CSUS Utility Master Plan

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1 12KV Electrical System

Executive Summary

This report provides an assessment of the existing 12KV Electric Utility System and a summary of previous reports for the purpose of developing the Utility Master Plan. Based on our assessment, the following are recommendations for the 12KV Electric Utility System:

Construct an additional 69KV-12KV substation with remote switchgear to accommodate further new construction projects. This new substation will provide the necessary capacity for planned construction per Proposed Campus Master Plan dated 2007 (see attached).

In a report by TSE (dated March 23, 2007), 8 locations were recommended for the new substation site. According to the cost summary provided in the previous report, each site is similar in cost ranging from $2.8M to $3.1M. It is recommended that the new site be chosen based on access for connection to the existing distribution system, practicality of location as it relates to the Campus Master Plan, and general aesthetics and appearance of the location. A more in-depth investigation (into the underground structure) is required to determine the location that would best meet this criteria.

In addition; following are recommendations to allow for critical buildings to be switched to alternate circuits in the case of a planned or unplanned power outage:

A. The concurrent Distribution Reliability Project (in re-design phase as of this report) proposes 8 switches. These switches will provide the back-up circuits necessary for the priority 1 buildings (see list below for priority 1 and priority 2 buildings).

B. In addition to these switches, it is recommended that a second circuit be provided for the transformer feeding El Dorado/Public Service Buildings (58/59) to allow for this priority 1 building to be switched as needed in the case of a power outage.

C. As a priority 2 building, The Well (41/109) should also be provided with a second circuit.

Introduction

This Initial Assessment will provide an overall evaluation of the existing 12KV Electrical System to be used for the purpose of developing a campus wide Utility Master Plan. Record drawings have been utilized to assess capacity versus load and potential system deficiencies that may cause significant disruption to campus activities. A site survey has been performed to determine the age and condition of main equipment and to assess the general accuracy of the record drawings. Previous reports (provided by others to CSUS) have been reviewed and expounded upon in this report as appropriate. At the time of this report, the Distribution Reliability Project (based on a previous study by TSE) was in the bidding process which included the addition of switches at a variety of locations thereby adding diversity to the system. The drawings for this project were obtained and reviewed to incorporate these changes, where relevant, into this report. Meter data, for the main campus circuits, was received in Sept. 2011 and reviewed for comparison to previous load estimates.

The following drawings and/or diagrams are included in this report:

<u>Figure 1.1</u> – Proposed Redundant Circuit Configuration: This drawing is a generic schematic of a proposed redundant configuration that would provide back-up circuits and flexibility for switching loads. Some existing transformers (priority buildings) are shown as well as examples of how new transformers would enter into the circuitry as new buildings are constructed. This schematic is intended to provide a simple depiction of a more complex configuration.

<u>Figure 1.2</u> – CSUS Proposed Power Distribution Plan: This drawing indicates locations recommended for new switches to improve reliability and provide back-up circuitry. The buildings shown on the plan are future buildings (indicated as priorities) per the Campus Master Plan. Also shown are suggested circuits for these buildings based on the proposed redundant circuit configuration. Also shown on this drawing is a list of existing building that have been identified as a priority for providing redundancy and back-up circuit options. The Priority 1 buildings have been addressed in the concurrent Proposed Reliability Project (likely to be separated into a phase 1 and phase 2 project). The Priority 2 buildings should be addressed as a phase 3 component in any future reliability plans.

<u>Table 1A</u> – Building Load List (included for reference only): This list includes all transformers (by associated building)

on campus that are included in the load study. This load information was retrieved from drawing UT-10 by The Engineering Enterprise dated 10/2010. The actual load analysis is based on meter information obtain recently.

Figure 1.3 – Load Analysis Graph: All loads on this graph are shown with a load factor of 1.25. This graph provides a view of the current electric load on the existing substation as well as the future loads that would occur with the next phase of planned buildings.

See Appendix A for CSUS Campus Master Plan and Facility Legend for reference.

The following buildings have been identified as priorities for new construction projects and are listed in descending order of priority:

1. Science II, Phase II (56A)
2. Classroom III (97)
3. Art Complex (51)
4. Performing Arts Center (30)
5. Parking Structure V (115)
6. Event Center (111)
7. Engineering 2 (105)
8. Student Housing Phase 5 (25)

In addition, the following buildings have been identified as critical for the purpose of prioritizing the locations requiring redundancy/switching and back-up power:

Priority 1:

1. AIRC (data center, 95)
2. El Dorado Hall/Public Service (59/58)
3. Capital Public Radio (108)
4. Central Plant (32)

Priority 2:

1. The Well (REWC, 41/109)
2. University Union (47)
3. Modoc Hall (81)
4. Placer Hall (56)
5. Sierra Hall (Dining, 44/46)

Buildings Planned for demolition to be replaced by Greenbelt:

Douglas Hall, Calaveras Hall, Alpine Hall, Brighton Hall, Humbolt Hall.

Existing System

The CSUS Campus is served by a single 69KV -12KV substation that is owned and maintained by CSUS. This substation is connected to Sacramento Municipal Utility District's (SMUD) 69KV system, which provides redundancy through two circuits to this location (Pocket Line 3 and Hurley Line 7). The substation feeds the main 1200 Amp switchgear located adjacent to the Central Plant as well as provides a 12KV feed to Hornet Stadium (this circuit is currently under consideration in the new Distribution Reliability Project to be used as a back-up circuit to feed circuits 1 and 2).

The main switchgear is also fed by a 12KV backup service provided by SMUD which is made from two different SMUD circuits. One circuit is fed from State University Drive West and the other SMUD circuit heads down from State University Drive East where it comes across the pedestrian bridge to the campus. There is a SMUD owned switch located on Sinclair Road that connects both these circuits to the main switchgear. The SMUD meter for these circuits is located within the main switchgear.

From the main switchgear, 12KV power is distributed to the campus via 6 circuits. These circuits are grouped into three pairs (1/2, 3/4, & 5/6) and configured as a radial topology system (branching out from a large power supply and radiates out into progressively lower voltages until the destination is reached). The circuit pairs are installed together along the same route and through the same vaults (both circuits must be off for access by personnel into the vault). Each of these circuits is electronically metered at the switchgear.

From the main switchgear, in addition to the six 12KV circuits listed above, the Central Plant is fed from a single radial feed circuit (circuit 8). Circuit 7 is not used, but has existing spare circuit breaker that is currently used as a back-up spare during maintenance procedures. To the north side of the switchgear, there are two spare conduits stubbed up at the concrete pad for further expansion of the switchgear. These conduits likely route out towards State University Drive West, although this has not been verified.

Adequacy of the Existing System

Based on a previous report by Taylor Systems Engineering in 2006, the existing substation and distribution system had some available load capacity at that time. This report was prior to the construction of the Recreation Wellness Events Center.

Based on the meter data provided 9/2011; the loads are slightly less than the previous estimated loads, but the capacity of the substation is still an issue (see Table 1A). Meter data was obtained for the eight circuits that make up the distribution system on campus. These loads were compared to the SMUD meter readings which are similar in value.

Proposed Improvements to the Existing System

1. Install a new Substation of equal capacity to the existing substation. See Figure 1.1, Proposed Redundant Circuit Configuration. The major cost of future development for the 12KV Utility Master Plan will be the new substation. The costs provided in the previous report by TSE will be useful for pre-planning purposes. The estimated cost of a new substation is $3M.
2. Install additional switchgear to allow for redundancy and back-up power. See Figure 1.2A/1.2B, Proposed Power Distribution Plan. The initial bid price for the Reliability Distribution Project was approximately $1.4M. Therefore an initial budget price of $175k per switch should be used.
3. Provide redundant circuits to critical buildings where the building is currently fed by only one circuit. Budget at $ 20,000 per 100 feet of construction.

Final Note

It is recommended that all future switchgear be installed in above-ground vaults configured with a separation between working spaces for each circuit and its associated equipment. This will allow for the ability to leave circuits hot during maintenance and repair on the equipment.

Figure 1.1

Proposed Redundant Circuit Configuration

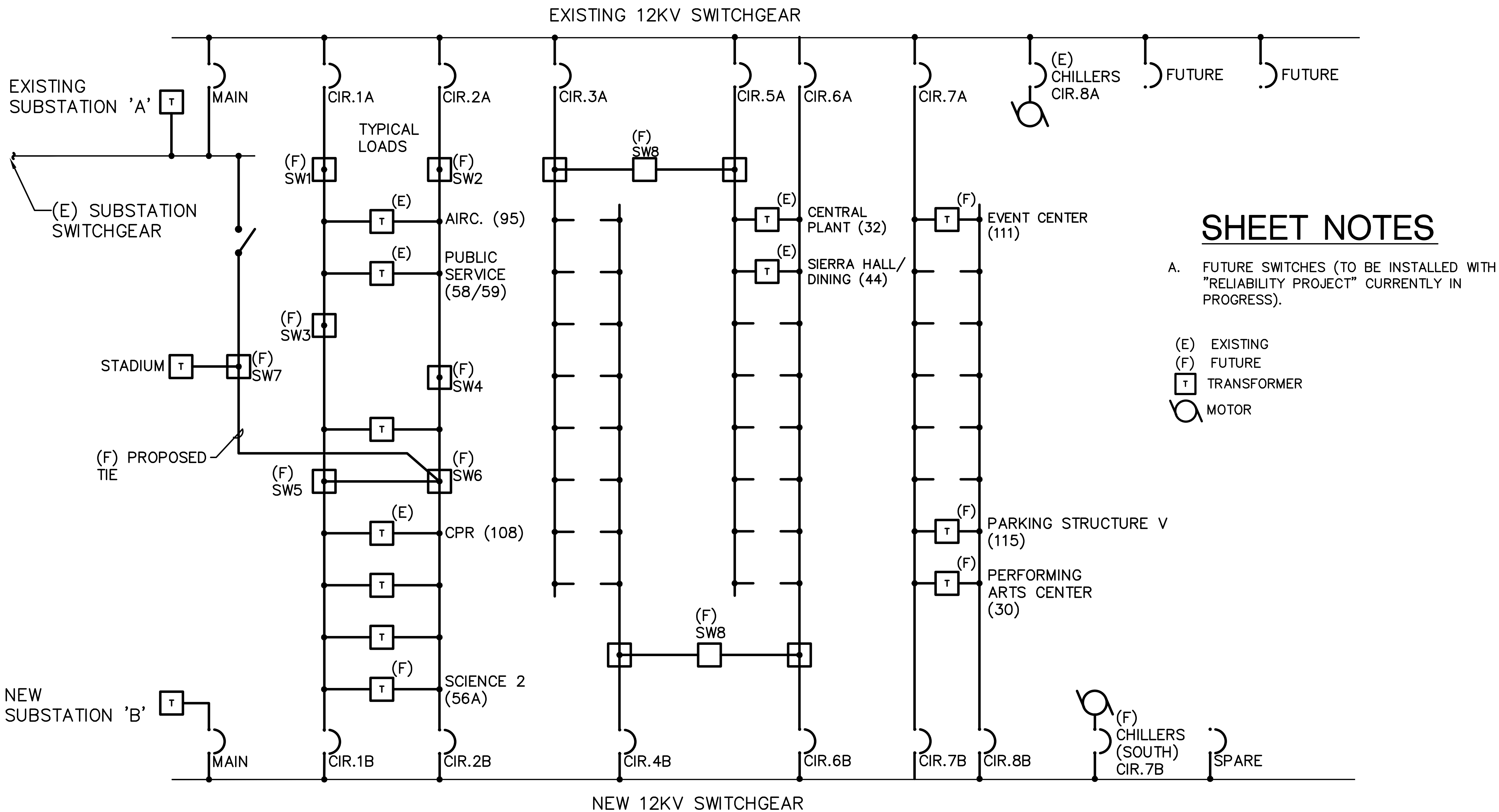


Figure 1.2

Overall Proposed Power Distribution Plan

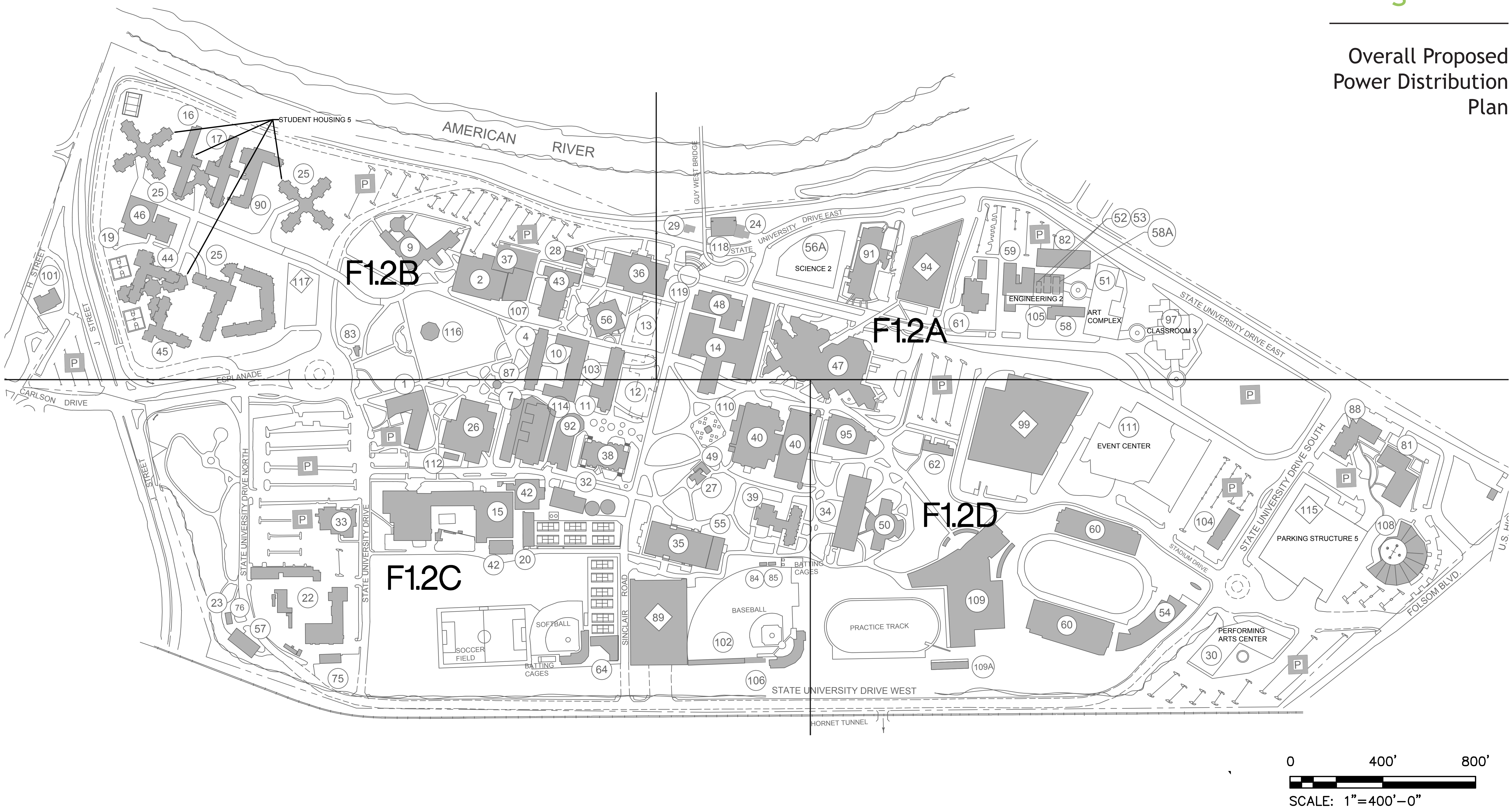


Figure 1.2A

Partial Proposed Power Distribution Plan

⬡ SHEET KEYNOTES

(NOTES APPLY TO F2A THRU F2D)

1 PROPOSED SWITCH LOCATION TO BE INSTALLED UNDER DISTRIBUTION RELIABILITY PROJECT.

2 PROPOSED CIRCUIT ON PROPOSED RECONFIGURED DISTRIBUTION PLAN (FIGURE 1 – PROPOSED REDUNDANT CIRCUIT CONFIGURATION).

EXISTING BUILDINGS

PRIORITY 1:

1. AIRC (DATA CENTER,95)
2. EL DORADO HALL/PUBLIC SERVICE (59/58)
3. CAPITOL PUBLIC RADIO (108)
4. CENTRAL PLANT (32)

PRIORITY 2:

1. THE WELL (REWC, 41/109)
2. UNIVERSITY UNION (47)
3. MODOC HALL (81)
4. PLACER HALL (56)
5. SIERRA HALL (DINING, 44/46)

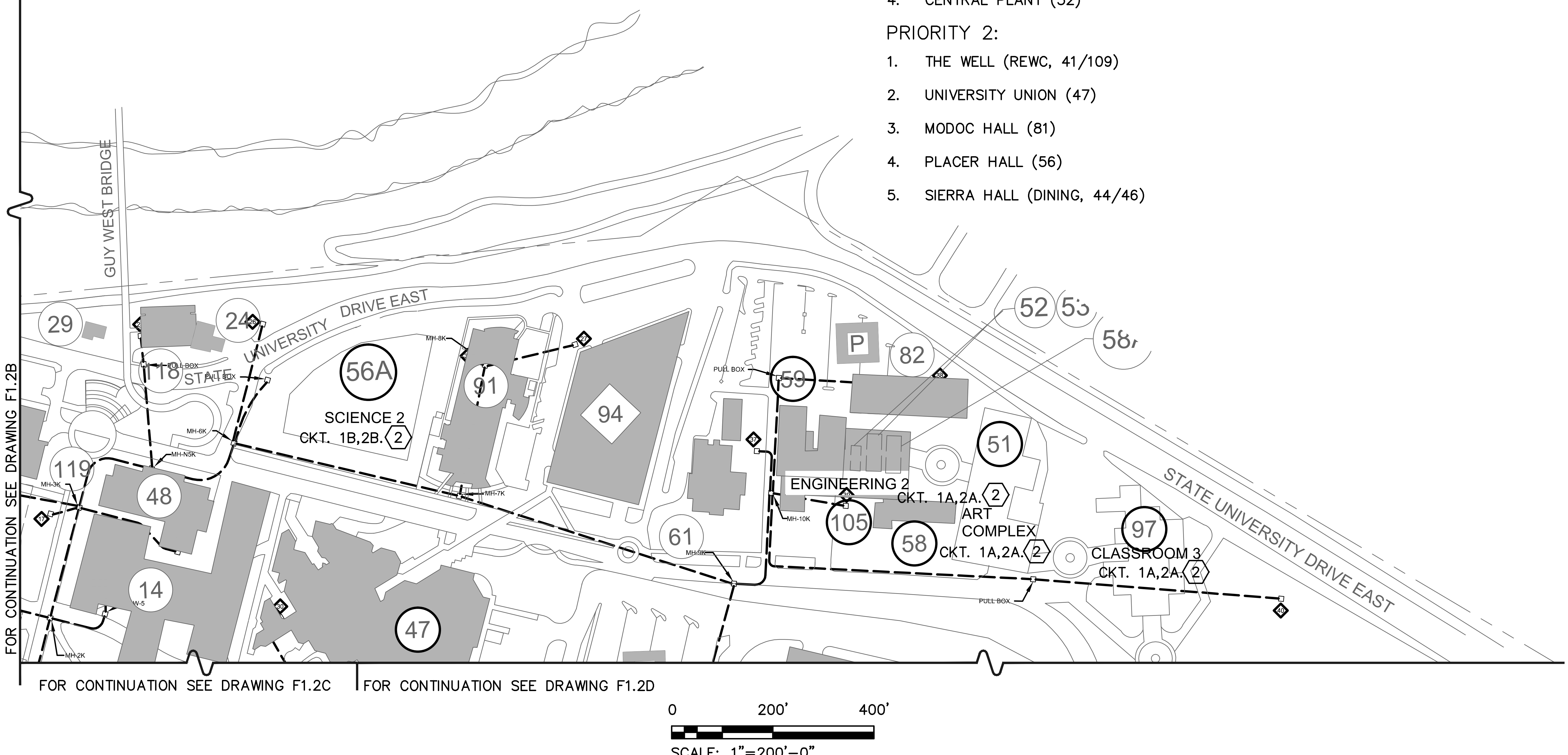


Figure 1.2B

Partial Proposed Power Distribution Plan

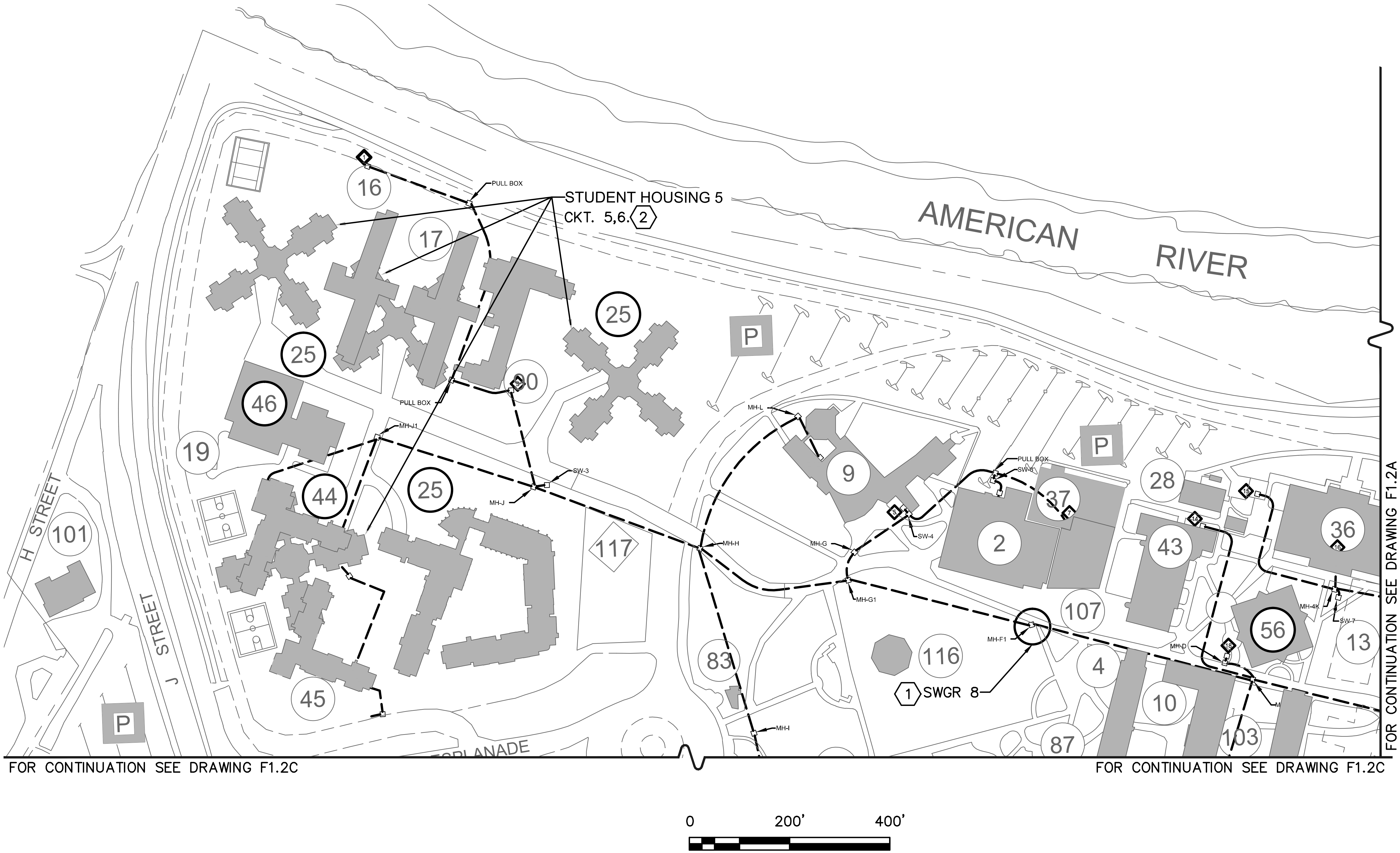


Figure 1.2C

Partial Proposed Power Distribution Plan

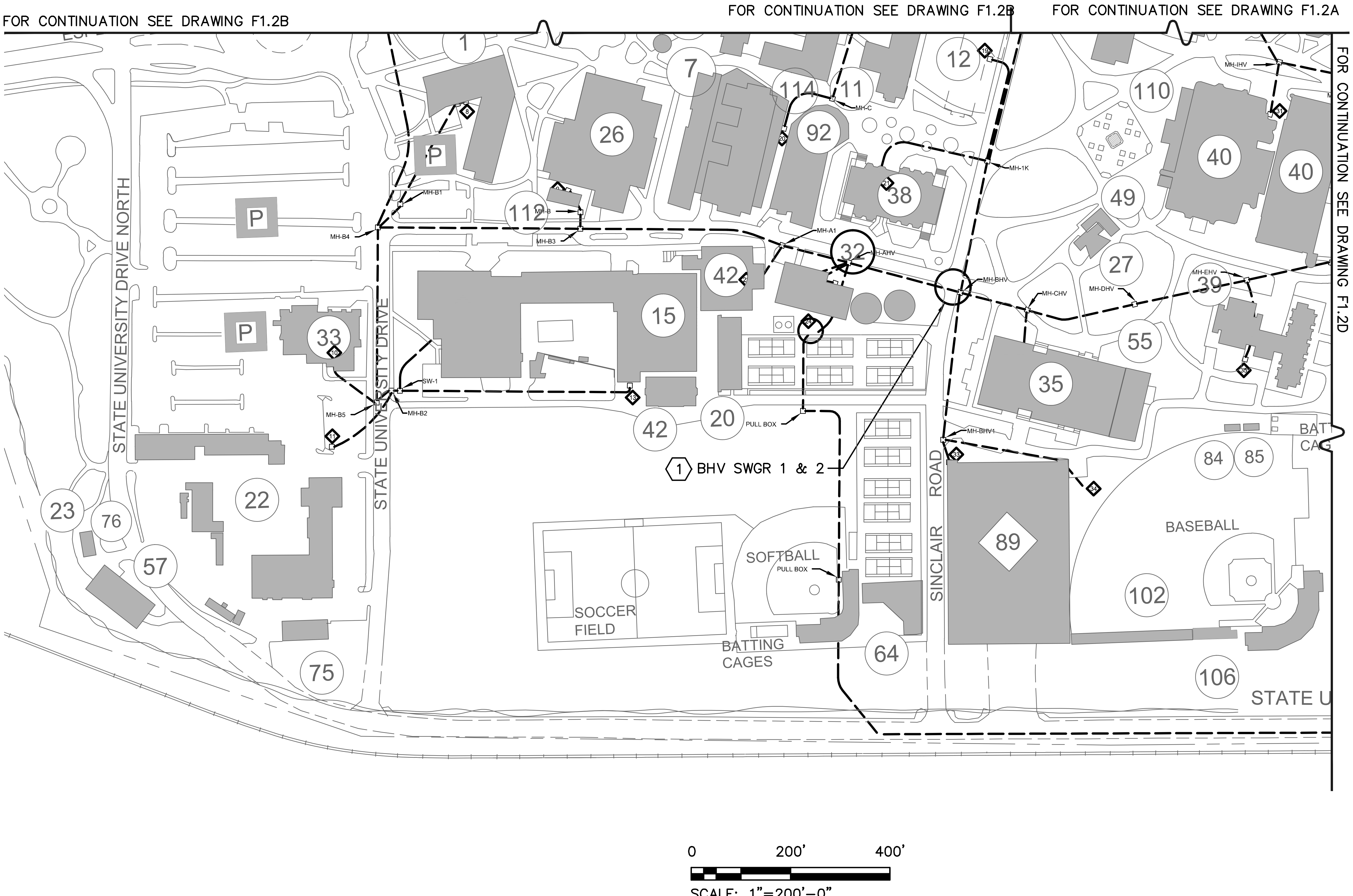


Figure 1.2D

Partial Proposed Power Distribution Plan

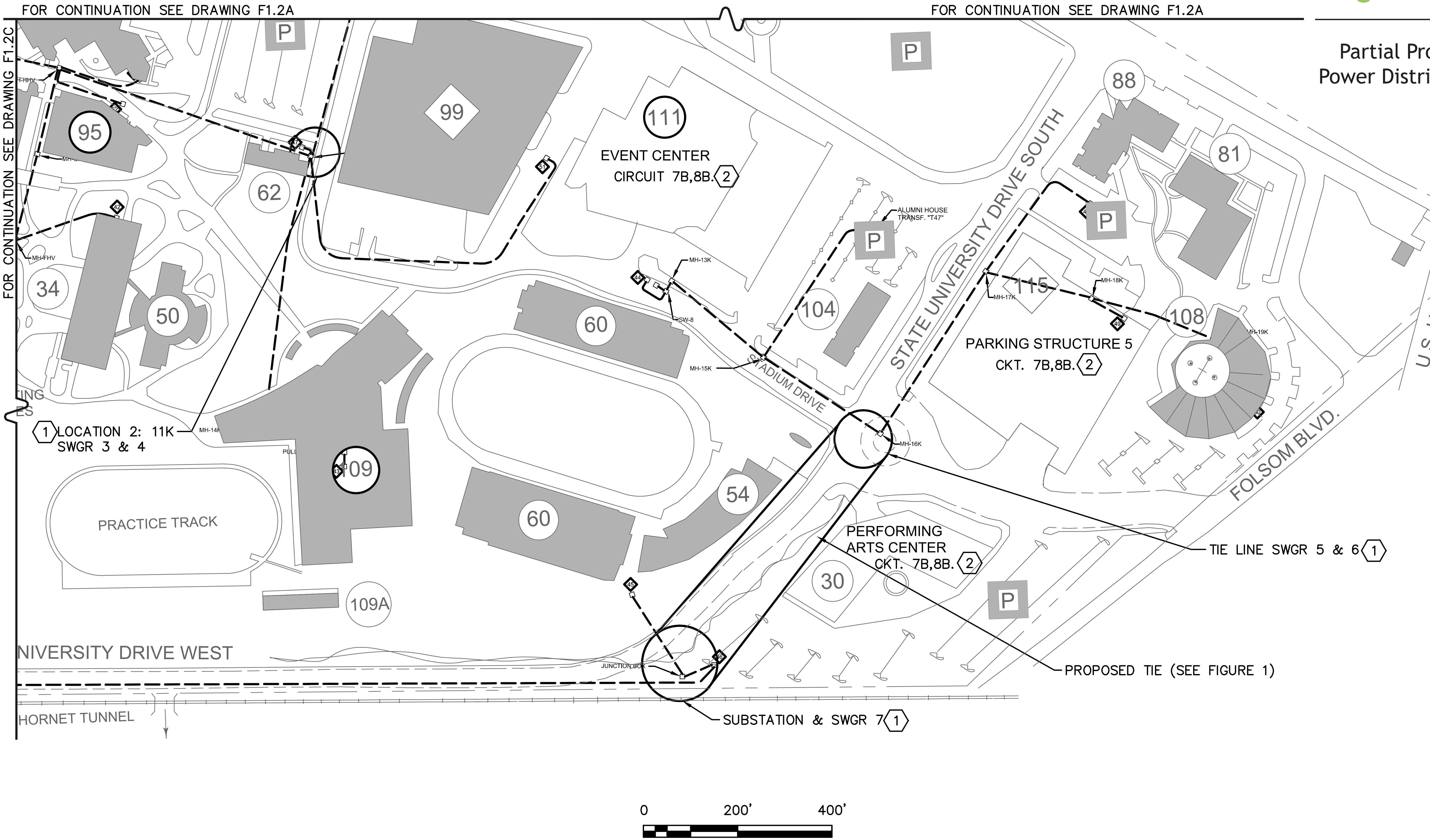


Table 1A

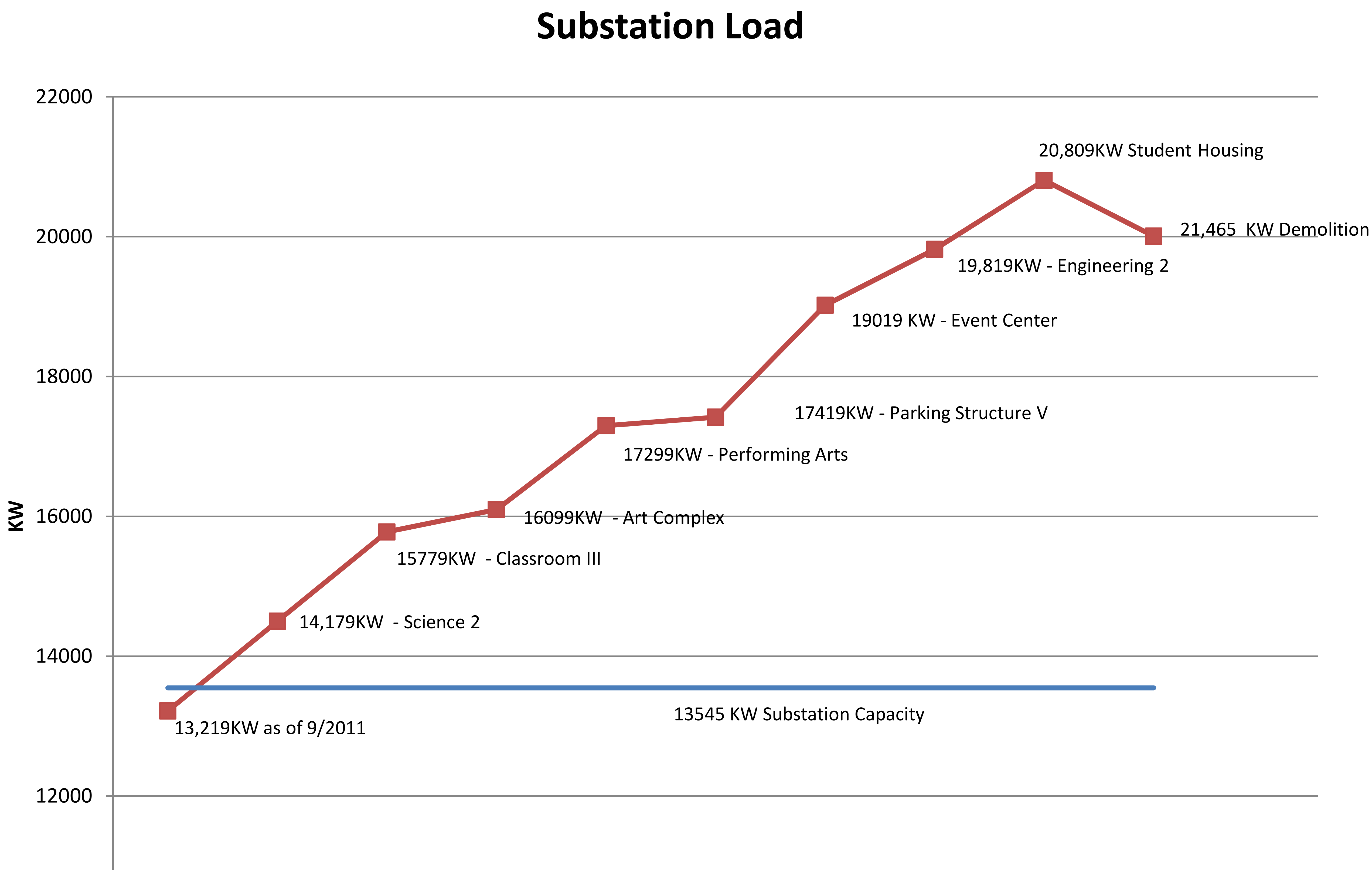
Load Schedule

LOAD SCHEDULE												
BLDG. NO.	BUILDING	TRANS KVA	DEMAND LOAD PER CIRCUIT ASSIGNMENT									
			1	2	3	4	5	6	7	8	other
1	SACRAMENTO HALL	500						400			
2	RIVERFRONT MKTNG.	300					226.4				
2	DEL NORTE	500					377.4				
2	LTG/MCC	225					169.8				
2	RIVERFRONT CNTR.	300					226.4				
4,10	DOUGLAS & CALVERAS HALLS	500			400						
7,11	KADEMA & ALPINE (NOTE 3)	300				200					
8	MARIPOSA HALL (NOTE 3)	1500			1100						
9	SHASTA HALL PADMOUNT	500					400				
9	SHASTA HALL (BASEMENT)	750						500			
12	ONECARD CENTER & ST. LTG.	500			400						
12,13	HUMBOLT & BRIGHTON	500				400					
14	SANTA CLARA HALL	1000			800						
15	YOSEMITE NORTH	300					200				
15	YOSEMITE SOUTH	300					200				
22	FACILITIES MGMT.	300					200				
25	STUDENT HOUSING (NOTE 3)	1000						800			
26	LASSEN HALL	750					500				
32	CENTRAL PLANT	225					200				
33	STUDENT HEALTH CNTR.	500						400			
34	TAHOE HALL	750	500								
35	CAPISTRANO	750	500								
36	SEQIOA 3 SUBSTATIONS	2250			1600						
38	EUREKA	500			350						
39	AMADOR HALL	1000		700							
41/109	REWC/THE WELL (NOTE 3)	2500	1800								
42	SOLANO HALL	1000						700			
43	MENDOCINO HALL	1500				1200					
44/46	SIERRA HALL/DINING COMMONS	1500						1200			
47	UNION ADDITION (NOTE 3)	2500		1800							
47	UNIVERSITY UNION	1000		700							
48	RIVERSIDE HALL	1500			1200						
56	PLACER HALL (NOTE 3)	1000			800						
58/59	PUBLIC SERVICES/EL DORADO HALL	300		200							
61	CHILD DEVELOPMENT	150	100								
62	BENICIA HALL (NOTES 3)	112.5	500								
62	NON DESTRUCT LAB (NOTES 3)	250		200							
81	MODOC HALL	1500		1617							
82	ART SCULPTURE	75		50							
88	NAPA HALL	500	465								
89	PARKING I	300	200								
90	DESMOND HALL	500					400				
91	HORNET BOOKSTORE	1500	1279								
94	PARKING II	300	256.3								
95	AIRC (Note 3) (data center)	2500		1800							
99	PARKING III	300	256.3								
99	PARKING 4	500	330								
104	ALUMNI HOUSE (NOTE 3)	300		200							
108	CAPITOL PUBLIC RADIO	400		397							
40N	LIBRARY I	2000	1500								
40S	LIBRARY II	2000		1500							
	UTAPS & SAC MODULARS	500	360								
	PUMPING PLANT	750	500								
	PARKING LOT 8	112.5		150							
	BROAD ATHLETIC CENTER	500		219.5							
	SOUTH BOOSTER PUMPS (NOTE 3)	112.5		100							
	WELL NO. 1	150		75							
	ARC MODULARS	112.5					99.8				
	STORM PUMPS AT WELL NO. 3	75					50				
-	CHILLER (SWITCHGEAR)	2500								1750	
-	FOOTBALL STADIUM	1000							800		
-	CHILLER	2500								2029	
-	FOOTBALL STADIUM	1000									700
56A	**SCIENCE 2, PH 2**	2500				2000					
-	**CHILLER - SOUTH**	2500							2000		
97	**CLASSROOM III**	2500							2000		
51	**ART COMPLEX**	750								600	
30	**PERFORMING ARTS**	2500								2000	
115	**PARKING STRUCTURE V**						1650				
111	**EVENT CENTER**								2000		
105	**ENGINEERING 2**								825		
25	**STUDENT HOUSING PHASE 5**					1320					
4,10,11,12,13	**Greenbelt (demolition of various bldgs)**				-400	-600					

*NOTE 3: DEMAND LOAD IS AN ASSUMPTION - PER DRAWING UT-10 DATED 01/09/2009 (BY ENGINEERING ENTERPRISE).

Figure 1.3

Load Analysis



2 Central Heating System (Steam)

Executive Summary

This report provides an assessment of the existing Central Plant's steam distribution system and a summary of previous reports for the purpose of developing the Utility Master Plan. Based on our assessment, the existing central plant and steam distribution system have plenty of future capacity to provide steam to proposed future growth buildings as described. The campus could extend a steam distribution line to the north end of the campus to provide up to 25,000 lb/hr of additional steam to the future Student Housing (25) buildings, and it could extend a steam distribution line to the south end of the campus to provide up to 50,000 lb/hr of additional steam to those future buildings. This can all be done without any significant degradation of performance to the existing upstream piping and systems.

(Note: Refer to Appendix Figure A1 and Table A1 for building names and building numbers referenced in this section)

In addition; following are recommendations of additions and improvements to the existing steam distribution system:

A. Replace the small amount of original 50+ year old steam distribution piping running from Lassen Hall (26) to the Health Center (33).

B. Connect The Well (109) to the main central plant's steam distribution system.

C. Install steam expansion joints at Steam Vault #12.

D. Extend steam distribution piping to the location of the new Science II building.

E. Extend steam distribution piping to the location of the new Engineering II (105) and Art Complex (51) buildings.

F. Extend steam distribution piping to the location of the new Classroom 3 (97) building.

G. Extend steam distribution piping to the location of the new Event Center (111).

H. Create a new central plant at the south end of the campus to provide steam services to the location of the new Performing Arts Center (30) and connect to the existing steam distribution system to help aid and act as a backup to the original central plant.

Previous Studies

There have been two previous Master-Plan studies on the steam system. The first report was prepared in 1966 by Kennedy Engineers as part of their master plan. A second master plan was developed by Boyle Engineering in 1989.

1966 Kennedy Engineers Report

The 1966 report provided background information on the existing central plant and distribution system. It described that the original central plant was installed in 1952 and used two 12,000 lb/hr and one 20,000 lb/hr gas-fired steam boilers with a total steam capacity of 44,000 lb/hr. However, the deaerator could only handle 36,000 lb/hr which limited the plant's total output capacity. The total design steam load of all the connected buildings at that time was 42,320 lb/hr, however, the maximum steam demand that the plant experienced was 23,000 lb/hr which equates to a 45% diversity factor for the site's 712,800 square-foot campus. The central plant delivered steam at 100 PSI throughout the steel piping distribution system to each building which was then reduced down via each building's pressure reducing station.

Most of the steam piping is sloped downwards with the flow of steam but almost half of the existing steam piping sloped upwards, counter flow to the direction of steam. This creates a limiting factor on the steam capacity that can be delivered because counterflow steam piping has a maximum velocity limit that is much lower than downward sloped piping, and will result in greatly reduced steam delivery.

The 1966 master plan noted some central plant deficiencies, such as the limited capacity of the counterflow steam piping and deaerator, safety device for the boilers, improved boiler combustion efficiencies, and improved steam-condensate pumping systems. The master plan recommended that the central plant be expanded to contain three 50,000 lb/hr gas-fired boilers and additional steam and condensate return piping in order to serve the estimated 120,000 lb/hr future peak steam load of the 3,550,200 square-feet planned campus. The expanded plant would allow for one boiler to be offline for maintenance or repairs for all but peak periods of load. The estimated cost of these recommendations was $650,000 (in 1966 dollars).

1989 Boyle Engineering Report

This report did not provide much information on the steam system for the master plan. It noted that there are two 40,000 lb/hr boilers serving the campus at an indicated 43% diversity factor. The existing piping in the concrete trenches and the preinsulated piping appeared to be deteriorated and was suggested that it all be replaced. The report also mentioned that the 12" main that delivers steam to the south campus could be capable of providing 120,000 lb/hr of steam. The master plan did not provide any recommendations of the steam plant in regards to the additional 1,170,783 of future net building square-footage (1,491,999 SF new minus 321,216 SF demolished).

Existing Conditions

CSUS provided access to electronic files of all the buildings on campus. The files contained Architectural, Structural, Civil, Mechanical, Plumbing, and Electrical information based on as-built drawings. Where data was not available, a site visit was conducted to gather the necessary information. The drawings and field investigations were studied and a comprehensive steam database was created on a building-by-building basis with the goal of determining each building's steam demand and how it relates back to the central plant. This summary information is presented in Table 2.1.

The drawings and existing campus steam piping maps were also analyzed and cross-checked with the latest information to verify the accuracy of the existing maps. A revised steam piping map was created based on this new information and presented in Figure 2.1. This map can be used to correlate the information shown in Table 2.1 with the actual location on the campus site.

The information in Table 2.1 and Figure 2.1 shows that the central plant provides steam to the campus through two main distribution networks. The north-campus is served by a 10" main and the south-campus is served by a 12" main. The total load of all the buildings connected to the central plant is currently shown to be 77,392 lb/hr. The total square footage of the connected buildings is approximately 2,200,000 sq-ft. This equates to an average building 'heat density' of approximately 30 sq-ft/lb-steam.

CENTRAL PLANT

The northern half of the central plant contains the steam boilers and the condensate return deaerating equipment. It houses two 45,000 lb/hr boilers and one 20,000 lb/hr boiler with a total steam capacity of 110,000 lb/hr which normally operates from November to April. The boilers provide steam at 90 PSI and the condensate returns at around 180°F. The typical maximum steam demand to the campus at any one time is about 50,000 lbs/hr so the plant has plenty of capacity and redundancy. As mentioned previously, the total connected steam load to the central plant is 77,392 lb/hr and with a maximum experienced steam demand of 50,000 lb/hr, this results in a heating diversity factor of about 65%.

The boiler room is maintained immaculately with relatively new boilers and equipment. The staff did note that the only piece of equipment that may need replacing in the near future would be the condensate return tank, which is at the end of its useful life.

Also refer to the staff Question & Answers for additional central plant information, Figure 2.3.

NORTH-CAMPUS STEAM DISTRIBUTION

The 10" north-campus main leaves the central plant and follows the route of the original 1952 campus distribution system with extensions and branches that serves newer buildings. Based on 100 PSI steam distribution pressure, Exhibit A shows the total steam load from all the connected buildings on this 10" main (indicated as pipe-segment 'BJ') to be 28,411 lb/hr with a steam velocity within the pipe of 3,379 ft/min. ASHRAE recommends a general high steam velocity to be between 8,000 and 12,000 ft/min with a maximum velocity of 15,000 ft/min for non-counterflow steam piping, however, CSUS Standards recommend not exceeding 10,000 ft/min. Therefore, the current steam delivery through the 10" main is well below its maximum calculated capacity of about 80,000 lb/hr. In analyzing the rest of the north-campus steam piping, there are not any apparent 'choke' points or excessive restrictions. As can be seen from Exhibit A, the most restricted pipe segments are the 4" segment M and the 4" segment Y. Pipe segment M delivers 6,958 lb/hr steam to Douglas Hall, Calaveras Hall, Alpine Hall, and Brighton Hall with the highest steam velocity at 5,173 ft/min. Pipe segment Y provides 6,644 lb/hr of steam to Yosemite Hall, Sacramento Hall, and the Health Center with a velocity of 4,939 ft/min. Again, these are well below their maximum allowable velocities for a 4" pipe and their calculated maximum capacities of 10,000 lb/hr.

FUTURE POTENTIAL SOLUTIONS

In order to provide steam to the proposed future buildings at the far north end of the campus, noted as Student Housing (25), the steam piping can be extended from Vault 15A (refer to Figure 2.1) just west of Shasta Hall (9), at the end of pipe segment B. This is the last steam vault at the end of the north-eastern steam distribution system. It is a 6" pipe that only carries the 4,200 lb/hr steam load for Shasta Hall (9) but is potentially capable of providing 25,000 lb/hr of additional steam with a resultant velocity of about 9,500 ft/min. This new pipe segment is noted as B1 and would be approximately 1,500 feet of new piping. When the load of this 'what-if' scenario is added to pipe segment B and projected back to the central plant, none of the upstream pipe segments are pushed beyond 10,000 ft/min (as can be seen in Table 2.2) and would therefore be capable of providing the additional capacity. The 25,000 lb/hr of steam could be capable of providing heat to approximately 750,000 sq-ft of new construction. However, this increased steam load will cause some additional pressure drops in the upstream pipe distribution system due to the increased steam flow and velocity. Currently, the pressure drop from the central plant to Vault 15A is estimated to be about 1 PSI because of the relatively low steam velocity in all the upstream piping, but the added load could increase the pressure drop to about 22 PSI at the end of pipe segment B1. This is an acceptable pressure drop for such a distance of pipe (ASHRAE recommends a maximum pressure drop of 25 PSI for 100 PSI steam systems).

Cost Estimates for 1500 feet of 6" steam and 3" condensate + Vault for segment B1

However, the north end of the campus already has an existing natural gas pipe distribution system and it may make more economical sense to provide the new buildings with their own localized boiler system using natural gas, rather than extending the central plant's steam lines to the new locations. Refer to Section 6 – Natural Gas.

SOUTH-CAMPUS STEAM DISTRIBUTION

A 12" south-campus steam main leaves the central plant and goes south towards Tahoe Hall (34) then turns east to a capped vault just to the south-east of the University Union (47). There is also a 12" branch that goes east (up Sinclair Road) and terminates at Vault #12 between Sequoia Hall (36) and Riverside Hall (48). Table 2.1 shows the total steam load from all the connected buildings on this 12" south-campus steam main (indicated as pipe-segment 'BF') to be 48,981 lb/hr with a steam velocity within the pipe of about 4,400 ft/min and is well below its maximum calculated capacity of about 110,000 lb/hr, 10,000 ft/min. When analyzing the remainder of the south-campus steam piping, there are not any apparent 'choke' points or excessive restrictions. As can be seen from Table 2.1, the most restricted pipe segment in the south-campus system is the 12" segment BF.

FUTURE POTENTIAL SOLUTIONS

In order to provide steam to the proposed future buildings at the far south end of the campus, the 10" steam piping could be extended from the Vault S-41, which is just south-east of the University Union (47). This 10" pipe could be extended south along the service road until it approaches State University Drive with multiple branches in-between and have a length of approximately 2,000 feet. Currently, the 10" steam pipe between Tahoe Hall (34) and Vault S-41 does not appear to have any steam loads connected to it and would be suitable for connecting to the future loads. The future pipe (noted as AN1) could be capable of providing up to 50,000 lb/hr of steam without adversely affecting the upstream system. The most restrictive pipe in this scenario would be the 10" pipe segment shown as BC which would be flowing 78,304 lb/hr of steam at just over 10,000 ft/min. The 50,000 lb/hr of steam flowing through pipe segment AN1 would have a velocity of about 6,000 ft/min and a resultant pressure drop at the end of about 23 PSI which is an acceptable pressure drop (refer to Figure 2.2). The 50,000 lb/hr of steam could be capable of providing heat to approximately 1,500,000 sq-ft of new construction.

Cost Estimates for 2000 feet of 12" steam and 6" condensate + 3 Vaults for segment AN1

When the 25,000 lb/hr of future north-campus load is combined with the 50,000 lb/hr load of the future south-campus, the total connected load on the central plant would be 152,392 lb/hr while all existing and new pipe velocities and pressure drops would be within acceptable parameters (as can be seen in Table 2.2), noted this exceeds the currently installed capacity of the central plant of 110,000 lb/hr.

After investigating and analyzing the campus's existing central plant and steam distribution system, it appears that it is very capable of delivering the necessary amount of steam to each building in a reliable manner. The overall demand on the system is well below it maximum capability which in turn results in an efficient steam delivery system and lower stresses throughout the system. With the observed maximum steam delivery of 50,000 lb/hr, a maximum connected load of 77,392 lb/hr, and a potential maximum plant generation of 110,000 lb/hr, this central plant has the capability of providing reliable steam well into the future.

Recommendations

The existing central plant and steam distribution system is very adequate and capable of future campus growth. Following are several topics/action items that can be performed based on the current plan and future master plan:

1. REPLACE ORIGINAL STEAM PIPING FROM LASSEN HALL TO THE HEALTH CENTER

The steam piping that's installed between Lassen Hall (26) and the Student Health Center (33) is the last remaining original steam piping on the campus. The staff has experience several leaks and other issues associated with 50+ year old piping. It is recommended that the existing steam and condensate piping be replaced with new preinsulated steam and condensate piping (Thermacor or equal) of appropriate size from Manhole #21 (just outside Lassen Hall) to the Student Health Center (33). This would also include branch lines to/from Manholes #23, 24, 25, 27, 28, 29 & 30 along with new associated steam traps and fittings in the Manholes and reconnect to the building connection points. During the pipe replacement process, new expansion loops would be added at appropriate locations.

The estimated cost of the task is approximately $$$$$$

2. EXTEND STEAM PIPING TO THE WELL

Currently, The Well (109) is heated by local hot-water boilers fueled by natural gas. We recommend connecting The Well to the central plant steam piping loop. Connecting The Well to the campus steam loop would enhance the purpose of the central plant in several ways, such as taking advantage of the plant's efficiency (economy of scale) and reducing maintenance (by not having to maintain another set of boilers). The simplest path to connect the steam piping to The Well would be to tie into the existing piping system between Tahoe Hall (34) and AIRC (95). This piping would route through the lawn and connect to the building's mechanical room. A few new vaults and expansion loops would need to be installed in addition to installing pressure reducing stations and heat exchangers.

The estimated cost of the task is approximately $$$$$$

3. INSTALLING EXPANSION JOINTS IN VAULT #12

The steam piping between Manholes #10 and #12 experiences expansions and contractions greater than can be handled by the current piping system. The staff has made numerous repairs to the piping flanges in Manhole #12 due to the excessive expansions. We recommend installing new expansion joints in the piping within Manhole #12. The expansion joints should be appropriately sized to absorb the anticipated expansions and contractions.

The estimated cost of the task is approximately $$$$$$

4. INSTALLING STEAM EXTENSION LINE TO NEW SCIENCE II BUILDING

The new Science II (56A) building will be constructed where Parking Lot 4 North is currently located, just north of the Hornet Bookstore (91). There are currently not any steam lines nearby but we would suggest that the steam lines extend from capped line at vault 41, just south of the University Union (47). This is a 10" line that would be more than capable of being extended to the Science II (56A) building. It should be able to deliver up to 40,000 lb/hr of steam without adversely affecting the upstream steam distribution system.

The estimated cost of the task is approximately $$$$$$

5. INSTALLING STEAM EXTENSION LINE TO EL DORADO HALL

The furthest steam piping to the south campus ends at vault #41, just south-east of the University Union (47). It would be beneficial to extend the steam piping towards El Dorado Hall (59). Since the steam pipe at vault #41 is a 10" pipe, it could be extended as a 10" or 8" to serve new buildings in the area (El Dorado Hall, Public Safety, Art Sculpture, and Parking Lot 4 South). The extended line could be capable of providing up to 40,000 lb/hr of steam.

The estimated cost of the task is approximately $$$$$$

6. BUILD A SECOND CENTRAL PLANT AT SOUTH CAMPUS

Since the furthest steam piping to the south campus ends at vault #41, just south-east of the University Union (47), there is currently no steam distribution possible to any project south of this point. While the south campus is currently mostly parking lots and parking structures, there will be a time in the future when new buildings will be constructed. One solution to provide steam would be to extend the steam piping from a point on the existing steam distribution system. But this would have a limited capacity and would be costly. A second solution would be to construct a new central plant at south end, possibility just south of Parking Structure III. This location would be central to the southern portion of the campus. Another benefit of this location would be to add an extension to the north and connect to the existing steam loop. This would provide for redundancy and possible enhanced capacity of the loops. The plant would be built with several new branches extended to the areas of new construction while being sized for all anticipated heating loads.

The estimated cost of the task is approximately $$$$$$

Questions and Answers with CSUS Staff

1. **What is the maximum steam capacity of each boiler?**
    a. Two boilers rated at 45,000 lb/hr.
    b. One boiler rated at 20,000 lb/hr.
    c. Each boiler has flue-gas economizer.
2. **What is the age of each boiler?**
    a. B-1; installed 1952, 12,000 lb/hr; replaced 1969, 45,000 lb/hr, replaced 2007, 45,000 lb/hr.
    b. B-2; installed 1952, 12,000 lb/hr; replaced 1969, 45,000 lb/hr, replaced 2007, 45,000 lb/hr.
    c. B-3; installed 1952, 20,000 lb/hr; replaced 1996, 20,000 lb/hr.
3. **What is the life expectancy of each boiler?**
    a. 30 years
4. **Which boilers can operate at the same time to distribute steam?**
    a. All can operate at same time.
5. **What is the total steam capacity available for distribution from the Central Plant?**
    a. Estimated to be 110,000 lb/hr.
6. **What is the peak-load steam pressure delivered from the boilers?**
    a. 90 PSI
7. **What is the maximum steam load experienced from the central plant?**
    a. 50,000 lb/hr.
8. **What is the temperature of the returned steam-condensate?**
    a. 160-180°F
9. **What is boiler operating schedule?**
    a. November to April.
10. **What is max capable pressure of campus loop/ system?**
    a. 100-125 PSI
11. **What is minimum steam pressure required in the loop to maintain the buildings?**
    a. 80-90 PSI
12. **What is the max pressure drop at a furthest pipe run?**
    a. 10 PSI
13. **What is the max allowed pressure drop at a furthest/future pipe run?**
    a. 10 PSI
14. **What are known deficiencies with the steam loop?**
    a. Piping between Humboldt Hall and Santa Clara Hall needs expansion loops/joints.
15. **Are there known weak points? Choke points?**
    a. None
16. **What are the different ages of the different portions of the steam loop?**
    a. Tunnel installed 1969 (From Central Plant to University Union).
    b. Most original piping (1952) replaced/upsized with preinsulated piping in 1994.
    c. Piping along Sinclair replaced/upsized in 2004.
    d. New extension piping from Tahoe Hall to Parking Structure 2 installed in 2004.
    e. Piping from Lassen Hall to Public Health still original (1952).
17. **What needs to be repaired soon?**
    a. Add expansion loops/joints to Piping between Humboldt Hall and Santa Clara Hall.
    b. Replace piping from Lassen Hall to Public Health.
18. **Any future boilers plan?**
    a. No
19. **Is most of the boiler room equipment OK or does any need replacing any time soon?**
    a. Steam condensate tank in Central Plant needs replacing ($75,000).
20. **How much counter flow steam piping is there and where?**
    a. None that they are aware of.
21. **Are there steam pipe maps with velocities and pressures?**
    a. No

22. **Is there back-up fuel for boilers or just NG?**
    a. Natural Gas only.
23. **What improvements were done to the campus CP based on the 1966 Kennedy Master Plan?**
    a. Unknown
24. **Was the counter flow problem resolved in later improvements?**
    a. They think so.
25. **What improvements were done to the campus CP based on the 1989 Boyle Master Plan?**
    a. Unknown
26. **What is the current steam vault/manhole numbering system?**
    a. Same as shown on CSUS Steam Map.
27. **Does Kadema Hall have boilers or steam?**
    a. Steam from Central Plant.
28. **We could not find steam information on Del Norte Hall (what is design capacity)?**
    a. Steam from Central Plant.
29. **We could not find chilled water information on Riverfront Center (what is design capacity)?**
    a. Steam from Central Plant.

Figure 2.1

Overall Existing Steam Distribution Plan

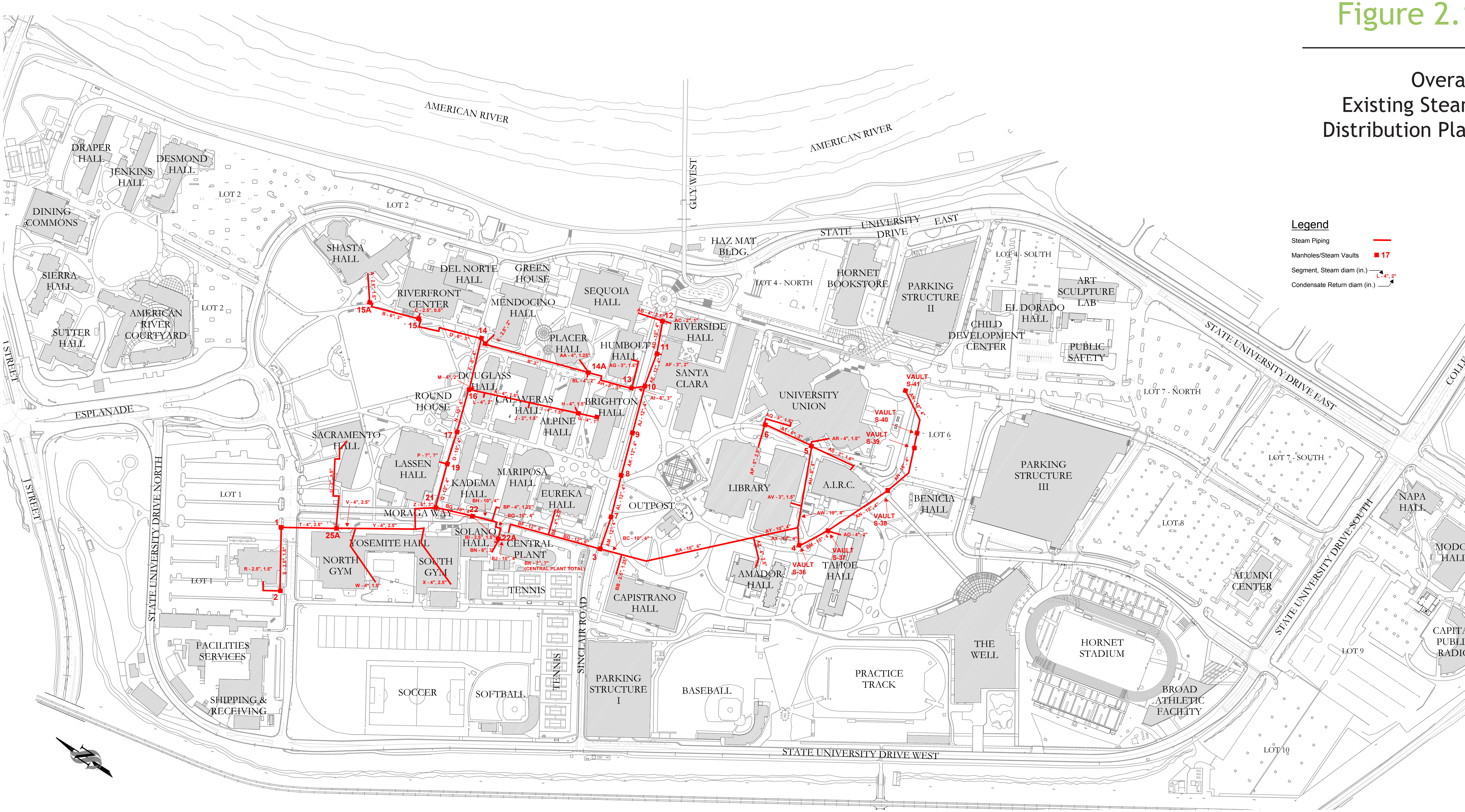


Figure 2.2

Overall Future Steam Distribution Plan

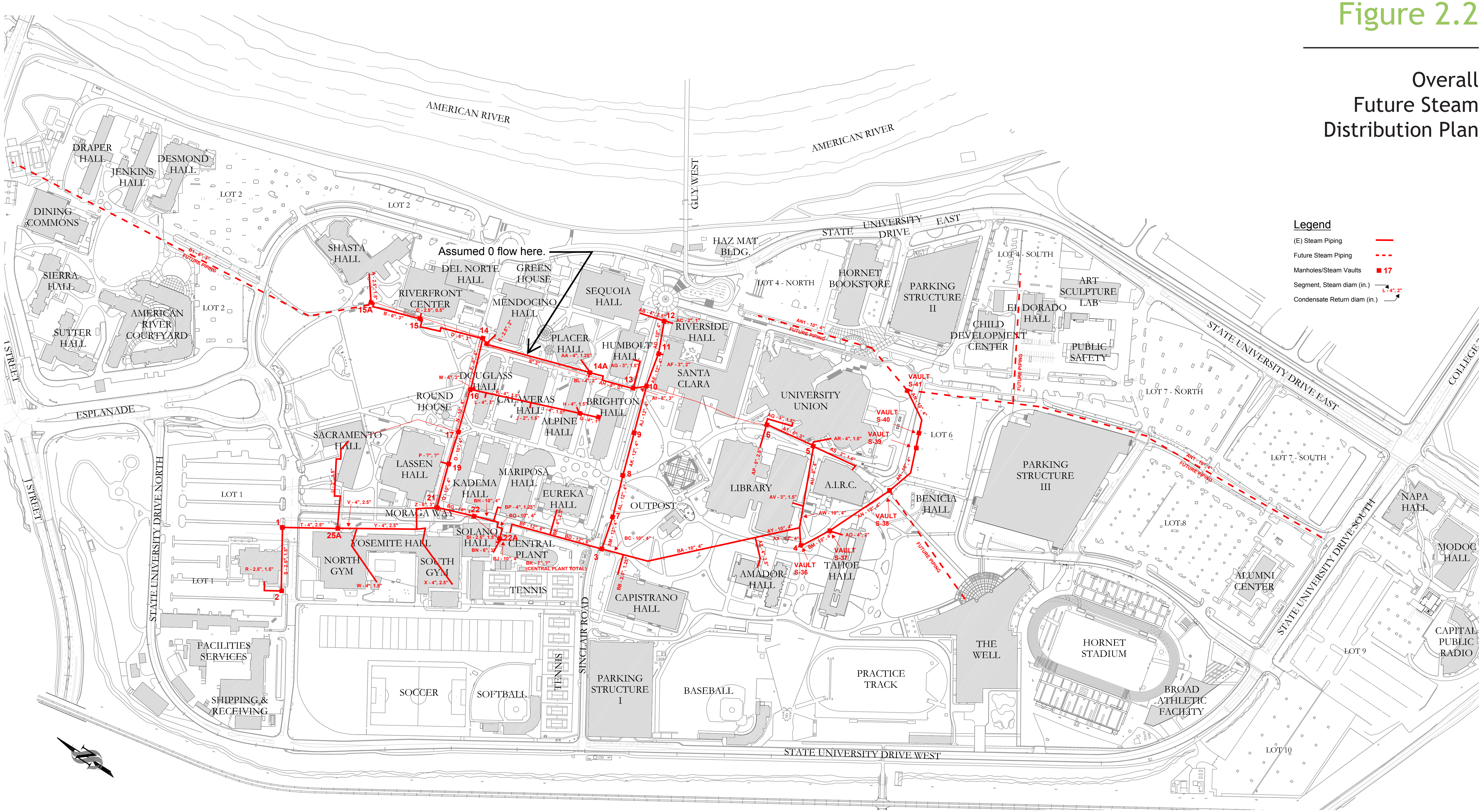


Table 2A

Existing Steam Piping Load Information

	Green = Bldgs. / Red > 8,000 fpm		STM: 970 BTU/lb		HX eff. 1	PSI: 90				Density: 0.23535 lb/ft^3			
			STEAM							CONDENSATE			
	PIPE	BUILDING	PIPE SEGMENT					FROM CENTRAL PLANT		PIPE SEGMENT			
BLDG #	SEG.	NAME	DIAMETER	LENGTH	#/hr	VELOCITY	ΔP (psi)	LENGTH	ΔP (psi)	DIAMETER	LENGTH	GPM	VELOCITY
9	A	Shasta	2.5 in.	108 ft.	4,200	8,725 FT/MIN	3.90	1569 ft.	4.70	1.5 in.	108 ft.	8.4 GPM	1.5 FT/SEC
	B	Pipe	6 in.	200 ft.	4,200	1,515 FT/MIN	0.09	1461 ft.	0.80	3 in.	200 ft.	8.4 GPM	0.4 FT/SEC
	B1	Future pipe	6 in.	1500 ft.	0	0 FT/MIN	0.00	2961 ft.	0.80	3 in.	1500 ft.	0.0 GPM	0.0 FT/SEC
2	C	Riverfront Center	2.5 in.	21 ft.	0	0 FT/MIN	0.00	1282 ft.	0.71	0.5 in.	21 ft.	0.0 GPM	0.0 FT/SEC
	D	Pipe	6 in.	283 ft.	4,200	1,515 FT/MIN	0.13	1261 ft.	0.71	3 in.	283 ft.	8.4 GPM	0.4 FT/SEC
43	E	Mendocino	2.5 in.	50 ft.	2,165	4,498 FT/MIN	0.48	1028 ft.	1.07	2 in.	50 ft.	4.3 GPM	0.4 FT/SEC
	F	Pipe	8 in.	201 ft.	6,365	1,291 FT/MIN	0.05	978 ft.	0.59	4 in.	201 ft.	12.7 GPM	0.3 FT/SEC
12	G	Brighton	4 in.	71 ft.	2,305	1,870 FT/MIN	0.07	1267 ft.	3.26	1 in.	71 ft.	4.6 GPM	1.9 FT/SEC
11	H	Alpine	2 in.	20 ft.	2,725	8,844 FT/MIN	0.93	1216 ft.	4.11	1.5 in.	20 ft.	5.5 GPM	1.0 FT/SEC
	I	Pipe	4 in.	186 ft.	5,030	4,082 FT/MIN	0.92	1196 ft.	3.19	1.5 in.	186 ft.	10.1 GPM	1.8 FT/SEC
10	J	Calaveras	4 in.	20 ft.	850	690 FT/MIN	0.00	1030 ft.	2.27	2 in.	20 ft.	1.7 GPM	0.2 FT/SEC
	K	Pipe	4 in.	173 ft.	5,880	4,771 FT/MIN	1.17	1010 ft.	2.27	1.5 in.	173 ft.	11.8 GPM	2.1 FT/SEC
4	L	Douglass	4 in.	20 ft.	1,079	875 FT/MIN	0.00	857 ft.	1.11	2 in.	20 ft.	2.2 GPM	0.2 FT/SEC
	M	Pipe	4 in.	60 ft.	6,958	5,647 FT/MIN	0.57	837 ft.	1.10	2 in.	60 ft.	13.9 GPM	1.4 FT/SEC
	N	Pipe	10 in.	167 ft.	13,323	1,730 FT/MIN	0.06	777 ft.	0.54	4 in.	167 ft.	26.7 GPM	0.7 FT/SEC
	O	Pipe	10 in.	127 ft.	13,323	1,730 FT/MIN	0.05	610 ft.	0.48	4 in.	127 ft.	26.7 GPM	0.7 FT/SEC
26	P	Lassen	3 in.	30 ft.	1,155	1,666 FT/MIN	0.03	513 ft.	0.46	2 in.	30 ft.	2.3 GPM	0.2 FT/SEC
	Q	Pipe	10 in.	172 ft.	14,478	1,880 FT/MIN	0.07	483 ft.	0.43	4 in.	172 ft.	29.0 GPM	0.7 FT/SEC
33	R	Student Health Center	2.5 in.	100 ft.	2,165	4,498 FT/MIN	0.96	1321 ft.	6.40	1.5 in.	100 ft.	4.3 GPM	0.8 FT/SEC
	S	Pipe	2.5 in.	240 ft.	2,165	4,498 FT/MIN	2.30	1221 ft.	5.44	1.5 in.	240 ft.	4.3 GPM	0.8 FT/SEC
	T	Pipe	4 in.	211 ft.	2,165	1,757 FT/MIN	0.19	981 ft.	3.14	2.5 in.	211 ft.	4.3 GPM	0.3 FT/SEC
	T1	Future pipe	4 in.	1200 ft.	0	0 FT/MIN	0.00	2181 ft.	3.14	2.5 in.	1200 ft.	0.0 GPM	0.0 FT/SEC
1	U	Sacramento	2 in.	380 ft.	2,036	6,609 FT/MIN	9.83	1150 ft.	12.78	1.5 in.	380 ft.	4.1 GPM	0.7 FT/SEC
	V	Pipe	4 in.	75 ft.	4,201	3,409 FT/MIN	0.26	770 ft.	2.95	2.5 in.	75 ft.	8.4 GPM	0.5 FT/SEC
15	W	N Yosemite	4 in.	238 ft.	2443.3	1,983 FT/MIN	0.28	933 ft.	2.97	2.5 in.	238 ft.	4.9 GPM	0.3 FT/SEC
15	X	S Yosemite	4 in.	287 ft.	2443.3	1,983 FT/MIN	0.33	748 ft.	1.01	2.5 in.	287 ft.	4.9 GPM	0.3 FT/SEC
	Y	Pipe	4 in.	234 ft.	6,644	5,392 FT/MIN	2.01	695 ft.	2.69	2.5 in.	234 ft.	13.3 GPM	0.9 FT/SEC
	Z	Pipe	6 in.	150 ft.	9,088	3,278 FT/MIN	0.32	461 ft.	0.68	3 in.	150 ft.	18.2 GPM	0.8 FT/SEC
56	AA	Placer	4 in.	60 ft.	2,062	1,673 FT/MIN	0.05	1341 ft.	0.98	1.25 in.	60 ft.	4.1 GPM	1.1 FT/SEC
58	AB	Sequoia	4 in.	100 ft.	9,750	7,912 FT/MIN	1.85	1389 ft.	2.83	2.5 in.	100 ft.	19.5 GPM	1.3 FT/SEC
48	AC	Riverside	2 in.	29 ft.	1,237	4,016 FT/MIN	0.28	1318 ft.	1.25	1 in.	29 ft.	2.5 GPM	1.0 FT/SEC
	AD	Pipe	10 in.	127 ft.	10,987	1,427 FT/MIN	0.03	1289 ft.	0.97	4 in.	127 ft.	22.0 GPM	0.6 FT/SEC
	AE	Pipe	12 in.	131 ft.	14,987	1,351 FT/MIN	0.02	1162 ft.	0.94	4 in.	131 ft.	30.0 GPM	0.8 FT/SEC
14	AF	Santa Clara	3 in.	20 ft.	4,000	5,771 FT/MIN	0.26	1182 ft.	1.21	2 in.	20 ft.	8.0 GPM	0.8 FT/SEC
13	AG	Humboldt	3 in.	137 ft.	2,268	3,272 FT/MIN	0.58	1218 ft.	1.50	1.5 in.	137 ft.	4.5 GPM	0.8 FT/SEC
	AH	Pipe	8 in.	200 ft.	2,062	418 FT/MIN	0.01	1281 ft.	0.93	3 in.	200 ft.	4.1 GPM	0.2 FT/SEC
	AI	Pipe	8 in.	50 ft.	4,330	878 FT/MIN	0.01	1081 ft.	0.93	3 in.	50 ft.	8.7 GPM	0.4 FT/SEC
	AJ	Pipe	12 in.	184 ft.	19,317	1,742 FT/MIN	0.06	1031 ft.	0.92	4 in.	184 ft.	38.6 GPM	1.0 FT/SEC
	AK	Pipe	12 in.	167 ft.	19,317	1,742 FT/MIN	0.05	847 ft.	0.86	4 in.	167 ft.	38.6 GPM	1.0 FT/SEC
	AL	Pipe	12 in.	163 ft.	19,317	1,742 FT/MIN	0.05	680 ft.	0.81	4 in.	163 ft.	38.6 GPM	1.0 FT/SEC
	AM	Pipe	12 in.	128 ft.	19,317	1,742 FT/MIN	0.04	517 ft.	0.77	4 in.	128 ft.	38.6 GPM	1.0 FT/SEC
	AN	Pipe	10 in.	623 ft.	0	0 FT/MIN	0.00	2021 ft.	1.67	4 in.	623 ft.	0.0 GPM	0.0 FT/SEC
	AN1	Future Pipe	10 in.	2000 ft.	0	0 FT/MIN	0.00	4021 ft.	1.67	4 in.	2000 ft.	0.0 GPM	0.0 FT/SEC
34	AO	Tahoe	4 in.	189 ft.	1,800	1,461 FT/MIN	0.12	1587 ft.	1.79	2 in.	189 ft.	3.6 GPM	0.4 FT/SEC
40	AP	N Library	5 in.	85 ft.	6,881	3,574 FT/MIN	0.26	1744 ft.	2.81	2.5 in.	85 ft.	13.8 GPM	0.9 FT/SEC
47	AQ	N Univ Union	3 in.	140 ft.	2,928	4,224 FT/MIN	0.99	1799 ft.	3.54	1.5 in.	140 ft.	5.9 GPM	1.1 FT/SEC
47	AR	S Univ Union	4 in.	79 ft.	2,928	2,376 FT/MIN	0.13	1544 ft.	2.21	1.5 in.	79 ft.	5.9 GPM	1.1 FT/SEC
95	AS	AIRC	3 in.	200 ft.	3,093	4,462 FT/MIN	1.57	1665 ft.	3.65	1.5 in.	200 ft.	6.2 GPM	1.1 FT/SEC
	AT	Pipe	6 in.	194 ft.	9,809	3,538 FT/MIN	0.48	1659 ft.	2.55	3 in.	194 ft.	19.6 GPM	0.9 FT/SEC
	AU	Pipe	8 in.	222 ft.	15,830	3,211 FT/MIN	0.34	1465 ft.	2.07	4 in.	222 ft.	31.7 GPM	0.8 FT/SEC
40	AV	S Library	3 in.	43 ft.	3,557	5,131 FT/MIN	0.45	1286 ft.	2.18	1.5 in.	43 ft.	7.1 GPM	1.3 FT/SEC
	AW	Pipe	10 in.	84 ft.	19,387	2,517 FT/MIN	0.06	1243 ft.	1.73	4 in.	84 ft.	38.8 GPM	1.0 FT/SEC
	AX	Pipe	10 in.	64 ft.	1,800	234 FT/MIN	0.00	1223 ft.	1.67	4 in.	64 ft.	3.6 GPM	0.1 FT/SEC
	AY	Pipe	10 in.	170 ft.	21,187	2,751 FT/MIN	0.15	1159 ft.	1.67	4 in.	170 ft.	42.4 GPM	1.1 FT/SEC
39	AZ	Amador	4 in.	115 ft.	4,066	3,300 FT/MIN	0.37	1104 ft.	1.89	2.5 in.	115 ft.	8.1 GPM	0.5 FT/SEC
	BA	Pipe	10 in.	515 ft.	25,253	3,279 FT/MIN	0.66	989 ft.	1.52	4 in.	515 ft.	50.5 GPM	1.3 FT/SEC
35	BB	Capistrano	2.5 in.	76 ft.	3,052	6,339 FT/MIN	1.45	550 ft.	2.31	1.25 in.	76 ft.	6.1 GPM	1.6 FT/SEC
	BC	Pipe	10 in.	85 ft.	28,304	3,675 FT/MIN	0.14	474 ft.	0.86	4 in.	85 ft.	56.6 GPM	1.4 FT/SEC
	BD	Pipe	12 in.	205 ft.	47,621	4,294 FT/MIN	0.37	389 ft.	0.73	6 in.	205 ft.	95.3 GPM	1.1 FT/SEC
38	BE	Eureka	4 in.	100 ft.	1,360	1,104 FT/MIN	0.04	284 ft.	0.39	2.5 in.	100 ft.	2.7 GPM	0.2 FT/SEC
	BF	Pipe (CP SOUTH)	12 in.	184 ft.	48,981	4,416 FT/MIN	0.35	184 ft.	0.35	6 in.	184 ft.	98.0 GPM	1.1 FT/SEC
	BG	Pipe	10 in.	144 ft.	23,565	3,060 FT/MIN	0.16	311 ft.	0.36	4 in.	144 ft.	47.1 GPM	1.2 FT/SEC
	BH	Pipe	10 in.	72 ft.	23,565	3,060 FT/MIN	0.08	167 ft.	0.20	4 in.	72 ft.	47.1 GPM	1.2 FT/SEC
42	BI	Solano	2.5 in.	18 ft.	3,196	6,639 FT/MIN	0.38	18 ft.	0.38	1.5 in.	18 ft.	6.4 GPM	1.2 FT/SEC
	BJ	Pipe (CP NORTH)	10 in.	0 ft.	28,411	3,689 FT/MIN	0.00	0 ft.	0.00	4 in.	0 ft.	56.8 GPM	1.5 FT/SEC
	BK	**Pipe (CP TOTAL)**			**77,392**							**154.8 GPM**	
	BL	Stub/Cap	4 in.	5 ft.	0	0 FT/MIN	0.00	1286 ft.	0.93	2 in.	5 ft.	0.0 GPM	0.0 FT/SEC
	BM	Pipe	10 in.	175 ft.	1,800	234 FT/MIN	0.00	1398 ft.	1.67	4 in.	175 ft.	3.6 GPM	0.1 FT/SEC
	BN	Stub/Cap	6 in.	5 ft.	0	0 FT/MIN	0.00	5 ft.	0.00	3 in.	5 ft.	0.0 GPM	0.0 FT/SEC
	BO	Pipe	10 in.	95 ft.	25,215	3,274 FT/MIN	0.12	95 ft.	0.12	4 in.	95 ft.	50.4 GPM	1.3 FT/SEC
92	BP	Mariposa	4 in.	67 ft.	1,649	1,339 FT/MIN	0.04	162 ft.	0.16	1.25 in.	67 ft.	3.3 GPM	0.9 FT/SEC

Table 2B

Future Steam Piping Load Information

	Green = Bldgs.		STM: 970 BTU/lb		HX eff. 1	PSI: 90				Density: 0.23535 lb/ft^3			
	Red > 8,000 fpm		STEAM							CONDENSATE			
	PIPE	BUILDING	PIPE SEGMENT					FROM CENTRAL PLANT		PIPE SEGMENT			
BLDG #	SEG.	NAME	DIAMETER	LENGTH	#/hr	VELOCITY	ΔP (psi)	LENGTH	ΔP (psi)	DIAMETER	LENGTH	GPM	VELOCITY
9	A	Shasta	2.5 in.	108 ft.	4,200	8,725 FT/MIN	3.90	1569 ft.	18.57	1.5 in.	108 ft.	8.4 GPM	1.5 FT/SEC
	B	Pipe	6 in.	200 ft.	29,200	10,531 FT/MIN	4.38	1461 ft.	14.67	3 in.	200 ft.	58.4 GPM	2.7 FT/SEC
	B1	Future pipe	6 in.	1500 ft.	25,000	9,017 FT/MIN	24.07	2961 ft.	38.74	3 in.	1500 ft.	50.0 GPM	2.3 FT/SEC
2	C	Riverfront Center	2.5 in.	21 ft.	0	0 FT/MIN	0.00	1282 ft.	10.29	0.5 in.	21 ft.	0.0 GPM	0.0 FT/SEC
	D	Pipe	6 in.	283 ft.	29,200	10,531 FT/MIN	6.20	1261 ft.	10.29	3 in.	283 ft.	58.4 GPM	2.7 FT/SEC
43	E	Mendocino	2.5 in.	50 ft.	2,165	4,498 FT/MIN	0.48	1028 ft.	4.58	2 in.	50 ft.	4.3 GPM	0.4 FT/SEC
	F	Pipe	8 in.	201 ft.	31,365	6,363 FT/MIN	1.20	978 ft.	4.10	4 in.	201 ft.	62.8 GPM	1.6 FT/SEC
12	G	Brighton	4 in.	71 ft.	2,305	1,870 FT/MIN	0.07	1267 ft.	5.62	1 in.	71 ft.	4.6 GPM	1.9 FT/SEC
11	H	Alpine	2 in.	20 ft.	2,725	8,844 FT/MIN	0.93	1216 ft.	6.47	1.5 in.	20 ft.	5.5 GPM	1.0 FT/SEC
	I	Pipe	4 in.	186 ft.	5,030	4,082 FT/MIN	0.92	1196 ft.	5.54	1.5 in.	186 ft.	10.1 GPM	1.8 FT/SEC
10	J	Calaveras	4 in.	20 ft.	850	690 FT/MIN	0.00	1030 ft.	4.63	2 in.	20 ft.	1.7 GPM	0.2 FT/SEC
	K	Pipe	4 in.	173 ft.	5,880	4,771 FT/MIN	1.17	1010 ft.	4.63	1.5 in.	173 ft.	11.8 GPM	2.1 FT/SEC
4	L	Douglass	4 in.	20 ft.	1,079	875 FT/MIN	0.00	857 ft.	3.46	2 in.	20 ft.	2.2 GPM	0.2 FT/SEC
	M	Pipe	4 in.	60 ft.	6,958	5,647 FT/MIN	0.57	837 ft.	3.46	2 in.	60 ft.	13.9 GPM	1.4 FT/SEC
	N	Pipe	10 in.	167 ft.	38,323	4,976 FT/MIN	0.49	777 ft.	2.89	4 in.	167 ft.	76.7 GPM	2.0 FT/SEC
	O	Pipe	10 in.	127 ft.	38,323	4,976 FT/MIN	0.37	610 ft.	2.40	4 in.	127 ft.	76.7 GPM	2.0 FT/SEC
26	P	Lassen	3 in.	30 ft.	1,155	1,666 FT/MIN	0.03	513 ft.	2.06	2 in.	30 ft.	2.3 GPM	0.2 FT/SEC
	Q	Pipe	10 in.	172 ft.	39,478	5,126 FT/MIN	0.54	483 ft.	2.03	4 in.	172 ft.	79.0 GPM	2.0 FT/SEC
33	R	Student Health Center	2.5 in.	100 ft.	2,165	4,498 FT/MIN	0.96	1321 ft.	7.54	1.5 in.	100 ft.	4.3 GPM	0.8 FT/SEC
	S	Pipe	2.5 in.	240 ft.	2,165	4,498 FT/MIN	2.30	1221 ft.	6.58	1.5 in.	240 ft.	4.3 GPM	0.8 FT/SEC
	T	Pipe	4 in.	211 ft.	2,165	1,757 FT/MIN	0.19	981 ft.	4.28	2.5 in.	211 ft.	4.3 GPM	0.3 FT/SEC
	T1	Future pipe	4 in.	1200 ft.	0	0 FT/MIN	0.00	2181 ft.	4.28	2.5 in.	1200 ft.	0.0 GPM	0.0 FT/SEC
1	U	Sacramento	2 in.	380 ft.	2,036	6,609 FT/MIN	9.83	1150 ft.	13.91	1.5 in.	380 ft.	4.1 GPM	0.7 FT/SEC
	V	Pipe	4 in.	75 ft.	4,201	3,409 FT/MIN	0.26	770 ft.	4.09	2.5 in.	75 ft.	8.4 GPM	0.5 FT/SEC
15	W	N Yosemite	4 in.	238 ft.	2443.3	1,983 FT/MIN	0.28	933 ft.	4.10	2.5 in.	238 ft.	4.9 GPM	0.3 FT/SEC
15	X	S Yosemite	4 in.	287 ft.	2443.3	1,983 FT/MIN	0.33	748 ft.	2.15	2.5 in.	287 ft.	4.9 GPM	0.3 FT/SEC
	Y	Pipe	4 in.	234 ft.	6,644	5,392 FT/MIN	2.01	695 ft.	3.83	2.5 in.	234 ft.	13.3 GPM	0.9 FT/SEC
	Z	Pipe	6 in.	150 ft.	9,088	3,278 FT/MIN	0.32	461 ft.	1.81	3 in.	150 ft.	18.2 GPM	0.8 FT/SEC
56	AA	Placer	4 in.	60 ft.	2,062	1,673 FT/MIN	0.05	1341 ft.	3.27	1.25 in.	60 ft.	4.1 GPM	1.1 FT/SEC
58	AB	Sequoia	4 in.	100 ft.	9,750	7,912 FT/MIN	1.85	1389 ft.	5.11	2.5 in.	100 ft.	19.5 GPM	1.3 FT/SEC
48	AC	Riverside	2 in.	29 ft.	1,237	4,016 FT/MIN	0.28	1318 ft.	3.54	1 in.	29 ft.	2.5 GPM	1.0 FT/SEC
	AD	Pipe	10 in.	127 ft.	10,987	1,427 FT/MIN	0.03	1289 ft.	3.26	4 in.	127 ft.	22.0 GPM	0.6 FT/SEC
	AE	Pipe	12 in.	131 ft.	14,987	1,351 FT/MIN	0.02	1162 ft.	3.23	4 in.	131 ft.	30.0 GPM	0.8 FT/SEC
14	AF	Santa Clara	3 in.	20 ft.	4,000	5,771 FT/MIN	0.26	1182 ft.	3.49	2 in.	20 ft.	8.0 GPM	0.8 FT/SEC
13	AG	Humboldt	3 in.	137 ft.	2,268	3,272 FT/MIN	0.58	1218 ft.	3.79	1.5 in.	137 ft.	4.5 GPM	0.8 FT/SEC
	AH	Pipe	8 in.	200 ft.	2,062	418 FT/MIN	0.01	1281 ft.	3.22	3 in.	200 ft.	4.1 GPM	0.2 FT/SEC
	AI	Pipe	8 in.	50 ft.	4,330	878 FT/MIN	0.01	1081 ft.	3.21	3 in.	50 ft.	8.7 GPM	0.4 FT/SEC
	AJ	Pipe	12 in.	184 ft.	19,317	1,742 FT/MIN	0.06	1031 ft.	3.21	4 in.	184 ft.	38.6 GPM	1.0 FT/SEC
	AK	Pipe	12 in.	167 ft.	19,317	1,742 FT/MIN	0.05	847 ft.	3.15	4 in.	167 ft.	38.6 GPM	1.0 FT/SEC
	AL	Pipe	12 in.	163 ft.	19,317	1,742 FT/MIN	0.05	680 ft.	3.10	4 in.	163 ft.	38.6 GPM	1.0 FT/SEC
	AM	Pipe	12 in.	128 ft.	19,317	1,742 FT/MIN	0.04	517 ft.	3.05	4 in.	128 ft.	38.6 GPM	1.0 FT/SEC
	AN	Pipe	10 in.	623 ft.	50,000	6,492 FT/MIN	3.11	2021 ft.	15.05	4 in.	623 ft.	100.0 GPM	2.6 FT/SEC
	AN1	Future Pipe	10 in.	2000 ft.	50,000	6,492 FT/MIN	9.98	4021 ft.	25.03	4 in.	2000 ft.	100.0 GPM	2.6 FT/SEC
34	AO	Tahoe	4 in.	189 ft.	1,800	1,461 FT/MIN	0.12	1587 ft.	12.06	2 in.	189 ft.	3.6 GPM	0.4 FT/SEC
40	AP	N Library	5 in.	85 ft.	6,881	3,574 FT/MIN	0.26	1744 ft.	12.74	2.5 in.	85 ft.	13.8 GPM	0.9 FT/SEC
47	AQ	N Univ Union	3 in.	140 ft.	2,928	4,224 FT/MIN	0.99	1799 ft.	13.46	1.5 in.	140 ft.	5.9 GPM	1.1 FT/SEC
47	AR	S Univ Union	4 in.	79 ft.	2,928	2,376 FT/MIN	0.13	1544 ft.	12.13	1.5 in.	79 ft.	5.9 GPM	1.1 FT/SEC
95	AS	AIRC	3 in.	200 ft.	3,093	4,462 FT/MIN	1.57	1665 ft.	13.57	1.5 in.	200 ft.	6.2 GPM	1.1 FT/SEC
	AT	Pipe	6 in.	194 ft.	9,809	3,538 FT/MIN	0.48	1659 ft.	12.48	3 in.	194 ft.	19.6 GPM	0.9 FT/SEC
	AU	Pipe	8 in.	222 ft.	15,830	3,211 FT/MIN	0.34	1465 ft.	12.00	4 in.	222 ft.	31.7 GPM	0.8 FT/SEC
40	AV	S Library	3 in.	43 ft.	3,557	5,131 FT/MIN	0.45	1286 ft.	12.11	1.5 in.	43 ft.	7.1 GPM	1.3 FT/SEC
	AW	Pipe	10 in.	84 ft.	19,387	2,517 FT/MIN	0.06	1243 ft.	11.66	4 in.	84 ft.	38.8 GPM	1.0 FT/SEC
	AX	Pipe	10 in.	64 ft.	51,800	6,726 FT/MIN	0.34	1223 ft.	11.94	4 in.	64 ft.	103.6 GPM	2.6 FT/SEC
	AY	Pipe	10 in.	170 ft.	71,187	9,243 FT/MIN	1.72	1159 ft.	11.60	4 in.	170 ft.	142.4 GPM	3.6 FT/SEC
39	AZ	Amador	4 in.	115 ft.	4,066	3,300 FT/MIN	0.37	1104 ft.	10.25	2.5 in.	115 ft.	8.1 GPM	0.5 FT/SEC
	BA	Pipe	10 in.	515 ft.	75,253	9,771 FT/MIN	5.82	989 ft.	9.88	4 in.	515 ft.	150.6 GPM	3.8 FT/SEC
35	BB	Capistrano	2.5 in.	76 ft.	3,052	6,339 FT/MIN	1.45	550 ft.	5.50	1.25 in.	76 ft.	6.1 GPM	1.6 FT/SEC
	BC	Pipe	10 in.	85 ft.	78,304	10,167 FT/MIN	1.04	474 ft.	4.05	4 in.	85 ft.	156.7 GPM	4.0 FT/SEC
	BD	Pipe	12 in.	205 ft.	97,621	8,802 FT/MIN	1.57	389 ft.	3.01	6 in.	205 ft.	195.3 GPM	2.2 FT/SEC
38	BE	Eureka	4 in.	100 ft.	1,360	1,104 FT/MIN	0.04	284 ft.	1.48	2.5 in.	100 ft.	2.7 GPM	0.2 FT/SEC
	BF	Pipe (CP SOUTH)	12 in.	184 ft.	98,981	8,925 FT/MIN	1.45	184 ft.	1.45	6 in.	184 ft.	198.0 GPM	2.2 FT/SEC
	BG	Pipe	10 in.	144 ft.	48,565	6,306 FT/MIN	0.68	311 ft.	1.50	4 in.	144 ft.	97.2 GPM	2.5 FT/SEC
	BH	Pipe	10 in.	72 ft.	48,565	6,306 FT/MIN	0.34	167 ft.	0.82	4 in.	72 ft.	97.2 GPM	2.5 FT/SEC
42	BI	Solano	2.5 in.	18 ft.	3,196	6,639 FT/MIN	0.38	18 ft.	0.38	1.5 in.	18 ft.	6.4 GPM	1.2 FT/SEC
	BJ	Pipe (CP NORTH)	10 in.	0 ft.	53,411	6,935 FT/MIN	0.00	0 ft.	0.00	4 in.	0 ft.	106.9 GPM	2.7 FT/SEC
	BK	**Pipe (CP TOTAL)**			**152,392**							**304.9 GPM**	
	BL	Stub/Cap	4 in.	5 ft.	0	0 FT/MIN	0.00	1286 ft.	3.22	2 in.	5 ft.	0.0 GPM	0.0 FT/SEC
	BM	Pipe	10 in.	175 ft.	51,800	6,726 FT/MIN	0.94	1398 ft.	12.88	4 in.	175 ft.	103.6 GPM	2.6 FT/SEC
	BN	Stub/Cap	6 in.	5 ft.	0	0 FT/MIN	0.00	5 ft.	0.00	3 in.	5 ft.	0.0 GPM	0.0 FT/SEC
	BO	Pipe	10 in.	95 ft.	50,215	6,520 FT/MIN	0.48	95 ft.	0.48	4 in.	95 ft.	100.5 GPM	2.6 FT/SEC
92	BP	Mariposa	4 in.	67 ft.	1,649	1,339 FT/MIN	0.04	162 ft.	0.51	1.25 in.	67 ft.	3.3 GPM	0.9 FT/SEC

3 Chilled Water

Executive Summary

This report provides an assessment of the existing Central Plant's chilled-water distribution system and a summary of previous reports for the purpose of developing the Utility Master Plan. Based on our assessment, the existing central plant and chilled-water distribution systems have some spare capacity available for some proposed future growth buildings as described. The campus could extend its chilled-water piping to the north end of the campus to provide up to 550 tons of additional chilled-water capacity to the future Student Housing (25) buildings, and it could extend a chilled-water system to the south end of the campus to provide up to 835 tons of additional chilled-water capacity to those future buildings. This can all be done without any significant degradation of performance to the existing upstream piping and systems.

(Note: Refer to Appendix Figure A1 and Table A1 for building names and building numbers referenced in this section)

In addition; following are recommendations of additions and improvements to the existing chilled-water distribution system:

A. Extend the chilled-water distribution piping to the location of the new Science II building.

B. Extend the chilled-water distribution piping to the location of the new Engineering II (105) and Art Complex (51) buildings.

C. Extend chilled-water distribution piping to the location of the new Classroom 3 (97) building.

D. Extend chilled-water distribution piping to the location of the new Event Center (111).

E. Create a new central plant at the south end of the campus to provide chilled-water services to the location of the new Performing Arts Center (30) and connect to the existing chilled-water distribution system to help aid and act as a backup to the original central plant.

Previous Studies

There have been two previous Master-Plan studies and a separate Thermal Energy Storage (TES) report on the chilled-water system. The first report was prepared in 1966 by Kennedy Engineers as part of their master plan. A second master plan was developed by Boyle Engineering in 1989. The TES report was created by Peters Engineering in 2000.

1966 Kennedy Engineers Report

The 1966 report provided background information on the existing central plant and distribution system which was only a steam producing plant. There was not a centralized chilled water plant on the campus at the time but several buildings had their own individual refrigeration and air-conditioning systems. The report went on to describe the pros and cons of several different cooling systems that were available at the time, such as continuing to provide cooling on an individual building basis, install steam-powered absorption chillers, or install typical central-plant type chillers with cooling towers. The report leaned towards recommending a central plant with chillers, cooling towers, pumps, and a chilled water distribution system.

Their worksheets estimated that the total connected cooling load of the campus would be about 4,000 tons to cool 2,412,700 sq-ft of total planned square-footage. This equates to about 600 sq-ft/ton on average. They also indicated that a typical central plant would experience a 75% diversity factor so they recommended the central plant to provide 3,000 tons of cooling. Kennedy's concept did include one steam-powered absorption chiller and two centrifugal chillers with the thought that the steam-powered absorption chiller would be more cost effective during partial-load situations where the cost per ton using natural gas would be cheaper than using peak-period electricity. They estimated the cost of the new central plant with 3,000 tons of chillers, cooling towers, pumps, and pipe distribution to be $1,060,000 (in 1966 dollars).

1989 Boyle Engineering Report

The Boyle Engineering report described that the central plant contained two 1,250 ton centrifugal chillers for a total capacity of 2,500 tons. The central plant records indicated a peak demand of only 1,400 tons. The chilled water is distributed from a 24" main that splits into two 16" mains, one going north and the other going south. The flow rate is based on 2-1/2 gpm/ton with a 10°F temperature differential between the supply and return water which makes the flow rate 6,250 gpm for 2,500 tons of cooling. They noted that the condition of the chiller systems was adequate with no indicated of equipment in need of immediate repair.

The report mentions that there is 1,100 tons of excess chilled water capacity and when converted to potential square-footage, it could condition 400,000 sq-ft of additional buildings. The central plant was planned to increase its cooling capacity to 5,000 tons and the Boyle Engineering report suggested installing localized chillers in the new buildings as they are built to supplement the chilled water capacity rather than increasing the capacity of the central plant. It indicated the advantages of doing this, such as more chillers equates to better redundancy, newer chillers are more efficient than the existing central plant's chillers, the central plant could be shut down if the remote chillers can handle the loop load, and the system's reliability would be increased with the proper loop cross-connections. A Thermal Energy Storage tank was also suggested to be added to the central plant to allow the plant to operate less during on-peak electricity periods. The TES would save energy costs and provide a cushion of cooling and act as a 'back-up' chiller.

2000 Peters Engineering Report

The Peters Engineering report describes the existing central plant with its existing 1,068,000 gallon Thermal Energy Storage (TES) tank. The tank was designed to provide 12,300 ton-hours of stored capacity with a 20°F temperature differential. The tank was intended to shift the cooling energy from the utility's 'super-peak' period (2:00pm – 8:00pm) to 'off-peak'. This is accomplished by running the chillers at night to 'charge' the TES when there is little load. Then the chillers will turn off at 2:00pm to avoid the large electoral load during the peak-period. At that time, the TES discharges its chilled water into the distribution system to provide cooling to the campus. Based on the campus' connected chilled-water load at the time the report was written (1,700,000 sq-ft of connected buildings), the TES ran out of capacity after 5:00pm and the chillers needed to be turned on to provide campus cooling.

The report suggested adding additional TES capacity to the top of the existing TES tank by adding an 8 foot section. This would bring the capacity of the TES to 1,220,000 gallons, or 14,500 ton-hours, and should keep the chillers offline until 8:00pm.

Existing Conditions

CSUS provided access to electronic files of all the buildings on campus. The files contained Architectural, Structural, Civil, Mechanical, Plumbing, and Electrical information based on as-built drawings. Where data was not available, a site visit was conducted to gather the necessary information. The drawings and field investigations were studied and a comprehensive chilled-water database was created on a building-by-building basis with the goal of determining each building's chilled-water demand and how it relates back to the central plant. This summary information is presented as Table 3.1.

The drawings and existing campus chilled-water piping maps were also analyzed and cross-checked with the latest information to verify the accuracy of the existing maps. A new chilled-water piping map was created based on this new information and presented as Figure 3.1. This map can be used to correlate the information shown on Table 3.1 with the actual location on the campus site.

The information in Table 3.1 and Figure 3.1 shows that the central plant provides chilled-water to the campus through two main distribution networks. A 24" chilled-water main pipe existing the central plant and splits into two 16" mains, one going north and the other going south. The total load of all the buildings connected to the central plant is currently shown to be 69,319,550 BTUH, or equivalent to 5,776 tons. The total square footage of the connected buildings is 1,937,070 sq-ft. This equates to an average 'cooling density' of approximately 335 sq-ft/ton.

CENTRAL PLANT

The southern half of the central plant contains the chillers and chilled-water pumps with the TES tank located just outside the south end of the building. The central plant houses three 1,250-ton Trane chillers with a total cooling capacity of 3,750 tons. The chilled-water is distributed to the campus loop via two 125 HP pump and is delivered at 40°F.

Also refer to the staff Question & Answers for additional central plant information, Figure 3.3.

NORTH-CAMPUS CHILLED WATER DISTRIBUTION

The 16" chilled-water main goes north and mostly follows the same path as the steam piping. Table 3.1 shows the total chilled-water load from all the connected buildings on this 16" main (indicated as pipe-segment 'BM') to be 28,822,198 BTUH, or 2,400 Tons. With a 13°F temperature differential, the flow through the pipe is 4,430 GPM with a velocity within the pipe of 7.1 ft/sec and a corresponding pressure drop of about 1 ft/100 ft. ASHRAE recommends that chilled-water piping be sized to not exceed a pressure drop of 4 ft/100 ft, however, CSUS Standards recommend that the pressure drop not exceed 3 ft/100 ft or a velocity of 10 ft/sec. So the current load on this pipe is below its maximum capacity of approximately 6,200 GPM, 3,360 Tons, velocity of 9.9 ft/sec, and pressure drop of 1.63 ft/100 ft. In analyzing the rest of the north-campus chilled-water piping, there are not any apparent 'choke' points or excessive restrictions. It can be seen from Table 3.1 that most of the distribution pipes have a velocity of less than 7 ft/sec. But the pipe with the fastest velocity of 11.5 ft/sec is pipe segment 'T' which serves Sequoia Hall (39) and Riverside Hall (48). This pipe was originally only for Sequoia Hall (39) but was then extended to Riverside Hall (48) which is why its capacity is relatively high.

Potential Future Solutions

There is a location where chilled-water can be accessed and extended towards the future buildings at the far north end of the campus, noted as Student Housing (25). The location would be from the 10" pipe segment N (refer to Figure 3.2) just west of Shasta Hall (9), at the end of pipe segment O.

Extending pipe N to the far north end of campus would give it's termination a total pipe length from the Central Plant of about 3,000 feet. This new pipe segment is probably only capable of providing about 1,000 GPM of chilled water to the far north end, which would be the equivalent of about 6,500,000 BTUH of cooling (550 tons) which is enough cooling capacity to condition approximately 182,000 square-feet of new floor area. This increased water flow will not cause too much of a restriction on the upstream piping, but the total length of this pipe from the central plant would have a resultant pressure drop at the end of almost 12 PSI which is what is limiting the flow of this segment.

Cost Estimates for 1500 feet of 10" chilled water supply and return piping for Segment N.

SOUTH-CAMPUS CHILLED WATER DISTRIBUTION

A relatively short length of 20" pipe heads south and splits into a 16" and a 12" main that mostly follows the same path as the steam piping. Table 3.1 shows the total chilled-water load from all the connected buildings on this 20" main (indicated as pipe-segment 'AR') to be 40,497,352 BTUH, or 3,375 Tons. With a 13°F temperature differential, the flow through the pipe is 6,230 GPM with a velocity within the pipe of 6.4 ft/sec and a corresponding pressure drop of about 0.6 ft/100 ft. So the current load on this pipe is below its maximum capacity of approximately 10,000 GPM, 5,400 Tons, velocity of 10.1 ft/sec, and pressure drop of 1.34 ft/100 ft. In analyzing the rest of the south-campus chilled-water piping, there are not any apparent 'choke' points or excessive restrictions. It can be seen from Table 3.1 that most of the distribution pipes have a velocity of less than 7 ft/sec. But the pipe with the fastest velocity of 8.5 ft/sec is pipe segment 'Q' which follows Sinclair Road towards Santa Clara Hall (14).

Potential Future Solutions

In order to provide chilled-water to the proposed future buildings at the far south end of the campus, a 12" chilled-water line could be extended from the tee-connection located in Lot-6 noted as pipe segment BF, which is just south-east of the University Union. This 12" pipe could be extended south along the service road until it approaches State University Drive with multiple branches in-between and have a new length of approximately 2,000 feet with a total length from the central plant of about 3,800 feet. Currently, the existing 12" pipe consisting of segments P, Q, and BU only serve the Bookstore (91) with a flow of 514 GPM. This new pipe segment is probably capable of providing about 1,500 GPM of chilled water to the far north end, which would be the equivalent of about 10,000,000 BTUH (835 tons) of cooling which is enough cooling capacity to condition approximately 280,000 square-feet of new floor area. This increased water flow will not cause too much of a restriction on the upstream piping, but the total length of this pipe from the central plant would have a resultant pressure drop at the end of almost 13 PSI which is what is limiting the flow of this segment.

Cost Estimates for 2000 feet of 10" chilled water supply and return piping for Segment BF

When the 550 tons of future north-campus load is combined with the 835 tons of the future south-campus, the total connected cooling load on the central plant would be about 7,200 tons. This would require about 13,300 GPM of chilled water distribution, and this is pushing the limit of the central plant's 24" main (segment BL) with the equivalent velocity of 10.0 ft/sec.

Recommendations

Following are several topics/action items that can be performed based on the current plan and future master plan:

1. EXTEND CHILLED-WATER PIPING TO THE WELL

Currently, The Well (109) is cooled by its own chillers and chilled-water distribution system. It could be more energy efficient to connect The Well to the central plant's chilled water loop. Connecting The Well (109) to the campus loop would enhance the purpose of the central plant in several ways, such as taking advantage of the plant's efficiency (economy of scale) and reducing maintenance (by not having to maintain another set of chillers and associated accessories). The simplest path to connect the steam piping to The Well (109) would be to tie into the existing piping system between Tahoe Hall (34) and AIRC (95). This piping would route through the lawn and connect to the building's mechanical room. A few new vaults and expansion loops would need to be installed in addition to modifying the existing building's chilled water distribution system.

The estimated cost of the task is approximately $$$$$$

2. INSTALLING CHILLED-WATER EXTENSION LINE TO NEW SCIENCE II BUILDING

The new Science II building will be constructed where Parking Lot 4 North is currently located, just north of the Hornet Bookstore. There are currently no chilled water lines nearby but we would suggest that the new chilled water lines extend from the chilled water manhole just south-west of the Hornet Bookstore. This is a 12" line that is more than large enough the handle the newly added cooling load of the Science II building

The estimated cost of the task is approximately $$$$$$

3. INSTALLING CHILLED-WATER LINE TO EL DORADO HALL

There are no chilled water lines near this eastern-most area of the campus. It would be beneficial to extend the lines to provide a source of chilled water for future buildings. There is a chilled-water manhole in Parking Lot #6 with a 12" pipe. A new chilled water piping system can be connected at the point and extended to serve new buildings in the area (El Dorado Hall, Public Safety, Art Sculpture, and Parking Lot 4 South).

The estimated cost of the task is approximately $$$$$$

4. BUILD A SECOND CENTRAL PLANT AT SOUTH CAMPUS

Since the furthest chilled water piping to the south campus is at Parking Lot #6, there is currently no chilled water distribution possible to any project south of this point. While the south campus is currently mostly parking lots and parking structures, there will be a time in the future when new buildings will be constructed. One solution to provide chilled water would be to extend the piping from a point on the existing chilled water distribution system. But this would have a limited capacity and would be costly. A second solution would be to construct a new central plant at south end, possibility just south of Parking Structure III. This location would be central to the southern portion of the campus. Another benefit of this location would be to add an extension to the north and connect to the existing chilled water loop. This would provide for redundancy and possible enhanced capacity of the loops. The plant would be built with several new branches extended to the areas of new construction while being sized for all anticipated heating loads.

The estimated cost of the task is approximately $$$$$$

Questions and Answers with CSUS Staff

1. **What is the maximum tonnage of each chiller?**
    a. 3 chillers, 1,250 Tons each, centrifugal.
2. **What is the age of each chiller?**
    a. CH-1 replaced in 2002, Trane R-123 (originally installed 1969, R-11).
    b. CH-2 replaced in 1998, Trane R-123 (originally installed 1969, R-11).
    c. CH-3 added in 2004, Trane R-123.
3. **What are the Chiller efficiencies?**
    a. Original chillers were approximately 0.80 kW/Ton.
    b. New chillers are approximately 0.566 kW/Ton.
4. **What is the anticipated life expectancy of each chiller?**
    a. 25 years
5. **What is the tonnage of each cooling tower cell?**
    a. 3 cooling towers, 1,500 Tons each, VFD gear-driven fans.

6 **What is the age of each cooling tower cell?**
    a. CT-1 replaced in 2002, Ceramic Unilite (originally installed 1969).
    b. CT-2 replaced in 2002, Ceramic Unilite (originally installed 1969).
    c. CT-3 added in 2002, Ceramic Unilite.

7. **Can the three chillers/cooling towers run at full capacity at the same time?**
    a. Yes
8. **What are the chiller's typical LWT and EWT when charging the TES?**
    a. LWT=39°F, ΔT= 20-24°F
9. **What is the Central plant's typical LWT and EWT during a peak cooling condition?**
    a. LWT=40°, EWT=60°F
10. **What is the Central Plant's maximum load experienced through the campus loop (GPM, ΔT)?**
    a. Estimated to be 4,000 GPM, ΔT=20°F (3,333 Tons).
11. **What is the pressure at the discharge pipe of the Central Plant's 24" distribution supply main?**
    a. 45 PSI
12. **What is the pressure at the receiving pipe of the Central Plant's 24" distribution return main?**
    a. 38 PSI
13. **What is the max allowed pressure drop at a furthest/future pipe run?**
    a. Estimated to be about 3 PSI.
14. **What is cooling season schedule?**
    a. Chilled water plant operates 24/7/365.
15. **What is the lowest possible LWT from the Central Plant?**
    a. 39°F
16. **What is the capacity of the TES (ton-hours)?**
    a. Originally installed in 1990, was 12,300 ton-hours, 1,068,000 gallons, 48 feet tall.
    b. Tank height increased in 2001 to 72 feet, 18,725 ton-hours, 1,625,000 gallons.
17. **How often and how long is it charged? (from what hour to what hour)?**
    a. Every day, usually from 10:00pm to 8:00am.
18. **What is the concept of the future TES?**
    a. 15,000 ton-hour tank next to existing tank.
19. **How noticeable are the energy savings once the TES was introduced ($/year savings)?**
    a. Not tracked.
20. **What is the pressure drop in the chilled water supply pipe at furthest run/building?**
    a. Essentially negligible.
21. **Any future chiller plans?**
    a. Probably yes, to add 4th 1,50 ton chiller when new TES is installed.
22. **What are the different ages of the different portions of the chilled water loop?**
    a. Most of the underground chilled water piping was replaced in 1994 with new preinsulated steel piping.
    b. The chilled water piping from Lassen Hall to the Student Health Center is still existing original (1969).

23. What are known deficiencies with the chilled water loop?

a. None noted (other than original piping needs to be replaced).

24. What needs to be repaired soon?

a. The chilled water piping from Lassen Hall to the Student Health.

25. Are there known choke points in the chilled water loop and where?

a. Pressure is lowest at Riverfront Center.

26. Are there chilled water pipe maps with GPM's and pressures?

a. No

27. What improvements were done to the campus CP based on the 1966 Kennedy Master Plan?

a. Unknown but the original Chilled Water plant was most likely based from the 1966 plan.

28. What improvements were done to the campus CP based on the 1989 Boyle Master Plan?

a. Unknown

29. What is the current chilled-water vault/man-hole numbering system?

a. Will get from Paul

30. What is the chilled-water pipe connection size at the capped stubs in Lot 6?

a. Unknown, probably 12"

31. Does Lassen Hall have a chiller or CHWS?

a. Central Plant provides cooling.

32. We could not find chilled water information on Riverfront Center (what is design capacity)?

a. 300 Tons

33. We could not find chilled water information on Brighton Hall (what is design capacity)?

a. Connected to Central Plant.

34. We could not find chilled water information on Sacramento Hall (what is design capacity)?

a. Connected to Central Plant.

35. We could not find chilled water information on Santa Clara Hall (what is design capacity)?

a. Connected to Central Plant.

36. We could not find chilled water information on Shasta Hall (what is design capacity)?

a. Connected to Central Plant.

37. Is the University Union on chilled water or does it have its own chilled-water central plant?

a. Has it's own chillers, but is connected to Central Plant as backup.

38. Does Yosemite hall or the Gyms have any chilled water?

a. Only at offices and classroom.

Figure 3.1

Overall Existing Chilled Water Distribution Plan

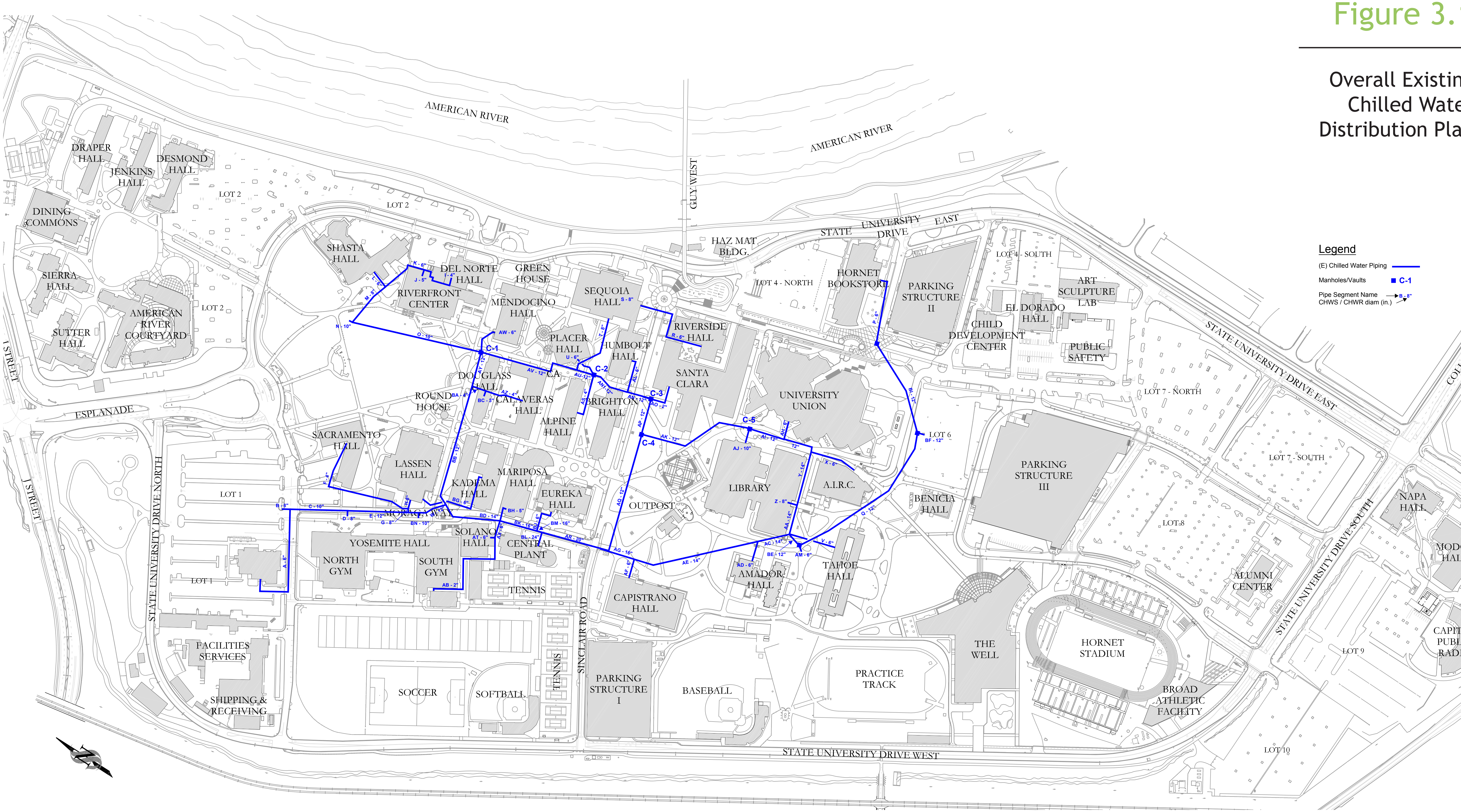


Figure 3.2

Overall Future Chilled Water Distribution Plan

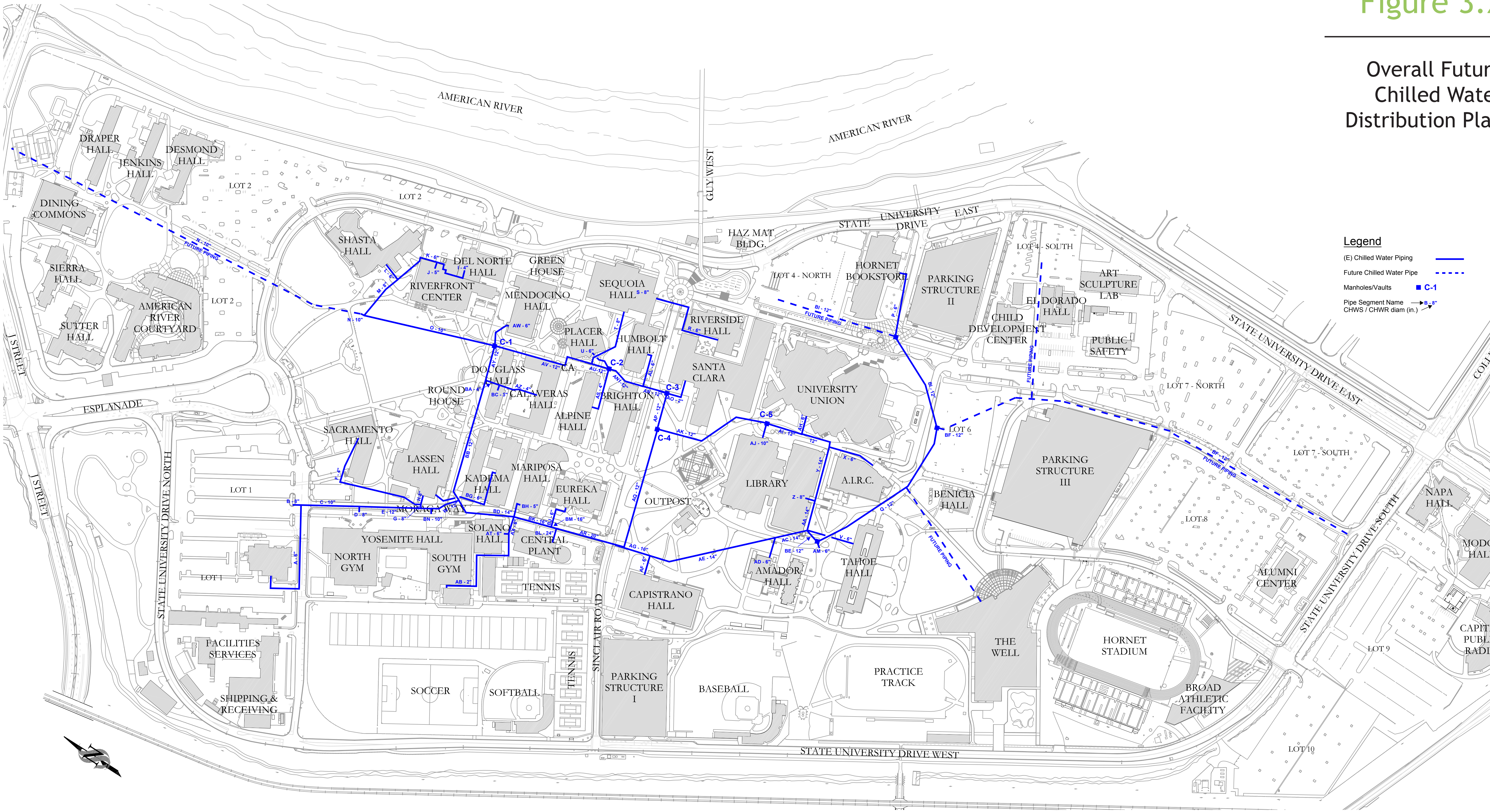


Table 3A

Existing Chilled Water Piping Load Information

BLDG #	Green=Bldg Red > 8.0 fps PIPE SEG.	BUILDING NAME	EWT: 53 CHILLED WATER PIPE SEGMENT DIAMETER	LWT: LENGTH	BTUH	40 F GPM	ΔT: 13 F VELOCITY	ΔP (psi)	FROM CENTRAL PLANT LENGTH	ΔP (psi)
33	A	Student Health Center	6 in.	470 ft.	800,000	123 GPM	1.4 FT/SEC	0.28	1542 ft.	2.00
	B	Stub/Cap (Future)	8 in.	1200 ft.	0	0 GPM	0.0 FT/SEC	0.00	2272 ft.	1.72
	C	Pipe	10 in.	219 ft.	800,000	123 GPM	0.5 FT/SEC	0.01	1072 ft.	1.72
	D	Stub/Cap	8 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	863 ft.	1.71
	E	Pipe	12 in.	270 ft.	800,000	123 GPM	0.3 FT/SEC	0.01	853 ft.	1.71
1	F	Sacramento	4 in.	500 ft.	486,000	75 GPM	1.9 FT/SEC	0.84	1098 ft.	2.60
	G	Pipe	8 in.	15 ft.	4,327,000	666 GPM	4.2 FT/SEC	0.05	598 ft.	1.76
26	H	Lassen	6 in.	35 ft.	2,416,000	372 GPM	4.2 FT/SEC	0.16	633 ft.	1.92
37	I	Del Norte	4 in.	169 ft.	1,770,000	272 GPM	7.0 FT/SEC	3.11	2089 ft.	8.45
2	J	Riverfront	5 in.	25 ft.	0	0 GPM	0.0 FT/SEC	0.00	1945 ft.	5.34
	K	Pipe	6 in.	185 ft.	1,770,000	272 GPM	3.1 FT/SEC	0.47	1920 ft.	5.34
9	L	Shasta	6 in.	71 ft.	855,000	132 GPM	1.5 FT/SEC	0.05	1806 ft.	4.91
	M	Pipe	8 in.	185 ft.	2,625,000	404 GPM	2.6 FT/SEC	0.24	1735 ft.	4.86
	N	Stub/Cap (Future)	10 in.	1500 ft.	0	0 GPM	0.0 FT/SEC	0.00	3050 ft.	4.62
	O	Pipe	10 in.	503 ft.	2,625,000	404 GPM	1.6 FT/SEC	0.22	1550 ft.	4.62
91	P	Bookstore	6 in.	264 ft.	3,340,000	514 GPM	5.8 FT/SEC	2.19	2390 ft.	5.28
	Q	Pipe	12 in.	640 ft.	3,340,000	514 GPM	1.5 FT/SEC	0.18	1746 ft.	2.99
48	R	Riverside Hall	6 in.	355 ft.	2,259,950	348 GPM	3.9 FT/SEC	1.43	2062 ft.	11.85
36	S	Sequoia	8 in.	10 ft.	9,457,500	1,455 GPM	9.3 FT/SEC	0.14	1707 ft.	10.42
	T	Pipe	8 in.	250 ft.	11,717,450	1,803 GPM	11.5 FT/SEC	5.23	1697 ft.	10.28
56	U	Placer	6 in.	90 ft.	3,300,000	508 GPM	5.8 FT/SEC	0.73	1327 ft.	5.80
34	V	Tahoe	6 in.	184 ft.	2,750,000	423 GPM	4.8 FT/SEC	1.06	1233 ft.	3.85
	W	Pipe	12 in.	131 ft.	5,127,000	789 GPM	2.2 FT/SEC	0.08	583 ft.	1.71
95	X	AIRC	6 in.	180 ft.	5,382,000	828 GPM	9.4 FT/SEC	3.61	1568 ft.	6.56
	Y	Pipe	14 in.	227 ft.	5,382,000	828 GPM	1.7 FT/SEC	0.07	1388 ft.	2.95
40	Z	S Library	8 in.	37 ft.	3,106,700	478 GPM	3.1 FT/SEC	0.07	1198 ft.	2.94
	AA	Pipe	14 in.	112 ft.	8,488,700	1,306 GPM	2.7 FT/SEC	0.08	1161 ft.	2.87
42	AB	Solano Annex	2 in.	437 ft.	0	0 GPM	0.0 FT/SEC	0.00	721 ft.	1.15
	AC	Pipe	14 in.	123 ft.	14,578,700	2,243 GPM	4.7 FT/SEC	0.25	1049 ft.	2.79
39	AD	Amador	6 in.	77 ft.	3,520,000	542 GPM	6.1 FT/SEC	0.70	1003 ft.	3.24
	AE	Pipe	14 in.	483 ft.	18,098,700	2,784 GPM	5.8 FT/SEC	1.48	926 ft.	2.54
35	AF	Capistrano	6 in.	74 ft.	2,856,000	439 GPM	5.0 FT/SEC	0.46	517 ft.	1.51
	AG	Pipe	16 in.	103 ft.	20,954,700	3,224 GPM	5.1 FT/SEC	0.22	443 ft.	1.05
47	AH	Univ Union	6 in.	70 ft.	0	0 GPM	0.0 FT/SEC	0.00	1455 ft.	5.26
	AI	Pipe	12 in.	137 ft.	0	0 GPM	0.0 FT/SEC	0.00	1385 ft.	5.26
40	AJ	N Library	10 in.	56 ft.	9,928,000	1,527 GPM	6.2 FT/SEC	0.29	1304 ft.	5.55
	AK	Pipe	12 in.	445 ft.	9,928,000	1,527 GPM	4.3 FT/SEC	0.95	1248 ft.	5.26
13	AL	Humboldt	6 in.	135 ft.	1,500,000	231 GPM	2.6 FT/SEC	0.25	1172 ft.	5.02
	AM	Stub/Cap	6 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	1116 ft.	2.80
	AN	Pipe	12 in.	94 ft.	9,214,652	1,418 GPM	4.0 FT/SEC	0.18	1037 ft.	4.76
	AN1	Pipe	12 in.	200 ft.	7,714,652	1,187 GPM	3.4 FT/SEC	0.27	1237 ft.	5.03
14	AO	Santa Clara	2 in.	119 ft.	400,000	62 GPM	6.3 FT/SEC	4.06	1062 ft.	8.65
	AP	Pipe	12 in.	140 ft.	9,614,652	1,479 GPM	4.2 FT/SEC	0.28	943 ft.	4.59
	AQ	Pipe	12 in.	463 ft.	19,542,652	3,007 GPM	8.5 FT/SEC	3.47	803 ft.	4.31
	AR	Pipe (CP South)	20 in.	285 ft.	40,497,352	6,230 GPM	6.4 FT/SEC	0.69	340 ft.	0.83
11	AS	Alpine	4 in.	180 ft.	1,260,000	194 GPM	4.9 FT/SEC	1.77	1417 ft.	6.83
42	AT	Solano	6 in.	18 ft.	2,975,000	458 GPM	5.2 FT/SEC	0.12	302 ft.	1.27
	AU	(Cross Connection Pipe)	12 in.	66 ft.	3,154,652	485 GPM	1.4 FT/SEC	0.02	1303 ft.	5.07
	AV	Pipe	12 in.	400 ft.	8,562,798	1,317 GPM	3.7 FT/SEC	0.65	1447 ft.	5.05
43	AW	Mendocino	6 in.	107 ft.	2,890,000	445 GPM	5.0 FT/SEC	0.68	1154 ft.	5.08
	AX	Pipe	6 in.	65 ft.	2,975,000	458 GPM	5.2 FT/SEC	0.44	284 ft.	1.15
	AY	Pipe	12 in.	134 ft.	14,077,798	2,166 GPM	6.1 FT/SEC	0.55	1047 ft.	4.40
10	AZ	Calaveras	4 in.	145 ft.	750,000	115 GPM	2.9 FT/SEC	0.54	1111 ft.	4.97
	BA	Pipe	4 in.	53 ft.	1,332,400	205 GPM	5.2 FT/SEC	0.58	966 ft.	4.43
	BB	Pipe	12 in.	461 ft.	15,410,198	2,371 GPM	6.7 FT/SEC	2.23	913 ft.	3.85
4	BC	Douglass	3 in.	20 ft.	582,400	90 GPM	4.1 FT/SEC	0.19	1019 ft.	5.00
	BD	Pipe	14 in.	233 ft.	20,537,198	3,160 GPM	6.6 FT/SEC	0.90	452 ft.	1.62
	BE	Pipe	12 in.	57 ft.	3,340,000	514 GPM	1.5 FT/SEC	0.02	1106 ft.	2.80
	BF	Stub/Cap (Future)	12 in.	2000 ft.	0	0 GPM	0.0 FT/SEC	0.00	3746 ft.	2.99
7	BG	Kadema	6 in.	334 ft.	1,425,000	219 GPM	2.5 FT/SEC	0.57	967 ft.	2.49
92	BH	Mariposa	5 in.	63 ft.	3,810,000	586 GPM	9.6 FT/SEC	1.62	282 ft.	2.34
	BI	Pipe	12 in.	380 ft.	3,340,000	514 GPM	1.5 FT/SEC	0.11	2126 ft.	3.09
	BJ	Eureka	6 in.	123 ft.	1,500,000	231 GPM	2.6 FT/SEC	0.23	198 ft.	0.46
	BK	Pipe	16 in.	144 ft.	27,322,198	4,203 GPM	6.7 FT/SEC	0.50	219 ft.	0.72
	BL	**Pipe (CP TOTAL)**	24 in.	55 ft.	**69,319,550**	**10,665** GPM	**7.6** FT/SEC	0.15	55 ft.	0.15
	BM	Pipe (CP North)	16 in.	20 ft.	28,822,198	4,434 GPM	7.1 FT/SEC	0.08	75 ft.	0.22
	BN	Stub/Cap	10 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	593 ft.	1.71

Table 3B

Future Chilled Water Piping Load Information

	Green=Bldg		EWT: 53	LWT:	40 F	ΔT:	13 F			
	Red > 8.0 fps		CHILLED WATER							
	PIPE	BUILDING	PIPE SEGMENT						FROM CENTRAL PLANT	
BLDG #	SEG.	NAME	DIAMETER	LENGTH	BTUH	GPM	VELOCITY	ΔP (psi)	LENGTH	ΔP (psi)
33	A	Student Health Center	6 in.	470 ft.	800,000	123 GPM	1.4 FT/SEC	0.28	1542 ft.	2.95
	B	Stub/Cap (Future)	8 in.	1200 ft.	0	0 GPM	0.0 FT/SEC	0.00	2272 ft.	2.67
	C	Pipe	10 in.	219 ft.	800,000	123 GPM	0.5 FT/SEC	0.01	1072 ft.	2.67
	D	Stub/Cap	8 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	863 ft.	2.66
	E	Pipe	12 in.	270 ft.	800,000	123 GPM	0.3 FT/SEC	0.01	853 ft.	2.66
1	F	Sacramento	4 in.	500 ft.	486,000	75 GPM	1.9 FT/SEC	0.84	1098 ft.	3.54
	G	Pipe	8 in.	15 ft.	4,327,000	666 GPM	4.2 FT/SEC	0.05	598 ft.	2.70
26	H	Lassen	6 in.	35 ft.	2,416,000	372 GPM	4.2 FT/SEC	0.16	633 ft.	2.86
37	I	Del Norte	4 in.	169 ft.	1,770,000	272 GPM	7.0 FT/SEC	3.11	2089 ft.	14.01
2	J	Riverfront	5 in.	25 ft.	0	0 GPM	0.0 FT/SEC	0.00	1945 ft.	10.90
	K	Pipe	6 in.	185 ft.	1,770,000	272 GPM	3.1 FT/SEC	0.47	1920 ft.	10.90
9	L	Shasta	6 in.	71 ft.	855,000	132 GPM	1.5 FT/SEC	0.05	1806 ft.	10.48
	M	Pipe	8 in.	185 ft.	2,625,000	404 GPM	2.6 FT/SEC	0.24	1735 ft.	10.43
	N	Stub/Cap (Future)	10 in.	1500 ft.	6,500,000	1,000 GPM	4.1 FT/SEC	3.56	3050 ft.	13.74
	O	Pipe	10 in.	503 ft.	9,125,000	1,404 GPM	5.7 FT/SEC	2.24	1550 ft.	10.19
91	P	Bookstore	6 in.	264 ft.	3,340,000	514 GPM	5.8 FT/SEC	2.19	2390 ft.	10.59
	Q	Pipe	12 in.	640 ft.	13,340,000	2,052 GPM	5.8 FT/SEC	2.37	1746 ft.	8.30
48	R	Riverside Hall	6 in.	355 ft.	2,259,950	348 GPM	3.9 FT/SEC	1.43	2062 ft.	15.40
36	S	Sequoia	8 in.	10 ft.	9,457,500	1,455 GPM	9.3 FT/SEC	0.14	1707 ft.	13.97
	T	Pipe	8 in.	250 ft.	11,717,450	1,803 GPM	11.5 FT/SEC	5.23	1697 ft.	13.83
56	U	Placer	6 in.	90 ft.	3,300,000	508 GPM	5.8 FT/SEC	0.73	1327 ft.	9.35
34	V	Tahoe	6 in.	184 ft.	2,750,000	423 GPM	4.8 FT/SEC	1.06	1233 ft.	6.78
	W	Pipe	12 in.	131 ft.	5,127,000	789 GPM	2.2 FT/SEC	0.08	583 ft.	2.65
95	X	AIRC	6 in.	180 ft.	5,382,000	828 GPM	9.4 FT/SEC	3.61	1568 ft.	9.49
	Y	Pipe	14 in.	227 ft.	5,382,000	828 GPM	1.7 FT/SEC	0.07	1388 ft.	5.88
40	Z	S Library	8 in.	37 ft.	3,106,700	478 GPM	3.1 FT/SEC	0.07	1198 ft.	5.87
	AA	Pipe	14 in.	112 ft.	8,488,700	1,306 GPM	2.7 FT/SEC	0.08	1161 ft.	5.80
42	AB	Solano Annex	2 in.	437 ft.	0	0 GPM	0.0 FT/SEC	0.00	721 ft.	1.50
	AC	Pipe	14 in.	123 ft.	24,578,700	3,781 GPM	7.9 FT/SEC	0.67	1049 ft.	5.72
39	AD	Amador	6 in.	77 ft.	3,520,000	542 GPM	6.1 FT/SEC	0.70	1003 ft.	5.76
	AE	Pipe	14 in.	483 ft.	28,098,700	4,323 GPM	9.0 FT/SEC	3.35	926 ft.	5.05
35	AF	Capistrano	6 in.	74 ft.	2,856,000	439 GPM	5.0 FT/SEC	0.46	517 ft.	2.16
	AG	Pipe	16 in.	103 ft.	30,954,700	4,762 GPM	7.6 FT/SEC	0.45	443 ft.	1.70
47	AH	Univ Union	6 in.	70 ft.	0	0 GPM	0.0 FT/SEC	0.00	1455 ft.	5.68
	AI	Pipe	12 in.	137 ft.	0	0 GPM	0.0 FT/SEC	0.00	1385 ft.	5.68
40	AJ	N Library	10 in.	56 ft.	9,928,000	1,527 GPM	6.2 FT/SEC	0.29	1304 ft.	5.97
	AK	Pipe	12 in.	445 ft.	9,928,000	1,527 GPM	4.3 FT/SEC	0.95	1248 ft.	5.68
13	AL	Humboldt	6 in.	135 ft.	1,500,000	231 GPM	2.6 FT/SEC	0.25	1172 ft.	5.44
	AM	Stub/Cap	6 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	1116 ft.	5.93
	AN	Pipe	12 in.	94 ft.	9,214,652	1,418 GPM	4.0 FT/SEC	0.18	1037 ft.	5.18
	AN1	Pipe	12 in.	200 ft.	7,714,652	1,187 GPM	3.4 FT/SEC	0.27	1237 ft.	5.45
14	AO	Santa Clara	2 in.	119 ft.	400,000	62 GPM	6.3 FT/SEC	4.06	1062 ft.	9.07
	AP	Pipe	12 in.	140 ft.	9,614,652	1,479 GPM	4.2 FT/SEC	0.28	943 ft.	5.01
	AQ	Pipe	12 in.	463 ft.	19,542,652	3,007 GPM	8.5 FT/SEC	3.47	803 ft.	4.72
	AR	Pipe (CP South)	20 in.	285 ft.	50,497,352	7,769 GPM	7.9 FT/SEC	1.03	340 ft.	1.25
11	AS	Alpine	4 in.	180 ft.	1,260,000	194 GPM	4.9 FT/SEC	1.77	1417 ft.	10.38
42	AT	Solano	6 in.	18 ft.	2,975,000	458 GPM	5.2 FT/SEC	0.12	302 ft.	1.62
	AU	(Cross Connection Pipe)	12 in.	66 ft.	3,154,652	485 GPM	1.4 FT/SEC	0.02	1303 ft.	8.62
	AV	Pipe	12 in.	400 ft.	8,562,798	1,317 GPM	3.7 FT/SEC	0.65	1447 ft.	8.60
43	AW	Mendocino	6 in.	107 ft.	2,890,000	445 GPM	5.0 FT/SEC	0.68	1154 ft.	8.63
	AX	Pipe	6 in.	65 ft.	2,975,000	458 GPM	5.2 FT/SEC	0.44	284 ft.	1.50
	AY	Pipe	12 in.	134 ft.	20,577,798	3,166 GPM	9.0 FT/SEC	1.11	1047 ft.	7.95
10	AZ	Calaveras	4 in.	145 ft.	750,000	115 GPM	2.9 FT/SEC	0.54	1111 ft.	7.97
	BA	Pipe	4 in.	53 ft.	1,332,400	205 GPM	5.2 FT/SEC	0.58	966 ft.	7.42
	BB	Pipe	12 in.	461 ft.	21,910,198	3,371 GPM	9.6 FT/SEC	4.27	913 ft.	6.84
4	BC	Douglass	3 in.	20 ft.	582,400	90 GPM	4.1 FT/SEC	0.19	1019 ft.	8.00
	BD	Pipe	14 in.	233 ft.	27,037,198	4,160 GPM	8.7 FT/SEC	1.51	452 ft.	2.57
	BE	Pipe	12 in.	57 ft.	13,340,000	2,052 GPM	5.8 FT/SEC	0.21	1106 ft.	5.93
	BF	Stub/Cap (Future)	12 in.	2000 ft.	10,000,000	1,538 GPM	4.4 FT/SEC	4.34	3746 ft.	12.63
7	BG	Kadema	6 in.	334 ft.	1,425,000	219 GPM	2.5 FT/SEC	0.57	967 ft.	3.44
92	BH	Mariposa	5 in.	63 ft.	3,810,000	586 GPM	9.6 FT/SEC	1.62	282 ft.	2.68
	BI	Pipe	12 in.	380 ft.	3,340,000	514 GPM	1.5 FT/SEC	0.11	2126 ft.	8.40
	BJ	Eureka	6 in.	123 ft.	1,500,000	231 GPM	2.6 FT/SEC	0.23	198 ft.	0.56
	BK	Pipe	16 in.	144 ft.	33,822,198	5,203 GPM	8.3 FT/SEC	0.74	219 ft.	1.07
	BL	**Pipe (CP TOTAL)**	24 in.	55 ft.	**85,819,550**	**13,203** GPM	**9.4** FT/SEC	0.22	55 ft.	0.22
	BM	Pipe (CP North)	16 in.	20 ft.	35,322,198	5,434 GPM	8.7 FT/SEC	0.11	75 ft.	0.33
	BN	Stub/Cap	10 in.	10 ft.	0	0 GPM	0.0 FT/SEC	0.00	593 ft.	2.65

4 Low Voltage Systems

Executive Summary

This report provides an assessment of the existing Telecommunication Utility Backbone System and top recommendations for providing redundant pathways to each building on the California State University Sacramento (CSUS) campus.

Introduction

CSUS is an old campus comprised of old and new buildings. As the campus grows, so does the importance of voice and network services. Twenty years ago primary communication was handled via phones and the early beginnings of computer networks. Now it's hard to imagine any higher education facility without the integration of computer networking. As time goes on every facet of education relies more and more on robust communication infrastructures to support campus-wide networks. As the dependence on network communication grows, so does the need for a dependable voice and network backbone cabling connecting the campus together and allowing reliable trouble-free communication. With the success of California State University Sacramento comes growth, with growth comes planning and striving to design a backbone system that meets the needs of the campus and provides redundancies to keep the information flowing when accidental interruption happen to the network infrastructure.

This report addresses the current voice and network backbone infrastructure condition and what improvements can be made to reduce the impact of loss of service to buildings throughout the campus. Additionally, this report addresses the locations throughout the CSUS campus where buildings lack the redundancy of communication backbone connection to the network and voice switch HUB.

We will also examine the potential to provide additional pathways for service providers such as AT&T, Comcast, SureWest and other voice/data service providers. The concern is that not only are the campus buildings reliant on the connection to the main network HUB but also reliant on the connection provided by service providers for connecting to the outside internet world. Redundant or dual service to the campus from the service providers will reduce the impact of a catastrophic loss of service due to reasons outside of CSUS control.

In this report references will be made to Figures and Drawings that refer to building numbers that can be found on the numbered building schedule (Figure ?). The main campus map is broken up into quadrants in order to examining the campus wide backbone infrastructure in more detail.

Existing Infrastructure

Currently, as with most campuses like CSUS, there is a central building from which all cable and physical infrastructure extends to other buildings throughout the campus. This is known as a "Star Configuration" because all pathways start at a central location and extend outward to other buildings. At CSUS this building is building #95, the Academic Information Resource Center or AIRC. This building houses all major computing and voice switching needs. All companies that provide data and voice circuits to the CSUS campus bring their services to this building. Before computer networks where integrated on the CSUS campus, all service provider cable (AT&T/PacBell) came into Capistrano Hall building #35. In years past, large amounts of outside plant, service provider, multi-pair copper cable came into the basement of this building and was cross-connected to the CSUS campus owned cable distribution system. After the AIRC building was constructed, service provider copper and fiber optic cable was re-routed to the 3rd floor Network Operations Center (NOC).

Pathways

A. Utility Tunnel: There is an underground utility tunnel (See Figure 2C, 2D) that comes out of the Central Plant Building (Bldg. #32) and runs South on Moraga Way. It continues pass Sinclair Road, running parallel to Capistrano Hall (Bldg. #35) then heading diagonal in a Southeast direction between Amador Hall (Bldg. #39) and Library South (Bldg. #40). The tunnel then turns due East running between Library South and the AIRC building (Bldg. #95) and continues to the University Union building (Bldg. #47). The underground tunnel is approximately 8' tall by 8' wide, 1,600 feet long with racking and cable tray to accommodate routing cable and steam pipes throughout the campus.

B. Conduit Pathways: Various sizes of conduits enter and exit the tunnel along the way delivering copper and fiber optic cable to buildings throughout the campus. Conduits may enter underground manholes or vaults in order to change direction to enter a building. These manholes or vaults are identified on the drawing as CMH for Communication Manhole or CV for Communication Vault. Pull boxes may exist at various locations between these vaults and manholes to facilitate pulling additional cable in.

Cable

A. Copper Cable: Most buildings have outside plant multi-pair copper cable routed into the building. Various sizes of multi-pair cable runs to each building.

B. Fiber Optic Cable: Most buildings have outside plant multi-strand fiber optic cable routed into the building. Various sizes of multi-strand fiber optic cable runs to each building.

Service Providers

A. AT&T Services: AT&T has been providing voice and data services to CSUS for years. As previously mentioned, all AT&T voice services originally came into Capistrano Hall (see figure 2C, 2D). After the AIRC was completed, AT&T voice services were transferred to the NOC. AT&T connects their copper and fiber optic cable to the campus from Folsom Boulevard. The conduits run across a parking lot from Folsom Boulevard on the West side of the Capital Public Radio Building (Bldg. 108) and extend to an AT&T vault on State University Drive South. From there the conduits run along State University Drive until it reaches a vault, heads due East, along the side of Parking Structure 1 and into Capistrano Hall. There is another AT&T feed to the campus that extends from further down on Folsom Boulevard and across the East side of the Capital Public Radio Bldg. to State University Drive South. This pathway heads due East and connects with a CSUS CV69 at the corner of State University Drive South and State University Drive East. We are assuming the AT&T cable enters into the CSUS conduit system.

B. SureWest Services: SureWest provides their services to CSUS on the North East side of the campus (see figure 2B). They route their services underground from a pole on J Street to CMH39 in front of the Dinning Commons (Bldg 46). From CMH39 SureWest fiber enters the CSUS conduit system in order to make their way to the ARIC building.

Proposed Improvements to the Existing System

Now that Interface Engineering has investigated the existing Telecommunication Backbone Infrastructure System, we can make some recommendations in reference to helping CSUS reduce their exposure to voice and data system failure because of catastrophic events beyond their control. Whether it is failure due to natural circumstances or unforeseen construction errors, loss of voice and data service to an entire building can be devastating to the operation and function of other buildings throughout the campus. Therefore, in this section, Interface Engineering will address, recommend, and outline what we believe to be the best way to achieve a backbone network infrastructure that facilitates redundant pathways to individual buildings in case an interruption occurs there are options to quickly bring a building back on-line. In addition to addressing redundancy of individual CSUS buildings, Interface Engineering will recommend separate pathways for service providers such as AT&T and SureWest.

Service Providers

A. AT&T: Currently there are redundant pathways from AT&T into the CSUS campus. The problem with these pathways is that they both service the campus from Folsom Blvd. If AT&T had a catastrophic failure on Folsom Blvd. the entire AT&T service to the campus could become disconnected (see figure 2D). Ideally, it would be best to have AT&T bring a second pathway into the CSUS campus off J Street.

B. SureWest: SureWest brings their service to the CSUS campus off J Street. Their connection comes off a pole that is located very close to the J Street Bridge. From there the conduits are routed underground between the Dinning Commons (Bldg #46) and Jenkins Hall (Bldg #17) and into CMH39. From CMH39, SureWest enters into the CSUS owned conduit system and routes their connections to AIRC (Bldg #95). Similarly, CSUS should request that SureWest bring an additional service to the CSUS campus from the Folsom Boulevard corridor in order to facilitate a redundant backup to their current service.

CSUS Buildings

A. AIRC Building (Bldg #95): THIS IS THE MOST IMPORTANT BUILDING ON CAMPUS in reference to voice and data distribution. This is the hub, the Network Operation Center (NOC) and ironically enough, there are NO redundant pathways into this building. The pathway into the AIRC building is via the Utility Tunnel. While there is ample space in the tunnel, there are other utilities like steam and chilled water. If ever there is a failure in the steam pipe it could damage the communication cable directly under the steam pipes. It is imperative that CSUS develop another pathway into the AIRC building to avoid such damage. The connection to the AIRC building is on the North side. We recommend there be another redundant pathway established into the building on the South side. Interface Engineering recommends installing a minimum of eight (8) 4" conduits out of the South side of the AIRC building and routing them to CMH29 in front of Benicia Hall (Bldg#62). This would be on the opposite side of the ARIC building from where the tunnel entrance is located, giving a complete separate redundant entrance into the AIRC building. This would ensure that CSUS would have options in the event of catastrophic failure.

B. CSUS Campus buildings: Other buildings on campus communicate with the AIRC building through a massive underground conduit system. This system is shown on Figures 2A-2D.

Figure 4.1

Overall Proposed Technology Distribution Plan

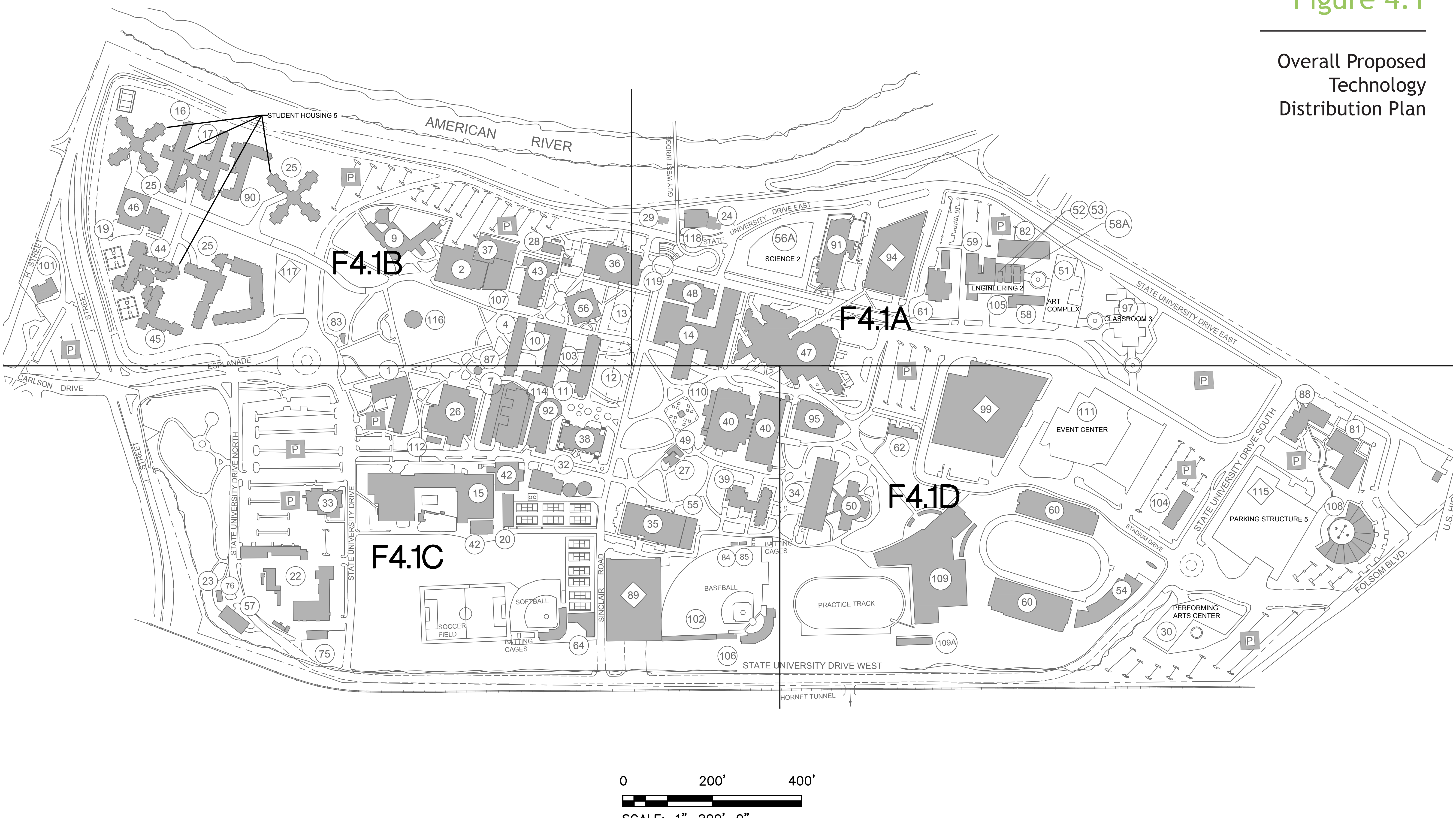


Figure 4.1A

Partial Proposed Technology Distribution Plan

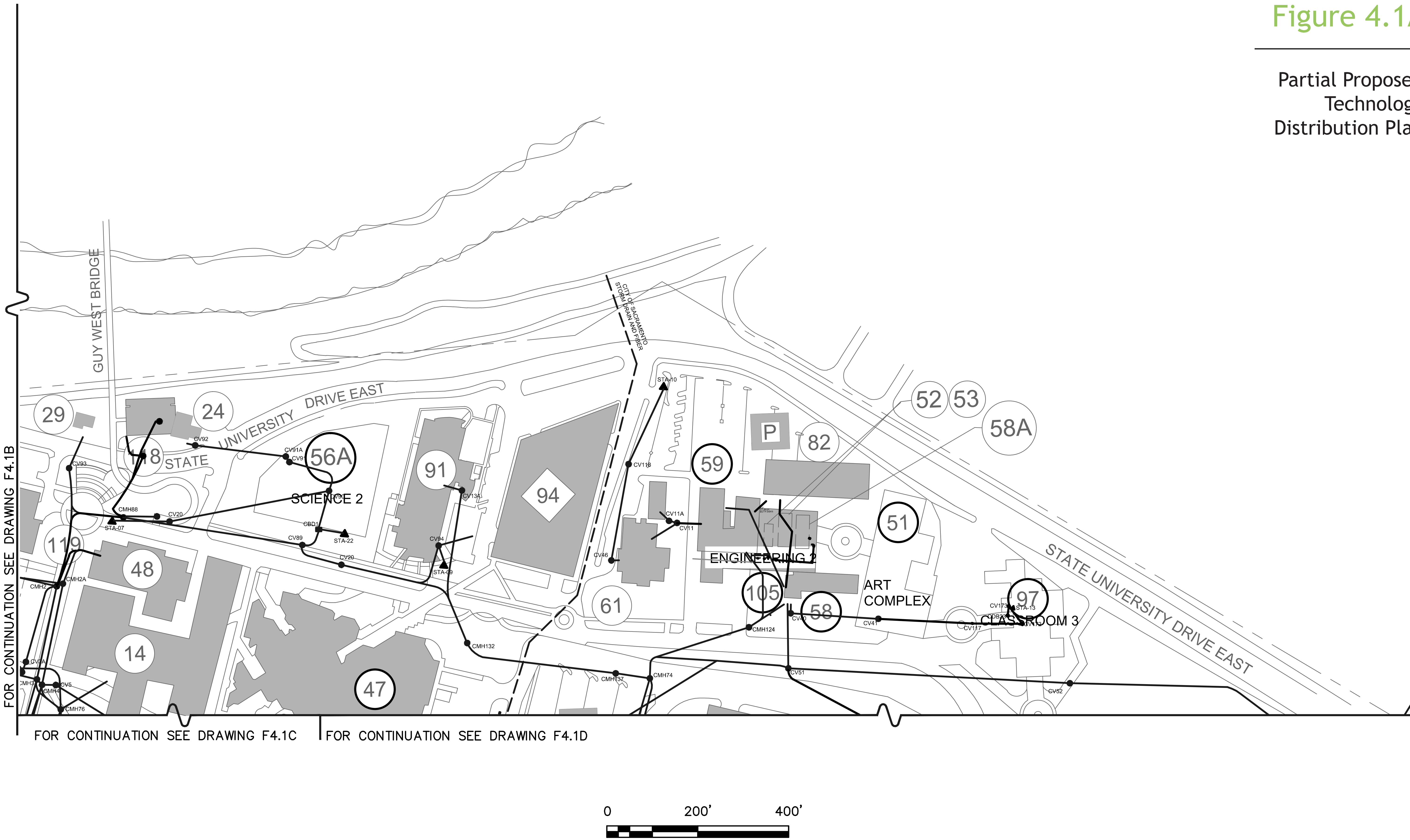


Figure 4.1B

Partial Proposed Technology Distribution Plan

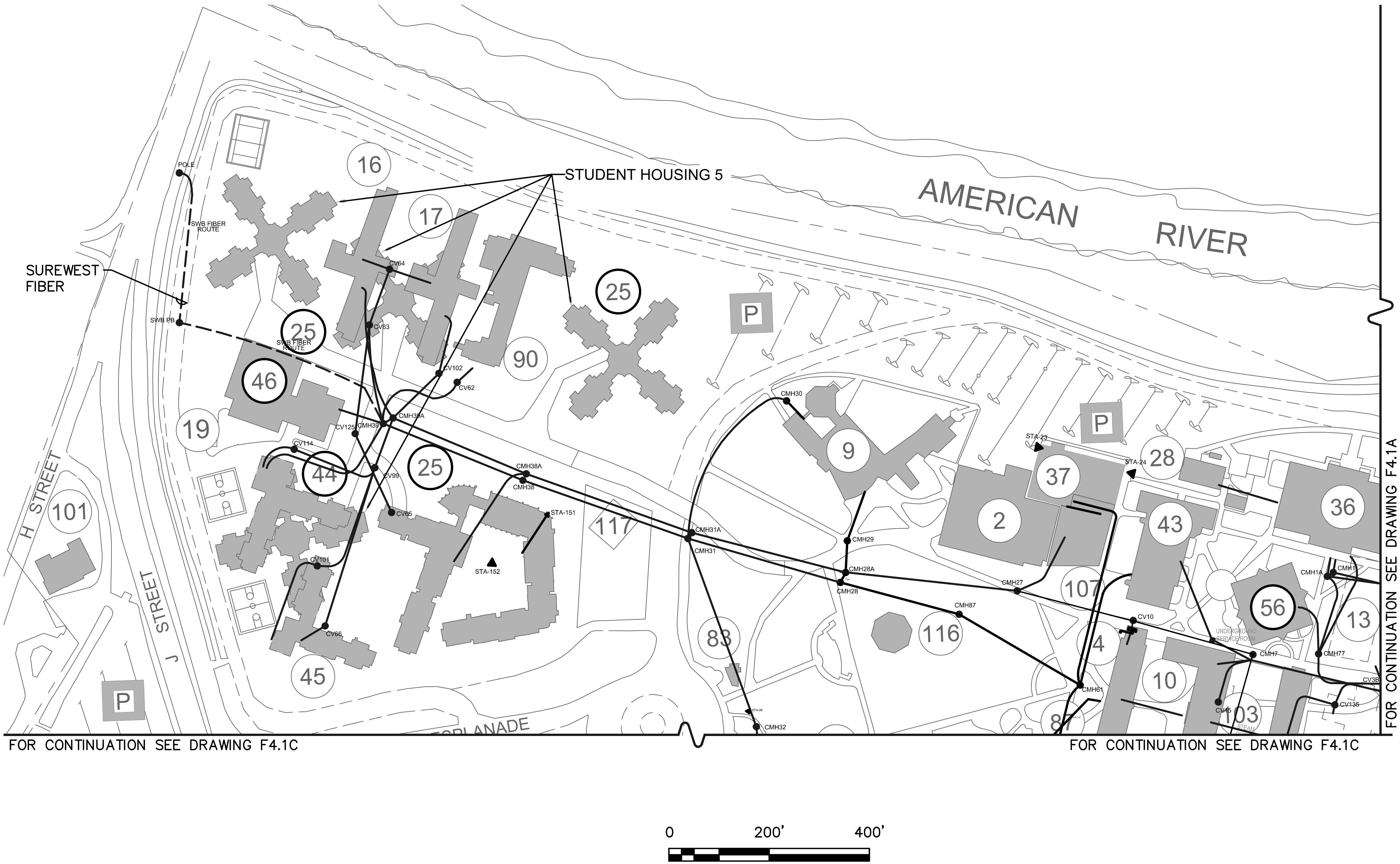


Figure 4.1C

Partial Proposed Technology Distribution Plan

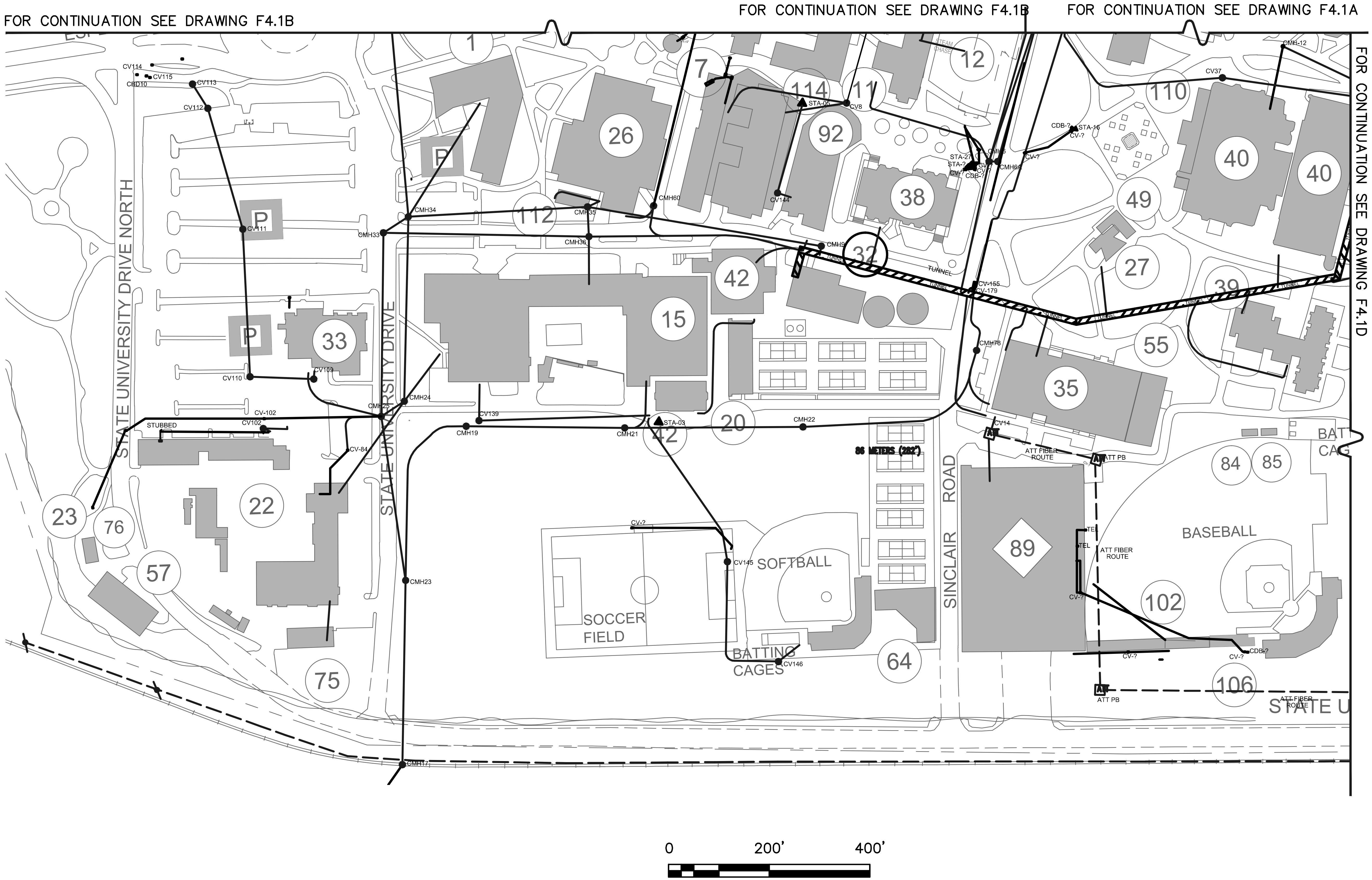


Figure 4.1D

Partial Proposed Technology Distribution Plan

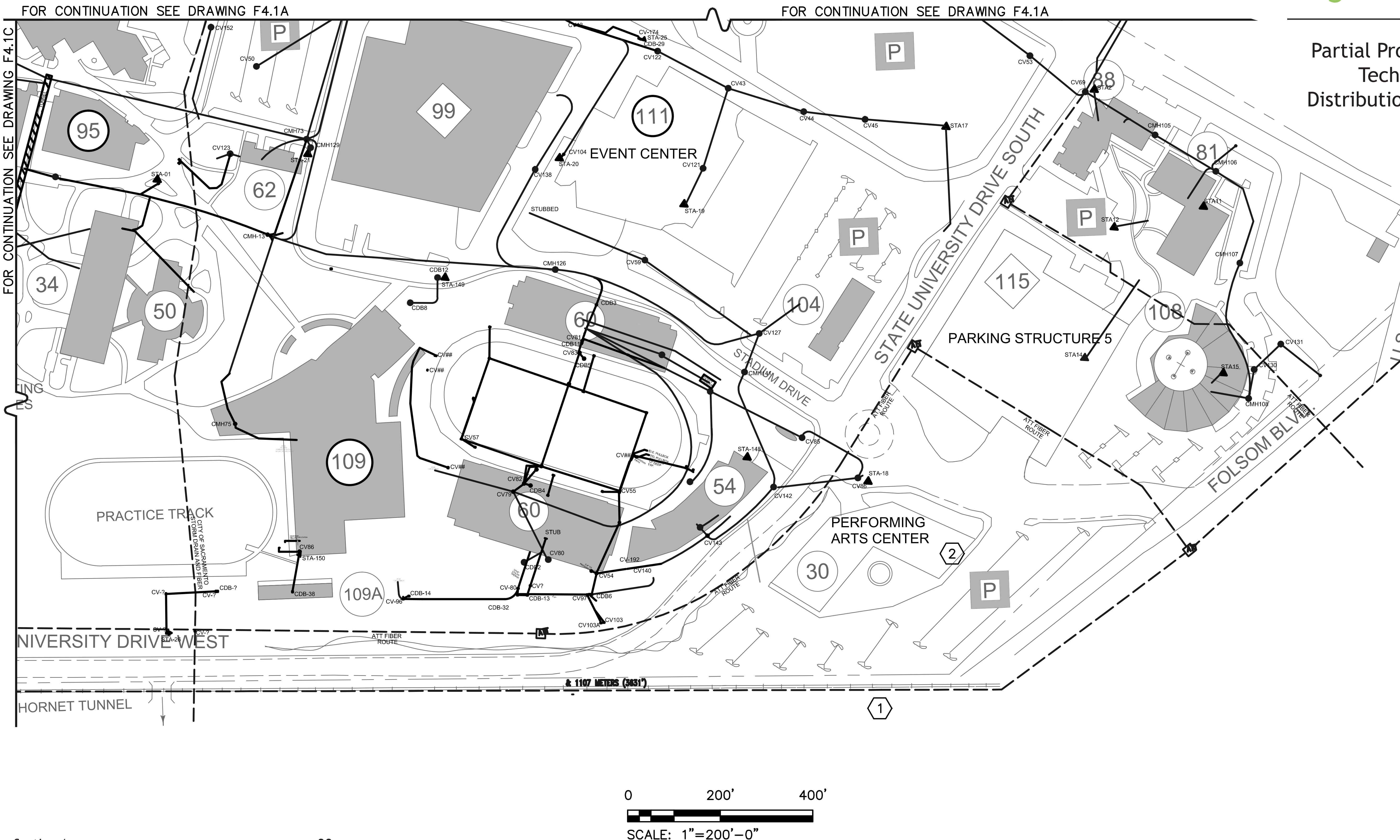


Table 4A

Technology Master Building List

CSUS MASTER BUILDING LIST - TECHNOLOGY									
BLDG #	ABR.	BUILDING NAME	Single Entrance	Multiple Entrance	CVXX/CMHXX	North	East	South	West
1	SAC	SACRAMENTO HALL	X		CMH34				X
2	RFC	RIVER FRONT CENTER	X		CMN27				X
4	DH	DOUGLAS HALL	X		CV10				
7	KDM	KADEMA HALL	X		CV8			X	
9	SHS	SHASTA HALL		X	CMN30/CMN29	X		X	
10	CLV	CALAVERAS HALL	X		CMN13			X	
11	ALP	ALPINE HALL	X		CMH6				X
12	BRH	BRIGHTON HALL	N/A	N/A					
13	HMB	HUMBOLDT HALL	X		CMN77	X			
14	SCL	SANTA CLARA HALL	X		CMH76	X			
15	YSM	YOSEMITE HALL (NORTH & SOUTH)		X	CMN36/CMN21/CV139		X		X
16	DRP	DRAPER HALL	X		CV64			X	
17	JNK	JENKINS HALL	X		CV64	X			
19	-	RESIDENCE HALL RECREATION FACILITY	N/A	N/A					
20	-	HANDBALL COURTS	X		TUNNEL		X		
22	-	FACILITIES SERVICES		X	CV84/CMN24				X
23	-	STORAGE BUILDING	N/A	N/A					
24	-	HAZARDOUS MATERIAL MGMT. BLDG.	X		CV92			X	
25	-	AMERICAN RIVER COURTYARD	N/A	N/A					
26	LSN	LASSEN HALL	X		CMN60				X
27	STH	OUTDOOR THEATER	X		TUNNEL				X
28	GRN	GREENHOUSES	X		CMN77			X	
29	EHS	ENVIRONMENTAL HEALTH & SAFETY	X		CV93				X
31	-	HORNET FOUNDATION OFFICES	N/A	N/A					
32	CP	CENTRAL PLANT	X		TUNNEL	X			
33	SHC	STUDENT HEALTH CENTER	X		CV109				X
34	TAH	TAHOE HALL	X		(3) TUNNEL				X
35	CPS	CAPISTRANO HALL		X	CV179/CMN178/CV14/ (2) TUNNEL	X	X	X	
36	SQU	SEQUOIA HALL		X	CMH1/CMN1A				X
37	BK	DEL NORTE HALL	X		CMN61			X	
38	EUR	EUREKA HALL	X		TUNNEL				X
39	AMD	AMADOR HALL		X	(2) TUNNEL		X		X
40	LIB	LIBRARY NORTH/SOUTH		X	CMN12/TUNNEL		X		X
41	FH	FIELD HOUSE	X		CV41	X			
42	SLN	SOLANO HALL	X		TUNNEL			X	
43	MND	MENDOCINO HALL	X		CMN3				X
44	SRA	SIERRA HALL	X		CMN38A		X		
45	STR	SUTTER HALL	X		CMN38A		X		
46	DC	DINING COMMONS	X		CMN39			X	
47	UU	UNIVERSITY UNION	X		TUNNEL				X
48	RVR	RIVERSIDE HALL	X		CMN2A	X			
49	-	FOOD SERVICE-OUTPOST	N/A	N/A					
50	-	CLASSROOM LABORATORY BUILDING	X		TUNNEL				X
51	-	ART COMPLEX	N/A	N/A					
52	-	SAC CITY UFD SCHOOL DISTRICT	X		CV40			X	

Table 4A

cont.

Technology Master Building List

BLDG #	ABR.	BUILDING NAME	Single Entrance	Multiple Entrance	CVXX/CMHXX	North	East	South	West
53	-	OFFICE OF EDUCATION	X		CV40			X	
54	-	ELI AND EDYTHE BROAD - ATHLETIC FIELD HOUSE	X		CV143			X	
55	-	CAPISTRANO HALL ADDITION	N/A	N/A					
56	PLR	PLACER HALL	X		CMN77			X	
57	-	STORAGE BUILDING	N/A	N/A					
58	PSB	PUBLIC SERVICES	X		CV40			X	
59	ELD	EL DORADO HALL	X		CV40			X	
60	-	HORNET STADIUM	X		CMH126		X		
61	CCC	CHILD DEVELOPMENT CENTER	X		CVH73			X	
61A	CCC	CHILD DEVELOPMENT CENTER ANNEX	X		CVIIA			X	
62	BNC	BENICIA HALL	X		CMN				
65	-	FOLSOM HALL	N/A	N/A					
73	-	WAREHOUSE	N/A	N/A					
75	-	RECEIVING	N/A	N/A					
81	MDC	MODOC HALL	X		CMN106		X		
82	ASL	ART SCULPTURE	X		CV40				X
83	-	BUS STOP CAFÉ	X		CMN31	X			
87	RND	ROUND HOUSE VENDING	N/A	N/A					
88	NPA	NAPA HALL	X		CV69	X			
89	PSI	PARKING STRUCTURE I	X		CV143		X		
90	DSM	DESMOND HALL	N/A	N/A					
91	-	HORNET BOOKSTORE/UEI OFFICES	X		CV134			X	
92	MRP	MARIPOSA HALL	X		TUNNEL				X
94	PSII	PARKING STRUCTURE II	N/A	N/A					
95	AIRC	ACADEMIC INFORMATION RESOURCE CENTER	X		TUNNEL	X			
97	-	CLASSROOM BUILDING III	X		CV72	X			
99	PSIII	PARKING STRUCTURE III	X		CV138			X	
101	-	CITY FIRE STATION	N/A	N/A					
102	-	BASEBALL STORAGE FACILITY PHASE II	N/A	N/A					
103	-	THEME STRUCTURE	N/A	N/A					
104	AC	ALUMNI CENTER	X		CV127	X			
105	-	ENGINEERING II	X		CMH104				X
106	-	BASEBALL STORAGE FACILITY	N/A	N/A					
107	-	CSUS FOUNDATION - FOOD SERVICE BUILDING	X		CMN27				X
108	CPR	CAPITAL PUBLIC RADIO	X		CMN108			X	
109	-	THE WELL	X		CMN13	X			
110	-	LIBRARY ADDITION/REMODEL	N/A	N/A					
111	-	EVENT CENTER	N/A	N/A					
112	TMP	SACRAMENTO HALL ANNEX	X		CMN35			X	
114	-	CLASSROOM BUILDING IV	X		CV8				X
115	-	PARKING IV	N/A	N/A					
116	-	GAZEBO	N/A	N/A					
117	-	PARKING STRUCTURE V	N/A	N/A					
118	-	CAFÉ	X		CMH88				X
119	-	OUTDOOR AMPHITHEATER	N/A	N/A					

5 Domestic Water

Executive Summary

The CSUS campus domestic water studies performed in 1966, 1989 and 2007 provide valuable information with respect to the current state of the domestic water system. Omni-Means reviewed these studies, extracted relevant historical data, and summarized key points in the report below.

The domestic water infrastructure at CSUS is adequate for the current state of the campus. The close proximity of the Fairbairn Water Treatment Plant ensures that the system has sufficient volume to meet the required domestic water needs and fire flows. There are; however, improvements that should be made to develop a more robust and efficient system. Aged pipes and undersized water mains have been identified and should be replaced as future buildout occurs or as separate capital improvements.

The majority of the domestic water supply comes from the Fairbairn service connection, with very little coming from the North Campus connection. This creates an unbalanced water distribution, with higher flows and pressures in the South Campus. An improved distribution will require modifications to the North Pump station as well as replacing select undersized main lines in the North Campus.

In 1966, Kennedy Engineers estimated that an ultimate student enrollment of 20,000 will yield an average daily water use of 660,000 gpd by 1985 (Kennedy, p. 1, 4). However, in 1989, Boyle Engineering reported an average daily water use of only 207,000 gpd for the 1986/87 school year (Boyle, 2-5). According to recent CSUS records, domestic water usage for fiscal years 2002 through 2011 ranged from 190,000 gpd to 214,000 gpd. A reasonable estimation of 10 gpd per capita yields a total daily flow of 250,000 gpd (25,000 full time equivalent students and faculty). This is consistent with the water usage records over the past eight years, as well as with the 1985 study.

The next step in the utility master plan process is to create a hydraulic computer model to provide a more detailed understanding of water distribution on the campus; which will aid in determining more focused capital improvement projects and serve as a tool for future building construction and for determining effects of the associated water demands. A hydraulic computer model allows users to simulate the campus water facilities at multiple rates of flow. Demand scenarios at specific locations can be simulated, observing the effects on pressure at any location in the hydraulic model. As each new development enters the design phase, appropriate analysis and actual fire flow tests as required by the State Fire Marshall will need to be conducted.

Introduction

This report has been prepared based on previous studies, data made available from CSUS and conversations with the City of Sacramento. The data received is not exhaustive or comprehensive. Any additional information may alter the conclusions of this report. The utility master plans from 1966 and 1989 were studied and analyzed as a baseline starting point for understanding the historic record of the campus domestic water system. The 2007 Domestic Water Study provides an analysis of future buildout projects, including the recently constructed WELL and Broad Athletic Facility.

Combining this information with data and CAD drawings from CSUS, a final assessment was performed and several recommendations have been made regarding future development and next steps for further development of the domestic water master plan.

Previous Studies

Each study is summarized below with pertinent information paraphrased. These summaries are written in the present tense to reflect what was true at the date each report was written. The following section titled “Summary of Existing Conditions” combines the information in each report with true present day data and field observations to establish which recommended improvements were actually constructed and the issues that remain.

1966 UTILITY MASTER PLAN (KENNEDY ENGINEERS)

The entire CSUS water service is supplied by a 14” City of Sacramento main that enters at the northwest corner of the campus. The residence halls receive their fire protection from irrigation wells adjacent to Draper Hall. All water service laterals were constructed in 1952 and 1953 of steel pipe. If the pressure at the supply meters is 40 psi or more, the campus should have sufficient head. However, hydraulic analysis shows deficiencies in fire flows in a number of locations. The most critical of these deficiencies is near the engineering building and future science building. 1500-2500 gpm is considered adequate fire flow.

With the aid of fire engine pumpers to boost hose pressure to the required "standard fire stream" of 250 gpm through a 1-1/8" nozzle with 45 psig at the base, the City of Sacramento requires a minimum main pressure at the hydrant of 20 psig. The Fire Marshall recommends 2500 gpm fire flow, 20 psig pressure and 300 feet hydrant spacing.

The average daily water usage for a full school day of 150,000 gpd is expected to jump to over 800,000 gpd by 1985 (Kennedy, p. 4), assumedly corresponding to an ultimate student enrollment of 20,000 full-time equivalent students (Kennedy, p. 1). Certain portions of the North campus do not have adequate fire flow. The fire flows provided by the hydro-pneumatic pump to the dormitories are also inadequate.

A number of improvements have been proposed by Kennedy Engineers. Notable is the proposal to disconnect the dormitory fire service from the irrigation lines and connect it to the City domestic water service. Also significant is the new water service main from the adjacent American River Water Filtration Plant. The City of Sacramento plans to build a new 24" main along the levee bordering the campus and across the American River to service future development. The campus will tie into this 24" main and service the future South Campus expansion as well as the existing dorms in the North Campus.

1989 UTILITY MASTER PLAN UPDATE (BOYLE ENGINEERING CORP.)

Water service to the CSUS campus is provided by three (3) City of Sacramento water meters. These water mains range in size from 6" to 14" in diameter and are made up of asbestos cement and steel.

Of the 32 fire hydrants tested, 20 had flow rates below 1,000 gpm and were painted yellow. 12 fire hydrants had flow rates above 1,000 gpm and were painted green. The service inspection performed by Nor-cal Fire Control in February of 1988 determined that the library, music and psychology buildings had problems in the dry stand pipe system. While some water pressures on campus were as low as 35 psi, most pressures were between 43 and 45 psi.

Flow data was analyzed based on the City mains as well as on individual meters located at the Food Service Building, Dormitories, University Union, Bookstore and Child Care. The existing average daily flow rate of 143.6 gpm is expected to increase to 311 gpm with the development of future buildings and the demolition of some existing buildings. Future maximum day flow rate is 809 gpm and future peak hour flow rate is 1,244 gpm.

Required fire flows were calculated based on requirements from the State Fire Marshal. The calculations determined that "if the existing campus system can provide the 4000 gpm fire flow demand, with a minimum residual pressure of 20 psi, then it will certainly meet the smaller flow demands which were calculated for other existing buildings" (Kennedy, 2-8). The future system will require a maximum fire flow demand of 5750 gpm, or 4312 gpm with the addition of automatic building fire sprinklers.

A computer model of the campus water system was compiled using the Hazen-Williams formula. Several scenarios were run to determine flow rates as they corresponded to pressure in the system. Deficiencies in the existing system led to 5 options for providing additional fire flow capacity. These options range from the installation of parallel pipes and a booster pump system to modifications of the existing pump station at the American River Water Treatment Plant.

2007 DOMESTIC WATER STUDY (TAYLOR SYSTEMS ENGINEERING, INC.)

This study analyzed the integration of the WELL, the Event Center and the Broad Athletic Facility into the CSUS domestic water system. The following future buildings were also considered: Performing Arts Center, Classroom III, Arts Complex, Parking Structure IV and Engineering II.

99% of the campus water usage is supplied by a 12-inch main from the City's E.A. Fairbairn Water Treatment Plant at the southeast corner of the campus. The remaining 1% of water usage is supplied by a 14-inch main that ties into the City's Discovery Park Pump Station at the northwest corner of the campus. An un-metered ¾-inch service connects the 60-inch Folsom Blvd. main to the Recycle Center.

A 12" main exits the North Campus by the dormitories to service the River Park Community on the north side of J Street. The River Park Community is not part of CSUS.

Taylor Engineering notes that the architectural footprints of the future Engineering II and Classroom III buildings in the south campus conflict with existing water lines. These water lines will need to be relocated.

Taylor Engineering drew the following conclusions (Taylor, p. 7):

1. Assuming reasonable accuracy for the estimations of water demand for future buildings, the existing and

proposed domestic water piping distribution is sized to sufficiently handle growth in the south campus.

2. The South Pump Station is capable of providing the increased domestic water flow rate to accommodate the south campus expansion.
3. The option of adjusting the domestic water control to increase supply from the North Pump Station should be considered.

Summary of Existing Conditions

DAILY WATER USAGE

In 1966, Kennedy Engineers estimated that an ultimate student enrollment of 20,000 will yield an average daily water use of 660,000 gpd by 1985 (Kennedy, p. 1, 4). In 1985, Boyle Engineering reported 75,470,738 gallons for the 1986/87 school year, or 207,000 gpd (Boyle, 2-5). According to recent CSUS records, domestic water usage for fiscal years 2002 through 2011 ranged from 190,000 gpd to 214,000 gpd.

There are a number of reasons why the 1966 projected increase did not occur. One reason may be the increased awareness of the need for water conservation and sustainability practices. Water efficient fixtures with auto flow shutoff for faucets are now the norm with any project. This drop in projected water usage may also be due to the campus evolving into a commuter campus rather than a campus with a higher number of on-campus residences.

A reasonable estimation of 10 gpd per capita yields a total daily flow of 250,000 gpd (25,000 full time equivalent students and faculty). This is consistent with the water usage records over the past eight years, as well as with the 1985 study.

PROJECTED PEAK WATER DEMAND OF SOUTH CAMPUS

The expansion of the South Campus is currently underway. The following projects studied in the 2007 Taylor study have been completed: Recreation Wellness Events Center (WELL), Broad Athletic Facility and Hornet Stadium. The table below displays the estimated water demands for the remaining future buildings. Taylor's estimates are shown alongside the more recent estimates from Interface Engineering. The following caveat from the 2007 Taylor Study remains valid:

> "It is recommended that the City of Sacramento Fire Department be consulted with regard to peak water flow demand. The fire protection water demands shown…are estimations only, and the fire department is responsible for providing actual required values. Also, consult the Campus insurance carrier as they have provisions for required fire protection water flow rates." (Taylor, p. 6)

Projected Peak Water Demand of South Campus

Building	2007 Fire Protection by Taylor (gpm)	2007 Potable Water by Taylor (gpm)	2012 Potable Water by Interface Engineering (gpm)
Event Center	1,000	110	280
Performing Arts	750	140	130
Classroom III	750	140	250
Arts Complex	750	80	100
Engineering II	750	105	170
TOTALS		**575**	**930**

EXISTING PRESSURE AND FLOWS

The existing system is currently adequate for providing required fire flows and pressure. However, some of the pipes are aged and undersized, resulting in uneven distribution throughout campus. The North Campus (north of Sinclair) is mostly networked 6" water lines with a few 4" and 8" water lines. The South Campus (south of Sinclair) is mostly networked with 10" and 12" water lines, with some 8" water lines. Replacement of aged and undersized pipes should be coordinated with efforts to improve overall water distribution.

The 2007 Taylor study reports two entrances for domestic water from the City and one exit from CSUS. According to Taylor, water enters CSUS at the southeast end of campus from the Fairbairn Water Treatment Plant and at the northwest end from the City's Discovery Park Pump Station. Water from the public 14" main entering at the northwest end of campus travels east through campus and then exits toward the north through the residence halls. This public 14" water line leaves the CSUS campus north boundary and provides the River Park residential community with its only supply of domestic water.

In a memorandum dated November 22, 2011, the City of Sacramento reports two service connections to CSUS: one at the southeast end of campus adjacent to the Fairbairn Water Treatment Plant and the other at the northeast end of campus adjacent to the dormitories and J Street. The latter is inconsistent with the findings of the 2007 Taylor study, reporting this as an exit point. Both of these service connections are reported to have a static pressure of approximately 46.5 psi (See Appendix for City of Sacramento Memorandum).

There are two booster pumps currently serving CSUS. One is in the North Campus adjacent to Shasta Hall, currently operating at 58 psi according to CSUS records (e-mail received 2/8/12). The other is near Lot 7 adjacent to the water main supplied from the Fairbairn Water Treatment Plant in the South Campus, currently operating at 62 psi (e-mail received 2/8/12). At the South Campus Pump Station, CSUS reported a pressure of 35 psi (lowest observation) from the Fairbairn Water Treatment Plant (e-mail received 2/8/12). This is low in comparison to pressures given in the water model from the memorandum received from the City of Sacramento. Some losses are expected between the backflow preventer, water meter, fittings and booster pump stations.

WORST CASE SCENARIOS

Taylor Systems Engineering conducted an analysis that considered the required fire flow at the WELL the worst case scenario with the highest fire protection water demand (1,750 gpm). The fire protection water demand at the WELL was added to the potable water demands for the South Campus buildout (985 gpm) and to the existing campus water demand (500 gpm). This yielded a worst case scenario of 3,235 gpm domestic water and fire flow demand. Given that the capacity of the South Campus is approximately 5,000 gpm at 15 fps (Taylor, p. 3), Taylor considered the water supply for the South Campus to be sufficient for future buildout.

However, in the 1989 Boyle study the Library was reported to have a fire protection water demand of 4,388 gpm. If this fire flow requirement is still accurate, the worst case scenario for the South Campus should be the fire flow at the Library, not the WELL. Using the Library fire flow as the worst case scenario (4,388 gpm), combined with the recently constructed WELL, Field House and Hornet Stadium (410 gpm), the "existing" South Campus domestic flow in 2007 (500 gpm), and the remaining future buildings (930 gpm), yields a total domestic water demand plus fire flow of 6,228 gpm. This total flow exceeds the current 5,000 gpm capacity of the South Campus. While there is probably sufficient capacity for the current state of the South Campus, at buildout some modifications will need to be made (assuming this scenario is still valid). As described below, an improved distribution between the North and South Campus service connections meet the buildout needs for domestic water usage and fire flow demand at the Library.

Proposed Improvements

REPLACE AGED AND UNDERSIZED WATER MAINS

Water distribution can be improved by upsizing the old 6" mains to 12" (primarily in the North Campus). See Appendix for exhibit showing proposed improvements. A number of existing domestic water facilities will also need to be relocated due to conflicts with future building locations. These future building projects should be used to relocate water mains into roadways, with adequate size and hydrant spacing. As each new development enters the design phase, appropriate analysis and actual fire flow tests as required by the State Fire Marshall will need to be conducted. A schedule of proposed replacements will be completed after completion of water main investigations currently under review by campus staff.

NORTH PUMP STATION

Improved distribution for the entire campus will require upgrades to or replacement of the North Pump Station.

With a pumping capacity of approximately 1,600 gpm (Taylor, p. 4), the existing North Pump Station is smaller in size and capacity than the South Pump Station (Taylor, p. 4), and serves 6" and 8" water mains. Upgrading to 12" water mains will require greater pumping capacity from the North Pump Station for a more balanced distribution throughout campus.

IMPROVED DISTRIBUTION

While it has been verified that there is sufficient water supply from the City to meet the current domestic water and fire flow demands of the campus, the majority of the water supply is coming from the Fairbairn Water Treatment Plant. In the event of an emergency causing the Fairbairn connection to shut down or lose some of the water supply, the existing campus water distribution system is not adequate to provide all flows from the North City service connection. A better balanced system with improved distribution will help to ensure that the campus water supply can remain functional in the event that the Fairbairn connection is compromised. The 2007 Taylor Study corroborates this conclusion, adding "It would also be more energy efficient as each pump station would be close to the geographic area it serves" (Taylor, p. 7).

Ultimate Master Plan Build Oout

According to the overall Campus Master Plan, there is a number of expansion projects expected to take place in the relatively near future. See Exhibit W-1 for details. As each new development enters the design phase, appropriate analysis and actual fire flow tests as required by the State Fire Marshall will need to be conducted. Water mains shown on the water improvement exhibit are preliminary, and are shown for planning purposes only.

Capital Improvement Program

A preliminary cost estimate has been prepared for each of the proposed domestic water improvements listed below (See Appendix). These cost estimates are for planning purposes and are subject to change based on fluctuations in the market and unforeseen design issues.

1. NORTH CAMPUS WATER MAIN DISTRIBUTION IMPROVEMENTS

As described in the Proposed Improvements section, this will entail upsizing old water mains and possible modifications to the North Pump Station.

2. VALVE INSTALLATIONS AND WATER MAIN ISOLATION (TO BE DETERMINED AT A LATER DATE)

In order to effectively isolate certain water mains, valves will need to be installed in various locations.

3. REDUNDANT BACKFLOW PREVENTER AT CITY METER CONNECTIONS

Redundant backflow preventers at City meter connections will serve to ensure that proper inspection and maintenance can be performed on backflow prevention devices without disrupting water flow to campus.

Further Action Items

HYDRAULIC COMPUTER MODEL

The next step in the utility master plan process is to create a hydraulic computer model to provide a more detailed understanding of water distribution on campus; which will aid in determining more focused capital improvement projects and serve as a tool for future building construction and the associated water demands. A hydraulic computer model allows users to simulate the campus water facilities at multiple rates of flow. Demand scenarios at specific locations can be simulated, observing the effects on pressure at any location in the hydraulic model. As each new development enters the design phase, appropriate analysis and actual fire flow tests as required by the State Fire Marshall will need to be conducted.

WATER ISOLATION MAP

Omni-Means is currently working on a water line isolation application with a GIS based geographical interface. This application will enable CSUS facilities management to identify the valves that must be closed to isolate a selected water line for maintenance or in the event of an emergency. After review of the available data sources, campus resources, and technologies, it has been determined that a GIS data base would be best developed using ArcGIS Server. As a separate task, this water line isolation application can be made available to CSUS facilities management staff over the facilities management network system or the internet to any internet ready device.

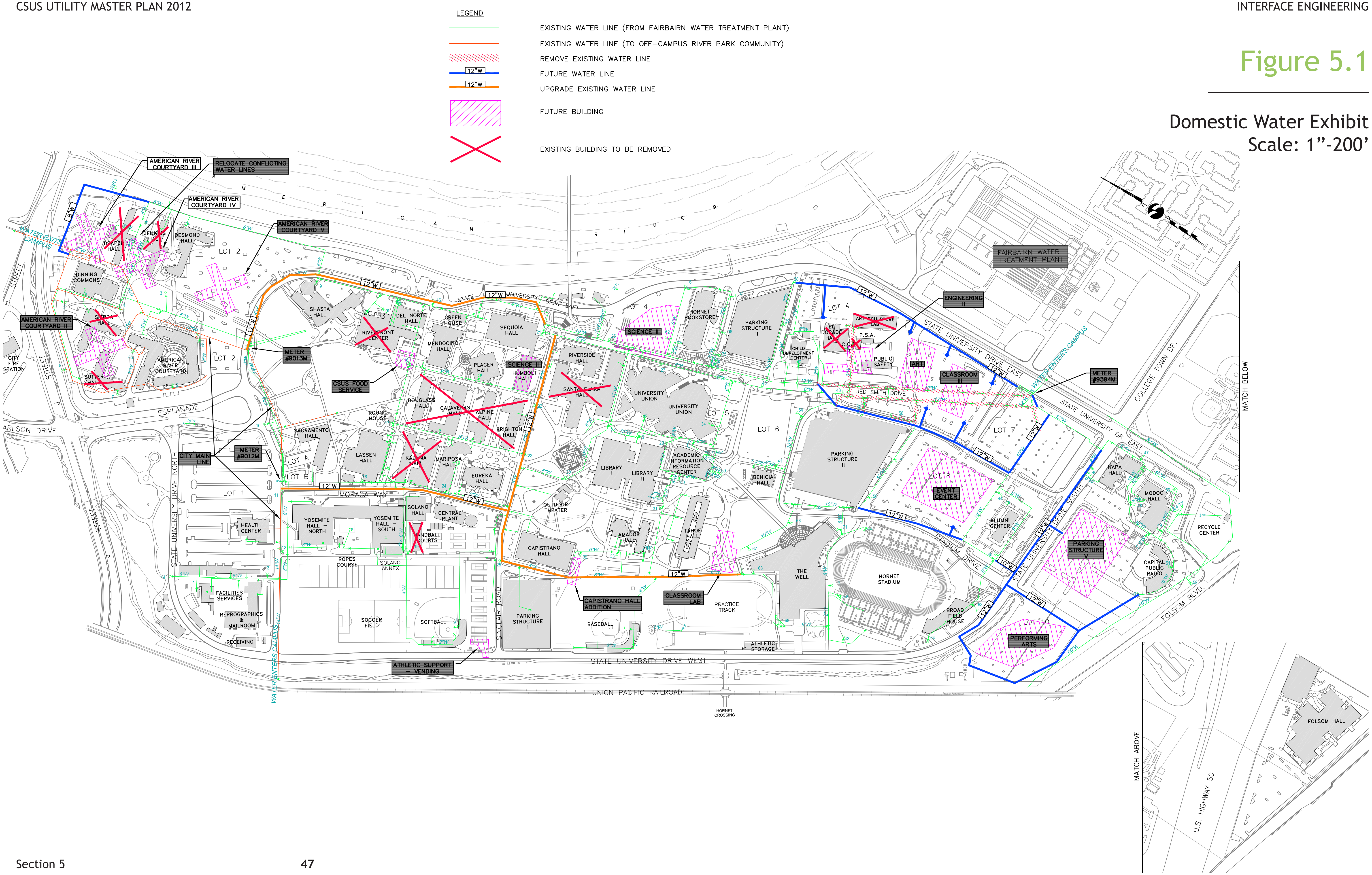


Figure 5.1

Domestic Water Exhibit
Scale: 1”-200’

Table 5A

City Water
Meter Record

CSUS Domestic Water Meter Record

	FY 02/03 ccf	FY 03/04 ccf	FY 04/05 ccf	FY 05/06 ccf	FY 07/08* ccf	FY 08/09 ccf	FY 09/10 ccf	FY 10/11 ccf
Jul	Unavailable				29,288	6,474	5,553	5,940
Aug					0	7,689	8,326	6,134
Sep					18,035	8,990	7,007	8,057
Oct					0	11,611	10,959	10,422
Nov					0	11,718	10,654	9,420
Dec					17,969	8,834	7,994	9,136
Jan					0	7,825	6,626	6,833
Feb					12,212	4,758	4,270	3,831
Mar					0	8,147	7,493	8,337
Apr					18,237	7,694	8,609	9,085
May					7,654	8,025	7,954	8,781
June					10,815	8,212	7,489	7,683
TOTAL	**104,623**	**100,345**	**86,446**	**98,241**	**114,210**	**99,977**	**92,934**	**93,659**
gpd	**214,405**	**205,639**	**177,155**	**201,327**	**234,052**	**204,884**	**190,451**	**191,937**

Notes:
*FY07/08 billing was sporadic
FY 02/03 - 05/06 received from 2007 Taylor Study
FY 07/08 - 10/11 received directly from CSUS

Table 5B

CSUS Private Water Meter Record

June 2009-May 2010

FY June 2009 - May 2010	Jun-09		Jul-09		Aug-09	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	485.70	$430.56	278.70	$244.21	405.30	$522.67
Modoc	483.00	$428.15	520.00	$455.65	464.00	$598.37
Napa	7.39	$6.55	7.08	$6.20	6.18	$7.97
MONTHLY TOTALS (CCF)	**976.09**		**805.78**		**875.48**	
	Sep-09		Oct-09		Nov-09	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	385.30	$322.92	14.80	$12.46	20.50	$17.77
Modoc	369.00	$309.26	152.00	$127.92	53.00	$45.93
Napa	7.53	$6.31	5.75	$4.84	4.35	$3.77
MONTHLY TOTALS (CCF)	**761.83**		**172.55**		**77.85**	
	Dec-09		Jan-10		Feb-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	5.40	$4.96	0.66	$0.68	13.04	$11.51
Modoc	20.00	$18.36	27.00	$27.79	28.00	$24.71
Napa	2.20	$2.02	3.25	$3.35	4.30	$3.80
MONTHLY TOTALS (CCF)	**27.60**		**30.91**		**45.34**	
	Mar-10		Apr-10		May-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	1.85	$1.61	81.43	$72.00	203.06	$181.67
Modoc	34.00	$29.63	54.00	$47.75	200.00	$178.93
Napa	5.10	$4.44	5.24	$4.63	4.33	$3.87
MONTHLY TOTALS (CCF)	**40.95**		**140.67**		**407.39**	
TOTAL FLOW FY 09/10 (CCF)	**4,362.44**					
TOTAL FLOW FY 09/10 (GPD)	**8,940**					

Table 5C

CSUS Private Water Meter Record

June 2010-May 2011

FY June 2010 - May 2011	Jun-10		Jul-10		Aug-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	369.50	$347.80	444.85	$475.72	444.85	$449.75
Modoc	333.00	$313.44	535.00	$572.12	480.00	$485.29
Napa	7.25	$6.82	7.26	$7.76	7.60	$7.68
	709.75		987.11		932.45	
	Sep-10		**Oct-10**		**Nov-10**	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	116.05	$112.68	31.36	$30.94	178.79	$176.80
Modoc	410.00	$398.11	185.00	$182.54	13.00	$12.86
Napa	5.75	$5.58	4.99	$4.92	3.10	$3.07
	531.80		221.35		194.89	
	Dec-10		**Jan-11**		**Feb-11**	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	3.50	$3.67	4.60	$5.64	5.60	$5.44
Modoc	14.00	$14.68	11.00	$13.48	17.00	$16.52
Napa	2.78	$2.91	2.58	$3.16	3.16	$3.07
	20.28		18.18		25.76	
	Mar-11		**Apr-11**		**May-11**	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	8.80	$8.74	157.60	$157.38	238.50	$239.36
Modoc	20.00	$19.85	212.00	$211.70	297.00	$298.07
Napa	5.94	$5.90	4.70	$4.69	4.35	$4.37
	34.74		374.30		539.85	
TOTAL FLOW FY 10/11 (CCF)	**4,590.46**					
TOTAL FLOW FY 10/11 (GPD)	**9,407**					

Table 5D

CSUS Private Water Meter Record

June 2011-Nov 2011

June 2011- Nov 2011	Jun-11		Jul-11		Aug-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	283.40	$300.36	283.40	$301.16	356.20	$368.22
Modoc	394.00	$417.58	426.00	$452.70	401.00	$414.53
Napa	5.87	$6.22	7.50	$7.97	6.55	$6.77
	683.27		716.90		763.75	

	Sep-11		Oct-11		Nov-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	250.10	$238.55	31.36	$30.80	23.32	$23.54
Modoc	400.00	$381.55	93.00	$91.35	26.00	$26.25
Napa	6.17	$5.89	5.33	$5.24	3.05	$3.08
	656.27		129.69		52.37	

TOTAL FLOW JUN-NOV '11 (CCF)	**3,002.25**
TOTAL FLOW JUN-NOV '11 (GPD)	**12,476**

Figure 5.2

City of Sacramento Estimated Hydraulic Conditions

DEPARTMENT
OF UTILITIES

ENGINEERING
SERVICES DIVISION

CITY OF SACRAMENTO
CALIFORNIA

1395 35th AVENUE
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November 22, 2011
BE:be

MEMORANDUM

TO: Charles C. Rutter, P.E., OMNI-MEANS, Ltd

FROM: Brett Ewart, Associate Engineer

SUBJECT: **ESTIMATED DOMESTIC WATER SUPPLY HYDRAULIC CONDITIONS FOR: CSUS CAMPUS CONNECTIONS**

The hydraulic performance of the City's water distribution system near the connection points to the California State University Sacramento water system has been estimated by utilizing the City's water model. Please refer to the attached map and graphs for location of analysis points and associated results.

The following assumptions were incorporated into this review:

1. Max Day water demand conditions were prevalent.

Based on these criteria, a Maximum Day Demand condition, steady state modeling analysis was performed. Two (2) hydraulic capacity curves were prepared to represent the performance of the existing system should a fireflow be extracted at either location shown on the attached map.

This analysis was not supported by a physical test of the water system. The results contained herein should be considered preliminary estimates, and should not be utilized for design of future water infrastructure or validation of the existing system. All applicants are encouraged to have a physical test of the system performed in order to more accurately understand actual system capacity.

Should you have any further questions please do not hesitate to contact me at 808-1725.

Cc Robert Thaung, Supervising Engineer.

Figure 5.3

City of Sacramento Estimated Hydraulic Conditions

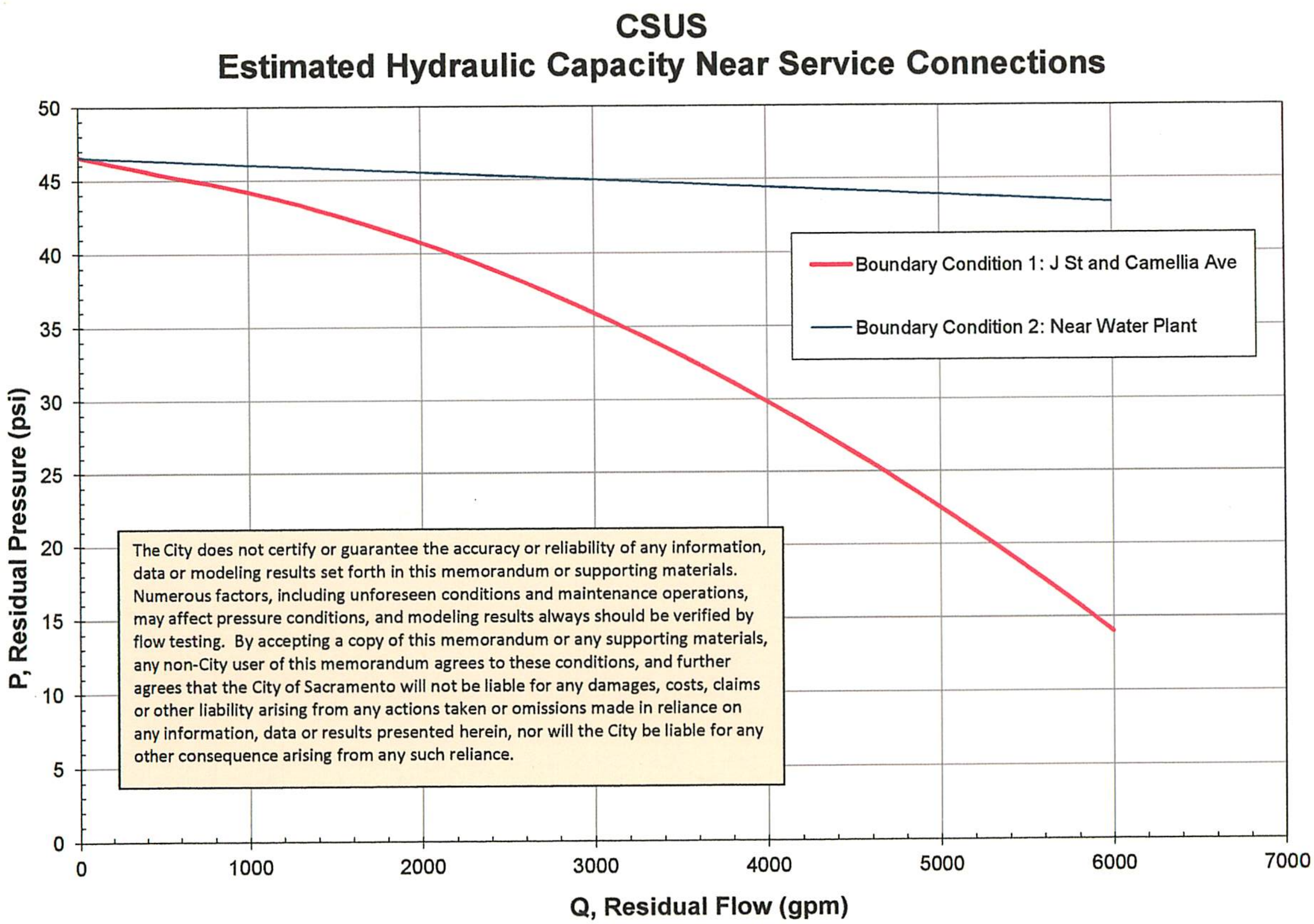
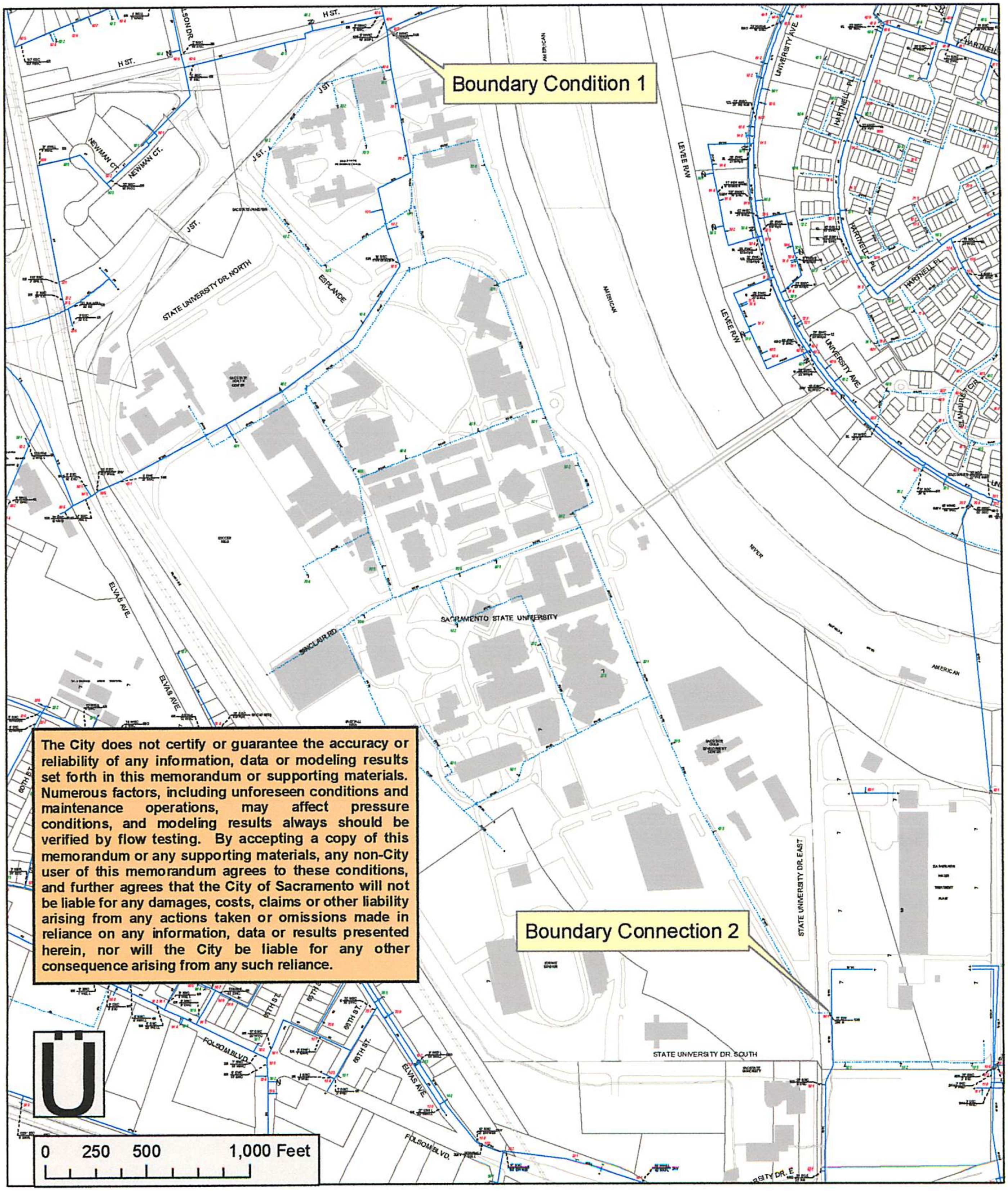


Figure 5.4

Estimated Hydraulic Boundary Condtions



6 Natural Gas

Executive Summary

- Previous Studies
- What analysis was done (bulk of study based on as-built drawings available)
- How it was analyzed (using existing data, interviews, and site obtained observations)
- Choke points
- Options for improvements

Previous Studies

There have been three previous Master-Plan studies on the Facilities Natural Gas Distribution System. The first report was prepared in 1966 by Kennedy Engineers as part of their master plan. A second master plan was developed by Boyle Engineering in 1989. The third master plan report was prepared by Taylor Systems Engineering in 2007.

1966 Kennedy Engineers Report

Kennedy Engineers 1966 report provided information on the existing gas distribution system. Previously, the campus gas distribution system consisted of three smaller gas systems which were called networks. Network-One distributed gas to the buildings in the center of the campus, this gas meter was located next to the Boiler House on Moraga Way. Network-Two distributed natural gas to the cluster of residence halls on the north side of campus. The gas meter for this system was located on the north side of campus. Both of these systems were considered “Firm” gas systems. Firm gas systems were defined as service not subject to peak demand interruption. Network Three was an “Interruptible” gas service which fed the Boiler House. This gas meter was also located next to the Boiler House on Moraga Way.

The natural gas load increase for Network-One was estimated to be from 3,345 CFH to 19,800 CFH. Network Two was estimated to increase from 5,800 CFH to 14,150 CFH and Network-Three was estimated to increase from 33,000 CFH to 150,000 CFH.

Their worksheets estimated that some additions and deletions of gas service would have to be staged and also recommended adding a loop system to maintain the continuance of gas service. The work and budget numbers that were generated were based on a 5 Year Plan and an overall remainder Master Plan. The 5 Year Plan was estimated to cost $7,000.00 and the Remainder of the Master Plan would cost $12,000.00 (in 1966 dollars).

1989 Boyle Engineering Report

This report provided CAD Utility Maps for all the utilities. The report mentioned that a natural gas distribution system with identification of meters, valves, pressure regulators, line sizes and locations was provided for the natural gas distribution system; however, this plan could not be found within the details and maps included within the report. The report mentioned that in 1987 the majority of the old gas lines were replaced and also mentioned that the replaced gas piping systems could have a 20 – 30 year trouble-free life span which could be doubled if inspected regularly and found to be sound.

2007 Taylor Systems Engineering, Inc. Report

This report was an extensive analysis that was conducted to provide natural gas service to the south side of the campus for the proposed new buildings that were planned in this area. This report mentioned that the utility rate for gas service from the central main gas meter, located next to the Central Plant, is considerably less than the utility rate for a separate gas service to a new building using a new tap to the existing 6” PG&E gas main running through the center of campus. As a result, it was desirable to try and utilize and extend the existing central campus gas distribution system from this central main gas meter to the south area of the campus to service the new buildings in this area.

ANALYZE EXISTING DATA

CSUS provided access to electronic files of all the existing buildings on campus. The files contained Architectural, Structural, Civil, Mechanical, Plumbing, and Electrical information based on as-built drawings. Where data was not available, site visits were conducted to gather the necessary information. Meetings were held with CSUS Staff that had the most knowledge about the natural gas distribution systems. The campus as-built drawings were reviewed and field investigations were made to cross-check and generate a comprehensive natural gas mapping plan. A database was created on a building-by-building basis with the goal of determining each building's natural gas peak demand to show how this demand affects the campus natural gas distribution system. A summary of this information that was gathered and calculated is presented in Table 6-B, SUMMARY OF NATURAL GAS DATA FOR CSUS.

This campus is served by an existing 6" high pressure gas (HPG) main, from PG&E, that is routed through the center of campus. The 6" HPG main provides natural gas at a pressure of 240 psi. There are a total of 9 existing gas connections to this 6" HPG main throughout its routing within the campus area. One connection occurs outside of campus, off of J Street, and this is used to serve a gas meter and gas distribution system for the Student Housing

Residence Hall Gas Meter

Complex located on the north side of campus. This gas distribution system operates at 5.0 psi medium pressure gas (MPG) . Campus installed gas meters and gas regulators, located at the buildings, are used to measure and regulate the gas pressure to low pressure gas (LPG) as the gas service enters the building. A large tap, on PG&E's 6" HPG line, occurs in the middle of campus, next to the Central Plant. This is a 4" HPG tap that feeds the central campus gas meter which supplies natural gas to the majority of the buildings in the middle of campus, at a 5.0 psi MPG distribution pressure, and also supplies the gas requirements for the boilers in the Central Plant at an elevated pressure of 35 psi. As a result of the central gas meters complexity, an enlarged detail has been provided which shows the inlet and multiple outlet gas line locations and sizes along with routing information to the different areas of the campus. This can be found on sheet F4.1F. Over the years, the central gas distribution system has been modified a few different times. The current natural gas mapping plan was generated to capture all the previous changes that have been made to this and other campus gas distribution systems. This central gas meter, provided by PG&E, also has gas sub-meters, which were installed by CSUS, to a few buildings

Central Campus Gas Meter

where gas consumption quantities were required for CSUS billing purposes. Gas regulators are installed, outside of each building, to modulate the gas pressure to low pressure gas as it entered each building. The locations of all the main gas meters (by PG&E), gas sub-meters (by CSUS), gas regulators and shut-off valves are also shown on the new natural gas mapping plan. These have been called-out with sheet notes indicating meters provided by PG&E (Sheet Note #1) or gas sub-meters installed by CSUS (Sheet Note # 2). The remaining 8 taps going into the 6" HPG main, are not as complicated and are shown on the new natural gas mapping plan. These remaining PG&E gas meters are located on the south side of the Campus. Please refer to Figures F4.1A through F4.1E.

As mentioned, CSUS provided access to their electronic drawing files. These files were used to gather natural gas load information, when it was available. When the natural gas load data could not be found, field investigations where conducted and/or conservative natural gas load estimates were calculated for each building based on each buildings usable square footage. A natural gas load of 40 BTUH/Sq.Ft was used for buildings not connected to the campus's steam distribution system. The 40 BTUH/SqFt. factor was used to account for the amount of comfort heating the building would require plus other natural gas utility loads within the building. When the campus's steam distribution system did serve a building, the natural gas load factor was reduced to 20 BTUH/Sq.Ft. The summary of all the natural gas loads that were used to each building can be found in Table 6.A. This information is labeled on a building by building basis. This table also summarizes each building number, building square footage, whether a building is connected to the Central Steam Heating System, and whether a building has an existing gas connection; and if so, what are the natural gas inlet and outlet sizes into and out of the gas regulator. Table 6.A summarizes the natural gas MBH capacity (calculated or varified) along with linear footage distance the regulator is located away from the main natural gas regulators. This evaluation did not consider the effects of the natural gas powered emergency generators that are distributed throughout the campus. It was assumed that other regularly operating natural gas systems would not be operating and this would result in excess natural gas capacity being available in the respective natural gas system to operate the emergency generator. The locations of the emergency generators, along with the routing location and size of the natural gas line, is also shown on the natural gas mapping plan. Please refer to Figures F4.1A through F4.1E for this information.

To evaluate the gas distribution system, Table 6A, originaly found within Chapter 12 of the 2010 California Plumbing Code (2010 CPC), was used for the two main natural gas systems distributing natural gas at 5.0 psi. This involved the gas systems supplying gas to the Residence Halls on the north side of Campus and the natural gas system in the central part of the Campus. Table 6A summarises the gas capacities that shall be used for gas distribution systems ranging in distance from 0 to 2000 feet away from the main gas regulator, which reduces the pressure to 5.0 psi. For distances greater than 2000 feet, Equation 12-2, the High-Pressure Gas Formula from Chapter 12 of the 2010 CPC, was used.

Equation 12-2 High-Pressure Gas Formula (1.5 psi [10.3 kPa] and above): [NFPA 54:6.4.2]

$$D = \frac{Q^{0.381}}{18.93\left[\frac{(P_1^2 - P_2^2)\cdot Y}{Cr \times L}\right]^{0.206}}$$

where:

D = inside diameter of pipe, inches

Q = input rate appliance(s), cubic feet per hour at 60°F (16°C) and 30-inch (759 mm) mercury column

P_1 = upstream pressure, psia (P_1 + 14.7)

P_2 = downstream pressure, psia (P_2 + 14.7)

L = equivalent length of pipe, feet

ΔH = pressure drop, inches water column (27.7 in. H_2O = 1 psi)

Equation 12-2:

The gas distribution system for the Residence Halls on the north side of Campus is currently being overloaded. The section of pipe shown between nodes A and B (Figure F4.1A), is a 2” line supplying the natural gas needs for the American River Courtyard building. This buildings gas load is currently at 8050 MBH with a total developed length of 657 ft. away from the medium pressure regulator. Entering the 2010 CPC Table 6A at the 700 ft. row, a maximum capacity of this 2” line is 7460 MBH. The other section of natural gas pipe that should be increased in size is the 2” section shown between points C & D, (F4.1A). This section of 2” gas pipe is currently connected to 7960 MBH of gas capacity at a total developed length of 1040 ft. Using the same data table mentioned above and using the 1100 ft. row, the maximum gas load for this section of pipe should be 5840 MBH. Currently this section of pipe is overloaded by 36%. If a usage diversity factor of 85% is used on the peak gas demand, the overloaded amount is decreased to 16%. This section of pipe should be increased to a 2-1/2” size to satisfy this existing load condition. The section of pipe between points D and E is currently overloaded by an extreme amount of 118% over it’s listed value on the data table provided. The natural gas load on this section was calculated to be 20,365 MBH with a total developed length of 1040 ft. The natural gas data table value for this section of pipe using the 1100 ft. row is 9,320 MBH. The only slight benefit of the 2-1/2” section of pipe is that this section is relatively short in length. The short length of run will not cause the large pressure drop that a longer section of this same size pipe would create. Future changes to the existing system should include increasing this section to a 4” pipe section. The current PG&E gas meter (Dresser Model 16M) is being used at close to its maximum capacity. If a diversity factor of 85% is used on the peak gas load, this meter is operating at 82% of its’ maximum capacity. If no diversity is used, then this gas meter is operating at 96.5% of its maximum capacity.

The future expansion of this area with the demolition of Desmond, Draper, Jenkins, Sierra, and Sutter Halls and the addition of the larger Residence Halls, a total of four new buildings plus a Parking Structure, will require that a larger gas meter be provided that will satisfy the requirements of a new calculated load of 46,000 MBH to handle the remaining building gas loads plus the new. The gas distribution main would need to be increased to a minimum 6” MPG line operating at 5.0 psi.

The central natural gas distribution system has a few areas of concern. The existing 2” natural gas line that serves the Bookstore, shown on plan P1.2 as the section of pipe between points N and O is overloaded by 52%. The Bookstore has a natural gas load of 5,000 MBH. The calculated maximum capacity of the existing 2” line with a total developed length of 2820 ft. is 3300 MBH. The main problem with this gas line is its distance from the main gas meter and regulator. At this distance the capacity of the 2” MPG line is greatly diminished. This gas line should be upgraded to a minimum 2-1/2” gas line. This same 2” gas line is served by an existing 4” gas line, shown as points M and N on Figure F4.1C. This section of gas line is fine and would normally have excess capacity to support future developments; however, based on information from plans for the existing gas infrastructure, this 4” gas line is served by a smaller 3” gas line that is being used at its maximum capacity. The 3” line shown between points I, J and K, on Figure F4.1C, and the continuation of this line at points H and I, shown on Figure F4.1C and continuing on Figure F4.1D, has an existing connected peak gas load capacity of 10,583 MBH. With a total developed length of 2820 ft., (including the furthest connected gas load that this 3” gas line supports), the maximum gas load that should be on this 3” line is 9800 MBH. With an assumed diversity factor of 85% off of the peak gas load capacity, the 3” gas line is at 92% of its maximum capacity. As a result of this gas line being at its upper limit, the existing 4” gas line is also limited to the lessor capacity that the 3” can support. Later parts of this report will discuss solutions to provide additional gas capacity to the existing 4” gas line.

The 1-1/4” gas line section shown on Figure F4.1C, between points K and L, should be changed to a larger gas line. This section of gas line supplies gas service to 6 gas submeters that serve 5 restaurants and radiant heaters, for the patio area at the University Union. The existing connected gas load was estimated to be 4000 MBH with a total developed length of 2704 ft. Using Equation 12-2, this gas service line should be increased to a minimum 2-1/2” line.

The existing 4” natural gas distribution loop, shown on Figures F4.1C & F4.1D and surrounding Douglas, Kadema, Mariposa, Eureka, Brighton Alpine, & Calaveras Hall is operating at about 59% of its’ total capacity. The peak gas load on the existing 4” gas loop system was calculated to be at 28,275 MBH. The 4” gas loop system has a maximum calculated capacity of 47,800 MBH. If a peak load diversity of 85% is used, the loop system operating capacity drops to 50% and therefore more natural gas taps can be connected to this gas distribution system.

The existing 6” MPG main, shown on Figure F4.1D, that originates from the central campus gas meter and is routed to the south side of campus, has plenty of reserve capacity to satisfy the future developments around its’ area of service. This 6” main is currently being used at 19% of its’ total capacity. The current connected load, on this gas main, was calculated to be at 9978 MBH. At a total developed length of 3514 ft. (for the gas service to Broad Athletic Facility), using Equation 12-2, the maximum capacity of this gas service was calculated to be 53,500 MBH. The existing 4” MPG main that is connected to the 6” MPG main also has plenty of reserve capacity. This 4” MPG section of pipe only has the Board Athletic Facility (BAF) connected to it. The peak gas capacity required to BAF is 2560 MBH. At a total developed length of 3514 ft., the maximum capacity of the 4” MPG main was calculated to be 18,500 MBH. Currently, this section of pipe is being used at 14% of its’ maximum capacity. The natural gas loads of the future Event Center, Performing Arts Center and Parking Structure #5 are calculated to be approximately 9830 MBH.

The future additions of Engineering II, the Art Complex, and Classroom III, on the east side of the campus, will require the extension of the 6” tap that exists next to Benicia Hall. This is shown as Point Q, on Figure F4.1D. This extension of pipe is required because the existing gas meters and gas distribution systems, on this side of campus, do not have the capacities required for these future building additions. Also, the extension of this line would not require the addition of a new tap, or the increase of an existing tap to the PG&E 6” HPG main running through the middle of campus. The calculated future natural gas load of 12,520 MBH and a total developed length of approximately 4,000 ft. will require that a minimum 4” MPG main be extended to the proposed areas of the new buildings. This new 4” MPG main could also be routed to connect up with the existing gas connection at Point M shown on Figure F4.1C to supplement the gas requirements that we stated as deficient in the earlier part of this report.

Table 6A

California Plumbing Code Table 12-11

SCHEDULE 40 METALLIC PIPE [NFPA 54: TABLE 6.2(e)]

						GAS:		NATURAL	
						INLET PRESSURE:		5.0 psi	
						PRESSURE DROP:		3.5 psi	
						SPECIFIC GRAVITY:		0.60	
	PIPE SIZE (inch)								
NOMINAL:	½	¾	1	1¼	1½	2	2½	3	4
ACTUAL ID:	0.622	0.824	1.049	1.380	1.610	2.067	2.469	3.068	4.026
LENGTH (ft.)	CAPACITY IN CUBIC FEET OF GAS PER HOUR								
10	3,190	6,430	11,800	24,200	36,200	69,700	111,000	196,000	401,000
20	2,250	4,550	8,320	17,100	25,600	49,300	78,600	139,000	283,000
30	1,840	3,720	6,790	14,000	20,900	40,300	64,200	113,000	231,000
40	1,590	3,220	5,880	12,100	18,100	34,900	55,600	98,200	200,000
50	1,430	2,880	5,260	10,800	16,200	31,200	49,700	87,900	179,000
60	1,300	2,630	4,800	9,860	14,800	28,500	45,400	80,200	164,000
70	1,200	2,430	4,450	9,130	13,700	26,400	42,000	74,300	151,000
80	1,150	2,330	4,260	8,540	12,800	24,700	39,300	69,500	142,000
90	1,060	2,150	3,920	8,050	12,100	23,200	37,000	65,500	134,000
100	979	1,980	3,620	7,430	11,100	21,400	34,200	60,400	123,000
125	876	1,770	3,240	6,640	9,950	19,200	30,600	54,000	110,000
150	786	1,590	2,910	5,960	8,940	17,200	27,400	48,500	98,900
175	728	1,470	2,690	5,520	8,270	15,900	25,400	44,900	91,600
200	673	1,360	2,490	5,100	7,650	14,700	23,500	41,500	84,700
250	558	1,170	2,200	4,510	6,760	13,000	20,800	36,700	74,900
300	506	1,060	1,990	4,090	6,130	11,800	18,800	33,300	67,800
350	465	973	1,830	3,760	5,640	10,900	17,300	30,600	62,400
400	433	905	1,710	3,500	5,250	10,100	16,100	28,500	58,100
450	406	849	1,600	3,290	4,920	9,480	15,100	26,700	54,500
500	384	802	1,510	3,100	4,650	8,950	14,300	25,200	51,500
550	364	762	1,440	2,950	4,420	8,500	13,600	24,000	48,900
600	348	727	1,370	2,810	4,210	8,110	12,900	22,900	46,600
650	333	696	1,310	2,690	4,030	7,770	12,400	21,900	44,600
700	320	669	1,260	2,590	3,880	7,460	11,900	21,000	42,900
750	308	644	1,210	2,490	3,730	7,190	11,500	20,300	41,300
800	298	622	1,170	2,410	3,610	6,940	11,100	19,600	39,900
850	288	602	1,130	2,330	3,490	6,720	10,700	18,900	38,600
900	279	584	1,100	2,260	3,380	6,520	10,400	18,400	37,400
950	271	567	1,070	2,190	3,290	6,330	10,100	17,800	36,400
1,000	264	551	1,040	2,130	3,200	6,150	9,810	17,300	35,400
1,100	250	524	987	2,030	3,030	5,840	9,320	16,500	33,600
1,200	239	500	941	1,930	2,900	5,580	8,890	15,700	32,000
1,300	229	478	901	1,850	2,770	5,340	8,510	15,000	30,700
1,400	220	460	866	1,780	2,660	5,130	8,180	14,500	29,500
1,500	212	443	834	1,710	2,570	4,940	7,880	13,900	28,400
1,600	205	428	806	1,650	2,480	4,770	7,610	13,400	27,400
1,700	198	414	780	1,600	2,400	4,620	7,360	13,000	26,500
1,800	192	401	756	1,550	2,330	4,480	7,140	12,600	25,700
1,900	186	390	734	1,510	2,260	4,350	6,930	12,300	25,000
2,000	181	379	714	1,470	2,200	4,230	6,740	11,900	24,300

Note: All table entries are rounded to 3 significant digits.

Table 6B

Summary of Natural Gas Data for CSUS

BLDG#	BUILDING NAME	SQ./FT.	STEAM HEATING (Y/N)	GAS CONNECTION (Y/N)	INLET SIZE "	OUTLET SIZE "	MBH CAPACITY	LINEAR FT
95	ACADEMIC INFORMATION RESOURCE CENTER	100,041	Y	N	-	-	0	
11	ALPINE HALL	30,550	Y	Y	3/4"	3/4"	50 MBH	1546 FT
104	ALUMNI CENTER	10,800	N	Y	1-1/4"	2-1/2"	992 MBH	0 FT
39	AMADOR HALL	67,138	Y	N	-	-	0	
25	AMERICAN RIVER COURTYARD	209,050	N	Y	2"	3"	8050 MBH	657 FT
82	ART SCULPTURE	12,040	N	Y	1-1/4"	2-1/2"	1782 MBH	206 FT
106	BASEBALL STORAGE FACILITY	1,430	N	N	-	-	0	
62	BENICIA HALL	7,000	N	Y	2"	1-1/4"	505 MBH	2338 FT
91	BOOKSTORE	93,170	N	Y	2"	2"	5000 MBH	2820 FT
12	BRIGHTON HALL	30,000	Y	N	-	-	0	
54	BROAD ATHLETIC FACILITY	26,235	N	Y	2"	4"	2560 MBH	3514 FT
10	CALAVERAS HALL	21,630	Y	N	-	-	0	
35	CAPISTRANO HALL	84,722	Y	N	-	-	0	
108	CAPITAL PUBLIC RADIO	19,838	N	Y	1-1/2"	3"	1710 MBH	0 FT
32	CENTRAL PLANT	13,569	N	Y	8"	8"	63050 MBH	126 FT
32	CENTRAL PLANT	13,569	N	Y	3/4"	3/4"	100 MBH	126 FT
61	CHILD DEVELOPMENT CENTER	11,054	N	Y	1-1/2"	2-1/2"	1075 MBH	0 FT
22	CUSTODIAL WAREHOUSE	13,193	N	Y	1-1/4"	1-1/2"	400 MBH	1961 FT
90	DESMOND HALL	53,683	N	Y	2"	4"	3900 MBH	1024 FT
31	DEL NORTE HALL	45,258	N	Y	1"	?	1810 MBH	
46	DINING COMMONS	22,747	N	Y	2-1/2"	2-1/2"	1085 MBH	139 FT
4	DOUGLAS HALL	38,212	Y	N	-	-	0	
16	DRAPER HALL	38,212	N	Y	1-1/2"	2-1/2"	1530 MBH	583 FT
59	EL DORADO HALL	12,172	N	Y	2"	?	250 MBH	0 FT
59	EL DORADO HALL	12,172	N	Y	1-1/4"	?	250 MBH	228 FT
38	EUREKA HALL	59,488	Y	Y	3/4"	1-1/4"	200 MBH	409 FT
22	FACILITIES SERVICES	58,024	N	Y	1-1/4"	1-1/4"	1970 MBH	1757 FT
28	GREENHOUSES	10,390	N	Y	1-1/2"	3/4"	416 MBH	1569 FT
20	HANDBALL COURTS	5,969	N	N	-	-	0	
24	HAZARDOUS MATERIALS MANAGEMENT	2,083	N	Y	1"	3/4"	100 MBH	2041 FT
24	HAZARDOUS MATERIALS MANAGEMENT (E.H.&S.)	?	?	Y	1-1/4"	?	100 MBH	1765 FT
60	HORNET STADIUM	245,465	N	N	-	-	0	
13	HUMBOLDT HALL	24,908	Y	Y	2"	2-1/2"	500 MBH	1295 FT
13	HUMBOLDT HALL	24,908	Y	Y	1-1/2"	1-1/2" & 2-1/2"	500 MBH	1467 FT
17	JENKINS HALL	38,212	N	Y	1-1/2"	2-1/2"	1530 MBH	766 FT
7	KADEMA HALL	14,497	N	Y	1-1/2"	2"	580 MBH	338 FT
7	KADEMA HALL	16,174	N	Y	2"	2"	647 MBH	444 FT
7	KADEMA HALL	16,174	N	Y	3"	2"	1250 MBH	443 FT
26	LASSEN HALL	80,445	Y	N	-	-	0	
40	LIBRARY NORTH	211,835	Y	N	-	-	0	
40	LIBRARY SOUTH	165,239	Y	Y	1-1/4"	3"	1083 MBH	1725 FT
92	MARIPOSA HALL	78,079	Y	Y	2"	4"	701 MBH	330 FT
43	MENDOCINO HALL	77,000	Y	Y	1-1/4"	3"	1295 MBH	1251 FT
81	MODOC HALL	85,402	N	Y	2"	4"	3259 MBH	0 FT
88	NAPA HALL	33,932	N	Y	2"	3"	1170 MBH	0 FT

Table 6B

cont.

Summary of Natural Gas Data for CSUS

BLDG#	BUILDING NAME	SQ./FT.	STEAM HEATING (Y/N)	GAS CONNECTION (Y/N)	INLET SIZE "	OUTLET SIZE "	MBH CAPACITY	LINEAR FT
27	OUTDOOR THEATER	2,160	N	Y	1"	1-1/4"	50 MBH	818 FT
89	PARKING STRUCTURE 1	494,208	N	N	-	-	E-GEN	
94	PARKING STRUCTURE 2	300,035	N	N	-	-	E-GEN	
99	PARKING STRUCTURE 3	983,620	N	N	-	-	GAS METER W/ GEN	
56	PLACER HALL	61,101	Y	Y	1-1/4"	4"	2700 MBH	1460 FT
58	PUBLIC SERVICE	11,892	N	Y	3/4"	1-1/4"	1200 MBH	0 FT
75	RECEIVING	6,825	N	Y	1"	2"	150 MBH	1933 FT
19	RESIDENCE HALL RECREATION FACILITY	1,152	N	Y	3/4"	2"	1000 MBH	584 FT
2	RIVER FRONT CENTER	40,198	Y	Y	1"	1-1/2"	2400 MBH	1379 FT
48	RIVERSIDE HALL	83,316	Y	Y	4"	1-1/2" & 1"	478 MBH	1449 FT
1	SACRAMENTO HALL	38,090	Y	N	-	-	0	
14	SANTA CLARA HALL	66,391	Y	N	-	-	0	
36	SEQUOIA HALL	191,137	Y	Y	2"	3"	2500 MBH	1607
9	SHASTA HALL	62,667	Y	N	-	-	0	
44	SIERRA HALL	41,662	N	Y	1-1/4"	1-1/4"	1666 MBH	254 FT
42	SOLANO HALL	66,320	Y	Y	2"	2"	1325 MBH	89 FT
33	STUDENT HEALTH CENTER	27,313	Y	Y	1-1/4"	3/4"	0	1513 FT
45	SUTTER HALL	40,102	N	Y	1-1/4"	1-1/4"	1604 MBH	545 FT
34	TAHOE HALL	64,764	Y	N	-	-	0	
47	UNIVERSITY UNION	162,268	Y	Y	3"	3"	E-GEN	2156 FT
47	UNIVERSITY UNION	162,268	Y	Y	3"	?	500 MBH	2276 FT
47	UNIVERSITY UNION	162,268	Y	Y	1-1/4"	?	4000 MBH	2704 FT
47	UNIVERSITY UNION	162,268	Y	Y	1"	3/4"	520 MBH	1785 FT
109	THE WELL (WELLNESS EDUCATION, LEISURE & LIFESTYLE)	150,845	N	Y	6"	3" & 6"	6913 MBH	2279 FT
15	YOSEMITE HALL	82,301	Y	Y	1-1/2"	?	1646 MBH	260 FT
15	YOSEMITE HALL POOL EQUIPMENT BUILDING		Y	Y	2"	?	970 MBH	1764 FT

Figure 6.1

Overall Proposed Gas Distribution Plan

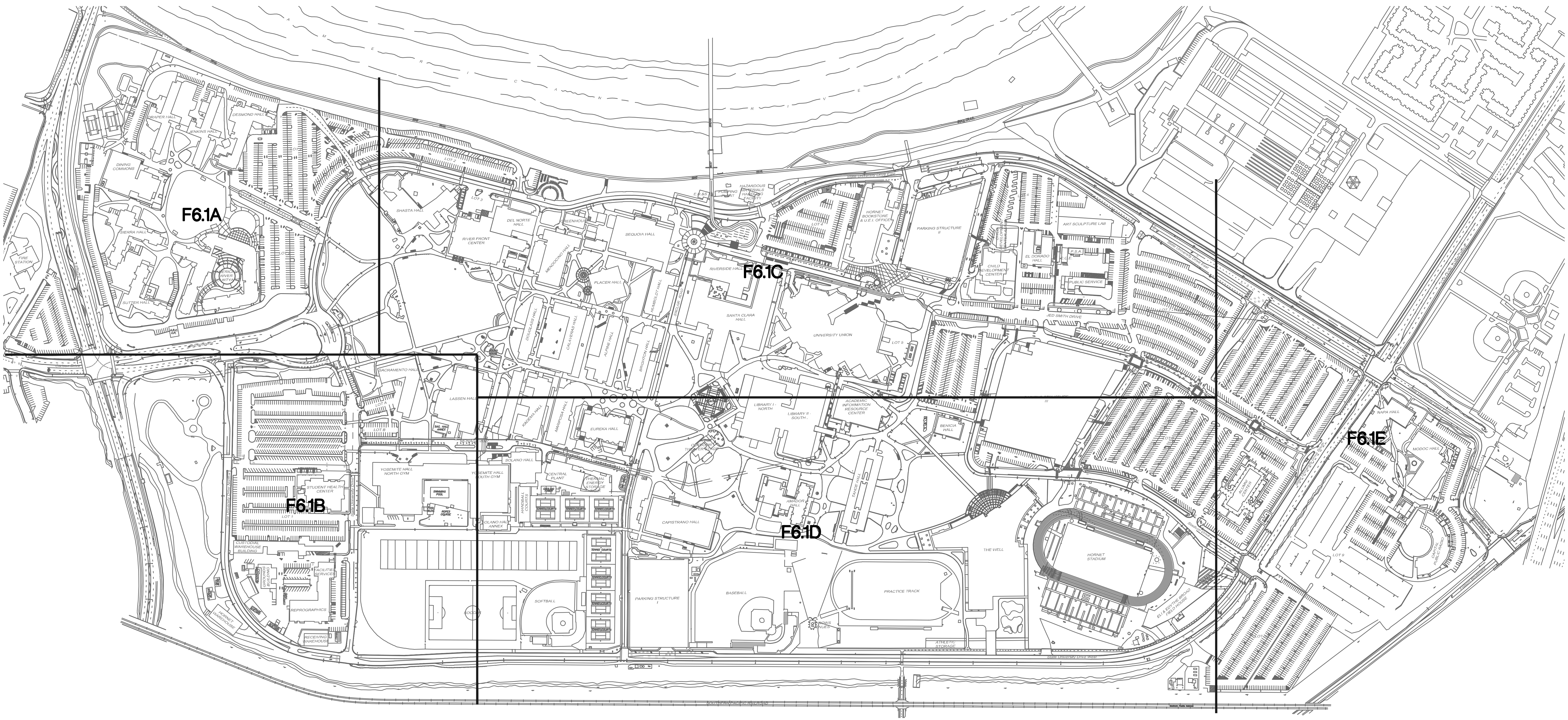


Figure 6.1A

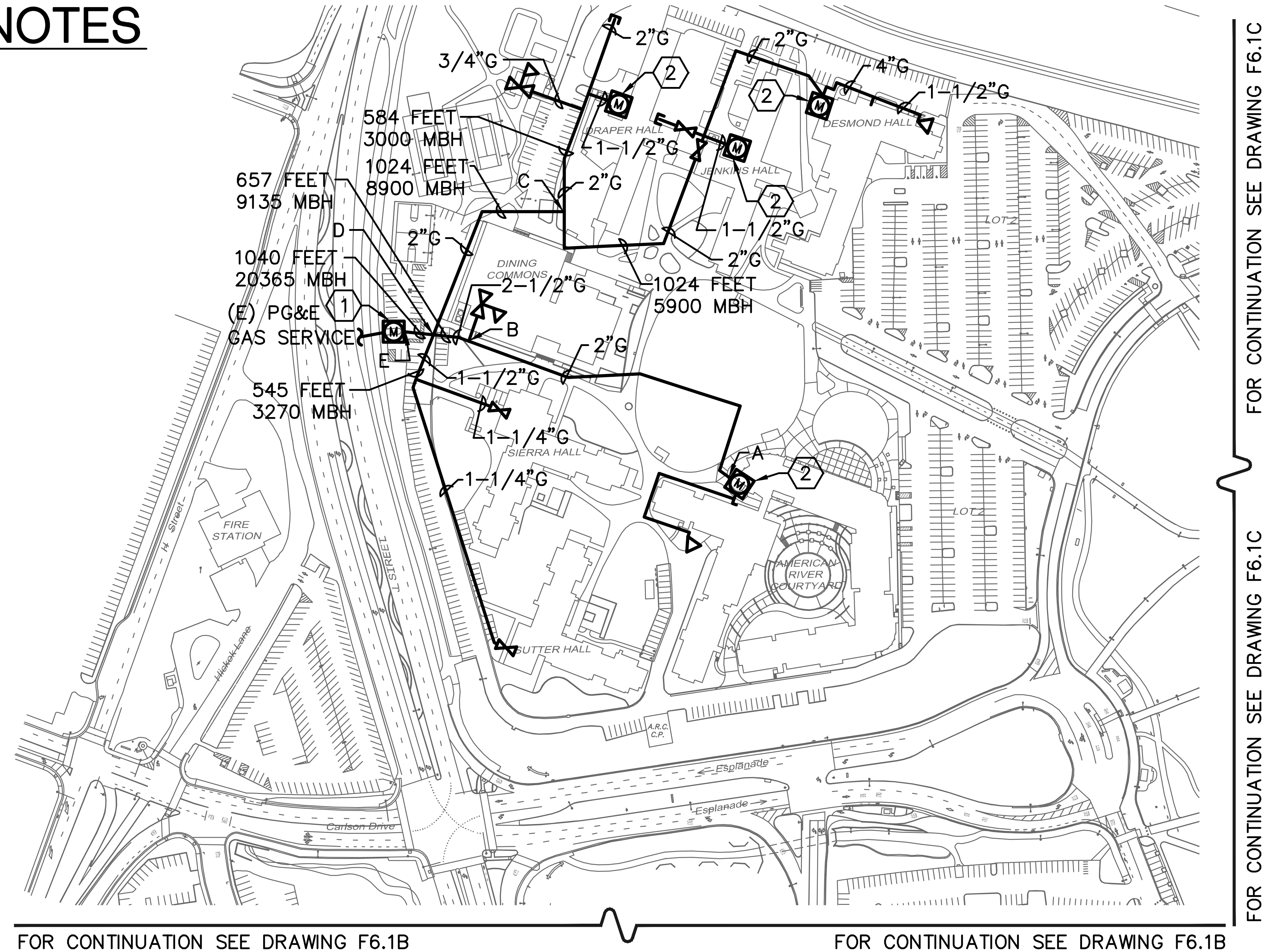
Partial Proposed Gas Distribution Plan

⬡ SHEET KEYNOTES

1 PG&E METER

2 CAMPUS SUBMETER

- SHUT–OFF VALVE
- PRESSURE REDUCING VALVE
- GAS METER
- GAS GENERATOR
- CONTINUATION
- PIPE CAP



0 200' 400'

SCALE: 1"=200'–0"

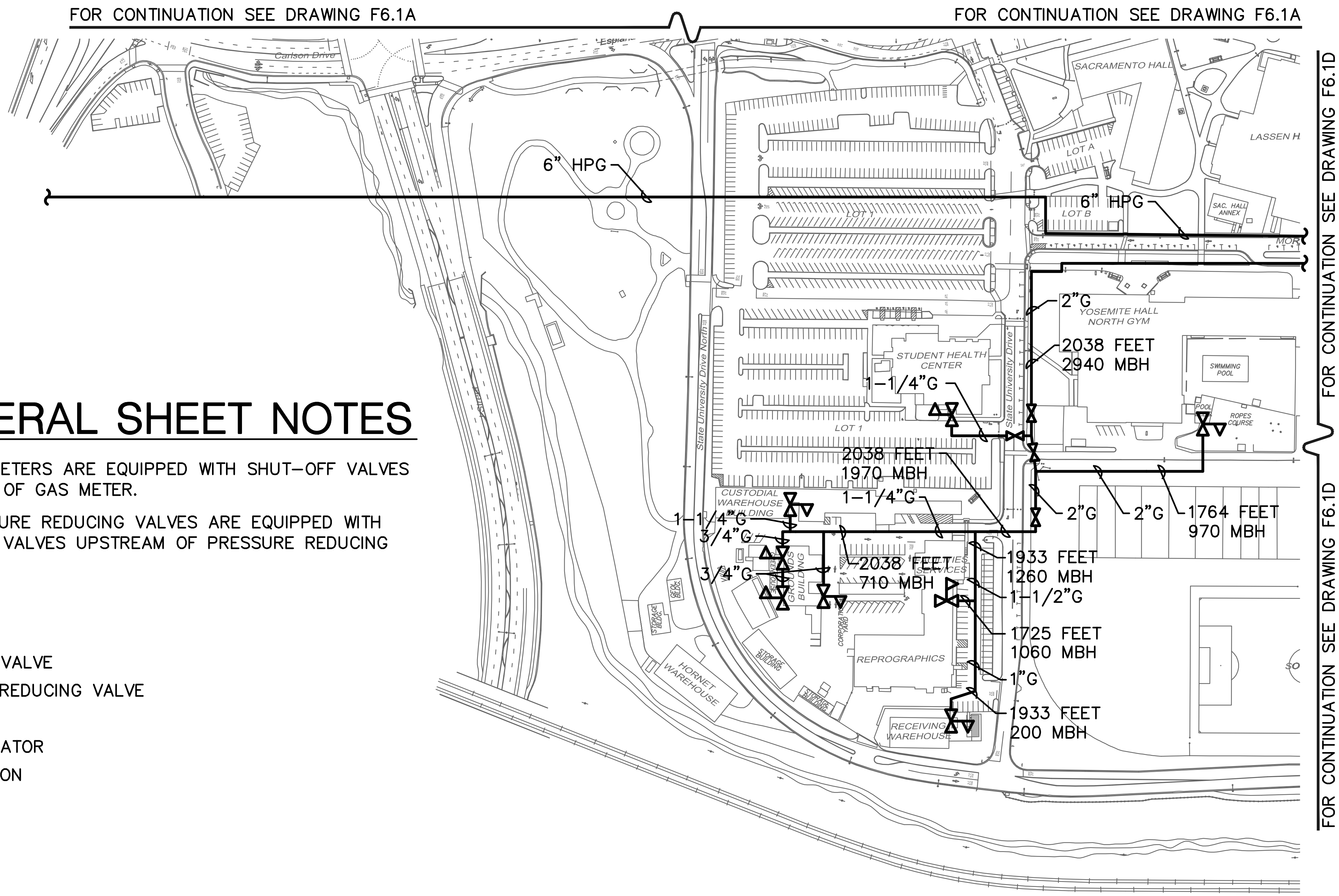
GENERAL SHEET NOTES

A. ALL GAS METERS ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF GAS METER.

B. ALL PRESSURE REDUCING VALVES ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF PRESSURE REDUCING VALVE.

Figure 6.1B

Partial Proposed Gas Distribution Plan



GENERAL SHEET NOTES

A. ALL GAS METERS ARE EQUIPPED WITH SHUT-OFF VALVES UPSTREAM OF GAS METER.

B. ALL PRESSURE REDUCING VALVES ARE EQUIPPED WITH SHUT-OFF VALVES UPSTREAM OF PRESSURE REDUCING VALVE.

SHUT-OFF VALVE
PRESSURE REDUCING VALVE
GAS METER
GAS GENERATOR
CONTINUATION
PIPE CAP

0 200' 400'

SCALE: 1"=200'-0"

Figure 6.1C

Partial Proposed Gas Distribution Plan

SHUT–OFF VALVE
PRESSURE REDUCING VALVE
GAS METER
GAS GENERATOR
CONTINUATION
PIPE CAP

GENERAL SHEET NOTES

A. ALL GAS METERS ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF GAS METER.

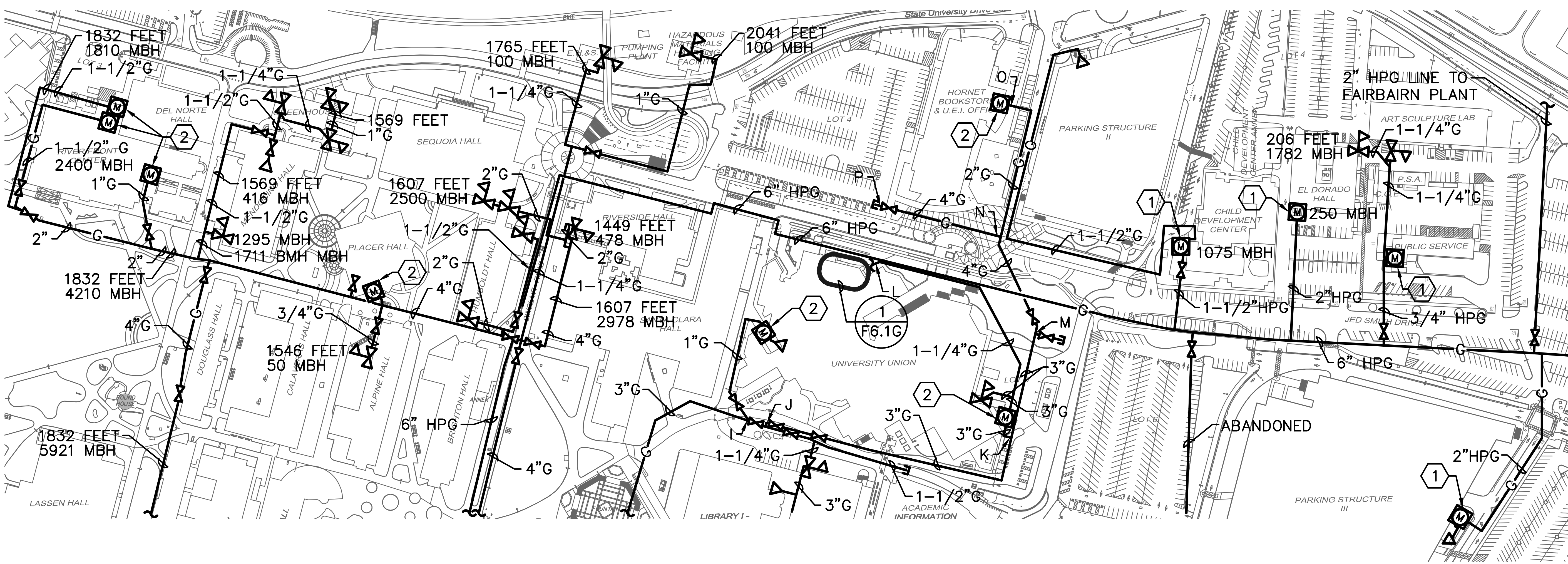
B. ALL PRESSURE REDUCING VALVES ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF PRESSURE REDUCING VALVE.

SHEET KEYNOTES

1 PG&E METER

2 CAMPUS SUBMETER

FOR CONTINUATION SEE DRAWING F6.1A
FOR CONTINUATION SEE DRAWING F6.1A
FOR CONTINUATION SEE DRAWING F6.1E
FOR CONTINUATION SEE DRAWING F6.1E



FOR CONTINUATION SEE DRAWING F6.1D
FOR CONTINUATION SEE DRAWING F6.1D

0 200' 400'

SCALE: 1"=200'–0"

Figure 6.1D

Partial Proposed Gas Distribution Plan

SHUT–OFF VALVE
PRESSURE REDUCING VALVE
GAS METER
GAS GENERATOR
CONTINUATION
PIPE CAP

GENERAL SHEET NOTES

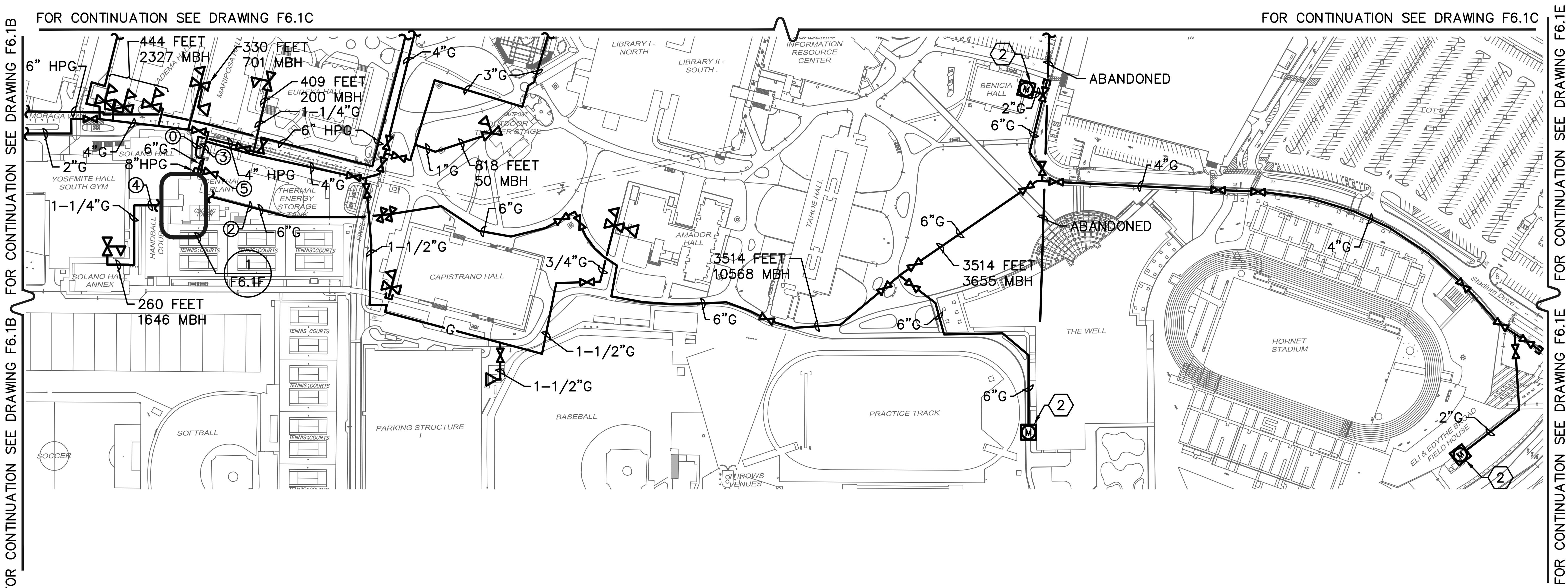
A. ALL GAS METERS ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF GAS METER.

B. ALL PRESSURE REDUCING VALVES ARE EQUIPPED WITH SHUT–OFF VALVES UPSTREAM OF PRESSURE REDUCING VALVE.

SHEET KEYNOTES

1 PG&E METER

2 CAMPUS SUBMETER

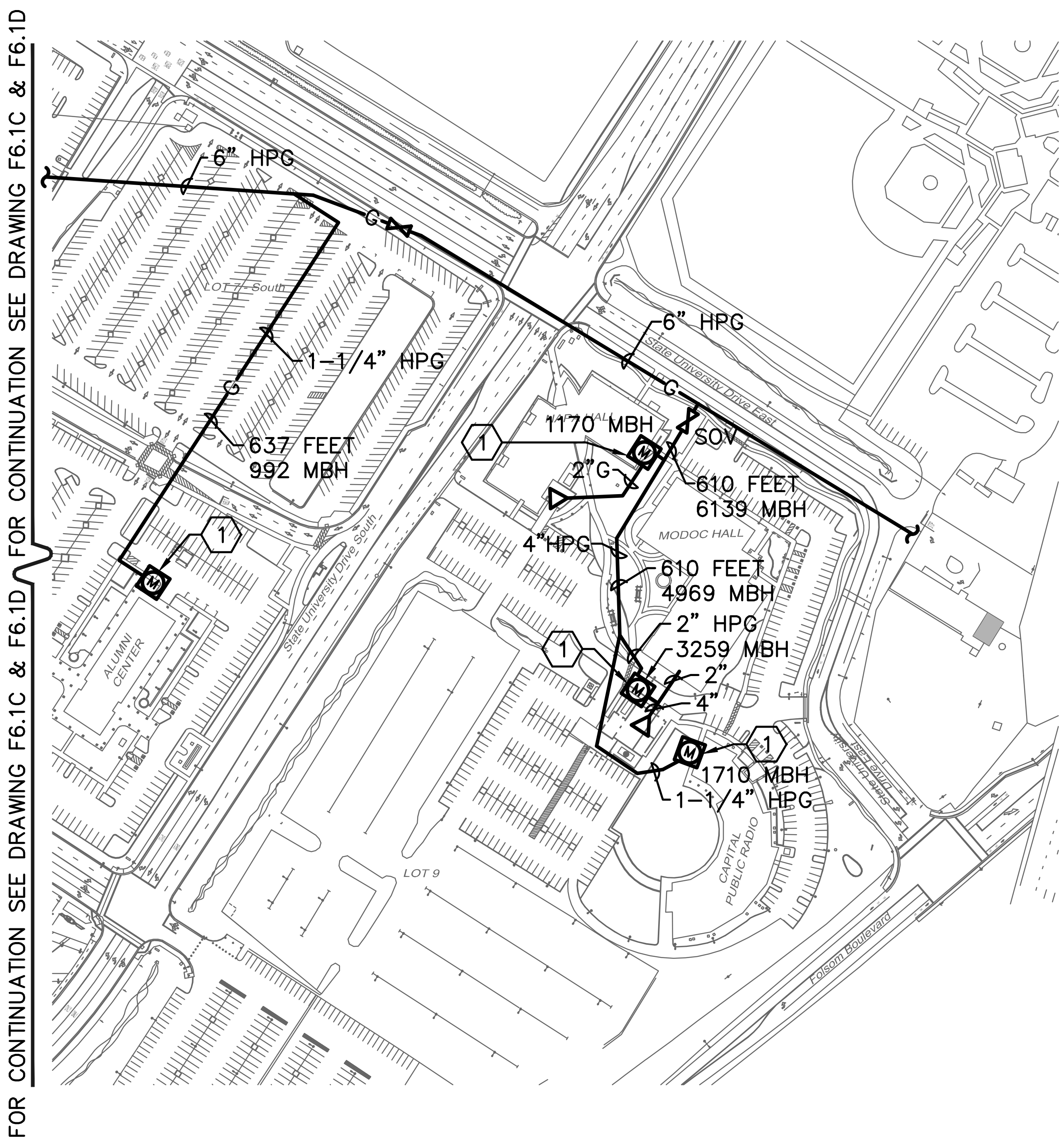


0 200' 400'

SCALE: 1"=200'–0"

Figure 6.1E

Partial Proposed Gas Distribution Plan



GENERAL SHEET NOTES

A. ALL GAS METERS ARE EQUIPPED WITH SHUT-OFF VALVES UPSTREAM OF GAS METER.

B. ALL PRESSURE REDUCING VALVES ARE EQUIPPED WITH SHUT-OFF VALVES UPSTREAM OF PRESSURE REDUCING VALVE.

SHEET KEYNOTES

1 PG&E METER

- SHUT-OFF VALVE
- PRESSURE REDUCING VALVE
- GAS METER
- GAS GENERATOR
- CONTINUATION
- PIPE CAP

0 200' 400'

SCALE: 1"=200'-0"

Figure 6.1F

Central Natural Gas Meter

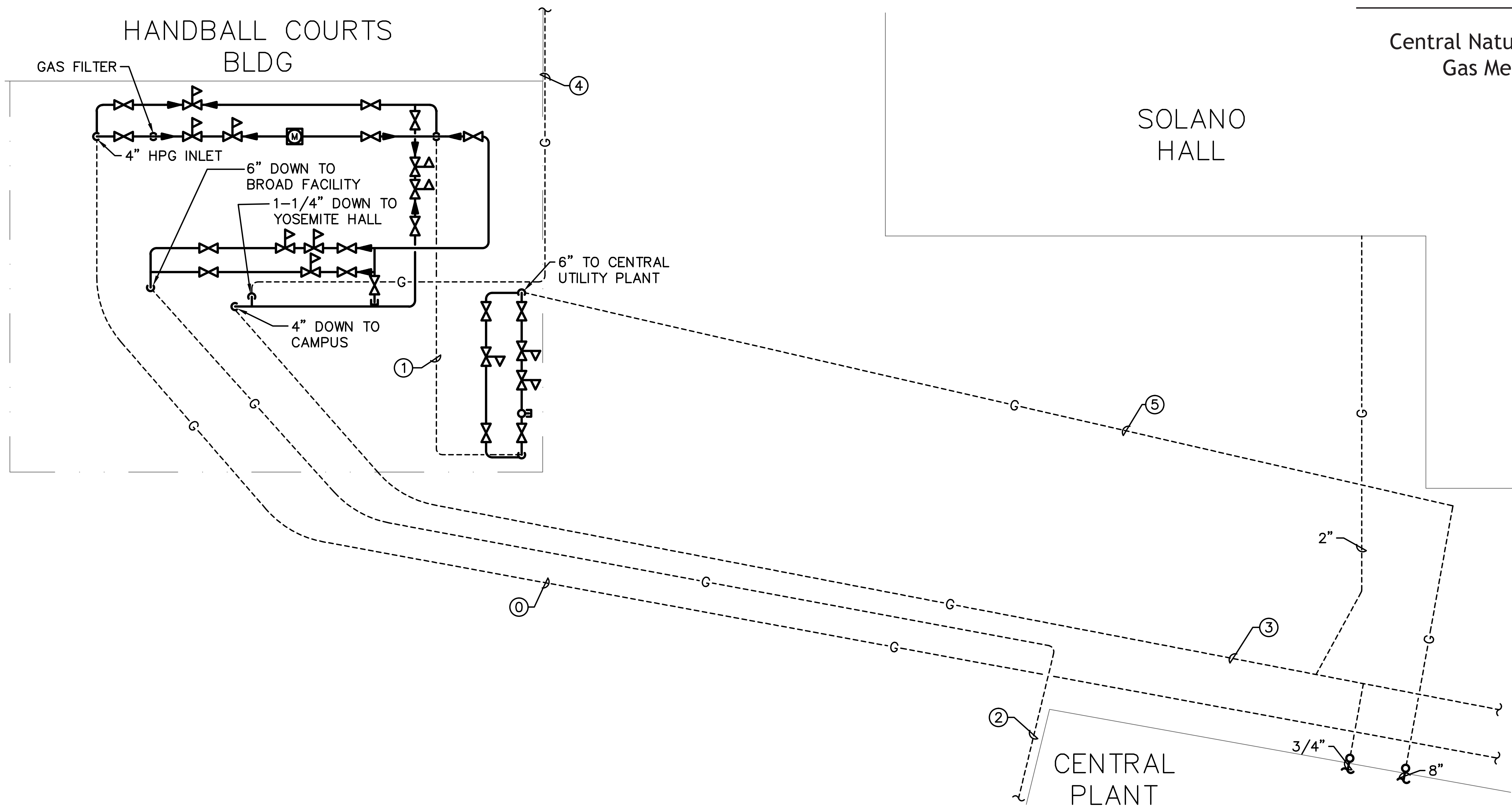
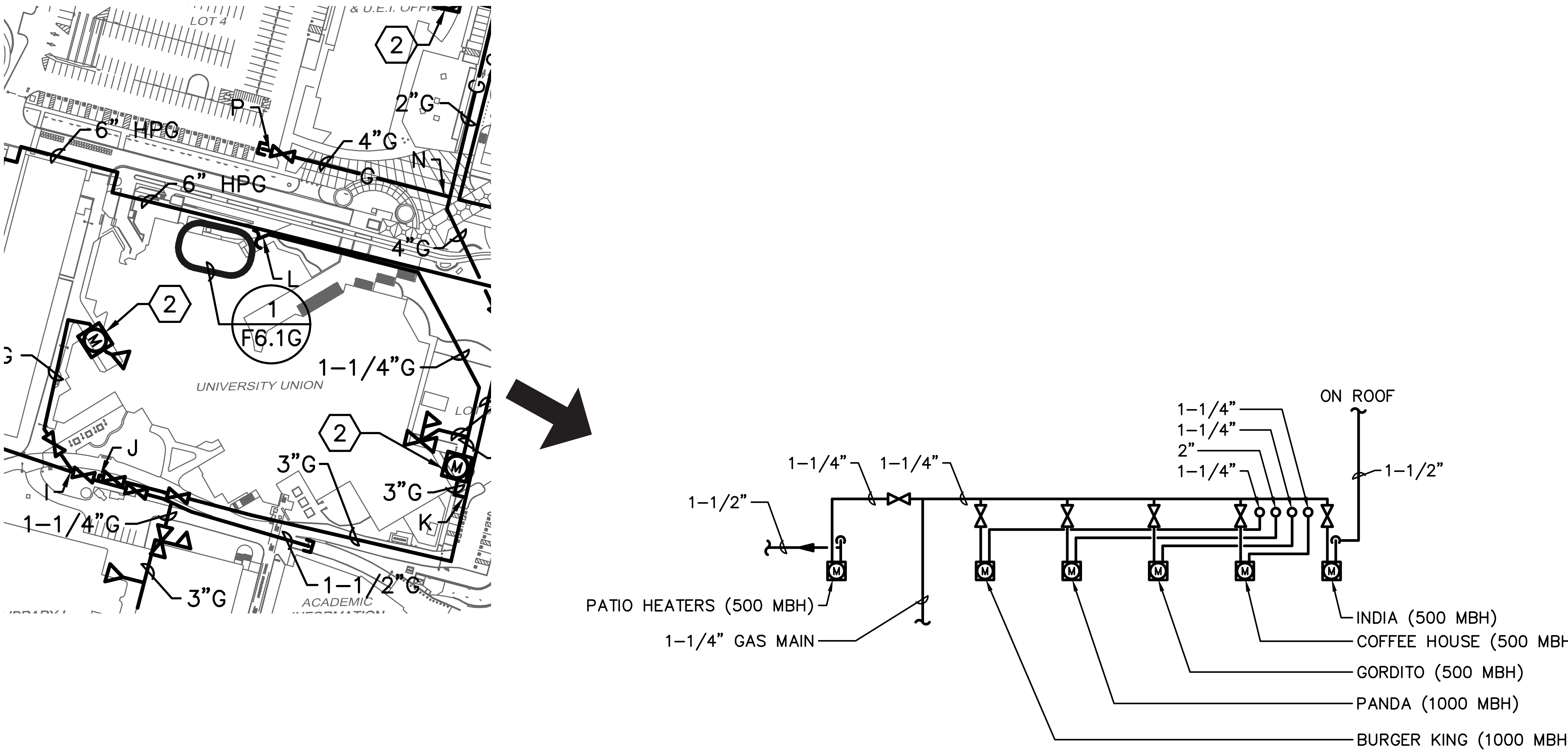


Figure 6.1G

University Union Gas Meter Bank Elevation Detail



7 Sanitary Sewer

Executive Summary

As recommended by the 2004 Sanitary Sewer Scoping Study, a portion of the South Campus sewer system should be conveyed to the system in College Town Drive. Parking Structure II, Child Development Center, El Dorado Hall, City Office of Education, Public Service Annex, Art Sculpture Lab and Public Safety building can all be rerouted to College Town Drive via gravity flow. The lift station at Parking Structure II can thus be eliminated, providing relief from the over capacity mainline along Sinclair Road. As the South Campus develops, the County sewer systems in both College Town Drive and Folsom Boulevard should be seriously considered as tie-ins. This is preferable to installing sewer force mains, as shown in the 2004 Sanitary Sewer Scoping Study, that route sewer flows to the already overloaded Sinclair Road system.

The 2004 Scoping Study also recommends tying into the "J" Street City sewer system near the dormitories on the north end of campus. As the American River Courtyard buildings II, III and IV are developed in that area, a new connection at "J" Street should be considered, providing further relief to the Sinclair sewer connection.

As each future improvement project reaches the design phase, a thorough sewer flow analysis should be performed to determine the actual effects on the overall sewer system.

Introduction

This report has been prepared based on previous studies, data made available from CSUS and conversations with the City and County of Sacramento. The data received is not exhaustive or comprehensive. Any additional information may alter the conclusions of this report. The utility master plans from 1966 and 1989 were studied and analyzed as a baseline starting point for understanding the historic record of the campus sewer system. Second, the 2000 City Memorandum, the 2004 Scoping Study and the 2007 Infrastructure Upgrades were reviewed to determine what analysis had already been done and what upgrades had actually been implemented. Combining this information with data and CAD drawings from CSUS, a final assessment was performed and several recommendations have been made regarding future development and next steps for further development of the sanitary sewer master plan.

Previous Studies

1966 UTILITY MASTER PLAN (KENNEDY ENGINEERS)

The entire sewage system discharges to a single trunk line along Sinclair Road. With the exception of a pumping facility just south of the dormitories, the entire campus is gravity flow. The Sinclair Road sewer trunk flows through a 6-inch Parshall Flume that has been declared "inaccurate due to construction deficiencies" (Kennedy, 10). The flume connects to a series of 12-inch steel and vitrified clay pipes, which tie into the City's 24-inch sewer line.

Because of the inaccuracy of the Parshall Flume, sewer flows were calculated by taking 75 percent of domestic water usage. In 1966, the average daily sewer flow for the campus was 110,000 gpd. The 1985 estimated flow was 615,000 gpd. General practice calculates peak sewer flow using a peak-to-average ratio of 1.5. This yields a peak flow of 640 gpm. The dormitories require a higher peak-to-average ratio of 3.5, yielding a peak flow of 1,000 gpm. Given that the capacity of the existing 12" trunk line is 735 gpm, an additional sewer trunk is recommended.

The sewage system for the existing North Campus is considered to have adequate capacity. The proposed South Campus will have a sewage system "totally independent of the existing system" (Kennedy, 11). The estimated 1985 peak flow for the South Campus is 700 gpm. The proposed trunk sewer will be constructed approximately 1,600 feet south of the existing trunk sewer (Kennedy, Plate 3), and will connect to the City's 24-inch sewer at the intersection of M Street and 61st Street. A Parshall Flume will be installed to monitor campus sewer flows.

1989 UTILITY MASTER PLAN UPDATE (BOYLE ENGINEERING CORP.)

There are five (5) sewage lift stations on the CSUS campus. All sewage leaves the campus through the 12-inch mainline along Sinclair Road. In 1985, Video Inspection Service Inc. of Fresno, California performed a TV inspection of the sewer mains. 28 building laterals were reported as improperly connected to the sewer mains, and in need of replacement.

Assuming sewer flows based on 80% of domestic water usage, the following flows were developed for both existing and future conditions. "PF" denotes peaking factor multiplied to the average daily flow to obtain the maximum day and the peak hour flows.

	Existing Flow (MGD)	Existing PF	Future Flow (MGD)	Future PF
Average Day	0.17	1.0	0.36	1.0
Maximum Day	0.45	2.7	0.93*	2.6
Peak Hour	0.74	4.5	1.43	4.0

*"If the dorms were omitted from future flow estimates, the maximum day flow rate would be approximately 0.75 mgd." (Boyle, 3-4)

A computer model was created using a program developed by Boyle Engineering. The model is based on existing pipe geometry and certain assumptions regarding flow from point sources. On the whole, Boyle concludes, "Preliminary computer analysis indicated the existing sewer system should have additional capacity for the proposed future building expansion" (Boyle, 3-7). As shown in the table above, the Future Maximum Day Flow is 0.93 mgd. This is within the 1.0 mgd capacity for the existing 12-inch sewer main. The caveat is that physical flow monitoring is necessary to verify the assumptions made by the computer model. Boyle reports that if flow monitoring indicates that the system exceeds the 1.0 mgd capacity of the existing 12-inch sewer main, a new parallel main would need to be constructed. This new parallel sewer main would extend 700 feet beyond the campus before discharging into the City's 24-inch line at the intersection of M Street and 61st Street (Boyle 3-7).

2000 MEMORANDUM: ANALYSIS OF CSUS SEWER OVERFLOWS AND CITY SUMP 32 (CITY OF SACRAMENTO DEPARTMENT OF UTILITIES)

City analysis of sewer overflow on Sept. 12 and 28, 2000 indicates that the CSUS overflows were caused primarily by root blockages between Elvas Ave. and the Southern Pacific Railroad. The surcharge caused by the bypass of Sump 32, which was required for maintenance, may have exacerbated the problem.

According to Central Valley RWQCB policy on combined sewer / storm drainage systems, any new City construction requires mitigation of any increased flows. Historically CSUS has been exempt from these mitigations due to no City reviews or permits required for a State University facility. At minimum CSUS should self regulate sewer flows to meet City and RWQCB requirements.

2004 SANITARY SEWER SCOPING STUDY (SANDIS HUMBER JONES)

This study was performed to analyze the impact of future construction on the existing sanitary sewer system. Recommendations were made both to solve existing problems as well as to provide capacity for the Master Plan build out. A number of the lift stations and pipe elements were recommended to be replaced or upgraded. Two additional outfalls were recommended to lessen the load on the existing sewer main along Sinclair Road. The dormitories on the north end would discharge to "J" Street, and a portion of the South Campus would discharge to College Town Drive. The study offers a number of reasons why adding additional outfalls is preferable to constructing an overflow facility: "This alternative [of additional outfalls and overall system upgrades] will considerably reduce the flow to the already overburdened main in Sinclair." (Section IV, paragraph 3). However, the exhibits in Appendix A do not reflect this approach. The exhibits show all future buildings, including the south campus buildout, tying into Sinclair with proposed force mains where necessary.

This report calculated peak flows as the summation of all fixture units operating at the same time. As stated in the report, "This produced very conservative flows" (Section II, paragraph 3). Consequently there was a significant discrepancy between the flows measured in the field and the calculated flows based on fixture units. The effects of wet weather were also not factored into flow calculations.

2007 UTILITY INFRASTRUCTURE UPGRADE (CARTER AND BURGESS)

In 2007, a number of existing sewer facilities were abandoned, removed or rehabilitated with new pipe lining. Several new sewer facilities were also installed. Most notable are the improvements associated with the University's discharge into the City's sewer system at the West end of Sinclair Road. A new Parshall Flume was installed, replacing the original faulty one. A new surge storage tank, wet well and lift station were also installed to handle peak flows from the sewer mains along State University Drive West. The surge tank and lift station were constructed in-lieu of the recommendation in the 2004 Scoping Study to not build an overflow facility.

Summary of Existing Conditions

The information and data currently available allow for a number of conclusions to be drawn. With the exception of Modoc Hall, Napa Hall and the Capital Public Radio building, the entire campus discharges to City of Sacramento facilities at the west end of Sinclair Road. As stated in the 2004 Scoping Study, the Sinclair Road sewer main is "overburdened" (Sandis Humber Jones, Section IV, paragraph 3), and additional sewer loads are not recommended. However, counter to this recommendation, a new surge tank and lift station was constructed as part of the 2007 sewer infrastructure upgrades. No new tie-ins at "J" Street or College Town Drive were implemented, and a parallel main line was not constructed along Sinclair Road.

While there have been no reported issues since the 2007 sewer infrastructure upgrades, the City has noted in the 2000 Memo that the University has not been held to the normal standards of mitigation associated with increased sewer loads because of different processing procedures for CSUS. The University needs to be aware that for every new development, CSUS is responsible for mitigating increased sewer loads. While the City may not directly monitor these mitigations, the University is still responsible and may be liable for overloaded City/County facilities downstream.

Due to the majority of the campus discharging at Sinclair Road, a reasonable estimate of sewer discharge can be made from the domestic water records. As stated in the 1989 Boyle Study, sewer flow rates can be estimated by "assuming approximately 80% of the domestic water will end up as sewage" (Boyle, 3-3). The majority of campus sewage discharges at the Sinclair connection. Only Napa Hall, Modoc Hall and the Capital Public Radio building discharge at College Town Drive. So a reasonable estimate of sewer discharge flows at the Sinclair connection can be made by taking the total domestic water flows, subtracting the domestic water flows contributing to the College Town connection, and multiplying by 80%. This estimate does not take into account wet weather flows, peak flows or storage at the various lift stations. See appendix for calculations and additional water usage data.

The approximation described above yields an estimated peak hour sewer discharge to the Sinclair connection of 1.0 cfs for fiscal years 2009 -2010 and 2010-2011. Corresponding average day and maximum day flows are 0.2 and 0.6 cfs respectively. The historic maximum rate of discharge to City of Sacramento facilities is 0.7 cfs.

On February 9, 2012 field measurements were taken of sewer flow levels at the Sinclair Road mainline just west of State University Drive West. At 10:32 AM a flow depth of 0.56' was measured. At 11:30 AM a flow depth of 0.40' was measured. Assuming that the plans for the 2007 Sewer Infrastructure Upgrades are accurate, these depths correspond to flows of 1.3 cfs at 10:32 AM and 0.7 cfs at 11:30 AM.

CSUS records also indicate similar flow depth measurements. On October 14, 2007 at 9:30 AM a flow depth of 1.37 cfs was observed in the Sinclair Road mainline. This is reported as a frequent peak event during class breaks.

CSUS facilities management personnel have indicated that there is a sewer maintenance schedule which cleans out the entire sewer system twice per year. Adherence to this maintenance schedule ensures that the sewer system is working properly with no tree roots or debris build up.

The City of Sacramento Department of Utilities was contacted with regard to the existing sewer connection at Sinclair Road. The City indicated that there have been no new sewer improvements downstream of the Sinclair Road connection that would impact the sewer capacity of CSUS. The County of Sacramento was contacted with regard to the College Town Drive connection. Sewer facilities maintained by the County are under the jurisdiction of Sacramento Area Sewer District (SASD), formerly called County Sanitation District – 1 (CSD-1). SASD has indicated that the existing 8" sewer line in College Town Drive is designed to accommodate the six parcels between State University Drive South, State University Drive East and Folsom Boulevard (See Appendix for aerial image). This area serves the existing buildings of Napa Hall, Modoc Hall and the Capital Public Radio building. This area also includes the future Parking Structure V and future Performing Arts building.

SASD has indicated that these six parcels in the South Campus were modeled with 4.15 ESD's per acre. SASD has also indicated that the existing 8" sewer line in College Town Drive has the capacity to serve the same area up to 10 ESD's per acre. Considering that this area is roughly 20 acres, there is an additional 35,000 gpd that can be added to the existing 8" sewer line. Given that sewer flows from the Fairbairn Water Treatment Plant remain constant, redirected flows from areas north of State University Drive South can be re-routed to College Town Drive and use this additional capacity. Additional flows exceeding 35,000 gpd will require upsizing the 8" sewer line and any associated downstream improvements, along with the associated sewer impact fees.

Proposed Improvements

1. COLLEGE TOWN DRIVE TIE-IN

The 8" main line in College Town Drive will be extended west along State University Drive South to serve the future South Campus buildings. All future development in Lot 7, including the Engineering II building, the future Art building and Classroom III will tie into this College Town Drive system. This provides a more robust long term solution, as the 12" sewer main along Sinclair Road already exceeds the City allowed flow. All additional development in the South Campus should also utilize this connection to College Town Drive.

2. ELIMINATE PARKING STRUCTURE II LIFT STATION

As an alternative to the future gravity line replacing the Parking Structure II Lift Station flowing toward the west (Line "C" as shown in the 2007 Sewer Infrastructure Upgrade), all sewer flows contributing to the Parking Structure II lift station will be rerouted to College Town Drive by gravity flow. Parking Structure II, the Child Development Center, El Dorado Hall, the Public Safety building, the Sacramento City Office of Education, and the Art Sculpture Lab will all discharge to College Town Drive. This will allow the future Science Building II to be built without overloading the existing Sinclair Road sewer main.

3. ELIMINATE BENICIA HALL LIFT STATION

As shown in the 2007 Sewer Infrastructure Upgrade, the lift station and force main at Benicia Hall will be reconstructed to gravity flow to State University Drive West. Recent improvements to the sanitary sewer system downstream of Benicia Hall have enabled the lift station to be removed and a gravity flow system to operate in its place.

4. ELIMINATE ALUMNI CENTER LIFT STATION

The existing lift station for the Alumni Center can be eliminated and tied into either the College Town Drive sewer system by gravity flow. This will eliminate the need for a lift station and provide relief for the surge tank near Sinclair Road and State University Drive West.

5. AMERICAN RIVER COURTYARD

The construction of the future dormitories in the north campus (American River Courtyard) will require a thorough study of the proposed sewer flows and its effects on the downstream sewer mains and surge tank. Consideration should be given to tying into the sewer system in "J" Street, as discussed in the 2004 Sanitary Sewer Scoping Study.

Ultimate Master Plan Build Out

According to the overall Campus Master Plan, there is a number of expansion projects expected to take place in the relatively near future. New development in the South Campus should consider tying into the County sewer system at College Town Drive. Placing additional loads on the existing outfall at Sinclair Road should not be allowed without diverting additional flows to the surge tank to mitigate peak flows. This will ensure that wastewater will continue to be metered out from the surge tank at the Sinclair connection within the reported City required maximum of 0.7 cfs.

Capital Improvement Program

A preliminary cost estimate has been prepared for each of the proposed sewer improvements discussed above (See Appendix). These cost estimates are for planning purposes and are subject to change based on fluctuations in the market and unforeseen design issues.

Further Action Items

As each future development project reaches the design phase, a more thorough investigation of impacts to the existing sewer system will need to be conducted. An accurate assessment of peak flows based on appropriate methodologies involving proposed occupancy per capita flows and peaking factors will need to be developed as a basis for designing the associated sewer system.

DETERMINE CURRENT PEAK FLOWS

Monitoring flows during peak hours at strategic points in the campus sewer system can serve as an accurate record of existing peak flows. The existing Parshall flume at the Sinclair Road outfall serves as one such monitoring point for the Sinclair 12" sewer main (when the surge tank is not discharging). These peak flows will determine whether the system is surcharged at certain points, and what improvements may be necessary to accommodate future projects.

PUMP AND SURGE TANK UPGRADES

The surge tank at Sinclair Road and State University Drive West needs to be analyzed with respect to future capacity. As new projects are designed, an analysis regarding impacts to the capacity of the surge tank needs to be conducted if it is determined that new project flows will contribute to this system. Appropriate upgrades to the existing surge tank or additional surge tanks may need to be constructed to accommodate future development.

The 2004 Scoping Study also identified three lift stations that need replacement: Library I, Amador Hall and Sequoia Hall. None of these improvements were completed in 2007. Each of these pumps will need to be reassessed and scheduled for replacement, either with future projects or with the ongoing maintenance cycles for the campus sewer systems.

Figure 7.1

Sanitary Sewer Exhibit

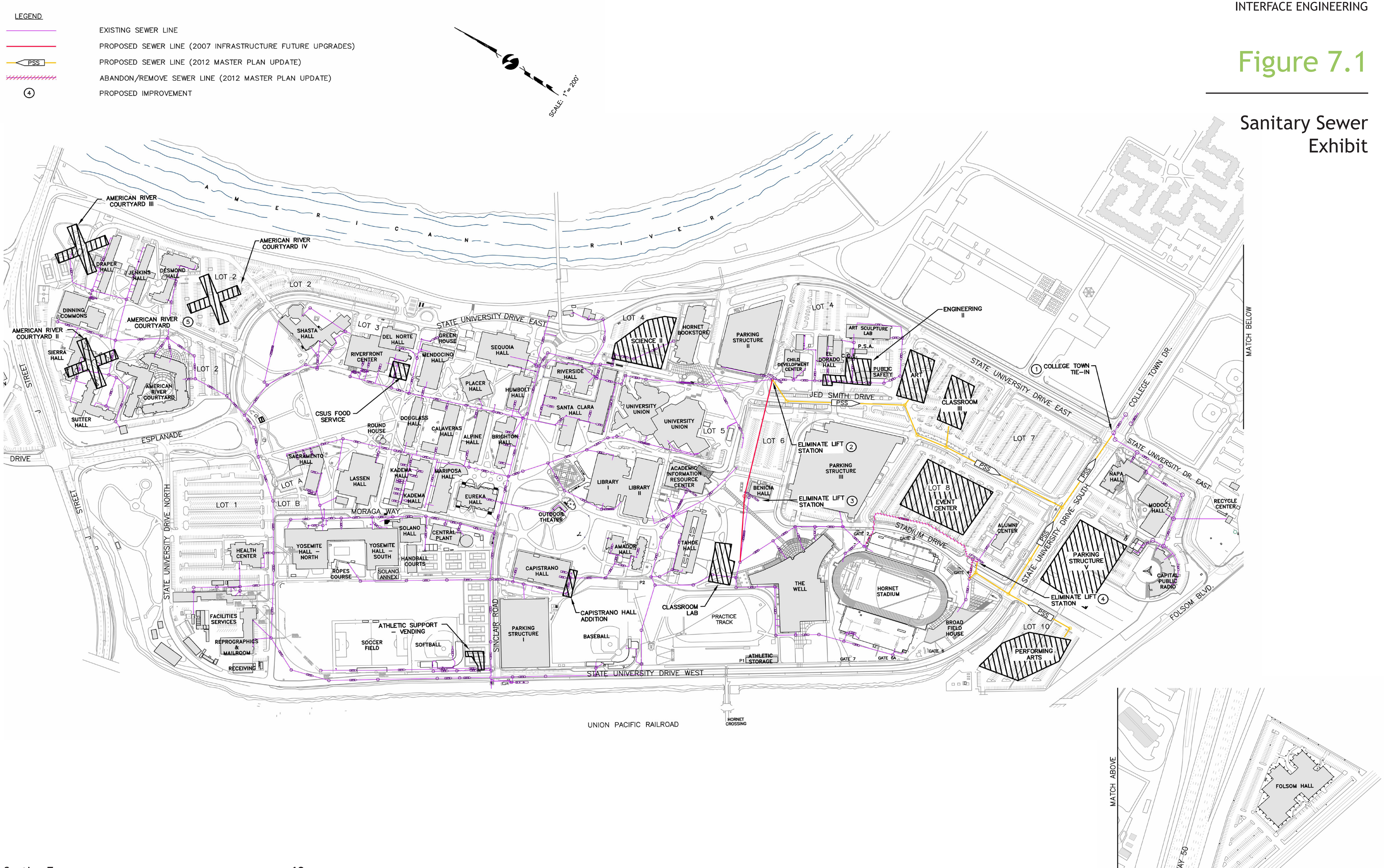


Figure 7.2

College Town
Sewer Line Email

From: Charles RUTTER
To: Tawa, Nick
Date: 2/21/2012 1:22 PM
Subject: Fwd: RE: RE: CSUS - Sewer and Water MP
Attachments: Sac University campus South Parcels.gif

>>> "Singh. Amandeep (SDA)" <singha@sacsewer.com> 2/21/2012 12:40 PM >>>

Hi Charles,
Attached is the parcel map info which we talked about. SASD has modeled these six parcels with 4.15 ESD's/acre. The 8" line has capacity to serve upto 10 ESD's/acre from these six parcels. The only variable is Fairbairn discharge. As long as the discharge from Fairbairn stays constant, these parcels can have abovementioned densities. Density beyond 10ESD's/acre will require upsizing the downstream sewer infrastructure.
If you have any questions please let me know.

Thanks,

Amandeep
916-876-6296

Figure 7.3

College Town Dr. Sewer Line Contributing Parcels

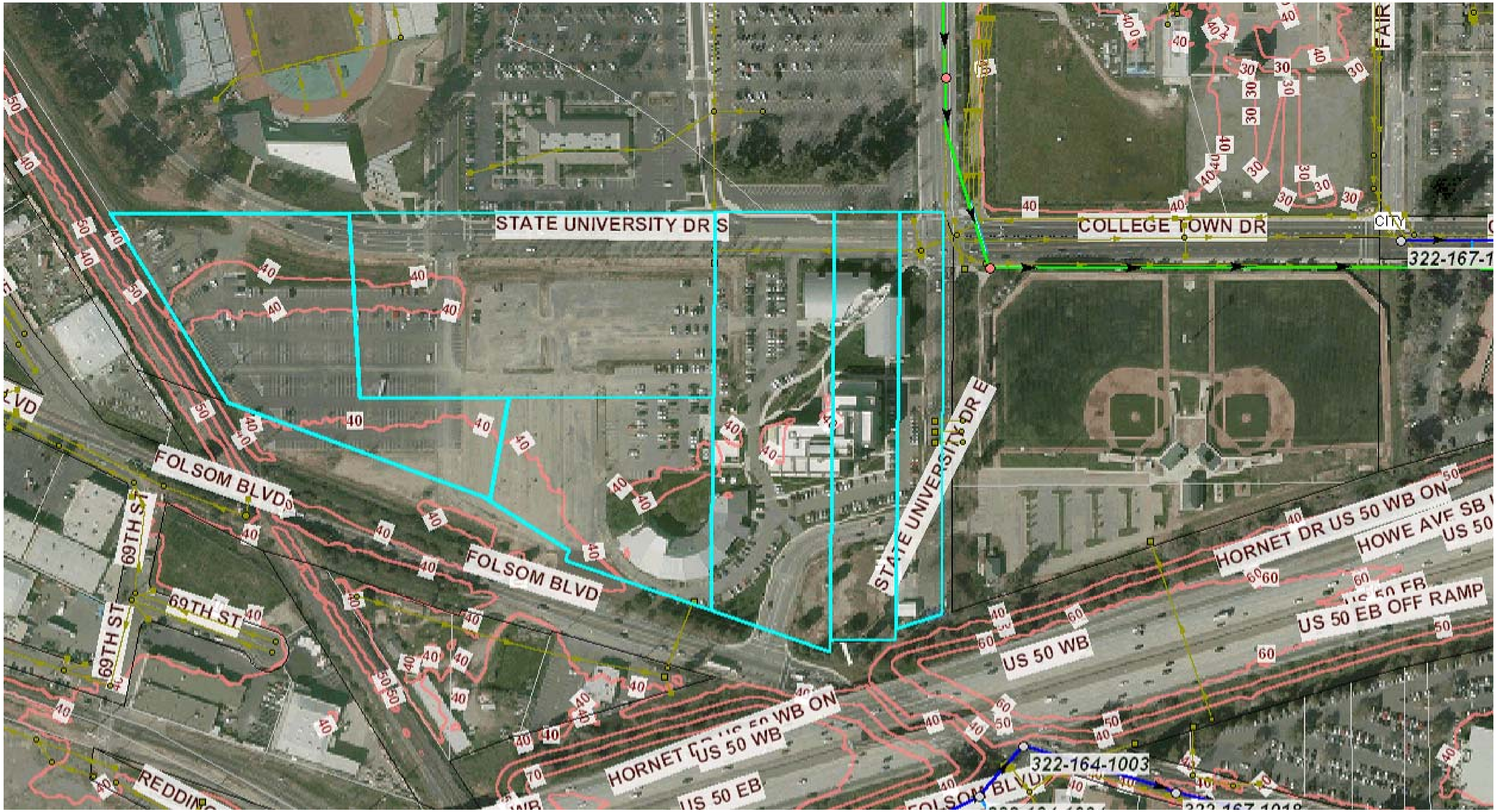


Table 7A

Estimated Sinclair Rd. Sewer Fows

Domestic Water Usage	FY 08/09 ccf	FY 09/10 ccf	FY 10/11 ccf	
Jul	6,474	5,553	5,940	
Aug	7,689	8,326	6,134	
Sep	8,990	7,007	8,057	
Oct	11,611	10,959	10,422	
Nov	11,718	10,654	9,420	
Dec	8,834	7,994	9,136	
Jan	7,825	6,626	6,833	
Feb	4,758	4,270	3,831	
Mar	8,147	7,493	8,337	
Apr	7,694	8,609	9,085	
May	8,025	7,954	8,781	
June	8,212	7,489	7,683	
TOTAL WATER USAGE (ccf)	**99,977**	**92,934**	**93,659**	
TOTAL WATER USAGE (gpd)	**204,884**	**190,451**	**191,937**	
Subtract Private Meters (gpd)	**N/A**	**8,940**	**9,407**	
Domestic Water (gpd)		**181,511**	**182,530**	
80% Domestic Water (gpd)		**145,209**	**146,024**	
80% Domestic Water (cfs)		**0.22**	**0.23**	
				Peaking Factor (PF)
Average Day		**0.22**	**0.23**	1
Maximum Day		**0.61**	**0.61**	2.7
Peak Hour		**1.01**	**1.02**	4.5

Table 7B

CSUS Private Water Meter Record

June 2009-May 2010

FY June 2009 - May 2010	Jun-09		Jul-09		Aug-09	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	485.70	$430.56	278.70	$244.21	405.30	$522.67
Modoc	483.00	$428.15	520.00	$455.65	464.00	$598.37
Napa	7.39	$6.55	7.08	$6.20	6.18	$7.97
MONTHLY TOTALS (CCF)	**976.09**		**805.78**		**875.48**	

	Sep-09		Oct-09		Nov-09	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	385.30	$322.92	14.80	$12.46	20.50	$17.77
Modoc	369.00	$309.26	152.00	$127.92	53.00	$45.93
Napa	7.53	$6.31	5.75	$4.84	4.35	$3.77
MONTHLY TOTALS (CCF)	**761.83**		**172.55**		**77.85**	

	Dec-09		Jan-10		Feb-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	5.40	$4.96	0.66	$0.68	13.04	$11.51
Modoc	20.00	$18.36	27.00	$27.79	28.00	$24.71
Napa	2.20	$2.02	3.25	$3.35	4.30	$3.80
MONTHLY TOTALS (CCF)	**27.60**		**30.91**		**45.34**	

	Mar-10		Apr-10		May-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	1.85	$1.61	81.43	$72.00	203.06	$181.67
Modoc	34.00	$29.63	54.00	$47.75	200.00	$178.93
Napa	5.10	$4.44	5.24	$4.63	4.33	$3.87
MONTHLY TOTALS (CCF)	**40.95**		**140.67**		**407.39**	
TOTAL FLOW FY 09/10 (CCF)	**4,362.44**					
TOTAL FLOW FY 09/10 (GPD)	**8,940**					

Table 7C

CSUS Private Water Meter Record

June 2010-May 2011

FY June 2010 - May 2011	Jun-10		Jul-10		Aug-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	369.50	$347.80	444.85	$475.72	444.85	$449.75
Modoc	333.00	$313.44	535.00	$572.12	480.00	$485.29
Napa	7.25	$6.82	7.26	$7.76	7.60	$7.68
	709.75		987.11		932.45	

	Sep-10		Oct-10		Nov-10	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	116.05	$112.68	31.36	$30.94	178.79	$176.80
Modoc	410.00	$398.11	185.00	$182.54	13.00	$12.86
Napa	5.75	$5.58	4.99	$4.92	3.10	$3.07
	531.80		221.35		194.89	

	Dec-10		Jan-11		Feb-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	3.50	$3.67	4.60	$5.64	5.60	$5.44
Modoc	14.00	$14.68	11.00	$13.48	17.00	$16.52
Napa	2.78	$2.91	2.58	$3.16	3.16	$3.07
	20.28		18.18		25.76	

	Mar-11		Apr-11		May-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	8.80	$8.74	157.60	$157.38	238.50	$239.36
Modoc	20.00	$19.85	212.00	$211.70	297.00	$298.07
Napa	5.94	$5.90	4.70	$4.69	4.35	$4.37
	34.74		374.30		539.85	

TOTAL FLOW FY 10/11 (CCF)	**4,590.46**
TOTAL FLOW FY 10/11 (GPD)	**9,407**

Table 7D

CSUS Private Water Meter Record

June 2011-Nov 2011

June 2011- Nov 2011	Jun-11		Jul-11		Aug-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	283.40	$300.36	283.40	$301.16	356.20	$368.22
Modoc	394.00	$417.58	426.00	$452.70	401.00	$414.53
Napa	5.87	$6.22	7.50	$7.97	6.55	$6.77
	683.27		716.90		763.75	

	Sep-11		Oct-11		Nov-11	
	CCF	$	CCF	$	CCF	$
Capital Public Radio	250.10	$238.55	31.36	$30.80	23.32	$23.54
Modoc	400.00	$381.55	93.00	$91.35	26.00	$26.25
Napa	6.17	$5.89	5.33	$5.24	3.05	$3.08
	656.27		129.69		52.37	
TOTAL FLOW JUN-NOV '11 (CCF)	**3,002.25**					
TOTAL FLOW JUN-NOV '11 (GPD)	**12,476**					

8 Storm Drain

Executive Summary

The CSUS campus drainage studies performed in 1966, 1989 and 2007 provide valuable information with respect to the historic drainage issues on campus. Omni-Means reviewed these drainage studies, extracted relevant historical data, and summarized key points in the report below.

Omni-Means then performed similar analyses regarding peak flows and pipe capacity. The Sac Calc computer program, which utilizes Sacramento County precipitation data and the Army Corps of Engineers' HEC-HMS (Hydrologic Modeling Software), was used to develop peak flows at various control points.

These peak flows were then applied to a Manning's hydraulic grade line analysis for each relevant drainage system. Many of the pipe systems were found to be over capacity. The solutions listed below are based on the observed deficiencies with respect to hydraulic grade lines and pipe capacity.

South Campus

1. Underground Detention at Lot 6.
2. Re-Route Portion of South Campus to Western Ditch (use pump for interim solution)
3. Upgrade Library II Pumps
4. Alter Tahoe Hall Outfall and Watershed
5. Re-route Library II Roof Drainage Across Stadium Drive
6. The WELL Lawn Underground Detention
7. Re-route Hornet Stadium to Western Ditch

North Campus

1. Re-route Sinclair Road Drainage
2. Utilize Green Area North of Douglass Hall for Detention
3. Re-route Additional Drainage to Storm Lift Station #2
4. Upsize Mainline along State University Drive East

The next step in the process is to compile an XPSTORM computer model (or equivalent). This will provide a comprehensive analysis of the entire campus' storm drainage system. Pump capacities, pipe systems, and ground elevations will be sync'ed together to provide a two-dimensional representation of how runoff moves through the campus during select storm events. A XPSTORM model will provide greater accuracy for surcharged pipes, as well as for when and where flooding occurs. The model will also provide greater clarity regarding how well the proposed solutions will operate. BMPs can be added to the model as well to test effectiveness. A XPSTORM model is highly recommended and will serve to move the campus storm drain master plan beyond the one-dimensional analyses that has taken place in the past.

Completion of this report is contingent upon the following information requested from the university:

1. Rainfall gauge data for storms that have caused flooding or other issues on the campus; with anotation as to where and what the nature of the flooding or issue was.
2. Consensus with City of Sacramento on short term and long term drainage capacity of Western Ditch.

Introduction

This report provides an overall analysis of the CSUS campus with regard to storm drainage. Specifically, it provides an assessment of the existing conditions, highlighting the causes of the current drainage issues and localized flooding. This report also takes into account potential future developments as outlined in the Campus Master Plan. Previous studies have been used for reference and comparison purposes. These studies have aided to establish a thorough understanding of the existing conditions. Based on this knowledge, a number of proposed solutions have been developed. These solutions serve not only to solve the existing drainage issues, but also to provide capacity for future development.

Previous Studies

Since moving to its permanent location in 1953, there have several studies done with regards to storm drainage. In 1966 Kennedy Engineers developed a Utility Master Plan of the entire campus. In 1989 Boyle Engineering Corporation provided an updated Utility Master Plan. In 2007, Carter and Burgess developed a South Campus Drainage Report.

1966 Utilities Master Plan (Kennedy Engineers)

Background information provided in the "Description of Site" section is helpful in understanding natural drainage patterns and potential drainage issues. The report states that the campus is the natural ponding area of the Sutter Sough, with a tributary area of approximately 7,000 acres. The City of Sacramento also uses the ditch adjacent to the railroad to convey flows from City Sump 31. At the date of the report (1966), the maximum discharge into the ditch was 60 cfs.

Kennedy Engineers also highlighted that the entire campus is reliant on pumps for effective drainage of the property. Also notable is that the then proposed library was being built on a natural low point. Consequently, the report describes "a recommended fill area centering about the location of the proposed library building. This nominal land fill area appears to be essential, not only in order to effect an efficient drainage pattern, but also to avoid a vulnerable low area near the center of campus activity" (Kennedy, 26). Evidently these words have proved prophetic, as localized flooding around the South Library, Academic Information Resource Center and University Union has been especially problematic in recent years.

In 1966, the only pump station was the original one built in 1952 near the east end of Sinclair Road, discharging directly into the American River. Kennedy Engineers recommended two (2) alternatives: 1) Re-route a portion of the west edge of campus to the ditch along the railroad levee via a new pump. 2) Continue to route all flows to the original pump. The former alternative was selected.

The report states, "Normally, storm water pumping facilities for drainage of an area solely dependent on pumped drainage would be recommended to meet the needs of a 25-year storm" (Kennedy, 27). However, the pumping facilities were designed to accommodate less than a 25-year storm for the following reasons. First, the proposed pump at the west end of campus was designed to accommodate a 5-year storm because the "turfed" areas could sustain ponding without damage (Kennedy, 9). Similarly, the "existing and enlarged" pump station on the east end of campus was sized only for a 10-year storm event, because the pipe network of Hornet Stadium was designed to provide detention.

Reinforced concrete pipe was recommended for all proposed storm drains: 12-inch minimum for mainlines and 10-inch minimum for laterals (Kennedy, 30). Additional capacity was recommended for the original pump station to accommodate the proposed improvements on the south side of campus. A recommendation was also made to contact the City of Sacramento to clarify the College's right to discharge into the west perimeter ditch (Kennedy, 29).

1989 Utility Master Plan Update (Boyle Engineering Corp.)

Citing the 1956 Agreement and Grant of Easement between the State of California and the City of Sacramento, Boyle Engineering writes, "CSUS has a storm drainage discharge agreement with the City of Sacramento for the on-site drainage channel. The City must accept any amount of storm drainage flow developed on campus into the on-site storm drainage channel." In other words, any amount of drainage generated on the CSUS campus can be re-routed into the ditch. Omni-Means is currently in contact with the City of Sacramento to confirm that this 1956 Agreement and Grant of Easement is still valid, and that no other agreements have been entered into.

According to this Master Plan Update the western drainage ditch also accepted drainage from 903 acres south of the campus. Citing the 65th Street Expressway Drainage Study (1987) by the Spink Corporation, the capacity of City Sump 31 was determined to be 129-139 cfs. The on campus ditch had a capacity of 153 cfs. Additionally, ARFCD (American River Flood Control District) Sump #5, where these flows ultimately discharge into the American River north of "J" Street, was determined to have a capacity of 170 cfs. The City now owns and operates Sump #5, and renamed it Sump #155. In 2001, Sump 31 pipelines were installed, redirecting the 903 acres of offsite drainage directly through the campus and into the American River.

In February of 1986, Sacramento experienced the equivalent of a 100-year storm event, with 2.63 in of rainfall in 24 hours, and 7.85 inches in seven days. The campus experienced no major flooding problems, but the water surface elevation of the American River was near the top of the levee.

At the time this Master Plan Update was completed (1989), there were 3 pumping stations. Listed by the university's current naming system, these are Storm Lift Stations 1, 3, and 4. Storm Lift Station 2 was built shortly after this Master Plan Update was completed.

Boyle Engineering Corp. estimated that a 10% increase in permeable land was expected through the removal of buildings and parking lots. This would have reduced the amount of peak runoff entering the storm drain system (Boyle, 4-5). The report references the "future campus master plan," but the precise location of these new permeable lands was not specified.

2007 South Campus Drainage Report (Carter and Burgess)

This study encompasses the area bound by Tahoe Hall to the north, State University Drive South, State University Drive East, and State University Drive West. Using StormCAD (Haestad Methods Inc.) and the Sacramento City and County Drainage Manual, Carter and Burgess analyzed the existing storm drainage system at 9 different phases of development. At the time of the report, Phase 2 was underway with the construction of the Bookstore. With the completion of the Recreation/Wellness Center (The Well), the campus is currently (2011) at the end of Phase 4. At each phase, the major existing storm drain facilities were determined to be either adequate or inadequate with regard to conveying various storm events.

On the whole, Carter and Burgess found many of the existing facilities to be inadequately sized and/or sloped. The report states, "The cause of the problems with the system is fairly simple. In short, the piping is too flat in slope and not big enough" (Carter and Burgess, 4). Pipe capacity for the 2-year, 5-year, 10-year and 100-year storm events was documented as "OK" for sufficient or "EX" for exceeded. See "Summary Table – End of Phase 4" (Carter and Burgess, 11). The report identifies areas of deficiency but did not offer solutions.

Synopsis of Previous Studies

As a whole, the campus storm drainage system has been historically undersized and generally inadequate. This is partly due to updates in published precipitation data. In recent years, the Army Corps of Engineers has increased storm event intensities to match the most current rainfall data. The campus' location at the natural outfall of Sutter Slough has posed problems for both onsite and offsite drainage. Offsite drainage must either be re-routed around the campus or through the campus. Drainage routed around the campus is conveyed through the Western Ditch, and through the campus via the Sump 31 pipelines constructed in 2001. Some on-site drainage naturally collects at the current location of the library. Pumps can redirect this drainage, but problems may arise with the lack of an overland release path for larger storms, as well as with power outages and other forms of pump failure. A series of modifications and adjustments will be necessary to solve the campus' current drainage problems.

Summary of Existing Conditions

As reported by CSUS campus maintenance, on-site flooding has occurred on the lower levels of the Library II South and the Academic Information Resources Center. An interim solution has been implemented that redirects roof runoff from the Library II South via dual 12" storm drains to the storm drainage system between Benicia Hall and Parking Structure III.

The loading dock of the University Union (Lot 5) has also experienced substantial flooding. This drainage system ties directly into the mainline for the south campus that runs from south to north along Jed Smith Drive. As the mainline backs up, the University Union drainage system also backs up.

Although not as detrimental to University property, the athletic fields along State University Drive West have also reported localized flooding. This, however, is consistent with the original design recommendation by Kennedy Engineers in 1966. Because this area is "mostly turfed," it "would sustain only limited damage if subjected to ponding for periods of reasonable duration." (Kennedy, 29)

The following analysis of hydrology and hydraulics explores theses reported existing deficiencies. The analysis also identifies other problem areas with hydraulic deficiencies that may not have not yet been manifested through surface flooding.

HYDROLOGY

Existing Drainage Sheds were defined based on CSUS Storm Drain CAD files and site reconnaissance. The CAD files are based on the North American Datum 1983 (NAD83) coordinate system. Peak flows were modeled using the SacCalc computer program, which applies Sacramento County rainfall data to the Army Corp or Engineers' HEC-HMS software. SacCalc calculates design flows using Sacramento County Hydrology Standards. SacCalc is the de facto standard in the City and County of Sacramento, and has the ability to route runoff hydrographs and simulate detention storage. For this study the kinematic wave method was used for hydrograph routing. See Appendix for Drainage Shed Maps and SacCalc output files.

Currently, there are five (5) main outfalls for the entire campus. All but one of these outfalls is located at a pump station. Storm Lift Station #1 is located at the East end of campus by the Guy West Bridge. This is the main outfall for the campus. The majority of the North side of campus drains to the original 3 pumps, which were constructed in 1952. The majority of the South campus drains to the 3 new pumps constructed in 1970. Storm Lift Station #2 is located at the Northeast corner of campus. It consists of 2 pumps constructed in 1989 and collects drainage from the student housing facilities. Storm Lift Station #3 has 1 pump constructed in 1984, and collects drainage from the Student Health Center, custodial buildings and a portion of Lot 1. Lift Station #4 has 2 pumps also constructed in 1984, and collects drainage from the athletic fields, Tahoe Hall, and a portion of the WELL building. The drainage shed labeled "Direct Outfall" collects drainage from Lot 1 and the botanical gardens on the north side of campus, just south of Esplanade. This drainage shed directly outfalls into the City maintained Western Ditch, where it changes course to a northerly alignment, away from the campus via culverts underneath "J " Street.

HYDRAULICS

Based on invert elevations on CSUS CAD files and As-Built drawings, hydraulic grade lines (HGL) were calculated along the main lines and areas requiring detailed study. The 10-year storm event was used for analysis, as general practice advises that the 10-year HGL be kept within the pipe. See Appendix for HGL worksheets. Note that the HGLs for most of the existing drainage systems are above the top elevation of the pipe. And in some cases, the HGL is also out of the ground. Once the HGL is out of the ground, the system is considered significantly over capacity, and the spreadsheets are no longer accurate representations of water levels. As stated in the Executive Summary, an XPSTORM (2D) model will be needed to further study surcharged pipe systems and overland flooding scenarios.

Storm drain elements are labeled according to the following nomenclature:

X – Existing

P – Proposed

N-MAIN – North Mainline draining to Storm Lift Station #1

S-MAIN – South Mainline draining to Storm Lift Station #1

A, B, C, etc. – Sub-reach

A-1, A-2, etc. – Sub-sub-reach

A-1a, A-1b, etc – Sub-sub-sub-reach

Manning's equation was used to compute the friction losses by solving for a value of the energy gradient, then computing the total friction losses as a product of the energy gradient and the length of the applicable pipe segment.

In addition to friction losses, entrance losses were determined and are a part of the summation of head (energy) losses occurring within the system. The head loss at an entrance to a conduit segment was calculated as follows,

hk = KV2/2g

Where, hk = Entrance Head Loss (ft)

V = Velocity in Conduit (ft/sec)

K = Entrance Loss Coefficient

2g = 64.4 ft/sec2

Entrance Loss Coefficients (K) are used as follows,

= 0.2 For Flared End Sections Used on Piping for Field Drainage Inlets

= 0.5 Used for Standard Drainage Manholes Where the Pipe is Flush with the Edge and is a Straight Run

= 0.9 Use for Drainage Inlets (although 0.5 can be justified in most situations)

= 0.9 Use for Drainage Manholes When the Direction of Flow Changes ≈45°

= 1.1 Used for Drainage Manholes When the Direction of Flow Changes ≈ 90°

Freeboard was calculated by taking the top of grate/rim elevation minus the HGL.

Methodology

Three (3) Sac-Calc Models were created to simulate different phases of improvements. The "EXISTING" model represents the existing campus. The north campus and the south campus are modeled as independent outfalls. The "EXISTING WITH DETENTION" model applies the Underground Detention under Parking 6 (See South Campus Priority 1 below) to the "EXISTING" model. The "PROPOSED" model incorporates Lot 6 Underground Detention as well as the re-routing of Sheds XS-8 through XS-11 to the Western Ditch and the Sinclair Road Drainage Improvements.

The flows produced by the Sac-Calc models were input into the hydraulic grade line spreadsheets in order to analyze the effectiveness of the proposed solutions. This traditional one-dimensional (1-D) approach is adequate for ensuring that the 10-year flow remains within the pipe. However, the next step is to incorporate variables such as overland surface flooding and pump station capacity through a two-dimensional (2-D) approach through the use of a XPSTORM model.

Proposed Solutions

The following improvements are broken into South Campus and North Campus. Each solution is ranked by priority, with "Priority 1" as the highest ranking priority. These solutions are based on the Hydraulic Grade Line calculations, and do not take into account pump capacity, overland flow patterns, or the overall timing sequence of campus drainage. It is recommended that an XPSTORM computer model be done as the next phase of this study.

South Campus Drainage Improvements

South Campus Priority 1: Underground Detention under Parking Lot 6

Currently, the majority of the mainline in the South Campus is over capacity. This causes water to back up into some of the contributing storm drain laterals. This is the primary cause of the flooding of the University Union loading dock (Lot 5). By detaining flows from Sheds XS-6 through XS-11, the downstream mainline will be able to adequately convey the 10-year HGL within the pipe. An underground network of 90" corrugated metal pipes would be installed beneath Parking Lot 6. The detention system will have a total volume of 5.0 ac-ft. Flows will enter at the southeast corner of Parking Lot 6. A series of weirs and orifices will release the water back into the mainline at the northeast corner of Parking Lot 6. See the storm drain system PS-MAIN in the Hydraulic Grade Line Calculations. Note that the mainline upstream of the proposed detention system will remain over capacity. This will help to provide additional detention, further alleviating the downstream mainline as well as reducing the required volume of the proposed detention system. Given that there are no reported flooding issues corresponding to the drainage sheds upstream of the proposed detention system, this is a viable option.

South Campus Priority 2: Re-route Sheds XS-8 through XS-11 to Western Ditch

Based on the 1956 agreement between the City of Sacramento and the State of California, the University has the right to discharge an "unlimited" amount of storm drainage into the City maintained Western Ditch. Realistically, physical characteristics such as ditch size, downstream facilities and pump station capacity limit the amount of drainage that can be added. Given that appropriate studies are conducted regarding the capacity of the Western Ditch, Sheds XS-8, XS-9, XS-10 and XS-11 can potentially be re-routed away from the South Campus Mainline, and into the Western Ditch.

As an interim solution, until further build out of the south campus, a pump will be installed at the southeast corner of Parking Structure III. All flows from Sheds XS-8, XS-9, XS-10 and XS-11 currently flow to this existing manhole. A new pump will be installed at this location, pumping these flows south along Jed Smith Drive, outfalling into the Western Ditch. In the future, when the Art Building, Classroom III and Event Center are constructed, the corresponding drainage systems will be designed to gravity flow to the ditch, and the pump will be removed. Both the interim and future solutions will re-route 29 cfs (10-year) away from Storm Lift Station #1 and into the ditch along State University Drive South, thus alleviating the over capacity 48" storm drain backing up into the University Union dock areas.

South Campus Priority 3: Upgrade Library II Pumps

The pumps at the east end of Library II convey flows from the drainage shed surrounding Library II, excluding the roof drainage. Currently there are two 600 gpm (1.3 cfs) pumps. Operating in tandem, these flows should be able handle the 100-year storm event of 1.9 cfs (See appendix for more detail). However, the lack of an overland release puts this area at risk when short storms of high intensity occur. In 2004, for example, a short cloud burst of 2 inches of rainfall in 20 minutes caused localized flooding. This equates to a rainfall intensity of 6 in/hr. Sustained over a longer period of time, this would have been considered a storm event in the range of 200 to 500 year recurrence intervals.

Normally, drainage systems are not designed to handle anything beyond the 100 year storm event. But given that the library is built on a natural low point with no overland release, larger pumps may be a valid consideration. A storm intensity of 6 in/hr yields a peak flow of 4.2 cfs (1900 gpm) for this 1.1 acre shed area. An additional lift station could be installed with a 600 gpm and 200 gpm pump to fit this scenario. The pumps can be programmed to alternate the three 600 gpm pumps, while the 200 gpm pump is used for low flows. See Appendix for more details.

South Campus Priority 4: Alterations to Tahoe Hall Outfall

Currently, Tahoe Hall and a portion of Amador Hall drain into a 12" pipe that flows West between the Baseball Field and Practice Track. This 12" pipe drains into a 15" pipe that flows from South to North along State University Drive West. (See Appendix for Cost Estimate)

4A. Check Hydraulic Grade Line of 12" Outfall At the current slope, this 12" pipe is undersized. (See Hydraulic

Grade Line Calculations, "Tahoe Hall.") An 18" or 24" pipe is recommended.

4B. Currently, the dual 12" pipes collecting drainage from the rain water leaders of Library II South are routed to the drainage system associated with Benicia Hall. Although this may help with local flooding, it is still contributing to a mainline (XS-MAIN) that is over capacity. The XS-MAIN drainage system runs south to north along Jed Smith Drive. As shown in the HGL worksheets, the majority of the 10-year XS-MAIN HGL is outside of the pipe. This is the primary cause of the flooding of the loading dock of University Union (Lot 5). A better solution is to re-route these flows to the Western Ditch via the Tahoe Hall drainage system. See Exhibit P3 for preliminary layout.

South Campus Priority 5: Re-route Library II Roof Drainage across Stadium Drive

Recently the roof drainage from Library II has been re-routed to the south in order to mitigate the localized flooding of Library II and the AIRC. These flows currently drain to the storm drain system associated with Benicia Hall. Re-routing these flows further to the south across Stadium Drive may further mitigate the possibility of localized flooding. Further analysis is needed to determine the actual effects on the overall storm drain system.

South Campus Priority 6: The WELL Lawn Underground Detention

The grass lawn area in front of the WELL may be a strategic location for building an underground detention system. Approximately half of Shed PS-7 would drain to this detention system, attenuating peak flows from Hornet Stadium and portions of Lot 8 and the WELL building. The fact that this area is not developed may contribute to the economic favorability of this improvement.

South Campus Priority 7: Re-route Hornet Stadium Runoff to Western Ditch

The South Master Plan notes the potential for an expansion and reconstruction of Hornet Stadium. As part of any future work on Hornet Stadium, consideration should be given to redirected drainage to the Western Ditch. A study would need to be performed to assess the capacity of the Western Ditch.

North Campus Drainage Improvements

North Campus Priority 1: Re-route Sinclair Road Drainage

The mainline for the north campus is labeled N-MAIN, with reaches N-A through N-M. As shown on the HGL worksheets, the 10-year HGL is above the top of pipe elevation for the entire system, and out of the ground for a majority of the system. As a solution, Shed XN-2 will be reduced by 30 acres, in order to reduce the amount of drainage flowing through this mainline. Flows will be redirected to Storm Lift Station #4 at the West end of Sinclair Road. The existing mainline in Sinclair Road conveys drainage from Parking Structure I toward the East, and outfalls into the original 3 pumps at Storm Lift Station #1. The existing mainline is severely over capacity for both the 10-year and 100-year storm events, with the potential for flooding. One solution is to flip the flow direction of a portion of the Sinclair Road mainline (N-MAIN). As Exhibit P1 shows, a new mainline along Sinclair Road will redirect drainage from Brighton Hall to Parking Structure I toward the West. Storm Lift Station #4 and the associated sump will need to be re-evaluated for capacity and volume storage.

North Campus Priority 2: Green Area of Shed XN-3 Used for Detention

This green area is bound by State University Drive East to the North, Douglass Hall to the South, Sacramento Hall and Lassen Hall to the West, and Shasta Hall and River Front Center to the East. The existing topographic map shows this area as a natural basin, with a drainage inlet at the low point. According to the NAD83 CAD drawings provided by the University, the invert elevation of the manhole near the low point is 23.00'. This is 4.4' below the outlet elevation in front of River Front Center, which means that water backs up until it reaches a water surface elevation of 27.40'. At this point water begins to exit the drainage system. However, this also means that there may perpetually be up to 4.4' of standing water in this drainage system. A better design would effectively detain flows without retaining standing water during dry weather. Such a detention system may also be able to detain flows from Shed XN-2, helping to mitigate hydraulic capacity issues along Sinclair Road (XN-MAIN) and University Drive East (XN2-A). This option requires further study.

North Campus Priority 3: Re-route Flows from XN-4 and XN-5 to Storm Lift Station #2

The mainline running along the North side of State University Drive East is over capacity. Re-routing flows from Sheds XN-4 and XN-5 to Storm Lift Station #2 will help to alleviate this problem. Further study is required to confirm the feasibility of these improvements. Pump capacity and pipe capacity will need to be evaluated.

North Campus Priority 4: Upsize Mainline along State University Drive East

The mainline running along the North side of State University Drive East is over capacity. By increasing pipe sizes and slopes, this problem can be mitigated. A new mainline should be constructed in the street, as the existing pipe runs along the edge of a number of buildings and beneath the Greenhouse. Pump capacity will need to be examined as part of this improvement.

Western Ditch

As discussed in the previous section, there are a number of improvements that involve re-routing flows to the Western Ditch. The 1956 Agreement and Grant of Easement between the City of Sacramento and the State of California clearly make the following statements:

> "The CITY shall immediately cause to be commenced and thereafter diligently prosecuted to completion the installation of additional machinery, equipment, and other facilities at the location of the pumping plant of the American River Flood Control District at its present location on the West bank of the American River slightly North of N Street so as to increase the pumping capacity of said pumping plant to not less than 180 cubic feet per second, and throughout the term hereof shall continuously maintain said pumping plant to such capacity of not less than 180 cubic feet per second." (p. 2, paragraph 4)

> "It is expressly understood that the STATE shall, at all times, have the right to discharge waters in unlimited quantities into said ditch." (p. 3, paragraph 1)

In short, the City of Sacramento is required to maintain what is now City owned and operated Sump 155 so that its operational pumping capacity does not drop below 180 cfs. The University also has the right to discharge drainage of "unlimited quantities" into the Western Ditch.

However, based on conversations with the City of Sacramento, adding substantial amounts of runoff to the Western Ditch is not advisable. According to the Basin 155 Interim Drainage Improvement Plan, the City has indicated that the pumping station at Sump 155 does not currently have a capacity of 180 cfs. Rather, in 1997 the pumping plant at Sump 155 had an observed outflow of roughly 155 cfs (Basin 155 Interim Drainage Improvement Plan, p. 2-2, 3-6).

The City also reserves its right to the original 60 cfs from Sump 31. The study titled Basin 155 Interim Drainage Improvement Plan (October 1997) discusses the City's non-compliance with the 1956 agreement while addressing the cause of flooding on campus along Jordan Way (currently State University Drive). A SSWMM-94 computer model was run to analyze the Western Ditch and to develop interim solutions to the flooding problems. Interim solutions included repairs and upgrades to Sump 155 as well as the development of concurrent drainage master plans for Basins 10 and 155. While some of the interim solutions have been implemented, the capacity of Sump 155 has not been increased to the 180 cfs required by the 1956 agreement.

The City believes that the maximum amount of runoff that can be safely added to the Western Ditch is 12 cfs. This 12 cfs is in addition to what was already planned for runoff from the campus buildout as shown on the 1991 CSUS Master Plan. Further study would be required to determine what can be safely added to the Western Ditch based on the development of the South Campus, which is now in various stages of review and change.

As each individual drainage improvement project is implemented, the University and the City will need to discuss how this issue will be handled. While the 1956 agreement grants the University the right to discharge "unlimited" amounts of drainage to the Western Ditch, there are obvious physical limitations to what can actually be discharged. These limitations will need to be further discussed as each individual improvement project progresses.

Ultimate Master Plan Build Out

According to the overall Campus Master Plan, there is a number of expansion projects expected to take place in the relatively near future. See Exhibit P2 for details. The proposed solutions discussed above have taken into account these future improvements. A further discussion will be contained in the Landscape/Irrigation section that will suggest disconnecting direct discharge to the storm drain system. This will reduce peak flow and help reuse rain water for landscaping and provide water quality benefits to any runoff.

Sustainable Design Strategies

As portions of the campus are reconstructed or newly designed, sustainable practices are expected to be appropriately applied. The idea behind low impact design with regard to storm drainage is to mimic the natural patterns of the water cycle as closely as possible. This involves design practices that maximize evapo-transpiration, infiltration and natural processes of water quality treatment. General sustainable design strategies are found in the CSUS Sustainable Design and Operations Strategies Report (HOK, Draft 7-21-08). The following are recommended practices for the CSUS campus.

- Reduction of runoff volume for new development: According to the Sustainable Design and Operations Strategies Report new development will be required to reduce the volume of runoff leaving the site by 25% if the pre-development site area is greater than 50% impervious (p. 39). If the pre-development site area is less than 50%, runoff volumes should not be increased. This standard should be applied to all new projects.
- Pervious paving: Porous asphalt or pervious concrete should be considered for parking lots or pedestrian sidewalks. Pervious paving reduces the runoff to storm drain systems, while recharging the groundwater table. Because the campus irrigation system is supplied entirely by wells, design practices that recharge the groundwater table serve to sustain campus landscaping.
- Disconnect impervious areas: Where ever possible, impervious surfaces should be broken up to decrease the accumulation of sheet flow and concentrated flow. This can be implemented in parking lots and sidewalks.
- Bioswales: Where concrete gutters currently collect shallow concentrated flows, bioswales should be considered. Bioswales provide a natural and sustainable solution for both peak flow mitigation as well as water quality treatment. When properly designed, bioswales add to the aesthetic value of the landscaping while providing a functional purpose.
  - Western Ditch: On a larger scale, the drainage channel formerly conveying flows from the City of Sacramento's Sump 31 is proposed to be used to convey campus drainage. Properly grading and landscaping this ditch will provide significant water quality mitigations. Drainage sheds currently discharging directly to the American River via Storm Lift Station #1 will be re-routed through 6,000 feet of vegetated bioswale.
- Green roofs: A major source of runoff volume on the CSUS campus is the building roofs. Currently, the building roofs are all impervious surfaces, contributing significantly to the storm drain peak flows. Various systems of roof vegetation can be implemented on both existing and new buildings. Roof vegetation retains up to 70% of precipitation through evapo-transpiration. Green roofs mimic the natural role of the tree canopy, where water is stored in leaves, branches and bark until it evaporates.
- Roof Cisterns: Runoff from rooftops can also be stored in above ground and below ground cisterns. These roof cisterns can be used for irrigation and landscaping purposes, decreasing the amount of energy and groundwater resources currently being used.
- Underground Detention: The proposed underground detention basin beneath Parking Lot 6, as well as any other forms of underground detention, should also consider incorporating water quality treatment devices. Absorbent flotation pillows can be utilized to collect hydrocarbons and other pollutants on the water surface. Strategically designed weirs and media filters will help to collect sediment and trash.

Capital Improvement Program

A preliminary cost estimate has been prepared for each of the proposed drainage improvements discussed above (See Appendix). These cost estimates are for planning purposes and are subject to change based on fluctuations in the market and unforeseen design issues. It must also be noted that the priorities involving re-routing drainage runoff to the Western Ditch will involve discussions with the City of Sacramento Department of Utilities. As noted in above in the section **Western Ditch**, resolution must be made between the University and the City as to how much drainage can be safely re-routed to the Western Ditch.

Further Action Items

The next steps in the process of building a more robust storm drainage system are described below.

XPSTORMMODEL

The SacCalc hydrologic model provides only the peak flows for individual drainage sheds and control points, while incorporating detention and routing. These peak flows are input into hydraulic grade line (HGL) spreadsheets to determine which pipe systems are inadequate. XPSTORM, or equivalent modeling software, takes this analysis to the next level. While the HGL worksheets analyze each pipe network individually, XPSTORM connects every pipe network together along with the ground surface elevation. This provides not only a more accurate water surface elevation, it also provides a 2-dimensional model of where and when flooding occurs. An XPSTORM model will also provide a better understanding of the effect of backwater on each pipe network, as well a more accurate analysis of how time intervals affect localized flooding. Ultimately, the model will verify the effectiveness of each of the proposed solutions. As future development occurs, the model can be updated and reassessed to insure that the entire campus drainage system functions effectively.

PUMP STATION EVALUATION

Flow capacity for each of the pump stations needs to be assessed by a contractor specializing in pump station evaluation. Because pumping efficiencies diminish over time, a thorough evaluation is needed to determine the actual performance capabilities of the pumps. This information is critical for ensuring the accuracy of the XPSTORM Computer Model.

INTERIM PROJECTS

All interim storm drain improvement projects will require further study to determine its effects on the overall storm drain system. An XPSTORM Model would be especially helpful in both determining and analyzing these effects.

As noted previously, any additional runoff added to the Western Ditch will require coordination with the City of Sacramento Department of Utilities. The City's dynamic computer model will need to be updated and various upgrades and maintenance of the Western Ditch and Sump 155 will also need to be made.

TOPOGRAPHIC SURVEY

Storm drain systems are generally designed to meet 10-year storm requirements. Runoff from larger storm events is conveyed via overland release paths. Due to the unique situation of the campus, many of the overland release paths are inadequate or non-existent. The result is localized flooding and property damage. In order to effectively critique and re-design overland release paths, a topographic survey is necessary.

Table 8E

Exhisting 10-Year Hydraulic Grade Line Calculations

Existing Storm Drainage Systems

ID	Invert In (Elevation)	Invert Out (Elevation)	Pipe Dia. (in)	Slope (ft/ft)	Length of Pipe (ft)	n	Area of Pipe (ft^2)	Q_{10} (cfs)	V (fps)	K_i	h_i Entrance Head Loss (ft)	h_f Friction Head Loss	h_L Total Head Loss	Flow Line (Elev.)	Top of Pipe (Elev.)	HGL (Elev.)	*	Grate/Rim (Elev.)	Free Board (ft)	V_{Max} Full Flow (fps) "Manning's"	Q_{max} (cfs) "Manning's"	Extra Capacity (cfs)	cover	check velocity	check freeboard	Notes
XN-MAIN			36					74.0						23.47	26.47	25.57	*									
XN-A	23.60	23.47	36	0.0019	67	0.013	7.07	74.0	10.47	0.5	0.13	0.82	0.96	23.60	26.60	26.53	*	32.30	5.77	4.16	29.4	(44.6)	5.70	*****		
XN-B	24.10	23.60	36	0.0046	108	0.013	7.07	34.0	4.81	0.5	0.32	0.28	0.60	24.10	27.10	27.13		35.02	7.89	6.43	45.5	11.5	7.92			
XN-C	24.60	24.10	36	0.0068	74	0.013	7.07	31.5	4.46	0.5	0.47	0.17	0.63	24.60	27.60	27.77		36.49	8.72	7.77	54.9	23.4	8.89			
XN-D	25.22	24.60	24	0.0020	312	0.013	3.14	31.2	9.93	0.5	0.08	5.93	6.01	25.22	27.22	33.78		35.25	1.47	3.22	10.1	(21.1)	8.03	*****		
XN-E	25.50	25.16	24	0.0020	172	0.013	3.14	26.1	8.30	0.5	0.08	2.28	2.36	25.50	27.50	36.14		34.42	-1.72	3.21	10.1	(16.0)	6.92	*****	****	
XN-F	25.60	25.50	24	0.0007	136	0.013	3.14	24.4	7.77	0.5	0.03	1.58	1.61	25.60	27.60	37.75		34.96	-2.79	1.96	6.1	(18.3)	7.36	*****	****	
XN-G	25.80	25.60	24	0.0012	169	0.013	3.14	19.2	6.13	0.5	0.05	1.22	1.27	25.80	27.80	39.02		33.84	-5.18	2.48	7.8	(11.4)	6.04	*****	****	
XN-H	25.90	25.70	24	0.0020	102	0.013	3.14	18.3	5.83	0.5	0.08	0.67	0.75	25.90	27.90	39.77		34.51	-5.26	3.20	10.0	(8.3)	6.61	*****	****	
XN-I	26.10	25.90	15	0.0030	67	0.013	1.23	16.8	13.72	0.5	0.06	4.55	4.62	26.10	27.35	44.39		35.25	-9.14	2.88	3.5	(13.3)	7.90	*****	****	
XN-J	26.50	26.20	15	0.0014	210	0.013	1.23	13.8	11.23	0.5	0.03	9.55	9.58	26.50	27.75	53.97		36.52	-17.45	1.99	2.4	(11.3)	8.77	*****	****	
XN-K	26.90	26.60	15	0.0018	171	0.013	1.23	1.4	1.13	0.5	0.04	0.08	0.12	26.90	28.15	54.09		34.40	-19.69	2.21	2.7	1.3	6.25		****	
XN-L	27.05	26.90	15	0.0021	71	0.013	1.23	0.9	0.74	0.5	0.05	0.01	0.06	27.05	28.30	54.15		33.55	-20.60	2.42	3.0	2.1	5.25		****	
XN-M	27.25	27.05	15	0.0014	140	0.013	1.23	0.8	0.63	1.1	0.07	0.02	0.09	27.25	28.50	54.24		34.30	-19.94	1.99	2.4	1.7	5.80		****	
XN2-A			30					43.7						23.34	25.84	26.53										
XN-A-1	23.80	23.34	30	0.0271	17	0.013	4.91	43.7	8.91	1.1	3.24	0.19	3.43	23.80	26.30	29.96		32.30	2.34	13.77	67.6	23.9	6.00			
XN-A-2	23.90	23.80	30	0.0071	14	0.013	4.91	43.7	8.91	1.1	0.86	0.16	1.01	23.90	26.40	30.98		32.29	1.31	7.08	34.7	(9.0)	5.89	*****		
XN-A-3	24.00	23.90	30	0.0004	262	0.013	4.91	43.7	8.91	0.5	0.02	2.97	3.00	24.00	26.50	33.97		32.11	-1.86	1.64	8.0	(35.7)	5.61	*****	****	
XN-A-4	24.78	24.00	30	0.0066	118	0.013	4.91	43.7	8.91	1.1	0.79	1.34	2.13	24.78	27.28	36.10		33.84	-2.26	6.81	33.4	(10.3)	6.56	*****	****	
XN-A-5	25.29	24.88	30	0.0025	163	0.013	4.91	40.0	8.15	1.1	0.30	1.55	1.85	25.29	27.79	37.95		36.60	-1.35	4.20	20.6	(19.4)	8.81	*****	****	
XN-A-6	25.96	25.39	24	0.0022	260	0.013	3.14	40.0	12.74	0.5	0.09	8.13	8.22	25.96	27.96	46.17		36.33	-9.84	3.38	10.6	(29.4)	8.37	*****	****	
XN-A-7	27.03	26.93	21	0.0003	336	0.013	2.40	40.0	16.64	1.1	0.02	21.42	21.44	27.03	28.78	67.62		36.40	-31.22	1.14	2.7	(37.3)	7.62	*****	****	
XN-A-8	27.30	27.03	18	0.0010	273	0.013	1.77	12.0	6.79	0.5	0.03	3.56	3.59	27.30	28.80	71.21		38.26	-32.95	1.87	3.3	(8.7)	9.46	*****	****	
XN-A-9	27.70	27.40	18	0.0013	236	0.013	1.77	10.7	6.07	0.5	0.04	2.46	2.49	27.70	29.20	73.70		38.26	-35.44	2.12	3.8	(7.0)	9.06	*****	****	
XN-A-10	28.14	27.70	18	0.0012	356	0.013	1.77	6.5	3.67	0.5	0.03	1.36	1.39	28.14	29.64	75.09		34.50	-40.59	2.09	3.7	(2.8)	4.86	*****	****	
XN-A-7			15					28.0						27.03	28.28	67.62										
XN-A-7a	27.82	27.03	15	0.0030	262	0.013	1.23	28.0	22.83	0.5	0.06	49.25	49.32	27.82	29.07	116.93		37.00	-79.93	2.89	3.5	(24.5)	7.93	*****	****	
XN-A-7b	28.19	28.00	15	0.0030	63	0.013	1.23	22.8	18.57	0.9	0.12	7.84	7.96	28.19	29.44	124.89		37.00	-87.89	2.89	3.5	(19.2)	7.56			
XN-A-7c	28.43	28.19	15	0.0030	82	0.013	1.23	22.8	18.57	0.9	0.12	10.20	10.32	28.43	29.68	135.21		37.00	-98.21	2.89	3.5	(19.2)	7.32	*****	****	
XN-A-7d	28.98	28.43	15	0.0030	184	0.013	1.23	17.0	13.86	0.5	0.06	12.75	12.82	28.98	30.23	148.02		37.40	-110.62	2.89	3.5	(13.5)	7.17	*****	****	
XN-A-7e	29.68	28.98	10	0.0030	232	0.013	0.55	7.6	13.92	0.5	0.04	27.86	27.90	29.68	30.51	175.92		36.88	-139.04	2.20	1.2	(6.4)	6.37	*****	****	
XN-A-7f	30.50	29.68	10	0.0023	349	0.013	0.55	6.2	11.40	0.5	0.03	28.12	28.15	30.50	31.33	204.07		36.20	-167.87	1.95	1.1	(5.2)	4.87	*****	****	
XS-MAIN			54					94.0						22.80	27.30	25.95	*									
XS-A	23.08	22.80	54	0.0017	165	0.013	15.90	94.0	5.91	1.1	0.44	0.38	0.82	23.08	27.58	26.77	*	35.00	8.23	5.10	81.1	(12.9)	7.42	*****		
XS-B	24.12	23.12	54	0.0030	330	0.013	15.90	90.0	5.66	0.5	0.36	0.69	1.05	24.12	28.62	27.82	*	37.22	9.40	6.82	108.4	18.4	8.60			
XS-C	24.51	24.12	48	0.0022	180	0.013	12.56	80.0	6.37	0.5	0.22	0.56	0.78	24.51	28.51	28.60		37.01	8.41	5.33	67.0	(13.0)	8.50	*****		
XS-D	25.16	24.51	48	0.0034	190	0.013	12.56	80.0	6.37	1.1	0.77	0.59	1.36	25.16	29.16	29.96		37.46	7.50	6.70	84.1	4.1	8.30			
XS-E	25.54	25.16	48	0.0043	89	0.013	12.56	74.9	5.96	1.1	0.96	0.24	1.20	25.54	29.54	31.16		36.33	5.17	7.48	94.0	19.1	6.79			University Union
XS-F	25.84	25.54	48	0.0012	250	0.013	12.56	57.0	4.54	0.5	0.12	0.39	0.52	25.84	29.84	31.67		35.81	4.14	3.97	49.8	(7.2)	5.97			
XS-G	27.25	25.84	36	0.0054	260	0.013	7.07	57.0	8.07	0.5	0.38	1.90	2.28	27.25	30.25	33.95		37.85	3.90	6.96	49.2	(7.8)	7.60	*****		
XS-H	27.66	27.25	30	0.0035	116	0.013	4.91	36.9	7.52	0.5	0.19	0.94	1.13	27.66	30.16	35.08		36.30	1.22	4.98	24.4	(12.5)	6.14	*****		
XS-I	28.00	27.56	30	0.0027	165	0.013	4.91	36.4	7.41	0.5	0.15	1.30	1.44	28.00	30.50	36.52		36.08	-0.44	4.32	21.2	(15.1)	5.58	*****	****	
XS-J	28.16	28.00	30	0.0020	82	0.013	4.91	32.0	6.52	0.5	0.11	0.50	0.61	28.16	30.66	37.13		35.50	-1.63	3.70	18.1	(13.9)	4.84	*****	****	
XS-K	28.58	28.16	30	0.0021	200	0.013	4.91	32.0	6.52	0.5	0.11	1.22	1.33	28.58	31.08	38.46		36.70	-1.76	3.84	18.8	(13.2)	5.62	*****	****	
XS-L	28.84	28.58	30	0.0026	100	0.013	4.91	30.0	6.11	0.5	0.14	0.54	0.68	28.84	31.34	39.13		36.50	-2.63	4.27	20.9	(9.1)	5.16	*****	****	
XS-M	29.42	28.84	24	0.0019	300	0.013	3.14	19.6	6.24	0.9	0.14	2.25	2.39	29.42	31.42	41.53		36.02	-5.51	3.17	10.0	(9.6)	4.60	*****	****	
XS-N	30.05	29.42	16	0.0029	221	0.013	1.40	14.0	10.03	0.5	0.07	7.36	7.43	30.05	31.38	48.95		36.65	-12.30	2.94	4.1	(9.9)	5.27	*****	****	
XS-O	30.41	30.27	16	0.0026	56	0.013	1.40	14.0	10.03	0.5	0.06	1.87	1.93	30.41	31.75	50.88		35.20	-15.68	2.81	3.9	(10.1)	3.45	*****	****	
XS-P	31.00	30.41	15	0.0026	226	0.013	1.23	3.6	2.94	0.5	0.06	0.70	0.76	31.00	32.25	51.64		37.40	-14.24	2.69	3.3	(0.3)	5.15	*****	****	
X-Tahoe Hall			15					17.4						29.00	30.25	29.50	*									
XT-1	27.60	27.30	15	0.0009	346	0.013	1.23	17.4	14.22	0.9	0.03	25.25	25.29	27.60	28.85	54.79		33.01	-21.78	1.55	1.9	(15.5)	4.16	*****	****	
XT-2	28.50	27.80	15	0.0020	349	0.013	1.23	17.4	14.22	0.9	0.08	25.47	25.55	28.50	29.75	80.33		34.85	-45.48	2.36	2.9	(14.5)	5.10	*****	****	
XT-3	29.96	29.00	12	0.0019	512	0.013	0.79	6.1	7.77	0.9	0.05	15.02	15.07	29.96	30.96	95.41		36.00	-59.41	1.97	1.5	(4.6)	5.04	*****	****	

*Denotes HGL is in pipe.

Table 8F

Proposed 10-Year Hydraulic Grade Line Calculations

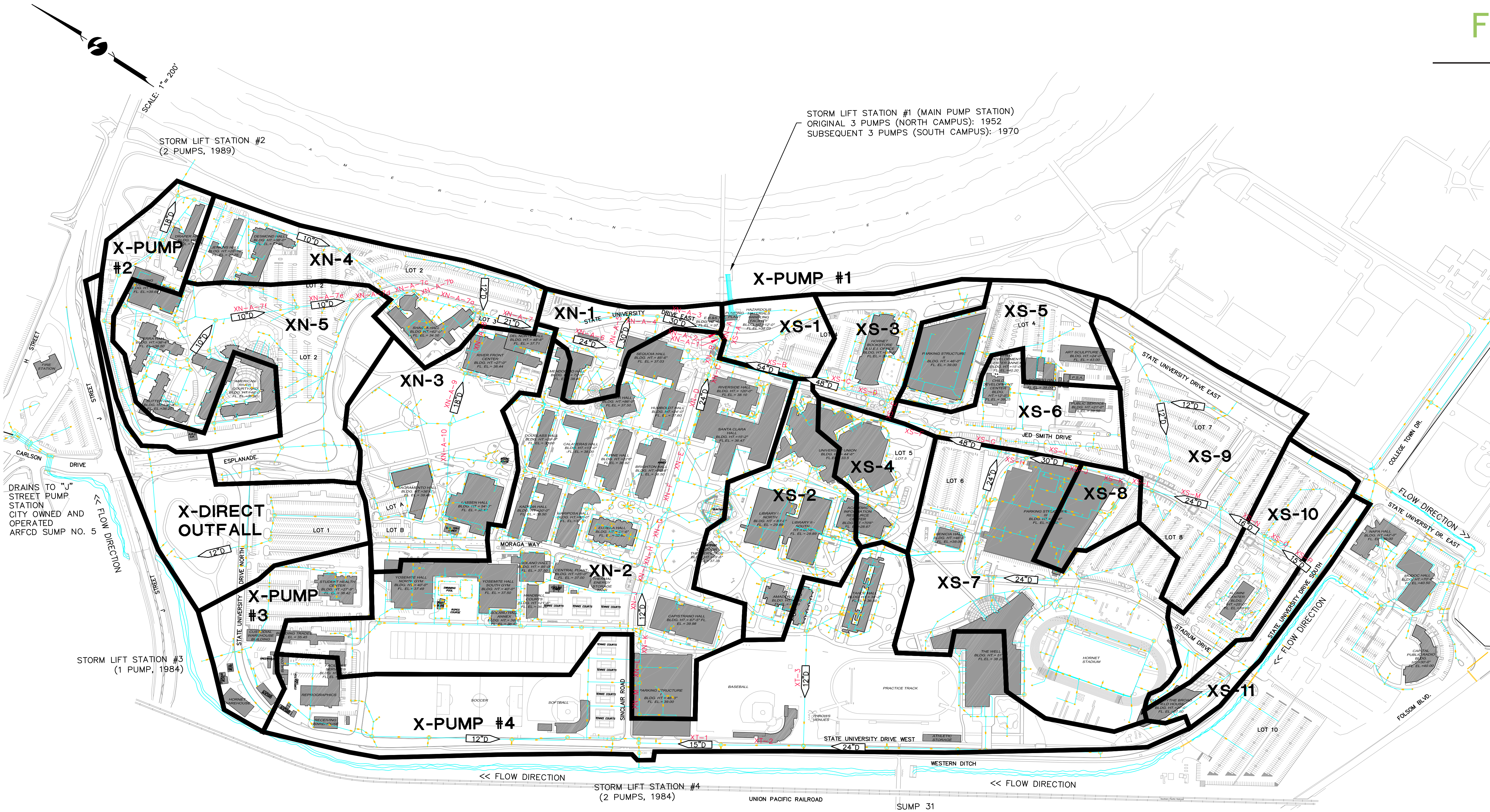
Proposed Storm Drainage Systems

ID	Invert In (Elevation)	Invert Out (Elevation)	Pipe Dia. (in)	Slope (ft/ft)	Length of Pipe (ft)	n	Area of Pipe (ft^2)	Q_{10} (cfs)	V (fps)	K_i	h_i Entrance Head Loss (ft)	h_f Friction Head Loss	h_L Total Head Loss	Flow Line (Elev.)	Top of Pipe (Elev.)	HGL (Elev.)	*	Grate/Rim (Elev.)	Free Board (ft)	V_{Max} Full Flow (fps) "Manning's"	Q_{max} (cfs) "Manning's"	Extra Capacity (cfs)	cover	check velocity	check freeboard	Notes
PN-MAIN			36					12.0						23.47	26.47	25.57	*									
PN-A	23.60	23.47	36	0.0019	67	0.013	7.07	12.0	1.70	0.5	0.13	0.02	0.16	23.60	26.60	25.73	*	32.30	6.57	4.16	29.4	17.4	5.70			
PN-B	24.10	23.60	36	0.0046	108	0.013	7.07	12.0	1.70	0.5	0.32	0.03	0.36	24.10	27.10	26.08	*	35.02	8.94	6.43	45.5	33.5	7.92			
PN-C	24.60	24.10	36	0.0068	74	0.013	7.07	7.2	1.02	0.5	0.47	0.01	0.48	24.60	27.60	26.56	*	36.49	9.93	7.77	54.9	47.7	8.89			
PN-D	25.22	24.60	24	0.0020	312	0.013	3.14	6.8	2.15	0.5	0.08	0.28	0.36	25.22	27.22	26.92	*	35.25	8.33	3.22	10.1	3.3	8.03			
PS-MAIN			54					40.0						22.80	27.30	25.95	*									
PS-A	23.08	22.80	54	0.0017	165	0.013	15.90	40.0	2.52	1.1	0.44	0.07	0.51	23.08	27.58	26.46	*	35.00	8.54	5.10	81.1	41.1	7.42			
PS-B	24.12	23.12	54	0.0030	330	0.013	15.90	36.0	2.26	0.5	0.36	0.11	0.47	24.12	28.62	26.93	*	37.22	10.29	6.82	108.4	72.4	8.60			
PS-C	24.51	24.12	48	0.0022	180	0.013	12.56	26.0	2.07	0.5	0.22	0.06	0.28	24.51	28.51	27.21	*	37.01	9.80	5.33	67.0	41.0	8.50			
PS-D	25.16	24.51	48	0.0034	190	0.013	12.56	18.1	1.44	1.1	0.77	0.03	0.80	25.16	29.16	28.01	*	37.46	9.45	6.70	84.1	66.0	8.30			
PS-E	25.54	25.16	48	0.0043	89	0.013	12.56	17.0	1.35	1.1	0.96	0.01	0.97	25.54	29.54	28.98	*	36.33	7.35	7.48	94.0	77.0	6.79			University Union
PS-F	25.84	25.54	48	0.0012	250	0.013	12.56	17.0	1.35	0.5	0.12	0.04	0.16	25.84	29.84	29.14	*	35.81	6.67	3.97	49.8	32.8	5.97			
PS-G	27.25	25.84	36	0.0054	260	0.013	7.07	57.0	8.07	0.5	0.38	1.90	2.28	27.25	30.25	31.41		37.85	6.44	6.96	49.2	(7.8)	7.60	*****		
PS-H	27.66	27.25	30	0.0035	116	0.013	4.91	36.9	7.52	0.5	0.19	0.94	1.13	27.66	30.16	32.54		36.30	3.76	4.98	24.4	(12.5)	6.14	*****		
PS-I	28.00	27.56	30	0.0027	165	0.013	4.91	36.4	7.41	0.5	0.15	1.30	1.44	28.00	30.50	33.99		36.08	2.09	4.32	21.2	(15.1)	5.58	*****		
PS-J	28.16	28.00	30	0.0020	82	0.013	4.91	32.0	6.52	0.5	0.11	0.50	0.61	28.16	30.66	34.59		35.50	0.91	3.70	18.1	(13.9)	4.84	*****		
PS-K	28.58	28.16	30	0.0021	200	0.013	4.91	32.0	6.52	0.5	0.11	1.22	1.33	28.58	31.08	35.92		36.70	0.78	3.84	18.8	(13.2)	5.62	*****		
PS-L	28.84	28.58	30	0.0026	100	0.013	4.91	30.0	6.11	0.5	0.14	0.54	0.68	28.84	31.34	36.60		36.50	-0.10	4.27	20.9	(9.1)	5.16	*****	****	
PS-M	29.42	28.84	24	0.0019	300	0.013	3.14	19.6	6.24	0.9	0.14	2.25	2.39	29.42	31.42	38.99		36.02	-2.97	3.17	10.0	(9.6)	4.60	*****	****	
PS-N	30.05	29.42	16	0.0029	221	0.013	1.40	14.0	10.03	0.5	0.07	7.36	7.43	30.05	31.38	46.42		36.65	-9.77	2.94	4.1	(9.9)	5.27	*****	****	
PS-O	30.41	30.27	16	0.0026	56	0.013	1.40	14.0	10.03	0.5	0.06	1.87	1.93	30.41	31.75	48.35		35.20	-13.15	2.81	3.9	(10.1)	3.45	*****	****	
PS-P	31.00	30.41	15	0.0026	226	0.013	1.23	3.6	2.94	0.5	0.06	0.70	0.76	31.00	32.25	49.10		37.40	-11.70	2.69	3.3	(0.3)	5.15	*****	****	
P-Tahoe Hall			36					17.4						29.00	32.00	30.20	*									
PT-1	27.60	27.30	36	0.0009	346	0.013	7.07	17.4	2.47	0.9	0.11	0.24	0.35	27.60	30.60	30.55	*	33.01	2.46	2.78	19.7	2.2	2.41			
PT-2	28.50	27.80	36	0.0020	349	0.013	7.07	17.4	2.47	0.9	0.25	0.24	0.49	28.50	31.50	31.03	*	34.85	3.82	4.23	29.9	12.5	3.35			
PT-3	29.96	29.00	24	0.0019	512	0.013	3.14	6.1	1.94	0.9	0.14	0.37	0.51	29.96	31.96	31.54	*	40.26	8.72	3.12	9.8	3.7	8.30			
PT-4	30.07	29.96	24	0.0020	54	0.013	3.14	6.1	1.94	0.9	0.15	0.04	0.19	30.07	32.07	31.73	*	40.20	8.47	3.26	10.2	4.1	8.13			
PT-5	34.95	30.07	12	0.0125	390	0.013	0.79	2.0	2.55	1.1	0.44	1.23	1.67	34.95	35.95	33.40	*	37.50	4.10	5.08	4.0	2.0	1.55			

*Denotes HGL is in pipe.

Figure 8.1

Existing Drainage Sheds



LEGEND

(thick line)	DRAINAGE SHED BOUNDARY
T-1	DRAINAGE SYSTEM ELEMENT (CORRESPONDING TO HGL CALCS)
(thin line)	EXISTING STORM DRAIN
XN-2	DRAINAGE SUB-SHED NAME (SEE ABBREVIATIONS TO RIGHT)
X-PUMP #4	DRAINAGE SHED WITH PUMPED OUTFALL

ABBREVIATIONS

X	EXISTING
P	PROPOSED
N	NORTH
S	SOUTH
W	WEST

Figure 8.2

Proposed Drainage Sheds

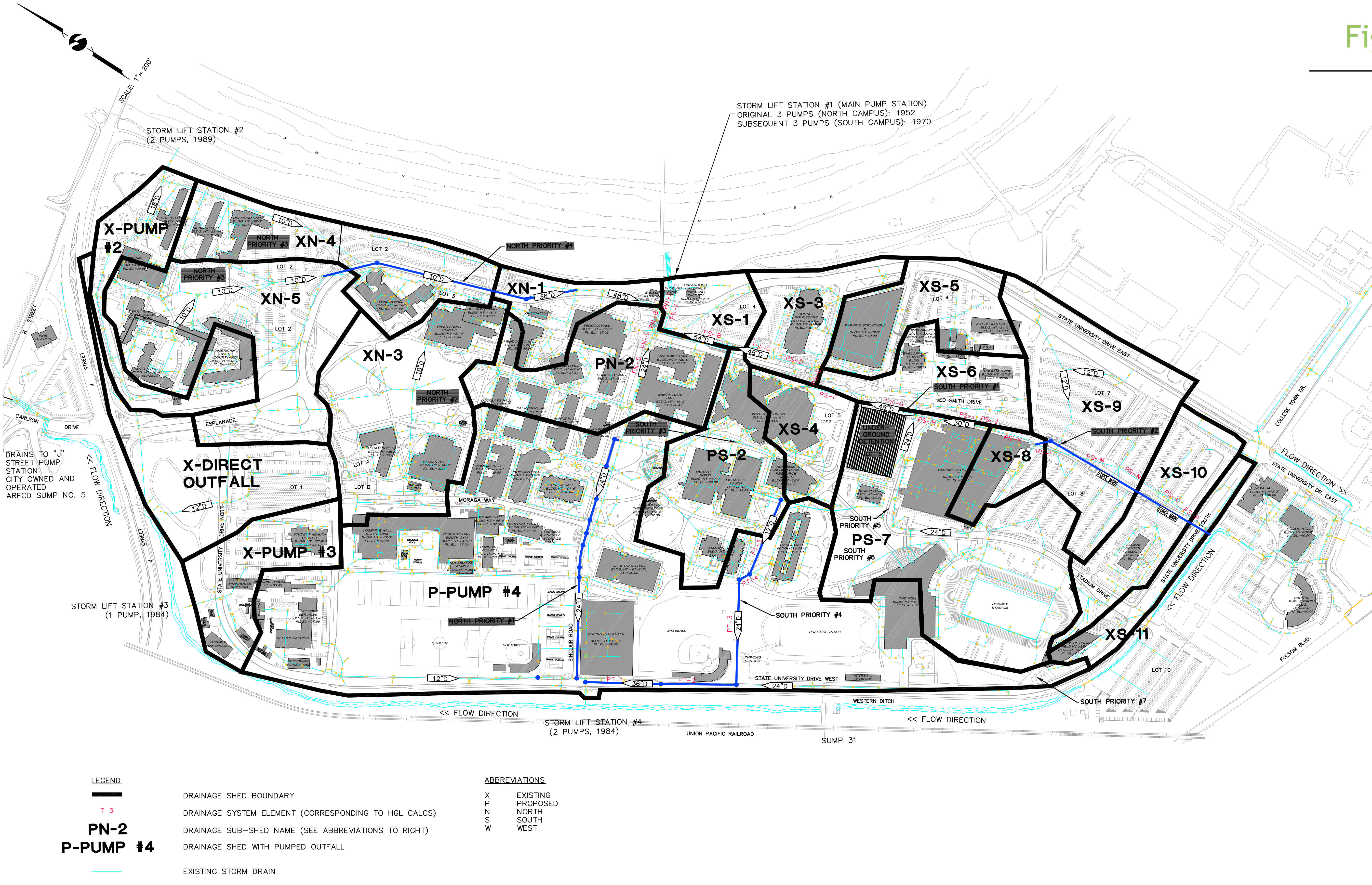


Figure 8.3

Proposed Drainage Sheds

Future Master Plan

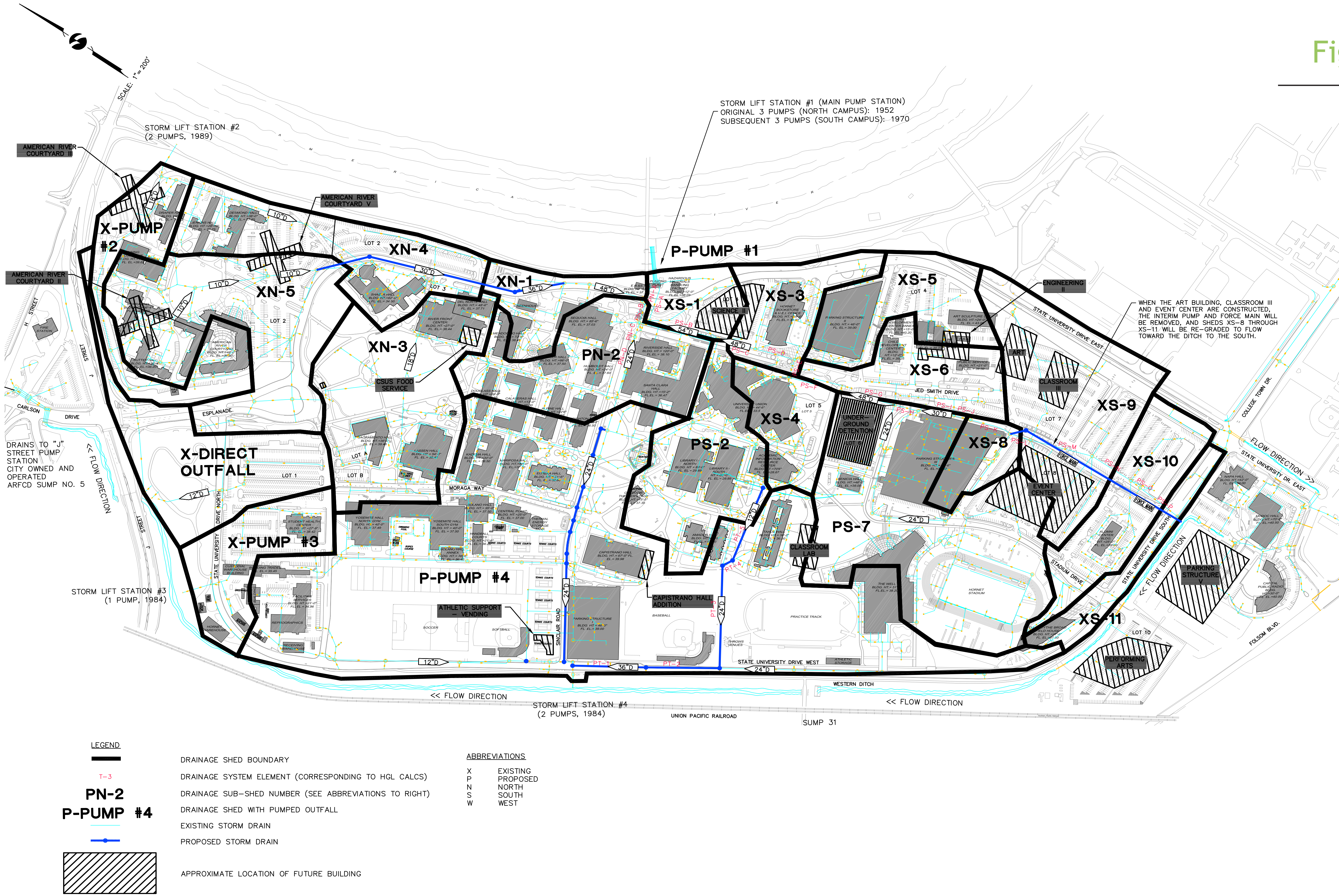
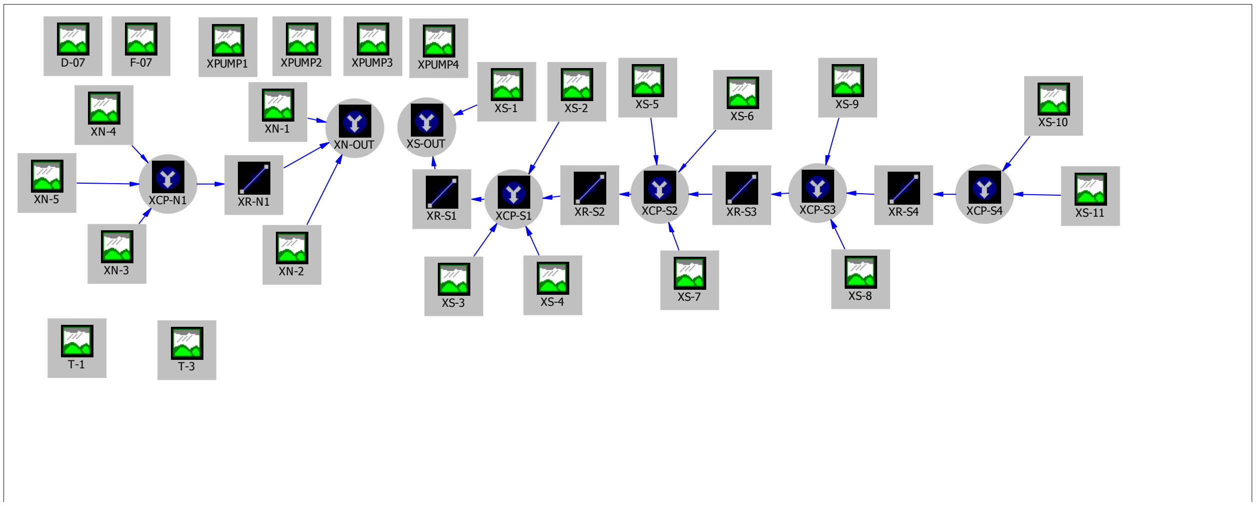


Table 8A

SAC-CALC Output

CSUS Storm Drainage Master Plan - EXISTING



Sacramento method results
(Project: CSUS Storm Drainage Master Plan - EXISTING)
(100-year, 1-day rainfall)

ID	Peak flow (cfs)	Time of peak (hours)	Basin area (sq. mi)	Peak stage (feet)	Peak storage (ac-ft)	Diversion volume (ac-ft)
D-07	11.	12:17	.01			
F-07	8.2	12:16	.01			
XPUMP1	283.	12:18	.27			
XPUMP3	13.	12:13	.01			
XPUMP4	52.	12:17	.05			
XPUMP2	11.	12:19	.01			
XN-1	7.1	12:15	.01			
XN-2	59.	12:22	.06			
XN-3	24.	12:14	.02			
XN-4	20.	12:11	.02			
XN-5	32.	12:14	.03			
XCP-N1	75.	12:13	.06			
XR-N1	75.	12:14	.06			
XN-OUT	132.	12:17	.13			
XS-2	18.	12:14	.02			
XS-3	13.	12:07	.01			
XS-4	11.	12:10	.01			
XS-5	19.	12:06	.01			
XS-6	21.	12:02	.01			
XS-7	43.	12:13	.03			
XS-8	6.2	12:11	.00			
XS-9	27.	12:13	.02			
XS-10	19.	12:08	.01			
XS-11	6.5	12:10	.00			
XCP-S4	25.	12:09	.02			
XR-S4	25.	12:10	.02			
XCP-S3	57.	12:11	.04			
XR-S3	57.	12:12	.04			
XCP-S2	123.	12:11	.10			
XR-S2	123.	12:12	.10			
XCP-S1	161.	12:12	.13			
XR-S1	161.	12:12	.13			
XS-1	8.6	12:10	.01			
XS-OUT	169.	12:12	.14			
T-1	7.3	12:15	.01			

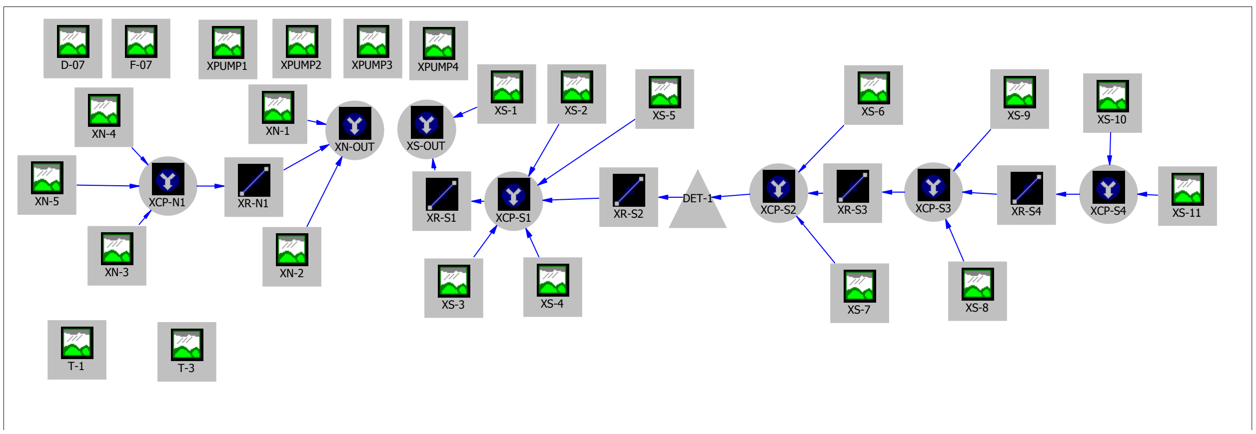
(10-year, 1-day rainfall)

ID	Peak flow (cfs)	Time of peak (hours)	Basin area (sq. mi)	Peak stage (feet)	Peak storage (ac-ft)	Diversion volume (ac-ft)
D-07	6.2	12:20	.01			
F-07	4.5	12:20	.01			
XPUMP1	155.	12:22	.27			
XPUMP3	6.8	12:18	.01			
XPUMP4	27.	12:21	.05			
XPUMP2	6.0	12:22	.01			
XN-1	3.7	12:19	.01			
XN-2	34.	12:25	.06			
XN-3	12.	12:18	.02			
XN-4	11.	12:14	.02			
XN-5	17.	12:16	.03			
XCP-N1	40.	12:16	.06			
XR-N1	40.	12:17	.06			
XN-OUT	74.	12:20	.13			
XS-2	10.	12:16	.02			
XS-3	7.9	12:06	.01			
XS-4	5.9	12:12	.01			
XS-5	12.	12:05	.01			
XS-6	12.	12:02	.01			
XS-7	25.	12:14	.03			
XS-8	3.4	12:14	.00			
XS-9	16.	12:14	.02			
XS-10	10.	12:10	.01			
XS-11	3.6	12:12	.00			
XCP-S4	14.	12:11	.02			
XR-S4	14.	12:12	.02			
XCP-S3	32.	12:13	.04			
XR-S3	32.	12:14	.04			
XCP-S2	69.	12:13	.10			
XR-S2	69.	12:13	.10			
XCP-S1	90.	12:13	.13			
XR-S1	90.	12:14	.13			
XS-1	4.7	12:12	.01			
XS-OUT	94.	12:14	.14			
T-1	4.1	12:17	.01			
T-3	2.0	12:03	.00			

Table 8B

SAC-CALC Output

CSUS Storm Drainage Master Plan - EXISTING with DETENTION



Sacramento method results
(Project: CSUS Storm Drainage Master Plan - EXISTING with DETENTION)
(100-year, 1-day rainfall)

ID	Peak flow (cfs)	Time of peak (hours)	Basin area (sq. mi)	Peak stage (feet)	Peak storage (ac-ft)	Diversion volume (ac-ft)
D-07	11.	12:17	.01			
F-07	8.2	12:16	.01			
XPUMP1	283.	12:18	.27			
XPUMP3	13.	12:13	.01			
XPUMP4	52.	12:17	.05			
XPUMP2	11.	12:19	.01			
XN-1	7.1	12:15	.01			
XN-2	59.	12:22	.06			
XN-3	24.	12:14	.02			
XN-4	20.	12:11	.02			
XN-5	32.	12:14	.03			
XCP-N1	75.	12:13	.06			
XR-N1	75.	12:14	.06			
XN-OUT	132.	12:17	.13			
XS-2	18.	12:14	.02			
XS-3	13.	12:07	.01			
XS-4	11.	12:10	.01			
XS-5	19.	12:06	.01			
XS-6	21.	12:02	.01			
XS-7	43.	12:13	.03			
XS-8	6.2	12:11	.00			
XS-9	27.	12:13	.02			
XS-10	19.	12:08	.01			
XS-11	6.5	12:10	.00			
XCP-S4	25.	12:09	.02			
XR-S4	25.	12:10	.02			
XCP-S3	57.	12:11	.04			
XR-S3	57.	12:12	.04			
XCP-S2	108.	12:12	.09			
DET-1	36.	12:46	.09	.0	6.6	
XR-S2	36.	12:47	.09			
XCP-S1	72.	12:12	.13			
XR-S1	72.	12:12	.13			
XS-1	8.6	12:10	.01			
XS-OUT	80.	12:12	.14			

T-3	3.2	12:03	.00			

(10-year, 1-day rainfall)

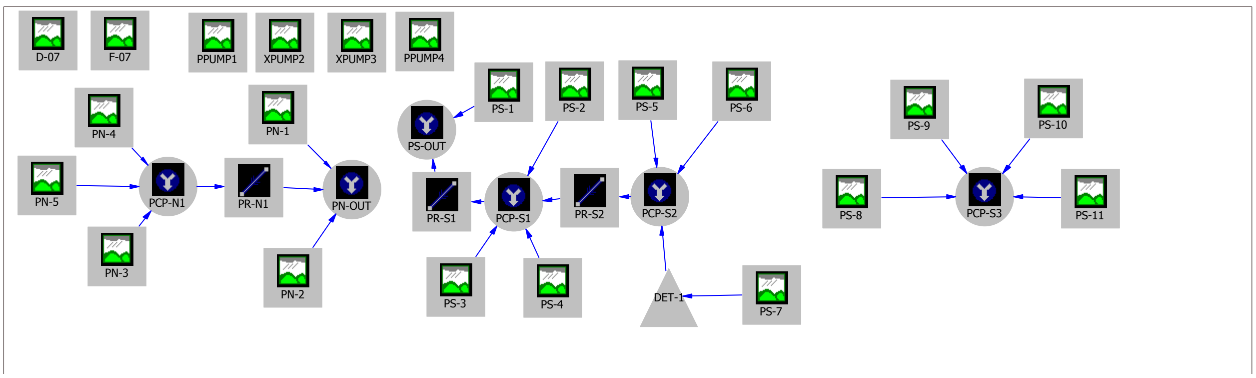
ID	Peak flow (cfs)	Time of peak (hours)	Basin area (sq. mi)	Peak stage (feet)	Peak storage (ac-ft)	Diversion volume (ac-ft)
D-07	6.2	12:20	.01			
F-07	4.5	12:20	.01			
XPUMP1	155.	12:22	.27			
XPUMP3	6.8	12:18	.01			
XPUMP4	27.	12:21	.05			
XPUMP2	6.0	12:22	.01			
XN-1	3.7	12:19	.01			
XN-2	34.	12:25	.06			
XN-3	12.	12:18	.02			
XN-4	11.	12:14	.02			
XN-5	17.	12:16	.03			
XCP-N1	40.	12:16	.06			
XR-N1	40.	12:17	.06			
XN-OUT	74.	12:20	.13			
XS-2	10.	12:16	.02			
XS-3	7.9	12:06	.01			
XS-4	5.9	12:12	.01			
XS-5	12.	12:05	.01			
XS-6	12.	12:02	.01			
XS-7	25.	12:14	.03			
XS-8	3.4	12:14	.00			
XS-9	16.	12:14	.02			
XS-10	10.	12:10	.01			
XS-11	3.6	12:12	.00			
XCP-S4	14.	12:11	.02			
XR-S4	14.	12:12	.02			
XCP-S3	32.	12:13	.04			
XR-S3	32.	12:14	.04			
XCP-S2	62.	12:13	.09			
DET-1	17.	13:11	.09	.0	4.7	
XR-S2	17.	13:12	.09			
XCP-S1	36.	12:08	.13			
XR-S1	36.	12:09	.13			
XS-1	4.7	12:12	.01			
XS-OUT	40.	12:10	.14			

T-1	4.1	12:17	.01
T-3	2.0	12:03	.00

Table 8C

SAC-CALC Output

CSUS Storm Drainage Master Plan - PROPOSED



Sacramento method results
(Project: CSUS Storm Drainage Master Plan - PROPOSED)
(100-year, 1-day rainfall)

ID	Peak flow (cfs)	Time of peak (hours)	Basin area (sq. mi)	Peak stage (feet)	Peak storage (ac-ft)	Diversion volume (ac-ft)
D-07	11.	12:17	.01			
F-07	8.2	12:16	.01			
PPUMP1	178.	12:18	.17			
XPUMP3	13.	12:13	.01			
PN-1	7.1	12:15	.01			
PN-2	22.	12:12	.02			
PN-3	24.	12:14	.02			
PN-4	20.	12:11	.02			
PN-5	32.	12:14	.03			
PCP-N1	75.	12:13	.06			
PR-N1	75.	12:14	.06			
PN-OUT	103.	12:14	.09			
PS-8	6.2	12:11	.00			
PS-9	27.	12:13	.02			
PS-10	19.	12:08	.01			
PS-11	6.5	12:10	.00			
PCP-S3	57.	12:11	.04			
PS-2	18.	12:14	.02			
PS-3	13.	12:07	.01			
PS-4	11.	12:10	.01			
PS-5	19.	12:06	.01			
PS-6	21.	12:02	.01			
PS-7	43.	12:13	.03			
DET-1	4.0	15:12	.03	.0	3.0	
PCP-S2	39.	12:04	.05			
PR-S2	39.	12:05	.05			
PCP-S1	72.	12:07	.09			
PR-S1	72.	12:08	.09			
PS-1	8.6	12:10	.01			
PS-OUT	80.	12:09	.09			
PPUMP4	101.	12:18	.10			
XPUMP2	11.	12:19	.01			

(10-year, 1-day rainfall)

	Peak	Time of	Basin	Peak	Peak

ID	(cfs)	(hours)	(sq. mi)	(feet)	(ac-ft)	(ac-ft)
D-07	6.2	12:20	.01			
F-07	4.5	12:20	.01			
PPUMP1	97.	12:22	.17			
XPUMP3	6.8	12:18	.01			
PN-1	3.7	12:19	.01			
PN-2	12.	12:13	.02			
PN-3	12.	12:18	.02			
PN-4	11.	12:14	.02			
PN-5	17.	12:16	.03			
PCP-N1	40.	12:16	.06			
PR-N1	40.	12:17	.06			
PN-OUT	55.	12:16	.09			
PS-8	3.4	12:14	.00			
PS-9	16.	12:14	.02			
PS-10	10.	12:10	.01			
PS-11	3.6	12:12	.00			
PCP-S3	32.	12:13	.04			
PS-2	10.	12:16	.02			
PS-3	7.9	12:06	.01			
PS-4	5.9	12:12	.01			
PS-5	12.	12:05	.01			
PS-6	12.	12:02	.01			
PS-7	25.	12:14	.03			
DET-1	2.6	15:00	.03	.0	1.6	
PCP-S2	25.	12:03	.05			
PR-S2	25.	12:04	.05			
PCP-S1	43.	12:06	.09			
PR-S1	43.	12:07	.09			
PS-1	4.7	12:12	.01			
PS-OUT	46.	12:07	.09			
PPUMP4	59.	12:18	.10			
XPUMP2	6.0	12:22	.01			

Table 8D

Flow Summary

EXISTING SHEDS

			Sac Calc				Pipe	Capacity	Within-Capacity?
XSUB-SHEDS	**A (sf)**	**A (ac)**	**Q_{10}**	**Q_{100}**	**Q_{10} cfs/ac**	**Q_{100} cfs/ac**	**Notes**	**cfs**	**(Yes/No)**
XN-OUT	**3,711,479**	**85**	**74**	**131**	**0.9**	**1.5**		**PUMP?**	**Yes**
XN-1	181,527	4	3.7	5.3	0.9	1.3			
XN-2	1,775,874	41	34	61	0.8	1.5	36"S=0.005	44	Yes
XCP-N1	**1,754,078**	**40**	**40**	**75**	**1.0**	**1.9**	**21"S=0.002**	**7**	**No**
XN-3	569,756	13	12	24	0.9	1.8			
XN-4	456,221	10	11	20	1.1	1.9			
XN-5	728,102	17	17	32	1.0	1.9	15"S=0.002	3	No
XS-OUT	**3,788,772**	**87**	**94**	**169**	**1.1**	**1.9**	**1969 PUMPS**	**PUMP?**	**Yes**
XS-1	152,801	4	4.7	8.6	1.3	2.5			
XCP-S1	**3,635,972**	**83**	**90**	**161**	**1.1**	**1.9**	**54" S=0.003**	**110**	**Yes**
XS-2	445,818	10	10	18	1.0	1.8		19	Yes
XS-3	237,852	5	7.9	13	1.4	2.4			
XS-4	201,890	5	5.9	11	1.3	2.4			
XCP-S2	**2,750,412**	**63**	**69**	**123**	**1.1**	**1.9**	**48" S=0.003**	**77**	**Yes**
XS-5	319,917	7	12	19	1.6	2.6			
XS-6	264,258	6	12	21	2.0	3.5			
XS-7	970,305	22	25	43	1.1	1.9			
XCP-S3	**1,195,933**	**27**	**32**	**57**	**1.2**	**2.1**	**30" S=0.002**	**18**	**No**
XS-8	120,579	3	3.4	6.2	1.2	2.2			
XS-9	596,532	14	16	27	1.2	2.0			
XCP-S4	**478,822**	**11**	**14**	**25**	**1.3**	**2.3**	**24" S=0.002**	**10**	**No**
XS-10	327,287	8	10	19	1.3	2.5			
XS-11	151,535	3	3.6	6.5	1.0	1.9			

EXISTING SOUTH CAMPUS SHEDS (WITH LOT 6 DETENTION)

			Sac Calc				Pipe	Capacity	Within-Capacity?
XSUB-SHEDS	**A (sf)**	**A (ac)**	**Q_{10}**	**Q_{100}**	**Q_{10} cfs/ac**	**Q_{100} cfs/ac**	**Notes**	**cfs**	**(Yes/No)**
XS-OUT	**3,788,772**	**87**	**40**	**80**	**0.5**	**0.9**	**1969 PUMPS**	**PUMP?**	**Yes**
XS-1	152,801	4	4.7	8.6	1.3	2.5			
XCP-S1	**3,635,972**	**83**	**36**	**72**	**0.4**	**0.9**	**54" S=0.003**	**110**	**Yes**
XS-2	445,818	10	10	18	1.0	1.8		19	Yes
XS-3	237,852	5	7.9	13	1.4	2.4			
XS-4	201,890	5	5.9	11	1.3	2.4			
XCP-S2	**2,750,412**	**63**	**62**	**108**	**1.0**	**1.7**	**48" S=0.003**	**77**	**Yes**
XS-5	319,917	7	12	19	1.6	2.6			
XS-6	264,258	6	12	21	2.0	3.5			
XS-7	970,305	22	25	43	1.1	1.9			
XCP-S3	**1,195,933**	**27**	**32**	**57**	**1.2**	**2.1**	**30" S=0.002**	**18**	**No**
XS-8	120,579	3	3.4	6.2	1.2	2.2			
XS-9	596,532	14	16	27	1.2	2.0			
XCP-S4	**478,822**	**11**	**14**	**25**	**1.3**	**2.3**	**24" S=0.002**	**10**	**No**
XS-10	327,287	8	10	19	1.3	2.5			
XS-11	151,535	3	3.6	6.5	1.0	1.9			

PROPOSED SHEDS (LOT 6 DETENTION, NEW PUMP, SINCLAIR ROAD IMPROVEMENTS)

PSUB-SHEDS	**A (sf)**	**A (ac)**	**Q_{10}**	**Q_{100}**	**Q_{10} cfs/ac**	**Q_{100} cfs/ac**		**cfs**	**(Yes/No)**
PN-OUT	**2,409,906**	**55**	**55**	**103**	**1.0**	**1.9**		**PUMP?**	**Yes**
PN-1	181,527	4	3.7	5.3	0.9	1.3			
PN-2	474,301	11	12	22	1.1	2.0	36"S=0.005	44	**Yes**
PCP-N1	**1,754,078**	**40**	**40**	**75**	**1.0**	**1.9**	**21"S=0.002**	**7**	**No**
PN-3	569,756	13	12	24	0.9	1.8			
PN-4	456,221	10	11	20	1.1	1.9			
PN-5	728,102	17	17	32	1.0	1.9	15"S=0.002	3	No
PS-OUT	**3,789,675**	**87**	**49**	**85**	**0.6**	**1.0**	**1969 PUMPS**	**PUMP?**	**Yes**
PS-1	152,801	4	4.7	8.6	1.3	2.5			
PCP-S1	**3,636,874**	83	**45**	**77**	**0.5**	**0.9**	**54" S=0.003**	**110**	**Yes**
PS-2	445,818	10	10	18	1.0	1.8		19	Yes
PS-3	237,852	5	7.9	13	1.4	2.4			
PS-4	201,890	5	5.9	11	1.3	2.4			
PCP-S2	**2,751,314**	**63**	**27**	**43**	**0.4**	**0.7**	**48" S=0.003**	**77**	**Yes**
PS-5	319,917	7	12	19	1.6	2.6			
PS-6	264,258	6	12	21	2.0	3.5			
PS-7	971,207	22	25	43	1.1	1.9			
PCP-S3	**1,075,354**	**25**	**32**	**57**	**1.3**	**2.3**	**TO DITCH**	**DITCH?**	**Yes**
PS-8	120,579	3	3.4	6.2	1.2	2.2			
PS-9	596,532	14	16	27	1.2	2.0			
PS-10	327,287	8	10	19	1.3	2.5			
PS-11	151,535	3	3.6	6.5	1.0	1.9			
PROP PUMP 4	**2,793,939**	**64**	**59**	**101**	**0.9**	**1.6**			

Abbreviations:
X: Existing
P: Proposed
N: North
S: South
W: West
CP: Control Point
OUT: Outfall

Appendix

Figure A.1

CSUS Campus Master Plan

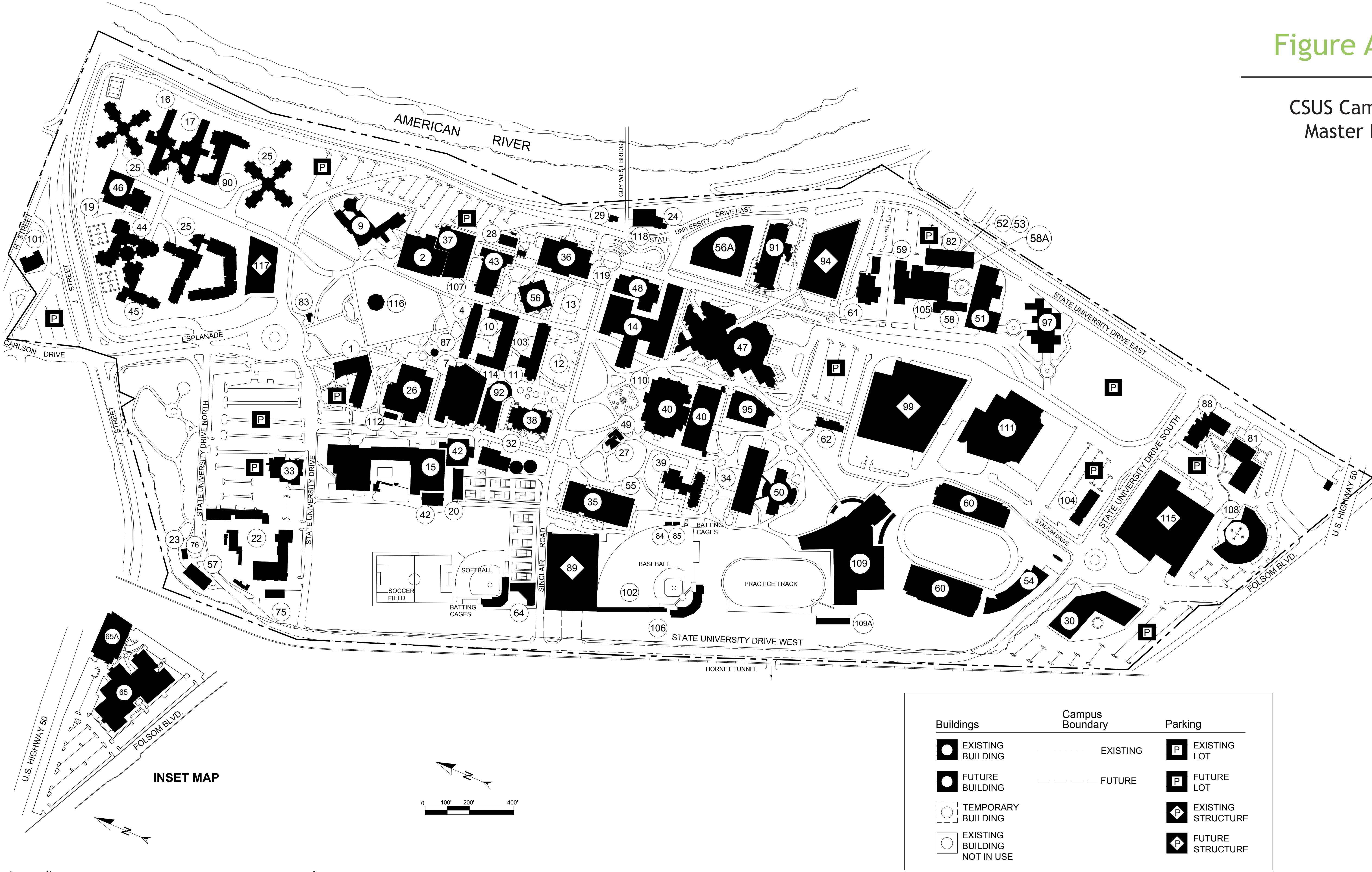


Table AA

CSUS Master Building List

BLDG. #	ABR.	BUILDING NAME	BUILDING NAME	ABR.	BLDG. #
1	SAC	SACRAMENTO HALL	ACADEMIC INFORMATION RESOURCE CENTER	AIRC	95
2	RFC	RIVER FRONT CENTER	ALPINE HALL	ALP	11
4	DH	DOUGLAS HALL	ALUMNI CENTER	AC	104
7	KDM	KADEMA HALL	AMADOR HALL	AMD	39
9	SHS	SHASTA HALL	AMERICAN RIVER COURTYARD		25
10	CLV	CALAVERAS HALL	ART COMPLEX		51
11	ALP	ALPINE HALL	ART SCULPTURE	ASL	82
12	BRH	BRIGHTON HALL	BASEBALL STORAGE FACILITY		106
13	HMB	HUMBOLDT HALL	BASEBALL STORAGE FACILITY PHASE II		102
14	SCL	SANTA CLARA HALL	BENICIA HALL	BNC	62
15	YSM	YOSEMITE HALL (NORTH & SOUTH)	BRIGHTON HALL	BRH	12
16	DRP	DRAPER HALL	BUS STOP CAFÉ		83
17	JNK	JENKINS HALL	CAFÉ		118
19		RESIDENCE HALL RECREATION FACILITY	CALAVERAS HALL	CLV	10
20		HANDBALL COURTS	CAPISTRANO HALL	CPS	35
22		FACILITIES SERVICES	CAPISTRANO HALL ADDITION		55
23		STORAGE BUILDING	CAPITAL PUBLIC RADIO	CPR	108
24		HAZARDOUS MATERIAL MGMT. BLDG.	CENTRAL PLANT	CP	32
25		AMERICAN RIVER COURTYARD	CHILD DEVELOPMENT CENTER	CCC	61
26	LSN	LASSEN HALL	CHILD DEVELOPMENT CENTER ANNEX	CCC	61A
27	STH	OUTDOOR THEATER	CITY FIRE STATION		101
28	GRN	GREENHOUSES	CLASSROOM BUILDING III		97
29	EHS	ENVIROMENTAL HEALTH & SAFETY	CLASSROOM BUILDING IV		114
31		HORNET FOUNDATION OFFICES	CLASSROOM LABORATORY BUILDING		50
32	CP	CENTRAL PLANT	CSUS FOUNDATION FOOD SERVICE BUILDING		107
33	SHC	STUDENT HEALTH CENTER	DEL NORTE HALL	BK	37
34	TAH	TAHOE HALL	DESMOND HALL	DSM	90
35	CPS	CAPISTRANO HALL	DINING COMMONS	DC	46
36	SQU	SEQUOIA HALL	DOUGLAS HALL	DH	4
37	BK	DEL NORTE HALL	DRAPER HALL	DRP	16
38	EUR	EUREKA HALL	EL DORADO HALL	ELD	59
39	AMD	AMADOR HALL	ELI AND EDYTHE BROAD ATHLETIC FIELD HOUSE		54
40	LIB	LIBRARY NORTH/SOUTH	ENGINEERING II		105
41	FH	FIELD HOUSE	ENVIROMENTAL HEALTH & SAFETY	EHS	29
42	SLN	SOLANO HALL	EUREKA HALL	EUR	38
43	MND	MENDOCINO HALL	EVENT CENTER		111
44	SRA	SIERRA HALL	FACILITIES SERVICES		22
45	STR	SUTTER HALL	FIELD HOUSE	FH	41
46	DC	DINING COMMONS	FOLSOM HALL		65
47	UU	UNIVERSITY UNION	FOOD SERVICE-OUTPOST		49
48	RVR	RIVERSIDE HALL	GAZEBO		116
49		FOOD SERVICE-OUTPOST	GREENHOUSES	GRN	28
50		CLASSROOM LABORATORY BUILDING	HANDBALL COURTS		20
51		ART COMPLEX	HAZARDOUS MATERIAL MGMT. BLDG.		24
52		SAC CITY UFD SCHOOL DISTRICT	HORNET BOOKSTORE/UEI OFFICES		91
53		OFFICE OF EDUCATION	HORNET FOUNDATION OFFICES		31
54		ELI AND EDYTHE BROAD ATHLETIC FIELD HOUSE	HORNET STADIUM		60
55		CAPISTRANO HALL ADDITION	HUMBOLDT HALL	HMB	13
56	PLR	PLACER HALL	JENKINS HALL	JNK	17
57		STORAGE BUILDING	KADEMA HALL	KDM	7
58	PSB	PUBLIC SERVICES	LASSEN HALL	LSN	26
59	ELD	EL DORADO HALL	LIBRARY ADDITION/REMODEL		110
60		HORNET STADIUM	LIBRARY NORTH/SOUTH	LIB	40
61	CCC	CHILD DEVELOPMENT CENTER	MARIPOSA HALL	MRP	92

BLDG. #	ABR.	BUILDING NAME	BUILDING NAME	ABR.	BLDG. #
61A	CCC	CHILD DEVELOPMENT CENTER ANNEX	MENDOCINO HALL	MND	43
62	BNC	BENICIA HALL	MODOC HALL	MDC	81
65		FOLSOM HALL	NAPA HALL	NPA	88
73		WAREHOUSE	OFFICE OF EDUCATION		53
75		RECEIVING	OUTDOOR AMPHITHEATER		119
81	MDC	MODOC HALL	OUTDOOR THEATER	STH	27
82	ASL	ART SCULPTURE	PARKING IV		115
83		BUS STOP CAFÉ	PARKING STRUCTURE I	PSI	89
87	RND	ROUND HOUSE VENDING	PARKING STRUCTURE II	PSII	94
88	NPA	NAPA HALL	PARKING STRUCTURE III	PSIII	99
89	PSI	PARKING STRUCTURE I	PARKING STRUCTURE V		117
90	DSM	DESMOND HALL	PLACER HALL	PLR	56
91		HORNET BOOKSTORE/UEI OFFICES	PUBLIC SERVICES	PSB	58
92	MRP	MARIPOSA HALL	RECEIVING		75
94	PSII	PARKING STRUCTURE II	RESIDENCE HALL RECREATION FACILITY		19
95	AIRC	ACADEMIC INFORMATION RESOURCE CENTER	RIVER FRONT CENTER	RFC	2
97		CLASSROOM BUILDING III	RIVERSIDE HALL	RVR	48
99	PSIII	PARKING STRUCTURE III	ROUND HOUSE VENDING	RND	87
101		CITY FIRE STATION	SAC CITY UFD SCHOOL DISTRICT		52
102		BASEBALL STORAGE FACILITY PHASE II	SACRAMENTO HALL	SAC	1
103		THEME STRUCTURE	SACRAMENTO HALL ANNEX	TMP	112
104	AC	ALUMNI CENTER	SANTA CLARA HALL	SCL	14
105		ENGINEERING II	SEQUOIA HALL	SQU	36
106		BASEBALL STORAGE FACILITY	SHASTA HALL	SHS	9
107		CSUS FOUNDATION FOOD SERVICE BUILDING	SIERRA HALL	SRA	44
108	CPR	CAPITAL PUBLIC RADIO	SOLANO HALL	SLN	42
109		THE WELL	STORAGE BUILDING		23
110		LIBRARY ADDITION/REMODEL	STORAGE BUILDING		57
111		EVENT CENTER	STUDENT HEALTH CENTER	SHC	33
112	TMP	SACRAMENTO HALL ANNEX	SUTTER HALL	STR	45
114		CLASSROOM BUILDING IV	TAHOE HALL	TAH	34
115		PARKING IV	THE WELL		109
116		GAZEBO	THEME STRUCTURE		103
117		PARKING STRUCTURE V	UNIVERSITY UNION	UU	47
118		CAFÉ	WAREHOUSE		73
119		OUTDOOR AMPHITHEATER	YOSEMITE HALL (NORTH & SOUTH)	YSM	15

Figure A.2

Proposed Future Growth Map

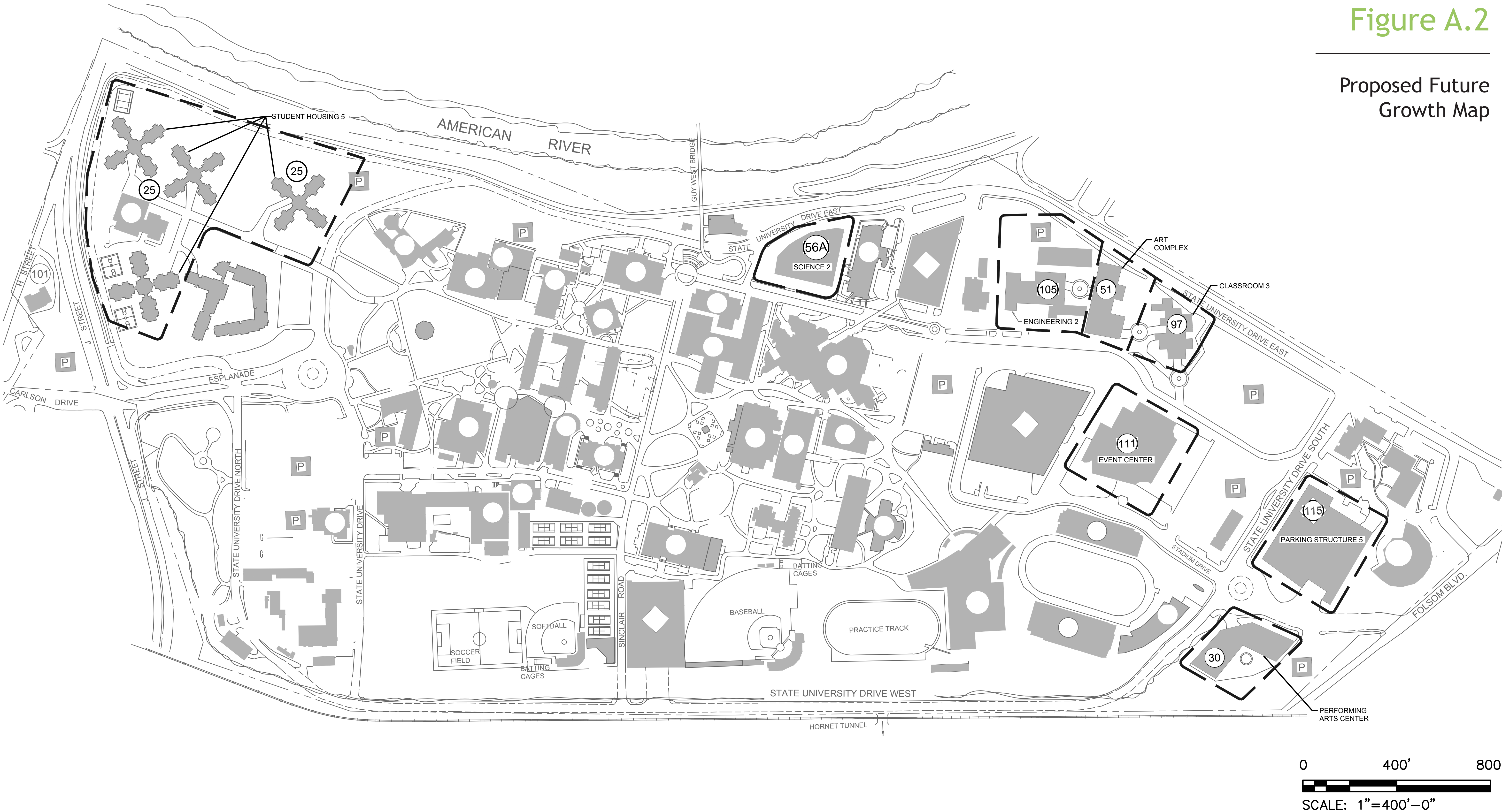


Table AB

Estimated Site Utility Requirements

CSUS Master Plan

Bldg. #	Proposed Future Facility	Estimated Site Utility Requirements							
		Projected Total Space	Chilled Water Demand (GPM)	Steam Demand (lbs)	Domestic Water (GPM)	Sanitary Sewer (GPD)	Storm Drainage (GPM)	Power (KW)	Natural Gas Demand (MBH)
25	Student Housing 5	600000 sf	30,000	16,000	1,200	100,000	600	990	13,800
30	Performing Arts Center	78,660 sf	4,000	2,300	130	12,000	1,100	1,200	3,150
51	Art Complex	51,000 sf	2,600	1,500	100	9,000	500	320	2,040
56A	Science 2	246,000 sf	12,500	7,200	415	45,000	1,335	960	9,840
97	Classroom 3	160,000 sf	8,100	4,700	250	20,000	1,100	1,280	6,400
105	Engineering 2	102,000 sf	5,200	3,000	170	15,000	700	800	4,080
111	Event Center	167,000 sf	8,500	4,900	280	25,000	1,600	1,600	6,680
115	Parking Structure 5		NA	NA	50	0	2,000	120	0