ELECTRICAL BREADTH STUDY

High Voltage Utility Relocation Plan and Distribution Systems Loss Analysis

Introduction

This study looks at the feasibility of reworking PSHMC's high voltage distribution plan into an integrated design that better accommodates the Parking Garage, Cancer Institute, and future Children's Hospital projects. To demonstrate breadth knowledge in electrical systems, an evaluation of service losses from the campus substation is performed, comparing the existing and proposed layout designs. The analysis also looks at constructability and value engineering issues with respect to the two plans.

Background

The PSHMC campus receives power from a substation located behind the University Physicians Centers (UPCs) and current Parking Garage project. Four 15kV lines, designated Hospital feeders A/B and Loop feeders A/B, provide electricity throughout the complex. Hospital A and B serve the main Hershey Medical Center complex, including the Cancer Institute and future Children's Hospital. Loop feeders A and B provide electricity to support facilities, such as the student housing complex, Parking Garage, and UPC 1 and 2. With the numerous construction projects involved in PSHMC's Master Plan for expansion, utility systems engineering is a critical element of the design. One of the key goals with recent construction was to separate the A and B lines whenever encountering a manhole; thus, each new junction has two manholes designated A and B. This separation makes construction and maintenance work safer due to the fact that all lines in a manhole can be de-energized.

Problem Statement

The substation currently routs all four feeders in an 8-conduit duct bank approximately 1,200 feet before it branches the circuits. The duct travels along the South side of the Parking Garage, across Centerview Drive and into two newly placed electric manholes (EMH) identified as 2120A and 2120 B. Just before reaching the manholes, the duct

splits such that both A lines enter 2120A, while both B lines tie in to 2120B. The placement of these manholes was a difficult task. Not only is Centerview Drive a high traffic route, but there is also an abutting PP&L line, Central Pennsylvania's electricity provider.

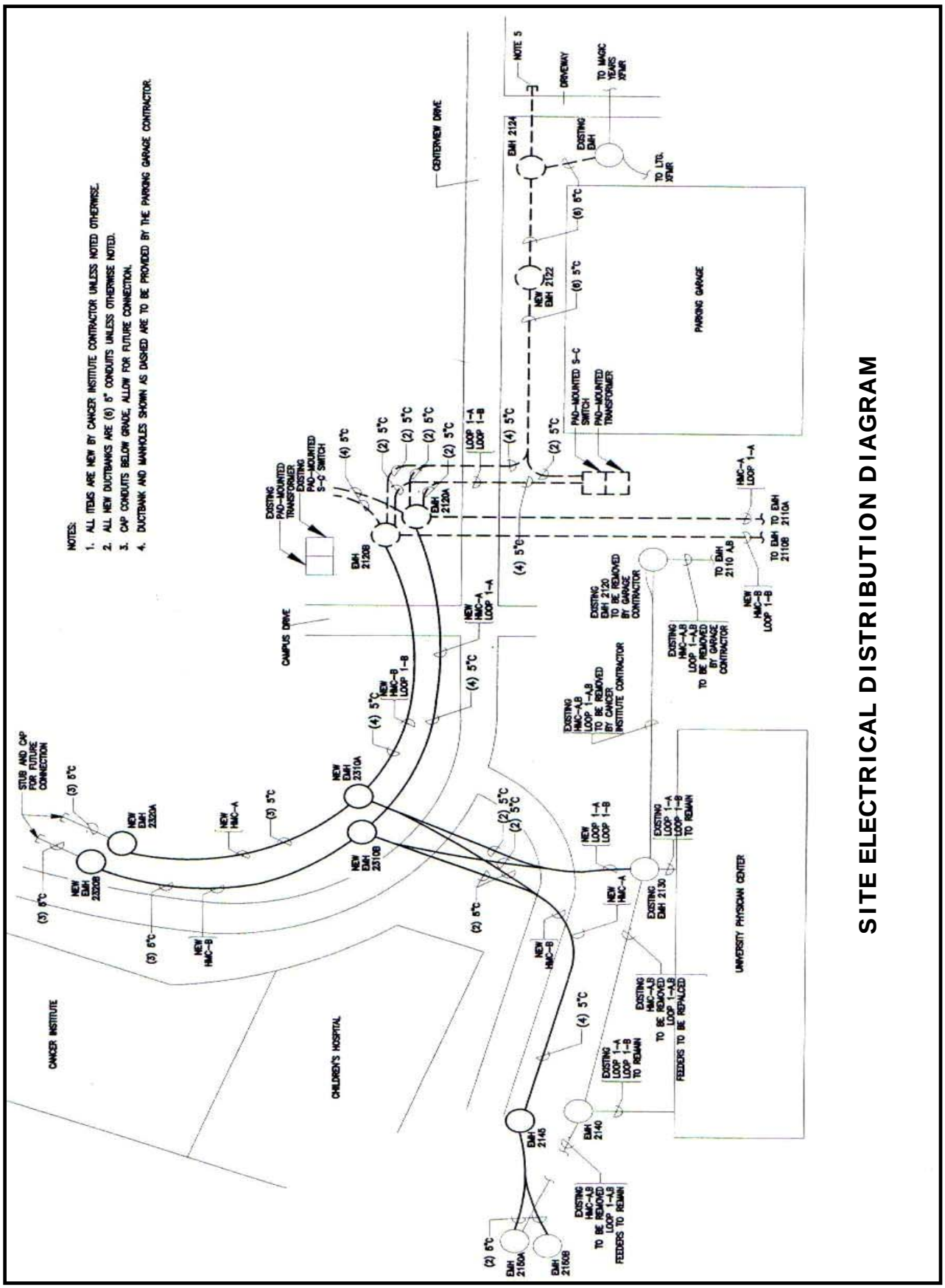
The overall site distribution plan calls for installation of seven new manholes to service the Parking Garage, Cancer Institute, and Children's Hospital. Aside from this there are three road crossings, one of which was completed in July, and extensive earthwork required. All of these issues contribute to an already logistically-strained campus. PSHMC and Gilbane have had to coordinate numerous plans for traffic and pedestrian rerouting for the Cancer Institute and Parking Garage projects. When the Children's Hospital gets underway, yet another road crossing will be required for the utility tie-in.

Proposal

To provide a more efficient means of servicing the current and upcoming construction projects at PSHMC, I will devise a new electric distribution plan that reduces the overall feeder distance from the central substation. This plan will consolidate construction costs by reducing the number of new manholes required, eliminating a road crossing and decreasing the overall linear distance of the new conduits. The shortened length will in turn decrease yearly costs incurred from power and voltage losses.

Preliminary Analysis

In order to develop a feasible and efficient site distribution plan, it is critical to gain a thorough understanding of the relationship between the feeders and the existing buildings and projects, as well as how they are distributed in each conduit. The following page depicts a comprehensive line diagram of the existing power plan, negating scale and dimensions.



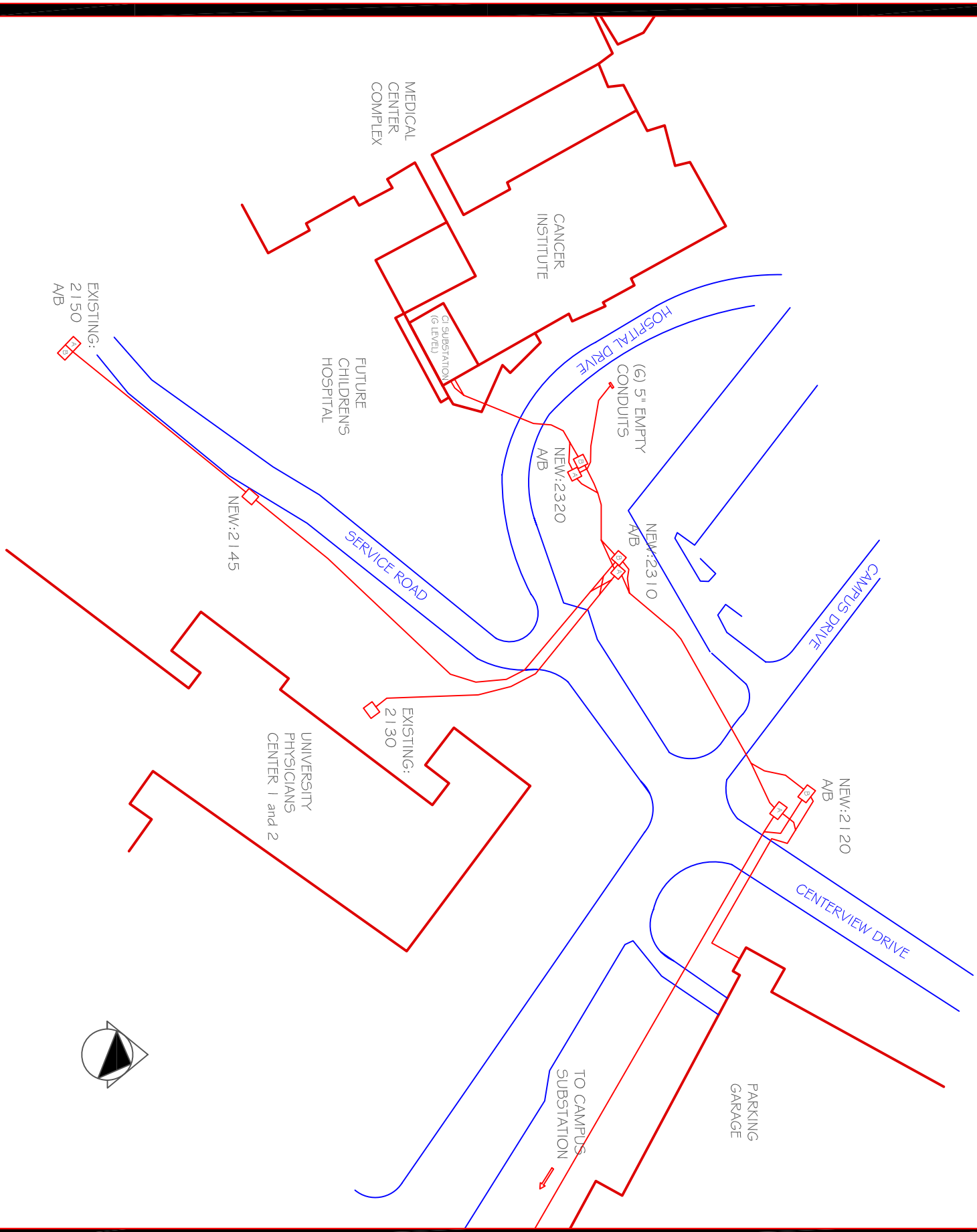
SITE ELECTRICAL DISTRIBUTION DIAGRAM

Existing Layout

The next page in this section shows the exact layout of the high voltage distribution plan in a manner that more accurately illustrates duct bank and manhole locations. PSHMC's East Campus feeders will be installed in phases corresponding to each new buildings' construction. The Parking Garage, now nearing completion, began the first phase of the distribution plan by installing EMH 2120 A and B. This required the first weekend road shutdown of Centerview Drive. The bulk of the utility work will be done with the Cancer Instititute phase, where the remaining five manholes and connecting duct banks will be placed. During this project, Hospital Drive will be taken over by site logistics. However, the active Campus Drive requires a weekend closing to install the ductbank connecting 2120 A/B to the new 2310 A/B. The last remaining step, which has yet to be coordinated, involves tying Children's Hospital into either 2310 or 2320. As of yet, no preliminary conduit is planned for installation across Hospital Drive during the Cancer Institute project. Thus, this road will require yet another temporary shutdown to install the duct bank. The table below summarizes the specifications for each duct bank segment of the existing layout, including the number of conduits and feeder routing schedule.

Figure 2. Existing Layout- Feeder Distribution Summary

DUCT BANK SEGMENT	CONDUITS PER SEGMENT	FEEDER DISTRIBUTION PER SEGMENT			
5" Conduit		Hospital 'A'	Hospital 'B'	Loop 'A'	Loop 'B'
Substation to EMH 2120 A/B	**8**- (4) Active, (4) Spares	X	X	X	X
2120 A/B to 2310 A/B	**8**- (4) Active (4) Spares	X	X	X	X
2120 A/B to Parking Garage	**4**- (2) Active (2) spares			X	X
2310 A/B to 2130	**4**- (2) Active (2) spares			X	X
2310 A/B to 2150 A/B (via 2145)	**4**- (2) Active (2) spares	X	X		
2310 A/B to 2320 A/B	**6**- (2) Active (4) spares	X	X		
2320 A/B to Cancer Institute	**6**- (2) Active (4) spares	X	X		
2320 A/B to Empty Termination	**6**- (6) spares				



SCALE	EXISTING SITE ELECTRIC DISTRIBUTION PLAN	PSHMC CANCER INSTITUTE
¼" = 40'		

PENNSTATE Milton S. Hershey Medical Center College of Medicine

Gilbane

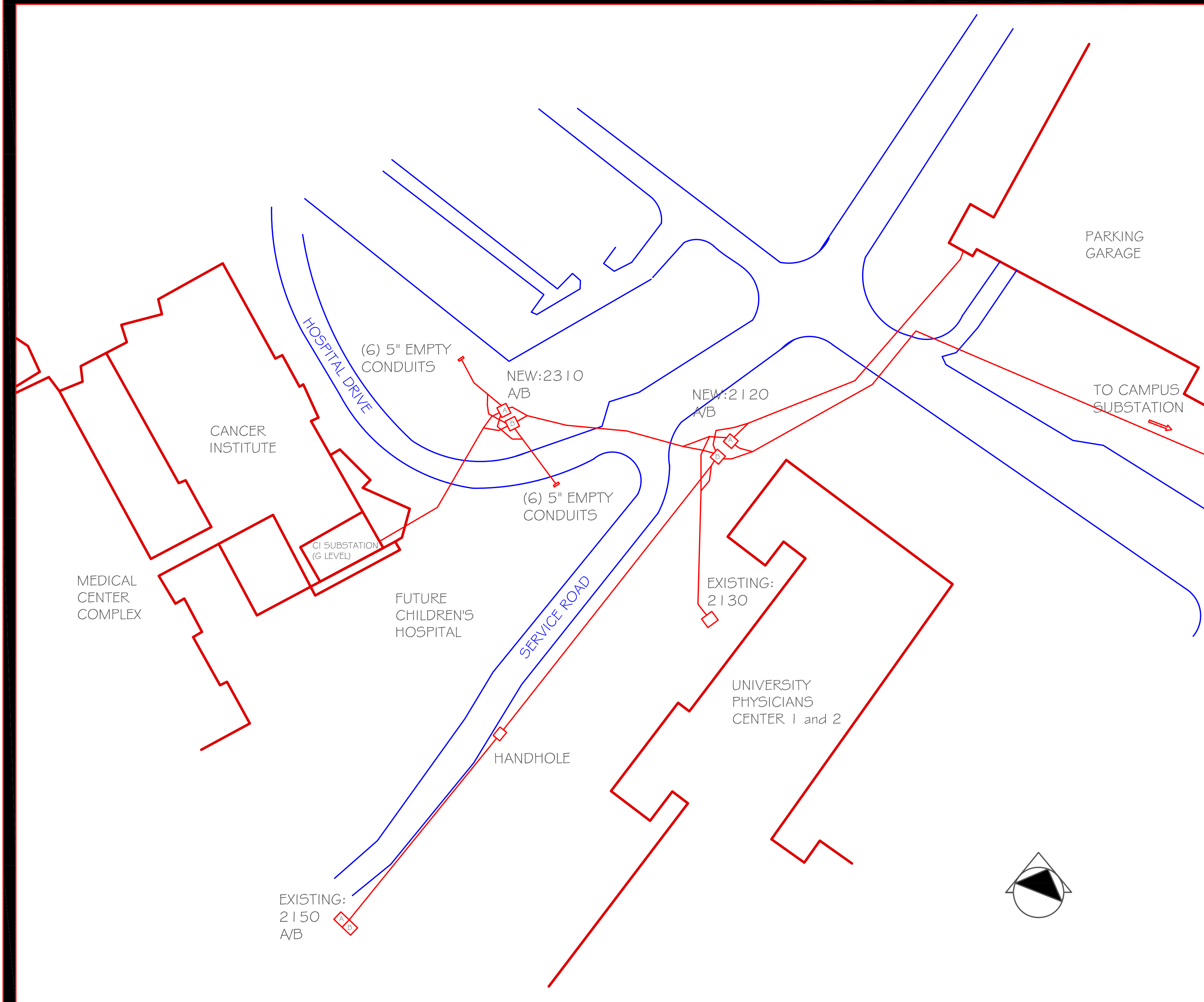
It is questionable why the current plan does not include empty conduits across Hospital Drive for the future Children's Hospital building. The unused conduits branching off of 2320 towards the front of the Cancer Institute building are being installed in anticipation of future construction. The same principle could easily have been applied here for Children's Hospital. OPP offered the reasoning that, since this project is still in the schematic design phase, installing empty conduits may simply be a waste of time if the electrical room does not mesh with the duct bank's location.

Proposed Layout Synopsis

On the next page is a full site plan showing the proposed high voltage distribution layout. Several improvements are made in this system. The design looks at PSHMC's East Campus from a broad perspective, rather than just focusing on one construction project at a time. Phasing all of the utility runs at once enables a better grasp of how each feeder is distributed throughout the new buildings and how they can be efficiently managed. Figure 3 presents a summary of the new plan's ductbank segments.

Figure 3. Proposed Layout- Feeder Distribution Summary

DUCT BANK SEGMENT	CONDUITS PER SEGMENT	FEEDER DISTRIBUTION PER SEGMENT			
5" Conduit, 3 Phases per Conduit		Hospital 'A'	Hospital 'B'	Loop 'A'	Loop 'B'
Substation to EMH 2120 A/B	**8**- (4) Active, (4) Spares	X	X	X	X
2120 A/B to Parking Garage	**4**- (2) Active (2) spares			X	X
2120 A/B to 2130	**4**- (2) Active (2) spares			X	X
2120 A/B to 2150 A/B	**4**- (2) Active (2) spares	X	X		
2120 A/B to 2310 A/B	**6**- (2) Active (4) spares	X	X		
2310 A/B to Cancer Institute	**6**- (2) Active (4) spares	X	X		
2310 A/B to Children's Hospital	**6**- (6) spares				
2310 A/B to Empty Termination	**6**- (6) spares				



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PSHMC CANCER INSTITUTE

PROPOSED SITE ELECTRIC DISTRIBUTION PLAN

SCALE $\frac{1}{4}$" = 40'

Comparative Analysis

The remainder of this study compares the existing and proposed layouts with respect to three core concerns for PSHMC and Gilbane: energy losses, constructability, and value engineering. Data and calculations are detailed further in Appendix B.

Systems Loss Comparison

With two feasible options, it is necessary to evaluate their performances with respect to energy costs. This analysis in particular is based on the direct relationship between distance and resistance; the longer a feeder has to travel, the greater the accumulated resistance and ultimately the greater the losses. Both voltage drop and power losses are examined, as voltage is pertinent to operating conditions and electricity costs are charged per kilowatt-hour used. Load demands and thermal conductance between conduits are considered constants in this study due to the fact that loading will not change, and any thermal impact is negligible compared to resistance losses.

High voltage lines, such as these four feeders, are installed to minimize losses. However, a side-by-side comparison is still necessary due to the fact that small losses can accumulate over time to equal a significant impact on energy costs.

Values herein are based on distribution plan take-offs, usage data from OPP's electrical monitoring system, and empirical specifications for the copper feeder wires. Since each line runs on a different amperage, and because the Hospital and Loop lines differ in total lengths, the study required analyzing each of the four feeders separately. Although usage data is for a 1-week period, it has been assumed to represent feeder averages for a year's time. The results of the study are summarized on the following page.

Figure 4. Line Loss Comparison

FEEDER DESIGNATION	CONDUIT LENGTH (linear ft.)	RESISTANCE (All Three Phases)	AVG. AMPS	AVG. VOLTS (kV)	VOLTAGE DROP (V)	AVG. LOSSES (Watts)	AVG. LOSSES PER YEAR (Watts)	ANNUAL COST OF LOSSES ($.0877/kWh)
Existing Layout								
Hospital A	2496	0.1662	86	14.06	14.30	1229.46	8526.47	$747.77
Hospital B	2496	0.1662	90	14.09	14.96	1346.49	8675.86	$760.87
Loop A	2007	0.1337	115	14.06	15.37	1767.74	10282.51	$901.78
Loop B	2007	0.1337	77	14.09	10.29	792.51	5364.92	$470.50
Total Length:	**9006' of conduit**				**Total Losses:**	**5136.2**	**32849.76**	**$2880.92**
Proposed Layout								
Hospital A	2331	0.1552	86	14.06	13.35	1128.49	7962.83	$698.34
Hospital B	2331	0.1552	90	14.09	13.97	1235.90	8102.34	$710.57
Loop A	1822	0.1213	115	14.06	13.95	1640.02	9334.69	$818.65
Loop B	1822	0.1213	77	14.09	9.34	735.25	4870.40	$427.13
Total Length:	**8306' of conduit**				**Total Losses:**	**4739.66**	**30306.43**	**$2635.79**
Estimated Energy Savings, Proposed Layout:								
Conduit Savings = 700 ft								
Wiring Savings = 700 linear ft. * 4 Wires = 2800 ft								
kWh Savings per Year = 2560.00 kWh								
Cost Savings per Year = $224.51								

It is evident from this analysis that, for four feeders, small distances add up to equal a significant amount of accumulated resistance in the copper wire. Taking a week's usage data from March 29th to April 4th and extrapolating over 8,760 hours (or 365 days), shortening the 3-phase conductor lines by a total of 2100' translates into $223 deducted each year from the electricity bill. Though this may not seem very substantial from PSHMC's perspective, it provides a good selling point in favor of the proposed layout.

Constructability Review

The new layout achieves three things with respect to constructability and initial costs. Though no single aspect saves a great deal of money, together these improvements can be considered highly beneficial from a construction and maintenance perspective.

Reduced Duct Bank Lengths

The first clear advantage of the proposed layout is the total reduced length for new duct bank installation. The distribution begins by having the (8)- 5" conduits coming from the substation run across Campus Drive as they reach the Southwest corner of the Parking Garage. The conduits then travel South to EMH 2120 A/B, moved from its original location at the corner of these two roads. The Parking Garage connection, containing both Loop feeders, is run back alongside the 8-conduit duct bank and installed during the Campus Drive shutdown. These are the only two segments that are lenghtened in the new plan. Figure 3 below summarizes the cost and schedule impact of the new layout with respect to duct bank installation and wiring costs.

Figure 5. Duct Bank, Conduit and Wiring Cost Comparison

Activity	Existing Layout (incl. O&P)	Proposed Layout (incl. O&P)
Duct banks (incl. excavation, pour)	$310,300	$313,563
PVC Conduit	$87,102	$84,636
Wiring (feeders & ground conductors)	$361,326	$314,880
Totals	**$758,728**	**$713,079**
Proposed Layout Savings- Duct Bank, Conduit and Wiring = $45,649		

Elimination of Manholes

By consolidating the duct banks, the new plan eliminates three manholes from the site. Manholes 2120 A and B serve as the hub of distribution throughout the site. As with the original plan, feeders split into their designated manholes and exit in an array of conduit that takes the necessary lines to their destinations. Also stemming from MH 2120 A/B is the Loop feeder connection to UPC and the Hospital feeder connections to EMH 2310 A/B. EMH 2145 is reduced to a simple handhole since the span between 2150 A/B and 2120 A/B is under the maximum 600' distance between manholes. Lastly, EMH 2320 A/B are able to be deleted completely from the plan, as approved by OPP's utility systems engineer during this study. These changes amount to a total savings of $9,050 in construction costs.

Fewer Road Crossings

The existing site power plan involves three road crossings- Centerview Drive, Campus Drive, and the intersection of Service Road and Hospital Drive. Installing the duct banks is a time-consuming process which requires temporary shutdowns of the routes, typically scheduled for weekends. Each crossing thus demands proper coordination between the hospital management and construction team so that traffic patterns can be reworked, permits obtained and notice given to hospital staff and visitors.

The new plan eliminates one of these road shutdowns by rerouting the main 8-conduit ductbank across Campus Drive before reaching the intersection with University Drive. What was once a right-angle crossing of two roads is reduced to a single shutdown of the less traveled route. Though cost savings are not significant here, benefits are realized to the schedule and logistics plan.

Value Engineering Considerations

The new layout takes utility systems engineering to a higher level of program management. Rather than waiting for plans to be finalized for these three projects, a comprehensive site plan is established that enables freedom in design, while still minimizing the extent of subsurface utilities work.

When looking at high voltage distribution from a broad perspective, the current total cost of construction amounts to $782,179, excluding any future costs for the Children's Hospital tie-in. The proposed system, which includes this empty conduit, costs $727,480, decreasing the high voltage package by 7%. Thus, advance planning would not be a waste of time as savings are still realized with the new layout. Further, as shown in the electrical study, added savings of $225 a year are realized as a result of the reduced conduit lengths. With the cost of energy continually growing, simple evaluations of distribution layouts can prove to be effective means of reducing the price of electricity incurred by large consumers such as PSHMC.

Lastly, sequencing the installation scheme all at once creates a streamlined approach that benefits the construction sites. Since the Parking Garage and Cancer Institute projects are running concurrently, it is possible to compress the activity to a couple weeks rather than months, without harming production rates for either project.

Recommendation

The proposed site power plan has its distinct advantages over the existing layout from both a construction and operation perspective. Benefits to cost, schedule, and sequencing is realized from a project management side, while value is added through savings in electricity costs. It is the recommendation of this analysis that the alternative site layout plan be adopted by PSHMC.