and the cold side is 22,000 GPM
- 2 °F approach temp
- Cold side:
    - Fluid: water
    - 36F EWT
    - 43F LWT
    - 10 psid
- Hot side:
    - Fluid: lake water
    - 45F EWT
    - 38F LWT
    - 10 psid
- Provide 10% extra plates for fouling

Each heat exchanger shall be provided with automated high-performance butterfly control valves for modulation of flow and automatic isolation.

1.3.6 CAMPUS COOLING WATER PUMP SYSTEM

Provide three vertical split-case pumps, sized in an N+1 arrangement for full capacity delivered with only two operating pumps. Pumps shall be mounted on a concrete housekeeping pad. Refer to the Lake Interface Pump Bldg Concept Plan for further details.

Each pump shall have the following characteristics:

- 11,000 GPM @ 70 ft head – 250 motor HP
- Variable speed drive
- Basis of Design: B&G VSX-VSC 14x16x17.5A

1.3.7 BUILDING AUTOMATION SYSTEM CONTROLS

Provide PLC control system with communication to facility network for integration with existing Campus Utility Plants (Power Plant, West CUP). Provide industrial quality instrumentation (temp & pressure sensors, flow meters, flow switches, etc.) and valves aligned with best practices for central utility plants.

1.4 Campus Cooling Water Piping

Campus Cooling Water shall be routed direct-buried from the Power Plant to the Lake Interface Equipment building as shown in Site Distribution Maps – CCW. Piping shall terminate outside of the Power Plant, 5’ from the building perimeter. Piping will be extended into the plant as part of SOW-P-7 WCUP HRCs and Cooling Towers.

Piping installations shall be assumed to be configured as follows:

- Campus Cooling Water Supply/Return (CCWS/R):
    - Direct bury: HDPE SDR 11, rated for 200psi in cold water applications, 1.5” insulation with jacket. With leak detection.

2.0 Precedent / Following Activities

This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

3.0 Attachments

Refer to the following supporting documents:

- Makai Ocean Engineering cost estimate for the Lake Interface system.
- Site Distribution Maps – CCW.
- Lake Interface Pump Bldg Concept Plan.
- Full report by Makai Ocean Engineering.

For reference to an existing installation, refer to this video on Cornell University’s Lake Source Cooling plant: https://youtu.be/hAK8L68VIRE?si=0906_cf-Rm4EuIEE&t=155

Affiliated Engineers

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

S-2

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Sewer Heat Recovery Equipment Building, Wet Well and Sewer Tie-In

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Construct a new Sewer Water Heat Recovery Equipment Building sewer water wet well, sewer main piping intercept, and all interconnecting piping.

SEQUENCE: *(1-2 sentences)*
This scope wants to be executed in sequence with SOW-P-7 WCUP HRCs and Cooling Towers and SOW-D-W-2 Sewer Heat Recovery Piping. This scope should be executed in sequence or after SOW-E-1 UW Substation.

1.0 Detailed Work Description

The Sewer Heat Recovery System provides heating and cooling energy to the WCUP via a piping connection to the WCUP via a new tunnel and direct-bury system. Refer to SOW-D-W-2 Sewer Heat Recovery Piping. Refer to Figure 1.0.1, below for a simple site layout.

High-level summary scope of work for the Sewer Heat Recovery System:

- Site enabling and excavation work associated with new Equipment building.
- Construct new Equipment building.
- Building houses sewer water heat recovery (SWHR) distribution pumps, heat exchangers, electrical equipment, and light soft spaces.
- Building to be 2 stories tall and approximately 11,200 SF. See Figure 1.0.2 below, for a simple layout. Each story shall allow for 180” clear dimension from the floor to bottom of structure for equipment maintenance.
- Construct a new intercept vault within the Burke-Gilman Trail and wastewater piping to/from a new wet well constructed for this purpose. Provide a temporary bypass system during vault construction.
- Restore surface to existing conditions in Burke-Gilman trail and public right-of-ways.
- Construct a new wet well located below the existing loading dock area of the Publication Services Building.

- Wet well located below drive aisle of publications services building. Submersible pumps are to be located in the wet well. Provide dedicated piping between wet well pumps and sewer heat recovery units (SHARC units).

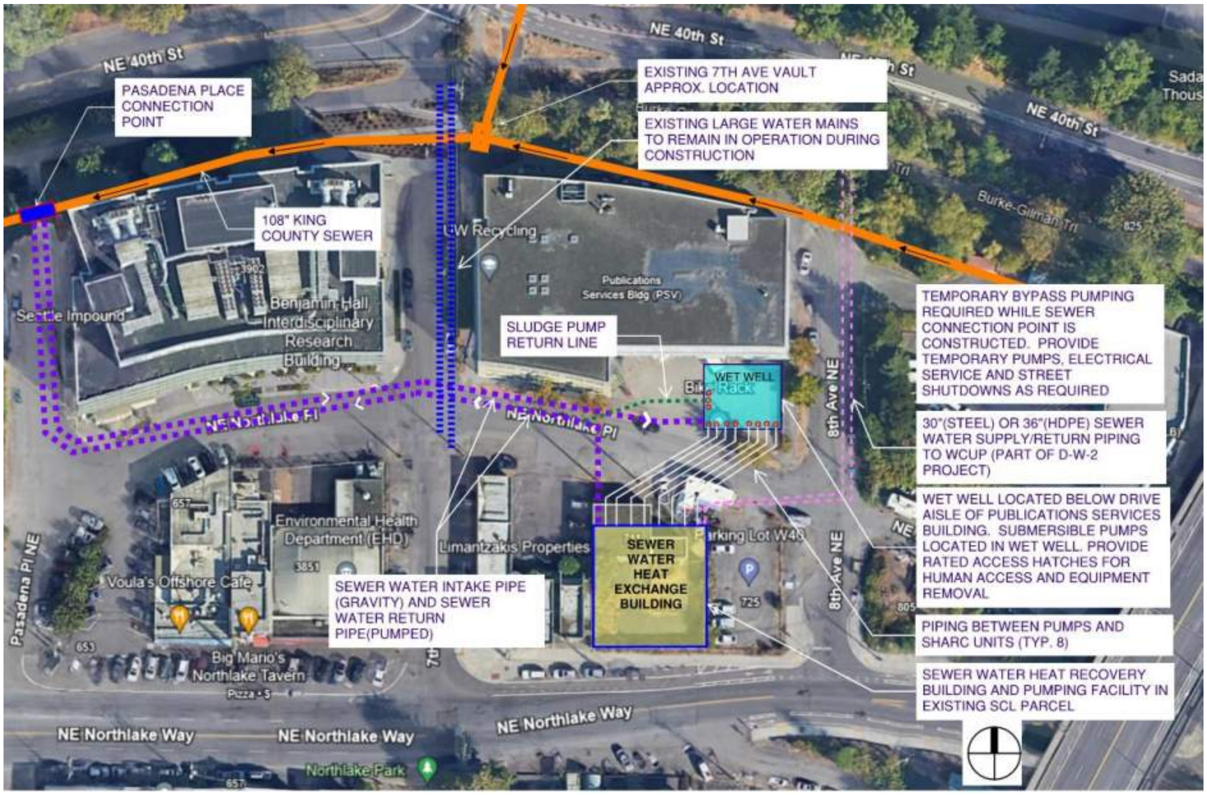


Figure 1.0.1 Sewer Water Heat Recovery Site Plan

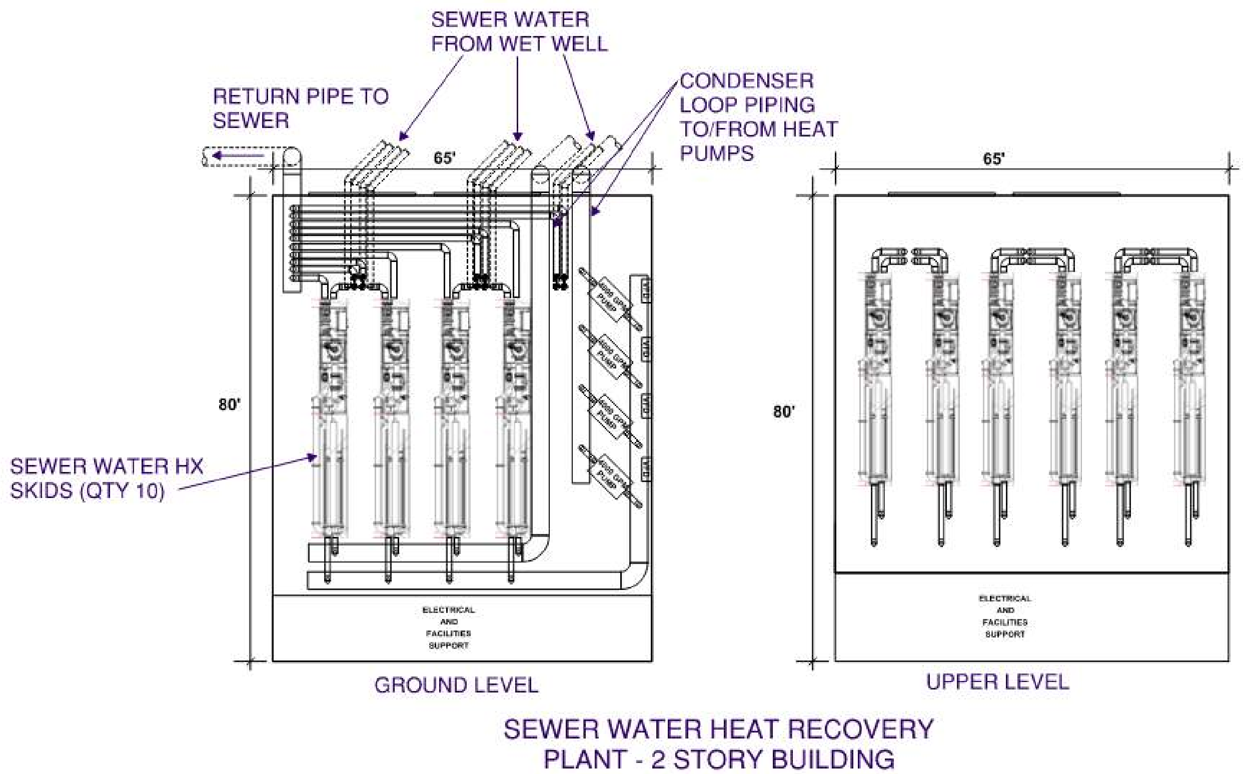


Figure 1.0.2 Sewer Water Heat Recovery Building – Simple Layout

1.1 Sewer Heat Recovery Equipment Building

1.1.1 SITE ENABLING WORK

Demolish existing structure. The existing lot is known to contain contaminated soils. Assume in the estimate an amount of remediation work consistent with a contaminated brownfield site.

Prepare the site for the new structure and buried utilities. Provide new water, sewer, and storm utility service connections. Provide on-site stormwater management such as bioretention planters and an allowance for water quality for parking stalls. Electrical power is to be fed from the new UW Substation.

1.1.2 BUILDING STRUCTURE AND SUPPORTING INFRASTRUCTURE

Construct the new building. The building structure shall be insulated per the current Seattle Energy Code as a fully conditioned building. Comply with existing Building Codes and best practices.

Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85 deg F.

Provide interior and exterior lighting systems.

Provide security and IT systems.

1.1.3 LAND ACQUISITION

Include land acquisition costs associated with acquiring the 711 NE Northlake Way site.

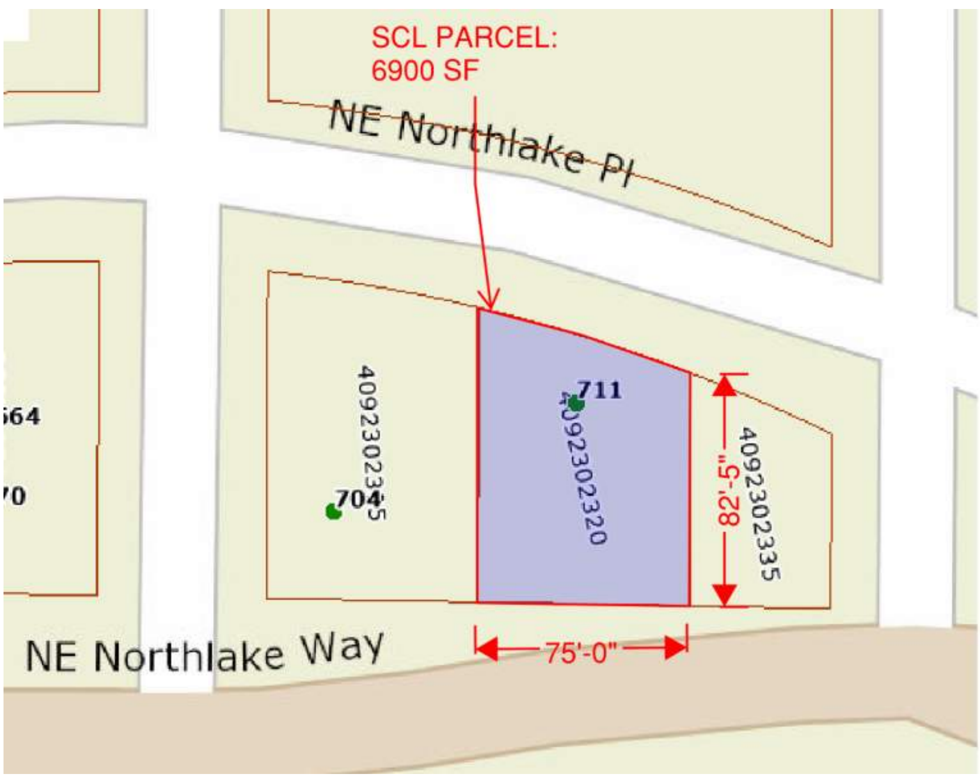


Figure 1.1.3 King County Parcel Viewer Map of Site Considered

1.1.4

1.1.5 SEWER WATER HEAT RECOVERY HX AND FILTRATION SYSTEM

Construct a complete sewer water heat recovery filtration and heat exchange system. Basis of design are SHARC 1212 packaged heat recovery units. Based on the total system target design of 54,000 MBH of heat source in the summer at 7-degree delta-T on the sewer water, (10) SHARC 1212 units are assumed to be included in this system. Each SHARC skid comes complete with its own macerator, SHARC filtration system, piping system with reverse-flow capabilities, heat exchanger, controls package, and single point electrical connection.

Each SHARC unit shall have a separate dedicated submersible sewer water pump located in the wet well to serve it. The submersible pumps wastewater from the wet well through the SHARC unit, and back to the sewer return line which is combined together and routed through the site back to the main waste line under the Burke-Gilman Trail.

1.1.6 SEWER WATER HEAT RECOVERY (SWHR) PUMP SYSTEM

Sewer Water Heat Recovery circulation pumps with VFDs: (5) pumps @ 150 HP

Provide sidestream filtration system sized for 5% of total flow.

1.1.7 ELECTRICAL SCOPE

Provide electrical infrastructure to support new Sewer Water Heat Recovery equipment building. A new service is provided from the UW Substation to the new building. Wet well pumps should be provided from electrical distribution gear located within the new Sewer Water Heat Recovery Equipment building.

Provide 35 kV rated three-phase loop feeder from UW substation to SWHR building. Provide double-ended unit substation switchgear rated for 3MW (4,000A) with 480V distribution bussing. Provide 480V distribution cabling to the following loads:

- Qty 5 SWHR pumps – 150 HP each (max 4 simultaneous operation)
- Qty 10 Sewer Water Circulation Pumps (submersible)– 125 HP each.
- Qty 10 SHARC 1212 units, each with a single point connection of 40 KW.
- Qty 3 Wet Well Sludge Pumps – 75 HP each (max 2 simultaneous operation)
- Qty 10-ton Packaged Rooftop unit.

Provide 480V power to support loads in the pump house including ventilation, freeze protection, and lighting. Provide 208V system for support loads within the pump house including controls, maintenance receptacles, and support loads. Provide metering integrated with UW's existing metering network.

1.1.8 BUILDING MECHANICAL AND PLUMBING SCOPE

Provide a 10-ton packaged rooftop DX unit for space conditioning of the building. Provide 12,000 CFM rooftop exhaust fan.

Provide toilet room, janitor service sink, and point-of-use electric water heaters.

1.2 Wastewater Main Intercept Vault and Wastewater Piping

A new sewer diversion structure / vault shall be provided to intercept the 108"Ø King County Metro Sewer Trunkline (invert elevation 23.12', approximately 20' below grade to top of pipe) at the Pasadena Place Connection Point. The diversion structure is estimated to be *approximately* 13'W x 20'L x 13'H precast vault with a channelized bottom to guide flow into the supply pipe to the wet well structure. Slide gates operated from above grade are provided to stop flow from entering the system. Note that the dimensions of the diversion structure noted above are rough order of magnitude and may need to be longer so a contingency should be applied.

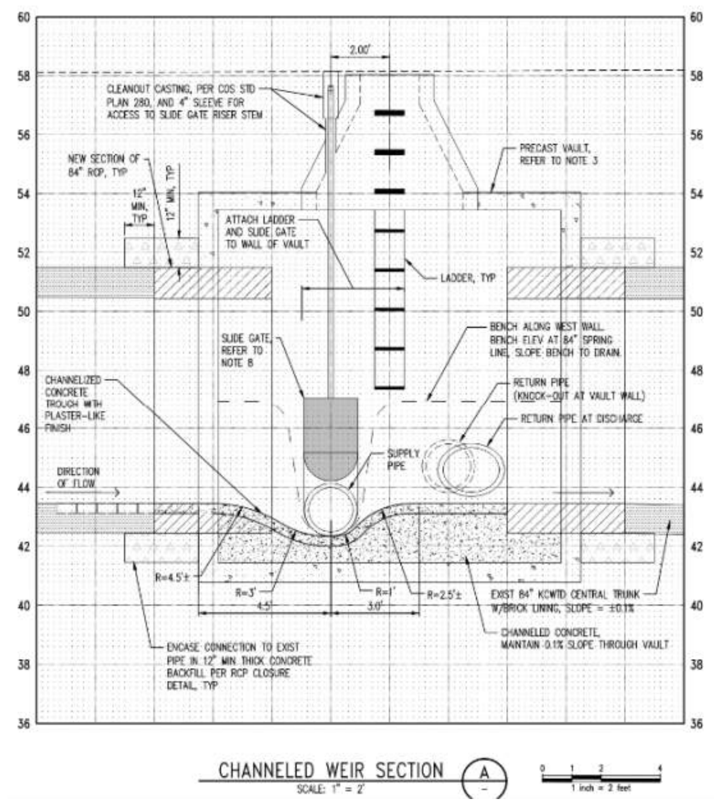


Figure 1.2.1 Example section (not project-specific) of an intercept vault.

Gravity waste (supply) pipe size shall be 30," butt-welded HDPE, C900 PVC, DIP, or RCP.

Pumped waste (return) pipe size shall be 36" carbon steel or 48" HDPE.

1.2.1 TEMPORARY CONVEYANCE / BYPASS DURING CONSTRUCTION

Facilitation of temporary bypass pumping and electrical generation. Bypass capacity shall be sized for a 30,000 GPM flow rate. Approved upstream and downstream bypass devices shall be installed prior to bypass operation.

Figure 1.2.1 Temporary bypass pumping trailers.

1.3 Wet Well

Install a below-grade wet well system with 270,000 gallon storage capacity minimum 10' below the existing sewer main invert elevation of 23.12'. Wet well dimensions are 50'W x 50'L x 15'D.

A wet well is an underground confined space structure consistent with municipal wastewater installations. The wet well includes an augering device on the inlet to remove large solids before entering the wet well.

Provide one submersible pump per SHARC unit in the wet well and a dedicated pipe between the pump and the SHARC unit (10 total). Submersible pumps deliver pressurized wastewater to the Sewer Heat Recovery Building heat exchangers. A dedicated 16” pipe shall route from the wet well to the Sewer Water Heat Recovery building and the dedicated SHARC HX unit, for each pump (10 total).

The wet well shall be configured and provided with internal weirs and septums in order to isolate half of the wet well pumps for maintenance while maintaining service in the other half.

1.4 Sewer Water Heat Recovery Piping

Sewer water heat recovery piping is provided under SOW-D-W-2. Assume 200 ft total of 36” HDPE SWHR supply/return piping from the point of connection of SOW-D-W-2 to the Sewer Water Heat Recovery building.

SWHRS/R (Sewer Water Heat Recovery Supply/Return) pipe material:

> Direct bury: HDPE SDR 11, rated for 200psi in cold water applications, 1.5” insulation with jacket. With leak detection.

2.0 Precedent / Following Activities

This scope wants to be executed in sequence with SOW-P-7 WCUP HRCs and Cooling Towers and SOW-D-W-2 Sewer Heat Recovery Piping. This scope should be executed in sequence or after SOW-E-1 UW Substation.

3.0 Attachments

None.

4.0 Constructability Commentary

There are large existing old water transmission mains (42-inch and 24-inch) running north-south in 7th Avenue NE between Ben Hall and Publications Services Building that need to remain in service during construction. For this reason, the baseline location shall be the Pasadena Place Connection Point, which avoids working parallel to these utilities will require temporary support for the installation of the sewer supply/return lines crossing 7th Avenue at Northlake Place.

King County will require the construction of the new intercept/diversion vault to be scheduled to take place during periods of low flow (July to late summer) to mitigate risk related to storm events. Sewer water bypass around the sewer main construction plugs during vault construction will necessitate significant temporary bypass pumping and electrical services. Assume 25,000 to 30,000 gpm temporary bypass capacity. The location of the bypass pumping will most likely be in public ROW. It should be assumed that public ROW will be shut down, requiring SDOT coordination.

The Burke Gilman Trail will need to remain open. If this is not possible, a bypass route will need to be established that works with SDOT. This would require wayfinding signage as a minimum with the possibility of striping, lane protection devices, etc.

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

S-3

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*

Air-Source Heat Pumps

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Construct a new Air-Source Heat Pump Equipment Building and yard, and interconnecting piping to/from the Air-Source Heat Pump system to the Power Plant. This scope of work is an alternate in lieu of the Scope of Work described in document SOW-S-1 Lake Interface System.

SEQUENCE: *(1-2 sentences)*
This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

1.0 Detailed Work Description

The Air-Source Heat Pump System provides heating and cooling energy to the Power Plant via heating or cooling the Campus Cooling Water which will connect the Power Plant to the Air-Source Heat Pump System. In heating mode, the Air-Source Heat Pump system adds heat to the chilled water supply, acting as a false load on the chilled water system to allow for generation of heating at the Power Plant Heat Recovery Chillers.

High-level summary scope of work for the Air-Source Heat Pump System:

- Site enabling and excavation work associated with a new Air-Source Heat Pump Equipment building.
- Construct a new Air-Source Heat Pump Equipment building in UW Parking Lot E-18.
- Construct a new Air-Source Heat Pump Equipment Yard in UW Parking Lot E-18.
- The building is constructed in the area of UW's East Campus which requires piles for structural foundation.
- Building houses heat exchangers and electrical gear.
- Provide new water, sewer, and storm utility service connections.

- Electrical power to be fed from the East Receiving Station at the Power Plant. Provide electrical switchgear, panels, and distribution. Provide metering integrated with UW's existing metering network.
- Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85°F.
- Direct-bury CCW piping between the Air-Source Heat Pump Equipment building and the Power Plant.

1.1 Background

The air-source heat pump system is an alternative to the lake interface system. Should the lake interface system not be pursued, the air-source heat pump system would act as an alternate source for heating and cooling.

The air-source heat pump system would be made up of many unitary air-source heat pumps, taking up a large site area and requiring significant maintenance. Campus-scale equipment appropriately sized for district energy applications is not yet available on the market.

In heating mode, the air-source heat pumps produce 70°F water from the outdoor air at a design ambient condition of 10°F. This acts as a false load on the chilled water system, allowing a heat recovery chiller to generate the design heating water supply temperature as if a simultaneous heating and cooling load existed.

In cooling mode, the air-source heat pumps can act as an additional source of cooling during peak load conditions, working in parallel with the other chillers at the Power Plant to directly produce campus cooling water.

A sketch of the heating mode operational concept is shown in Figure 1.1.1.

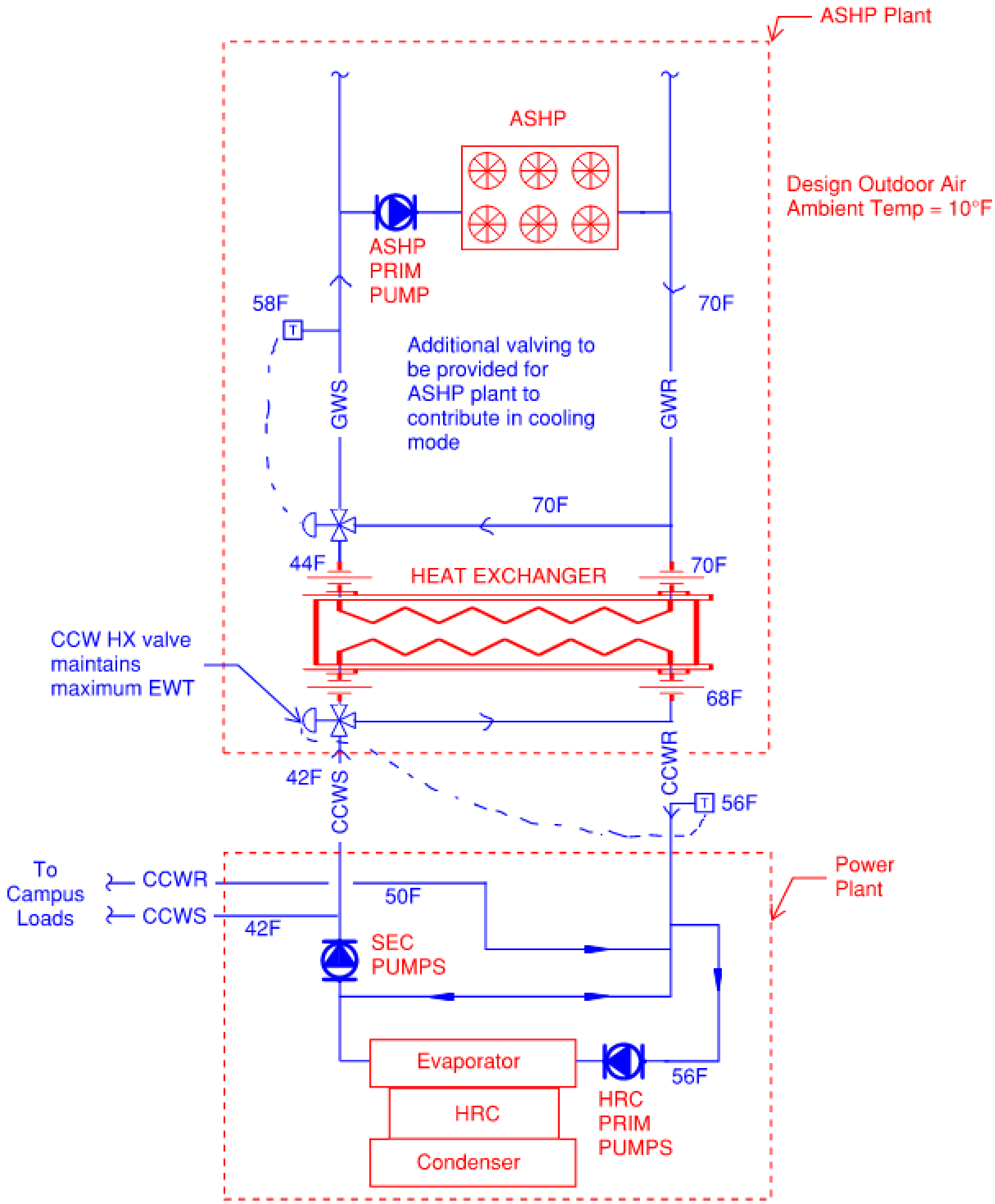


Figure 1.1.1. ASHP and HRC conceptual diagram.

1.2 Air-Source Heat Pump System Equipment

Air-source heat pumps would be located in the East Campus near the existing fields north of the IMA building. A mechanical yard will be constructed, enclosing 54 heat pumps each provided with a dedicated pump. The yard enclosure shall act as a security and line of sight enclosure and be constructed of materials consistent with the campus aesthetic. The yard shall have a footprint of roughly 240′ x 180′, which allows for spacing between the air-source heat pumps, and an elevated rack system shall collect the flow from each heat pump into a pipe header. A 30″ glycol water supply and return header will run along one side of the yard, collecting 12″ headers from each row (qty 8) of air-source heat pumps. The array of heat pumps will always operate in a common mode (heating or cooling) so only one header system will be provided.

The basis of design for the heat pumps is Trane ACXA2302, 230 nominal tons with R-454B refrigerant rated for standard cooling conditions and provided with 25% propylene glycol solution. Heat pumps are provided with across-the-line starters and high fault rated circuit breakers. Each unit shall be provided with a pump package. An exterior concrete pad/foundation will be provided for anchoring heat pumps.

Glycol / air-source heat pump piping installations shall be assumed to be configured as follows:

- Glycol Water Supply/Return (GWS/R):
    - Welded carbon steel piping, 2″ insulation with exterior-rated aluminum jacket, mounted on rollers.

1.3 Air-Source Heat Pump Equipment Building

1.3.1 SITE ENABLING WORK

Prepare the site for the new structure and buried utilities. Provide new water, sewer, and storm utility service connections. Electrical power is to be fed from the East Receiving Station at the Power Plant.

1.3.2 BUILDING STRUCTURE AND SUPPORTING INFRASTRUCTURE

Construct the new Air-Source Heat Pump Equipment building in UW Parking Lot E-18. The building is constructed in in the area of UW's East Campus which requires piles for structural foundation. The building structure shall be insulated per the current Seattle Energy Code as a fully conditioned building. Comply with existing Building Codes and best practices.

The structure is similar to, but significantly larger than that shown in the Lake Interface Pump Building Concept Plan under SOW-S-1, without the wet well. The electrical room will be significantly larger due to the large increase in load being provided at 480V. The building would be approximately 8,000 sq ft in area with a footprint of 50’ x 160’ with a structure height of 24’. A detailed drawing is not provided for this building. The electrical room would be 6,000 sq ft and take up the majority of the building, with the remaining space used for heat exchangers and facility operations.

Provide 15 kV rated three-phase loop feeder from the Power Plant / East Receiving Station (ERS) to the Air-Source Heat Pump Building. Provide 15 kV rated double ended switchgear at Air-Source Heat Pump Equipment Building rated for 27 MW. Provide metering integrated with UW’s existing metering network.

Provide (9) 3MW unit substations with 13.8 kV primary, 480V secondary, and 4,000A busses for distribution to 480V air-source heat pumps. Provide a 500A feeder to each Air-Source Heat Pump package (Qty. 54 at 480 MCA each). This electrical equipment would be located in the Air-Source Heat Pump Equipment building, indoors.

Provide 480V transformer for support loads in Air-Source Heat Pump Building including ventilation, freeze protection, and lighting.

Provide 208V system for support loads within Air-Source Heat Pump Building including controls, maintenance receptacles, and support loads.

Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85°F. Provide 100-ton air-cooled chiller and associated AHU for cooling of electrical room.

Provide interior and exterior lighting systems.

Provide security and IT systems.

1.3.3 HEAT EXCHANGERS

Provide four heat exchangers, sized in an N+1 arrangement for full capacity through three operating heat exchangers. Each heat exchanger shall have the following characteristics:

- Material 304 SS
- Plate and frame gasketed cross-flow
- 2 °F approach temp
- Cold side:

- Fluid: water
- 42°F EWT
- 68°F LWT
- 14,500 GPM
- 10 psid

- Hot side:
  - Fluid: glycol water
  - 70°F EWT
  - 44°F LWT
  - 16,500 GPM
  - 10 psid
- Provide 10% extra plates for fouling

Each heat exchanger shall be provided with automated high-performance butterfly control valves for modulation of flow and automatic isolation.

1.3.4 BUILDING AUTOMATION SYSTEM CONTROLS

Provide PLC control system with communication to facility network for integration with existing Campus Utility Plants (Power Plant, West CUP). Provide industrial quality instrumentation (temp & pressure sensors, flow meters, flow switches, etc.) and valves aligned with best practices for central utility plants.

1.4 Campus Cooling Water Piping

Campus Cooling Water shall be routed direct-buried from the Power Plant to the Air-Source Heat Pump Equipment building as shown in Site Distribution Maps_ASHP. Piping shall terminate outside the Power Plant, 5′ from the building perimeter. Piping will be extended into the plant as part of SOW-P-7 WCUP HRCs and Cooling Towers.

Piping installations shall be assumed to be configured as follows:

- Campus Cooling Water Supply/Return (CCWS/R):
  - Direct bury: HDPE SDR 11, rated for 200psi in cold water applications, 1.5″ insulation with jacket. With leak detection.

2.0 Precedent / Following Activities

This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

3.0 Attachments

Refer to the following supporting documents:

- Site Distribution Maps_ASHP

Scope of Work Description

PROJECT NUMBER: *(Examples: S-1, D-1-2)*

S-4

STATUS:

COMPLETE

TITLE: *(Short and descriptive name for the project)*
Geothermal System

SUMMARY DESCRIPTION: *(1-2 sentence description of the project)*
Construct a new Geothermal Equipment Building, closed-loop geothermal field, and interconnecting piping to/from the geothermal system to the Power Plant. This scope of work is an alternate in lieu of the Scope of Work described in document SOW-S-1 Lake Interface System.

SEQUENCE: *(1-2 sentences)*
This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

1.0 Detailed Work Description

The Geothermal System provides heating and cooling energy to the Power Plant by using a piping system that will connect the Power Plant to the Geothermal System and allow the chillers to interface with their evaporator or condensers to the geothermal system. In heating mode, the Geothermal system adds heat to the chilled water supply, acting as a false load on the chilled water system to allow for generation of heating at the Power Plant Heat Recovery Chillers. In the cooling mode, the Geothermal system rejects the heat from the chiller condensers into the ground loop.

High-level summary scope of work for the Geothermal System:

- Installation of closed-loop geothermal heat exchanger consisting of quantity 4,750 350' deep vertical boreholes with HDPE piping installed and spaced 20' on center. The geothermal loop will be located on the east campus and be arranged in a way to allow for future building construction within the geothermal grid.
- Site enabling and excavation work associated with the new Geothermal Equipment building.
- Construct the new Geothermal Equipment building in UW Parking Lot E-8.

- The building is constructed in the area of UW's East Campus which requires piles for structural foundation.
- Building houses heat exchangers, pumps, and electrical gear.
- Provide new water, sewer, and storm utility service connections.
- Electrical power to be fed from the East Receiving Station at the Power Plant. Provide electrical switchgear, panels, and distribution. Provide metering integrated with UW's existing metering network.
- Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85°F.
- Direct-bury piping between the Geothermal Equipment building and the Power Plant.

1.1 Background

The Geothermal system is an alternative to the lake interface system. Should the lake interface system not be pursued, the Geothermal system would act as an alternate source for heating and cooling.

The Geothermal system would be made up of thousands of geothermal boreholes, taking up a massive site area and likely create an obstacle to future east campus development.

1.2 Closed-loop Geothermal Field Design and Installation

The geothermal field would be located in the East Campus north of the existing fields and the IMA building. Refer to Site Distribution Maps_Geothermal for the required area. At any existing sports fields, assume a complete removal and restoration of the field.

Two sets of 36" geothermal water supply and return headers will run along each side of the field, collecting headers from underground prefabricated geothermal vaults.

Below-grade geothermal field vaults shall be provided. These prefabricated cylindrical HDPE vaults contain the piping header to individual 4" diameter branch piping to approximately 15-20 bores per branch. Assume 10 such vaults. Vaults do not have any electrical connection and are a confined space.

Each borehole shall be drilled to a depth of 350' and be provided with a 1-1/4" HDPE SDR 11 pipe supply and return pipe with U-bend at the bottom of the loop. Each loop shall be individually pressure tested for zero leaks over a 30-minute period.

No glycol shall be used in the geothermal system.

Geothermal piping installations shall be assumed to be configured as follows:

- Geothermal Water Supply/Return (GEOS/R):
    - Above-ground (within the equipment building): Welded carbon steel piping, 2" insulation with exterior-rated aluminum jacket, mounted on rollers.
    - Direct bury: HDPE SDR 11, rated for 200psi in cold water applications. Butt-weld fittings shall be utilized.

1.3 Geothermal Equipment Building

1.3.1 SITE ENABLING WORK

Prepare the site for the new structure and buried utilities. Provide new water, sewer, and storm utility service connections. Electrical power is to be fed from the East Receiving Station at the Power Plant.

1.3.2 BUILDING STRUCTURE AND SUPPORTING INFRASTRUCTURE

Construct the new Geothermal Equipment building in UW Parking Lot E-8. The building is constructed in the area of UW's East Campus which requires piles for structural foundation. The building structure shall be insulated per the current Seattle Energy Code as a fully conditioned building. Comply with existing Building Codes and best practices.

The structure is similar to that shown in the Lake Interface Pump Building Concept Plan under SOW-S-1, without the wet well but roughly the same size. In lieu of a wet well, pumps are provided for the circulation of the geothermal field. A detailed drawing is not provided for this building.

Provide 15 kV rated three-phase loop feeder from the Power Plant / East Receiving Station (ERS) to the Geothermal Building. Provide double ended switchgear at Geothermal Equipment Building rated for 1 MW. Provide metering integrated with UW's existing metering network.

Provide 480V transformer for support loads in Geothermal Building including ventilation, freeze protection, and lighting.

Provide 208V system for support loads within Geothermal Building including controls, maintenance receptacles, and support loads.

Furnish HVAC equipment for building heating/cooling typical of an equipment building for freeze protection and cooling to 85°F.

Provide interior and exterior lighting systems.

Provide security and IT systems.

1.3.3 HEAT EXCHANGERS

Provide four heat exchangers, sized in an N+1 arrangement for full capacity through three operating heat exchangers. Each heat exchanger shall have the following characteristics:

- Material 304 SS
- Plate and frame gasketed cross-flow
- Total system flow on both the hot side and cold side is 22,000 GPM
- 2 °F approach temp
- Cold side:
    - Fluid: water
    - 36°F EWT
    - 43°F LWT
    - 10 psid
- Hot side:
    - Fluid: lake water
    - 45°F EWT
    - 38°F LWT
    - 10 psid
- Provide 10% extra plates for fouling

Each heat exchanger shall be provided with automated high-performance butterfly control valves for modulation of flow and automatic isolation.

1.3.4 GEOTHERMAL PUMP SYSTEM

Provide three vertical split-case pumps, sized in an N+1 arrangement for full capacity delivered with only two operating pumps. Pumps shall be mounted on a concrete housekeeping pad.

Each pump shall have the following characteristics:

- 11,000 GPM @ 50 ft head – 200 motor HP
- Variable speed drive
- Basis of Design: B&G VSX-VSC 14x16x17.5A

1.3.5 Campus Cooling Water Pump System

Provide three vertical split-case pumps, sized in an N+1 arrangement for full capacity delivered with only two operating pumps. Pumps shall be mounted on a concrete housekeeping pad.

Each pump shall have the following characteristics:

- 11,000 GPM @ 70 ft head – 250 motor HP
- Variable speed drive
- Basis of Design: B&G VSX-VSC 14x16x17.5A

1.3.6 Building Automation System Controls

Provide PLC control system with communication to facility network for integration with existing Campus Utility Plants (Power Plant, West CUP). Provide industrial quality instrumentation (temp & pressure sensors, flow meters, flow switches, etc.) and valves aligned with best practices for central utility plants.

1.4 Campus Cooling Water Piping

Campus Cooling Water shall be routed direct-buried from the Power Plant to the Geothermal Equipment building as shown in Site Distribution Maps_Geothermal. Piping shall terminate outside the Power Plant, 5′ from the building perimeter. Piping will be extended into the plant as part of SOW-P-7 WCUP HRCs and Cooling Towers.

Piping installations shall be assumed to be configured as follows:

- Campus Cooling Water Supply/Return (CCWS/R):
    - Direct bury: HDPE SDR 11, rated for 200psi in cold water applications, 1.5″ insulation with jacket. With leak detection. Butt weld fittings.

2.0 Precedent / Following Activities

This work is relatively independent of other ERP work. This project should be constructed in sequence with the SOW-P-8 Power Plant Heat Recovery Chillers project.

3.0 Attachments

Refer to the following supporting documents:

- Site Distribution Maps_Geothermal

9.13.2 Scope of Work Attachments

Section redacted for security reasons.

9.14 Seattle City Light Documents

Section redacted for security reasons.

9.15 Detailed Distribution Descriptions

Section redacted for security reasons.