THE PENNSYLVANIA STATE UNIVERSITY –
DEPARTMENT OF ARCHITECTURAL ENGINEERING

AE Fifth Year Senior Thesis

Technical Report #1:
Construction Project Management

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10/5/2007

Faculty Consultant : Dr. Riley

The Carl J. & Ruth Shapiro Cardiovascular Center at the Brigham & Women's Hospital in Boston MA

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Executive Summary

The Carl J. and Ruth Shapiro Cardiovascular Center is a 10-story addition to the Brigham & Women's Hospital located on 70 Francis Street in Boston Massachusetts. Its location in the heart of medical research campuses in a major metropolis deems the site extremely congested, and this is evidenced by the lack of any laydown area for materials during construction of this project. The building will afford the hospital 134 new patient-care rooms and will also give the hospital new state-of-the-art Operating Rooms and Imaging technology. The facility will also contain a mixed-use first and second level, containing coffee shops and newspaper stands amidst a lobby area with full height glass fascade and plant gardens throughout the lobby. One final major point about the building is that LEED "green" design components of sustainability were considerable for this project, and the building is striving for a Silver LEED rating.

The primary project team members are the owner, Partners Healthcare System, the construction manager is William A. Berry & Son, Inc., and the architecture firms of Cannon Design and Chan Krieger & Associates designed the facility.

A remarkable undertaking for a project team and owner given the limited space to work in downtown Boston, the report illustrates a milestone project summary schedule, followed by a brief description of the key building systems. Next there is an analysis of the costs associated with the project. The project was originally estimated for a certain price, but with some unique additions to the project scope and the decision to try for LEED certification, the cost of the total project was increased from the original bid. The costs of the project were then compared with those of similar projects using D4 Cost Estimating software; however the conclusions were not as expected. The site layout plan illustrates the site congestion mentioned above, with no laydown areas for steel or other building material storage sites.

Local conditions of the site again attribute to not only a congested project site, but also heighten the necessity for the project team to diligently monitor all major steps in the construction process because of the neighboring structures, particularly the existing hospital that is still operational at the time of construction. A description of the client and the reasons for building this addition meld the function of the hospital with the goals of the owner. The hospital serves as a research facility for many students but also provides quality healthcare for the citizens of not only Boston or Massachusetts, but people from around the country and abroad as well. The ability for the hospital to meet the increasing demands for patients as well as the goals of the hospital to maintain a high level of research and development and implement state-of-the-art technology advancements here pressed the need for this project's construction.

Project Schedule Summary

The Project schedule is located in Appendix A. The key elements of the foundation are making sure the footings are properly cured before removing the gang formwork, and also the connection of the piers and footings to the steel columns. Structural elements of importance are the approval of the structural steel design and the topping out milestone. In terms of the finishing sequences, the patient room installations are very important, specifically because almost all the patient rooms on levels 5 and above have showers within the rooms, so it is important to make sure all waterproofing and quality control workmanship are considered. Substantial completion is a major milestone on this project, and also the commissioning and final inspections tasks serve as milestones.

Building Systems Summary

Yes	No	Work Scope	If Yes, see sections below for answers to questions
X		Demolition Required?	Types of materials, lead paint, or asbestos?
X		Structural Steel Frame	Type of bracing, composite slab?, crane size/ type/ location
X		Cast in Place Concrete	Horiz. and Vert. Formwork types, concrete placement methods
X		Precast Concrete	Casting location, connection methods, crane size/ type/ locations
X		Mechanical System	Mech. Room locations, system type, types of distribution systems, types of fire suppression
X		Electrical System	Size/ capacity, redundancy
X		Masonry	Load bearing or veneer, connection details, scaffolding
X		Curtain Wall	Materials included, construction methods, design responsibility
x		Support of Excavation	Type of excavation support system, dewatering system, permanent vs. temporary

Demolition

Minor demolition was needed to remove an oil tank from an old existing structure on site. Also, upon further investigation, certain soils were found to be contaminated from this oil tank and needed to be cleaned and tested before construction began. Finally, all existing utilities were terminated and any materials unsuitable within the proposed building footprint were disposed of in accordance with the local, state, and federal regulations, ordinances, and statutes.

Structural Steel Frame

Bracing was all galvanized HSS shapes, with sizes varying on location and spans. The composite slabs for the floors consist of 3" composite steel floor decks with 5 ½" lightweight concrete and Welded Wire Fabric reinforcement (6" x 6" W2.1 x W2.1). A tower crane and site utility crane were used extensively on the project.

Cast in Place Concrete

The 5" Slab on Grade is normal weight concrete and in reinforced with 6"x6" W2.9xW2.9 Welded Wire Fabric. All formwork was European gang formwork that acted similar to a slip, but the onsite utility crane lifted the gangs up each lift. This is because the foundation wall thickness changes as it goes up, from 24" to 18", preventing a slip formwork from being utilized. All concrete was placed using a concrete pump, although some of the footings used a crane and bucket. For locations of the cranes and concrete pump, refer to the "Site Plan of Existing Conditions" section on page 10.

Precast Concrete

Minimal use of precast concrete, except for bump-out floors on the east side of the site. This is to accommodate the delivery and installation of the MRIs, because there is no existing loading dock for this building. The floor uses a block-and-plank system, and the site utility crane lifted these into place, but again not until after the arrival of the MRI equipment.

Mechanical System

The entire 4th floor is left for mechanical and electrical equipment, with intermediate mechanical rooms located in the sublevels and on the other various levels in the building. There are also 2 level rooftop Air handling units that are walk-through. The mechanical systems include an all-water system for some heating and an air-water system for heating and cooling. Distribution of these systems is through both variable and constant-volume systems. The fire suppression component utilizes a dry sprinkler system at air intake plenums and emergency generator enclosures, while a standpipe/ wet sprinkler system is implemented throughout the remainder of the building. The wet sprinklers are at 165°F and 286°F ratings, with some using a pre-action single zoned double interlock mechanism.

Electrical System

The electrical systems are located predominantly on the 4th floor. The 15 kV switchgear, in 3-phase, on 4 wire with a solid ground at 60 Hz run this system. The max voltage is 15 kV, and the impulse in 95 kV, with the short circuit rated at 37kA RMS. The redundancy is provided by 3 UL 2200 Listed Diesel Engine driven generator sets, where each generator gives 1250 kW, 1562.5 kVA standby-rated. These generators provide transition time, from instant failure of normal power source to emergency generator power source, of 10 seconds or less.

Masonry

Concrete masonry units of load bearing use are installed as various interior wall systems and other interior components of the building. Lintels, corners, jambs, headers, and some bull nose units are all CMU materials used for the Carl J. & Ruth Shapiro Cardiovascular Center. These components are used in the creation of seismic clips and interior walls supported by the composite deck on the project.

Curtain Wall

Beginning at the 4th floor mezzanine level and going up the height of the building is a unitized aluminum and glass curtain wall system that uses halfin anchors embedded in the concrete slabs. The entire 4th floor curtain wall consists of louvers that allow for natural ventilation and air intake. The 3rd floor down is all a built in place curtain wall, using light-gauge studs with DensGlass exterior sheathing, standoff brackets, and a spray foam insulation 3" thick.

Support for Excavation

There is a 6" diameter perforated PVC pipe, with the perforations oriented downward, for permanent dewatering drainage system under the foundation. Above and around this pipe is a minimum 6" layer of crushed stone that proceeds upward to the mud slab under the concrete slab-on-grade.

Project Cost Evaluation

The project went through several design changes since the beginning of the design phase in order to accommodate advancements in technology and the growth potential of the hospital. The following figures are based on the Conceptual Cost Estimates given on 12/19/03:

Actual Building Construction Cost (CC) = $ 121,669,000.00

Actual Bldg CC per Square Foot = $121,669,000 / 427,000 SF = $285.24/gsf

Total Project Cost = $166,000,000.00

Total Project Cost per Square Foot = $166,000,000 / 427,000 SF = $390.14/gsf

Major Building Systems Costs and Costs per Square Foot:

- Mechanical System = $17,000,000; $42.15/gsf
- Electrical System = $15,500,000; $36.30/gsf
- Structural System = $7,900,000; $18.49/gsf
- Radiation Shielding = $4,370,000; $10.24/gsf
- Windows, Glass, & Glazing = $12,900,000; $30.20/gsf

A parametric estimate for the project was generated using ***D4Cost 2002*** Estimating software by taking several projects within the software system and True Averaging their systems costs. These numbers were then attributed to the parameters of the Carl J. & Ruth Shapiro project in Boston. The D4 report is located in Appendix B at the back of this report (Paper copy only).

The D4 Cost estimate gave a Total Building Cost = $123,071,000; or $273.49/ SF

Using RS Means 2007 Square Foot Cost data, a Total Square Foot Estimate has been generated. However, the scope of the Carl J. & Ruth Shapiro Center is so unique that it did not conform to many of the given standards in RS Means, i.e. the building is a 10-story hospital facility, while the RS Means section for hospital only goes up to 8 stories. There was also a problem finding the appropriate exterior wall for the building in the RS Means tables; the Carl J. & Ruth Shapiro Center uses a unitized aluminum and glass curtainwall, where the only options in the Hospital section were for Face Brick or Precast Concrete Panels. Therefore, three Square foot estimates were generated: one from section M.340 – Hospital 4-8 Story, one from M.360 – Hotel 8-24 story, and finally one using M.480 – Office 11-20 story. This was done in order to find an estimate that closely resembles the actual cost estimates. The backup sheets taken from RS Means are found in Appendix C at the back of the Report.

Hospital 4-8 Story: use Precast Concrete Panels w/ exposed aggregate and Steel frame figures.

Total SF = 450,000

Assume: Cost per SF estimated at $210/SF (base estimate not including basement levels or common additives)

Total Square Foot Cost = 450,000 SF x $210/SF = **$94,500,000.**

Hotel 8-24 Story: Use Glass & Metal Curtainwalls & Steel Frame line.

Total SF = 450,000

Cost per SF = $135.00 (base estimate not including basement level additions or common additives)

Total Square Foot Cost = 450,000 SF x $135/SF = **$60,750,000**

Office 11-20 Story: Double Glazed Heat Absorbing Tinted Plate Glass Panels & Steel Frame

Estimate was not considered because RS Means Cost/SF too low

Total SF = 450,000

Cost per SF = Interpolate between 400,000 and 600,000 numbers

(450000-400000)/(600000-400000) = 0.25; take Cost/SF for 400k and multiply by 0.75, and Cost/SF for 600k and multiply by .25:

(116.65 x 0.75) + (113.0 x 0.25) = $115.74/SF

Total Square Foot Cost = 450,000 SF x $115.74/SF = **$52,081,875**

The differences in the costs from the actual estimates and these projected estimates are a compilation of several factors. In RS Means, as mentioned above, the project is much more complex and unique than the generalized projects listed in RS Means, and with the more complex buildings the costs are greater. The complexities of LEED rating points and sustainable design afford much higher costs than typical systems also, which cannot be accounted for in the RS Means estimate.

With the D4 Estimating Software, again the complexities of the Carl J. and Ruth Shapiro Center cannot be accounted for in this program. By simply comparing square footages and

Site Plan of Existing Conditions

The Carl J. & Ruth Shapiro Cardiovascular Center's location neighbors the existing Brigham & Women's Hospital. The site itself contained several multifamily homes which were demolished and relocated. Also adjacent to the site for the Cardiovascular Center is a brick parking garage and office building, which also abuts the job trailers when the construction begins. Please refer to the site plan drawing located in Appendix C.

Local Conditions

In Boston, the preferred method of construction for the high-rise buildings is steel frame with lightweight concrete slabs, due to the seismic issues. The floor deck concrete must be machine troweled in order to achieve the appropriate tolerances for hospitals. Both of these conditions were satisfied on this project. In terms of interesting site conditions, the construction team was required to connect the new structure to the existing hospital in 3 places: the bridge connection above Francis Street, as well as the connection through Francis Street of the hospital to two of the sublevels of the new project. Francis Street was also relocated and moved slightly, all while maintaining 100% traffic.

Parking for construction workers was available through the use of the adjacent parking decks near the site. Space on the site itself was extremely tight, with no available lay down areas for materials and no loading dock to the building. In terms of the existing site, 6 homes were relocated before construction began by Brigham & Women's Hospital. The bearing capacity of the soil is 8 tons per square foot, or 16 kilo pounds per square foot (ksf). The building foundation did move below the water table, making the water prevention a crucial step during its construction. The total waste costs, including the dumpsters and recycling costs, was difficult to determine due to fluctuating costs for trucking, however an allowance of $470,000 was made.

Client Information

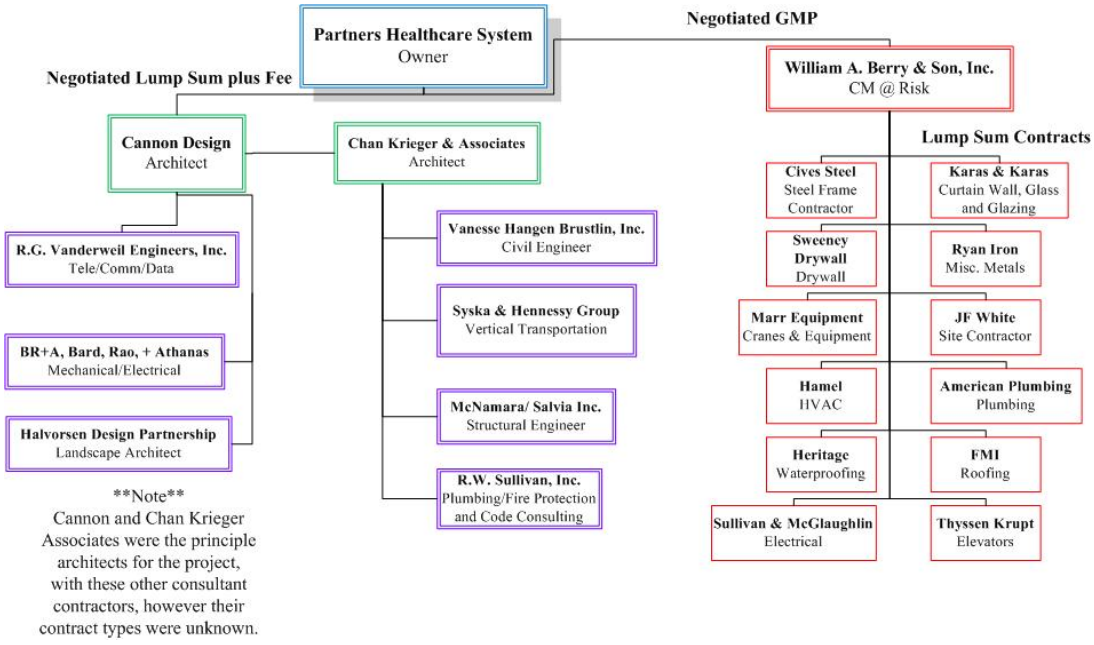
Partners Healthcare is a non-profit healthcare corporation that owns a number of in and out-patient facilities throughout the North and South Shores of Massachusetts. Their primary reason for building The Carl J. & Ruth Shapiro Cardiovascular Center at The Brigham & Women's Hospital in Boston is for the increased need for patient care. This is a mission critical facility because it will give the hospital 134 new patient beds. There is a direct correspondence for pro forma business, so this facility will allow for the immediate aid for more emergency patients. It is also part of the long-term expansion of the several research hospitals located at the Longwood campus.

The neighbors of this area put a lot of restrictions on construction efforts, such as work hours and site layout. The relationship between Partners and its neighbors at Longwood is so critical to the continued growth and strides in the advancement of healthcare technology and research that it is important for both sides to see the gains for all parties involved. Because the entire area consists of active medical campuses, the noise cannot go beyond a specific level, the hours of construction are regulated, but the main goal is quality, which can never be sacrificed. The expectations of Partners is that the Construction Manager will deliver the project when it is needed, and that because of the nature of healthcare, and the continuous advancements in this field of science, the Construction Manager must also be able to accommodate future technological marvels and incorporate them into the schedule and design of the facility.

The owner expects that the Carl J. & Ruth Shapiro Cardiovascular Center is fulfilled to their design criteria, with additional consideration placed into the design to allow for any future advancements in the realm of new healthcare technologies and processes. Currently, the new cardiovascular center incorporates state-of-the-art imaging and Ors, but offers care in other areas than just cardiovascular. With the new patient rooms and space for offices, the building can accommodate more patients in the event of a critical catastrophe with a wide variety of injuries and emergency care necessities.

Project Delivery System

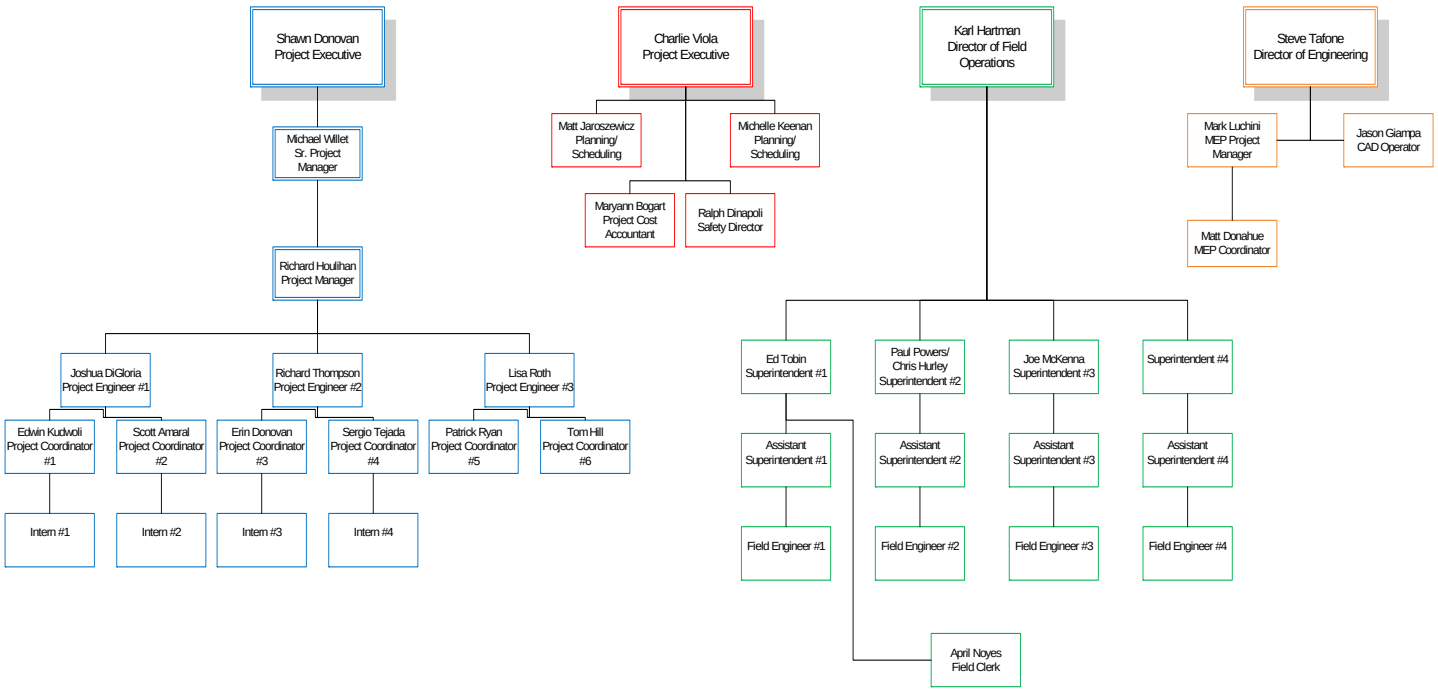
William A. Berry & Son, Inc. is the Construction Manager at Risk for this project. They are contracted with the owner using a Guaranteed Maximum Price contract (GMP). The architectural design was a joint effort by Cannon Design and Chan Krieger & Associates, and their contract type was not specifically given, but it can be assumed to be a negotiated lump sum plus fee or cost plus fee contract. The other design engineers contracted and/or consulted with those lead architects on the project to generate all of the drawings for the project. These design firms and engineers did not hold contracts with the Construction Manager, but rather with either Cannon Design or Chan Krieger, and their contract types were not given, but assume it was a fixed fee contract or lump sum. William A. Berry & Son, Inc. subcontracted much of the trade work to several subcontractors on a lump sum competitive bid contract, and usually chose the lowest bid. Many of these subcontractors have done work with Berry before, and also have performed work with this client before. A picture of the organizational chart is below, but a larger version can be found in Appendix D (paper copy only).



All of the subcontractors must have an up-to-date and valid Certificate of Insurance before beginning work on the construction site. Also, William A. Berry & Son., Inc. provides information regarding specific Bonding information within all of their Subcontracts, indicating the proper amount of insurance funding for each of the major Insurance types: General Liability, Workman's Compensation, Automobile Liability, and Excess Liability. Because the subcontractors on this project have worked with both the owner and the CM on the project before, these rules should not be difficult to abide by, and it also helps in the selection of subcontractors because the entities on the project have worked together before. Also, the contract types seem appropriate because if there were any issues in the past, they have been addressed already and corrected for this project.

Staffing Plan

William A. Berry & Son, Inc. is the Construction Manager at Risk on this project. The size of the project definitely serves as the determining factor for staff size of the project. Provided below is a snapshot of the project staffing plan and a larger version will be provided in Appendix C.



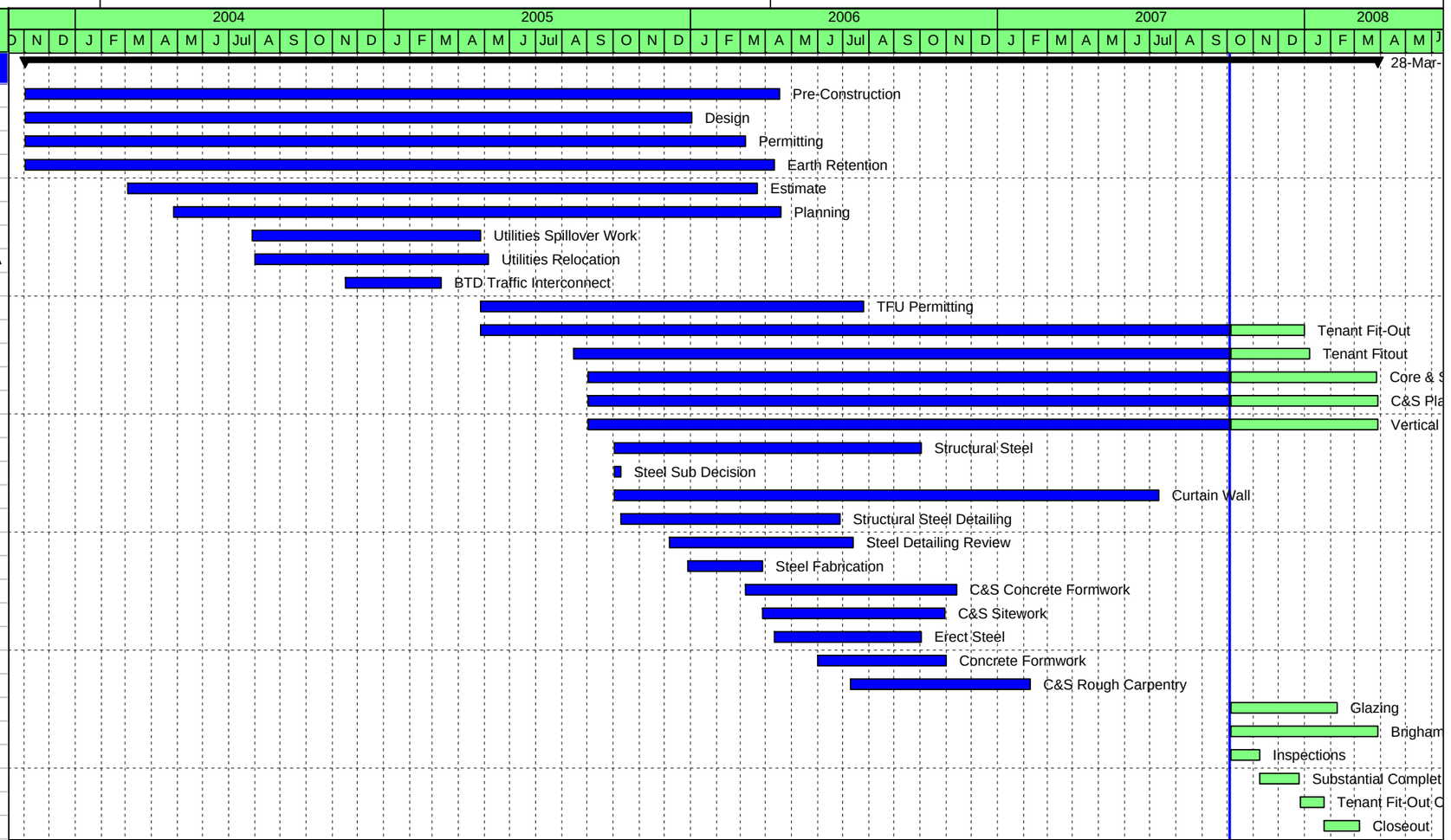
There are 2 project executives on the project and 2 project managers who control the work of 3 project engineers. Those three project engineers then allocate responsibilities to two project coordinators each. Four internship positions were reserved in order to allow students studying construction management or architectural engineering in the area the opportunity to work on this project. All of these individuals work together to make sure the drawings are accurate and up to date for the team in the field, check submittals, and generate the meeting minutes and cost reports. They will also be called upon to verify RFIs and the Certificates of Insurance, and any other administrative duties for the project. The project cost accountant and safety director also make up this branch of the staff and again are important for the safety and accounting necessities of the project.

The field staff consists of a Director of field operations, superintendents and assistant superintendents, the field engineers and a field clerk. The Director of Engineering takes charge of the MEP coordination and drawing reproduction with his staff of CAD operator and MEP Project manager and coordinator.

Appendix A – Project Schedule

On the following page

Activity ID	Activity Name	Schedule % Complete	Original Duration	Start	Finish
70 Francis Street Su...		0%	1124	03-Nov-03 A	28-Mar-08
A1000	Pre-Construction	0%	1	03-Nov-03 A	18-Apr-06 A
A1010	Design	100%	548	03-Nov-03 A	03-Jan-06 A
A1040	Permitting	100%	593	03-Nov-03 A	07-Mar-06 A
A1080	Earth Retention	100%	617	03-Nov-03 A	10-Apr-06 A
A1020	Estimate	100%	521	03-Mar-04 A	21-Mar-06 A
A1030	Planning	100%	502	27-Apr-04 A	18-Apr-06 A
A1060	Utilities Spillover Work	100%	190	29-Jul-04 A	27-Apr-05 A
A1050	Utilities Relocation	100%	194	02-Aug-04 A	05-May-05 A
A1070	BTD Traffic Interconnect	100%	79	17-Nov-04 A	11-Mar-05 A
A1250	TFU Permitting	100%	317	27-Apr-05 A	26-Jul-06 A
A1240	Tenant Fit-Out	88.24%	703	27-Apr-05 A	01-Jan-08
A1260	Tenant Fitout	86.83%	627	15-Aug-05 A	07-Jan-08
A1090	Core & Shell	83.81%	633	02-Sep-05 A	27-Mar-08
A1100	C&S Plant and Equipment	83.81%	633	02-Sep-05 A	28-Mar-08
A1230	Vertical Transportation	84.47%	628	02-Sep-05 A	28-Mar-08
A1140	Structural Steel	100%	254	03-Oct-05 A	02-Oct-06 A
A1150	Steel Sub Decision	100%	6	03-Oct-05 A	10-Oct-05 A
A1220	Curtain Wall	100%	452	03-Oct-05 A	11-Jul-07 A
A1160	Structural Steel Detailing	100%	182	10-Oct-05 A	27-Jun-06 A
A1170	Steel Detailing Review	100%	153	07-Dec-05 A	13-Jul-06 A
A1180	Steel Fabrication	100%	62	29-Dec-05 A	27-Mar-06 A
A1120	C&S Concrete Formwork	100%	1	07-Mar-06 A	13-Nov-06 A
A1110	C&S Sitework	100%	152	28-Mar-06 A	30-Oct-06 A
A1190	Erect Steel	100%	122	11-Apr-06 A	02-Oct-06 A
A1130	Concrete Formwork	100%	108	01-Jun-06 A	01-Nov-06 A
A1200	C&S Rough Carpentry	100%	150	10-Jul-06 A	09-Feb-07 A
A1210	Glazing	0%	91	05-Oct-07	08-Feb-08
A1290	Brigham & Women's Ext...	0%	126	05-Oct-07	28-Mar-08
A1310	Inspections	0%	25	05-Oct-07	08-Nov-07
A1270	Substantial Completion	0%	34	09-Nov-07*	26-Dec-07
A1280	Tenant Fit-Out Closeout	0%	21	27-Dec-07*	24-Jan-08
A1300	Closeout	0%	30	25-Jan-08*	06-Mar-08



Actual Work | Remaining Work | Critical Remaining Work | Milestone | Summary

TASK filter: All Activities

Appendix C – Site Plan

Sami Boulos - Construction Option
Faculty Consultant: Dr. Riley

The Carl J. & Ruth Shapiro Cardiovascular Center at the Brigham & Women's Hospital

Boston, Massachusetts

Legend:

Property Line

Fence Line

No. Revision Date Apprvd.

Designed by HFM Drawn by JWP Checked by MSJ

CAD checked by Approved by

Scale 1"=20' Date DATE

Project Title

PROJ1
PROJ2

STREET
CITY

Issued for

ISSUED1
ISSUED2

CONST

Drawing Title

Site Plan
Plan

Drawing Number

C-2

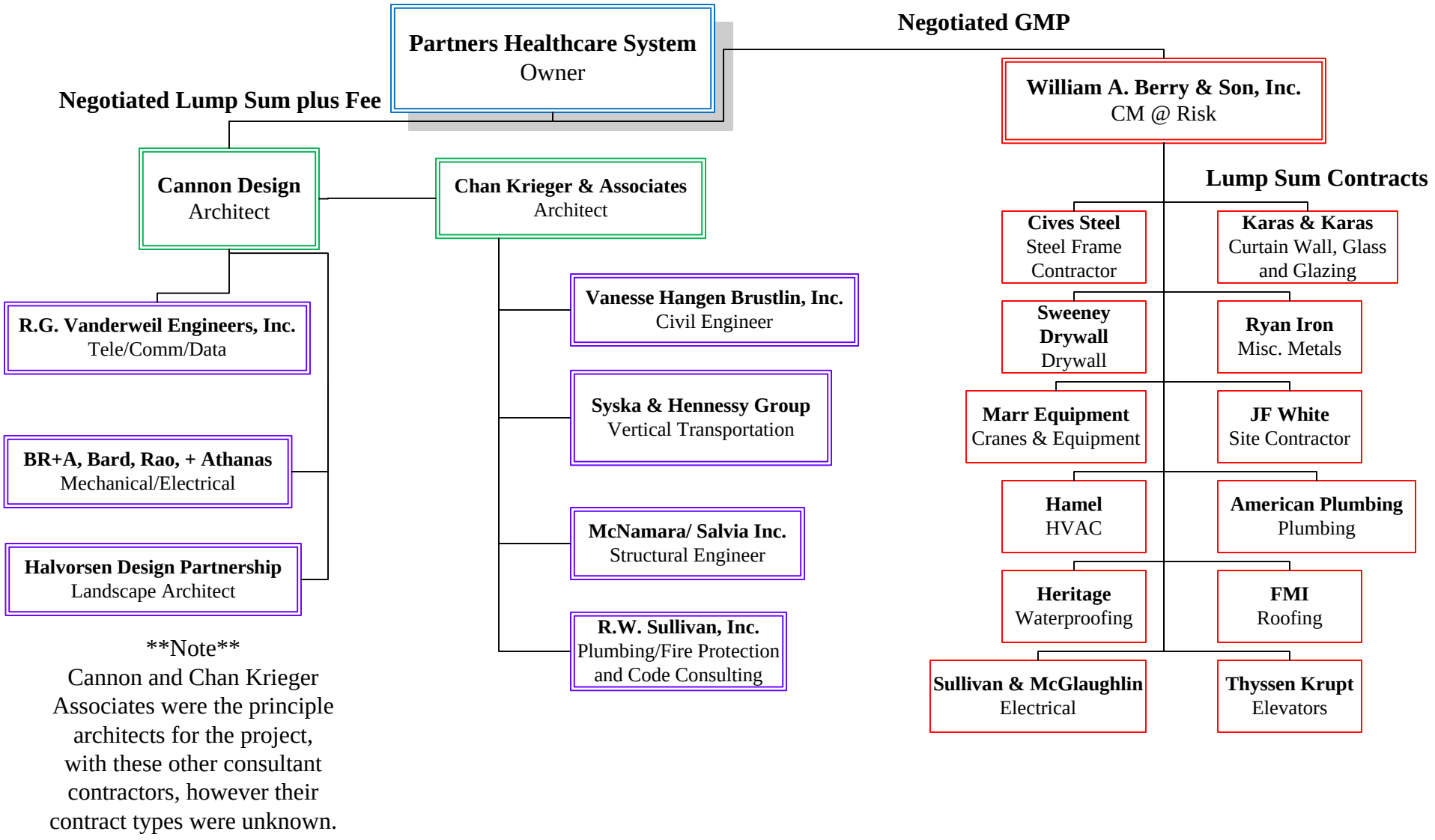
Sheet of #

Project Number

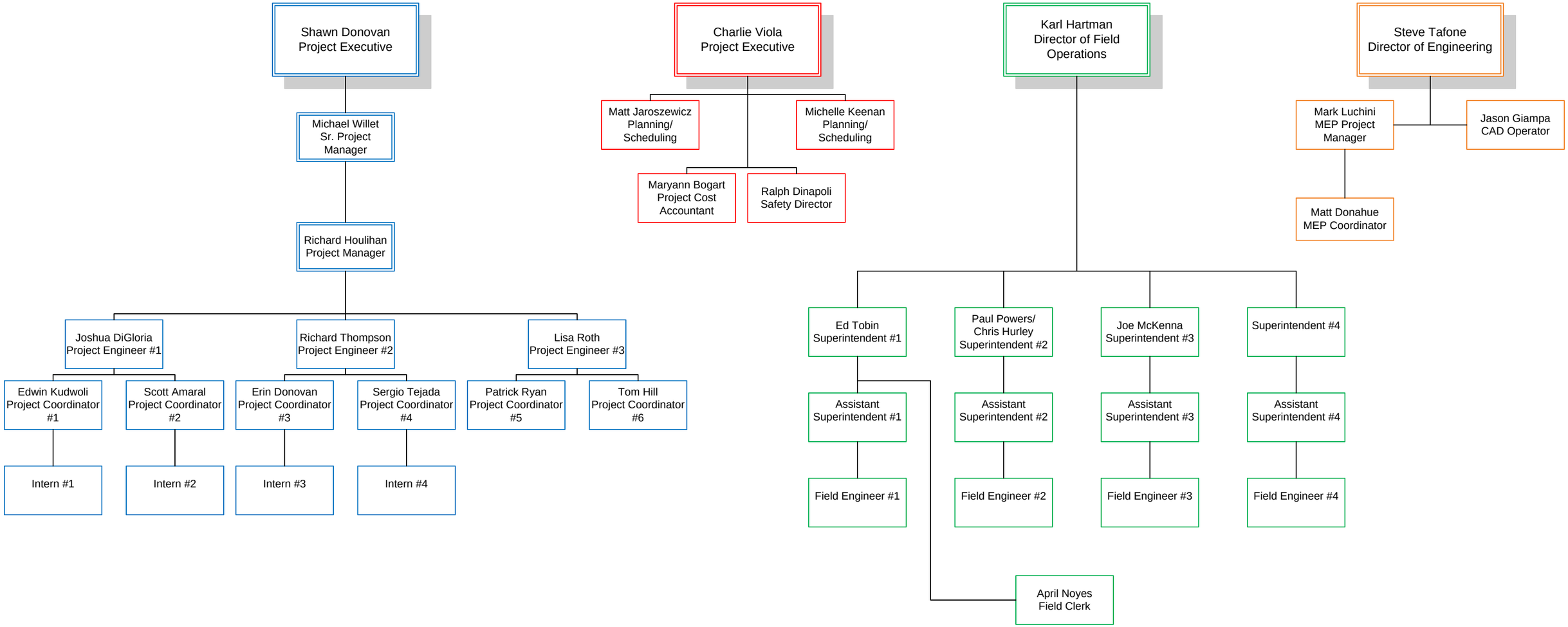
JOB#

P:\Thesis\Tech 1\Modified Site Plan.dwg

Appendix D – Organizational Chart for Project and Staffing Plan (WAB)



Note
Cannon and Chan Krieger Associates were the principle architects for the project, with these other consultant contractors, however their contract types were unknown.


Shawn Donovan
Project Executive
Michael Willet
Sr. Project Manager
Richard Houlihan
Project Manager
Joshua DiGloria
Project Engineer #1
Richard Thompson
Project Engineer #2
Lisa Roth
Project Engineer #3
Edwin Kudwoli
Project Coordinator #1
Scott Amaral
Project Coordinator #2
Erin Donovan
Project Coordinator #3
Sergio Tejada
Project Coordinator #4
Patrick Ryan
Project Coordinator #5
Tom Hill
Project Coordinator #6
Intern #1
Intern #2
Intern #3
Intern #4
Charlie Viola
Project Executive
Matt Jaroszewicz
Planning/ Scheduling
Michelle Keenan
Planning/ Scheduling
Maryann Bogart
Project Cost Accountant
Ralph Dinapoli
Safety Director
Karl Hartman
Director of Field Operations
Ed Tobin
Superintendent #1
Paul Powers/ Chris Hurley
Superintendent #2
Joe McKenna
Superintendent #3
Superintendent #4
Assistant Superintendent #1
Assistant Superintendent #2
Assistant Superintendent #3
Assistant Superintendent #4
Field Engineer #1
Field Engineer #2
Field Engineer #3
Field Engineer #4
April Noyes
Field Clerk
Steve Tafone
Director of Engineering
Mark Luchini
MEP Project Manager
Jason Giampa
CAD Operator
Matt Donahue
MEP Coordinator

Appendix E – RS Means Backup Sheets

Please refer to the Paper copy of this document for these documents.