Mid-Atlantic Data Center 5
Ashburn, Virginia

Senior Thesis
Final Report

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Project Team

Owner: DuPont Fabros Technology
CM: Holder Construction Company
Architect: Donnally Vujcic Associates, LLC
MEP Engineer: CCG Facilities Integration, Inc.
Structural Engineer: Rathgeber/Goss Associates
Civil Engineer: Rinker Design Associates, PC
Fire Engineer: EBL Fire Engineering

Project Overview

Function: Data Center
Size: 360,000 SF Total
180,000 SF Raised Floor
23,000 SF Office Space
Height: 2 Stories
Construction: 2 phases
Redundancy: N+2
Construction Dates: Feb. 1, 2008-March 2009
Delivery Method: CM @ Risk w/ Cost + Fee
Pursuing LEED Gold Certification

Structural System

Foundation: cast-in-place 30"x30" piers, footings, & foundation walls
48" and 60" diameter drilled caissons
Framing: precast concrete shear walls, columns, & spandrel beams
Facade: Tex-Cote applied on the precast concrete
Glazed aluminum curtain wall system for the office facade
Roof: precast concrete double-tees with 3" concrete slab and TPO membrane roof

Mechanical System

(2) 9,900-11,535 CFM AHU's in Office Area
Equipment per phase
(3) 14,400-23,000 CFM AHU's in Chiller Plant
(8) 1080 ton Chillers
(8) 3240 GPM Cooling Towers
(1) 500,000 GAL Thermal Energy Storage Tank
(240) 18,000 CFM Computer Room Air Conditioning Units
(2) 50,000 GAL Underground Diesel Storage Tanks

Electrical System

34.5 kV Total Utility Power
36.4 MW Total Critical Load
Equipment per phase
(8) 600 V Pad-Mounted Transformers w/ Integral VFI
(16) 2500 kW Engine-Generators
(16) UPS Systems
(8) Motor Control Centers

E-Portfolio: http://www.engr.psu.edu/ae/thesis/portfolios/2009/lah326

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THE PENNSYLVANIA STATE UNIVERSITY

Dr. John Messner
Dr. David Riley
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Jim Gawthrop
Courtney Yip

HOLDER CONSTRUCTION COMPANY

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Mark Bacus
Paul Jorgensen
Greg Smith
Aaron Martens
Angel Holthus
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Mark Maska
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Josh Thompson
Jason Bell
Jason Fleege
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DUPONT FABROS TECHNOLOGY

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Faran Kaplan
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Hasmukh Patel
Ron Runnion

CCG INTEGRATED FACILITIES, INC.

John Hamburger
Tommy Breard
Mike Mckenna

CARLISLE SYNTEC

Chris Cope
Mike Meier

THE MORIN COMPANY, LLC

Steve Wanishin

EXECUTIVE SUMMARY

The following document is a comprehensive analysis that focuses on current industry issues and construction methods involving the construction of the Mid-Atlantic Data Center 5 (MADC5) located in Ashburn, Virginia. There are four main topics of discussion with a construction management emphasis in each topic. Included are project background information, a critical industry issue, an analysis of a building construction process, and two analyses of energy efficient building design practices.

The critical industry issue investigates the current economy's affect on the construction industry with an emphasis on the status of MADC5. Research reveals that construction projects are struggling to secure loans to begin and continue construction, therefore projects are forced to postpone until further notice or shutdown completely. After analyzing the owner's construction expenditures, construction schedule, and existing revenue, a project execution plan was developed that ultimately provides a 6 month shorter construction schedule and $33,251,400 of additional revenue while remaining above the suspension point.

The first analysis takes a look into the concrete construction process with a focus on reducing the amount of time that the concrete subcontractor is on-site by utilizing an alternative slab design. This evaluation compares a continuous slab-on-grade in lieu of the existing slab-on-grade with trenches and the effects on subsequent trades. The results show that the continuous slab-on-grade is easier to construct, quicker by 15 days, and saves the owner $1,170,828.

The remaining two technical analyses concentrate on energy efficiency savings pertaining to the electrical and mechanical systems and their impacts on construction costs, schedule, and environment. The first analysis looks at the electrical and energy impacts of a thin-film photovoltaic system utilized to power the building lighting load. This investigation reveals that installing the thin-film PV system would produce a yearly energy cost savings of $46,770, has no impact on the overall construction schedule, and prevents 962,914 lbs. of CO_2 from entering the atmosphere. The second analysis evaluates the mechanical and energy impacts of implementing water-side economizers. Results show that the water-side economizers produce a yearly energy costs savings of $182,472, have no impact on the overall construction schedule, and prevent the emissions of 4,704 lbs. of CO_2.

INTRODUCTION

The Mid-Atlantic Data Center 5 (MADC5), located in Ashburn, VA, is a 360,000 square foot, precast data center for DuPont Fabros Technology. The site is approximately 30 miles west of Washington, D.C. and just north of the Washington Dulles International Airport. This area has been hailed as the “Washington Dulles Technology Corridor” and according to TIME Magazine; it carries “more than half of all traffic on the internet. The region is home to more telecom and satellite companies than any other place on earth.”

The data center houses computer equipment rooms on raised access floor, administrative offices, facility support spaces, and facility infrastructure spaces with extremely intricate mechanical, electrical, and communication systems. In fact, the electrical design for the data center has been copyrighted due to its extremely efficient and state of the art design. The structure is a single-story precast shell structure with an electrical penthouse housing emergency generators to make the overall building two stories. Approximately 80% of the project is considered to be MEP related construction.

Holder Construction Company is the construction managing entity utilizing a CM-at-Risk delivery method for the construction of MADC5. The overall project schedule has an expected duration of 14 months beginning in February 2008 and ending in April 2009 with an estimated budget set at $170,916,000.   Up until November 2008, the project was approximately 60% complete with 500 on-site personnel. Unfortunately, due to economical conditions and extenuating circumstances, the MADC5 project was suspended until March 1, 2009. The project is now projected to be completed in June 2009.

Despite being a building that consumes a great deal of energy, a 12,795 ton mechanical cooling load and a 36.4MW total electrical critical load, MADC5 is pursuing LEED Gold Certification at 40 points. Once certified, this will be the first LEED building for the owner, one of several LEED certified data centers constructed by Holder, and second LEED Gold data center in the country.

PROJECT OVERVIEW

CLIENT INFORMATION

"Our data center philosophy is to design and develop highly efficient data centers with increased power densities and high reliability that provide an optimized solution for our tenants."

The owner of the project, DuPont Fabros Technology, is a leader in data center development and operation in the United States. The company prides itself on its ability to own, develop, operate, and manage some of the most highly advanced and secure data centers. DuPont Fabros has attracted prominent national and international clients over the years, such as Microsoft and Yahoo!. DuPont currently has three data centers located in Ashburn, VA, one in Reston, VA, one in Bristow, VA, and one in Elk Grove Village, IL. Currently, data centers are in construction in Ashburn, VA, Santa Clara, CA, and Piscataway, NJ. DuPont Fabros considers these three projects as one job entitled Project Seven. In the near future, DuPont intends to develop two more data centers in Ashburn (MADC6 and MADC7) and another in Santa Clara. Thus, it is obvious to see that DuPont Fabros' main reason for constructing MADC5 is purely and simply…growth. As technology continues to expand across the world, there becomes a greater need for buildings to house, power, and cool computer servers that support such technology. Where there is a need for data centers, DuPont will provide.

In general, cost, schedule, and safety are all fundamental expectations for DuPont Fabros. The owner expects that the project will come in under budget due to the up-front exhaustive cost analysis. Both the owner and CM continue to work throughout the project to discover value engineering ideas to further increase cost savings. It is extremely important that the project finish on time primarily for bank and marketing reasons. The owner markets that the data center will be finished and ready to move in at a certain date and it is vital that the said date is reached. Otherwise, there is a potential for a great loss of money. In order to do assure the schedule is reached, the construction management company reviews the schedule weekly and looks to shorten the schedule as much as possible. Lastly, the owner strives for a completed project with no lost days of work as a result of injury. As long as the aforementioned expectations are reached, the owner will be quite satisfied.

DuPont Fabros is highly interested in three key sequencing issues. The first being the design portion of the project. The design and construction document stage of the project is one of the largest tasks that the owner and designers go through prior to any construction. The next crucial stage involves permitting. Receiving building and land permits can make or break a project, thus striking a great interest in the owner. Lastly, MADC5 is a two-phase construction project. As such, the owner is extremely interested in the completion of Phase 1 as quick and complete as possible. The shell of Phase two will be constructed and finished along with the complete build-out of Phase 1. Once enough tenants become interested, the construction of Phase 2 will commence (Phase 2 design was completed along with Phase 1).

PROJECT DELIVERY SYSTEM

The MADC5 project utilizes a construction manager at-risk delivery method with Holder Construction Company. DuPont selected Holder based on their longtime standing relationship and trust that Holder will successfully perform the work. Actually, Holder has been hailed as the number one firm data center contractor by ENR, which explains why DuPont has selected them for all of their projects.

In such a CM-at-Risk delivery method, the owner holds contracts with the design team – architect and engineers – while the construction management company holds contracts with the subcontractors. Since the construction manager guarantees the cost and schedule, the risk is allocated to the CM. Throughout this delivery method Holder will be responsible for conducting Owner-Architect-Contractor meetings and Subcontractor meetings to facilitate cost and schedule management. In addition, even though there is not a contract between the contractor and design teams, there still remain open lines of communication between all parties. All in all, the owner, contractor, and design team has taken the team approach to successfully deliver MADC5.

CONTRACT TYPES

There are three main contract types utilized throughout the project including a standard form of agreement between owner and contractor with a cost plus fee, guaranteed maximum price (GMP), and lump sum.

The owner would not release the information regarding the type of contract that they hold with the design team.

DuPont holds a Standard Form of Agreement between Owner and Contractor with a cost plus fee with Holder Construction. In the past, DuPont has held a GMP contract with Holder, however DuPont decided to change based on the repetitive nature of the design. MADC5 is a near replica of ACC4, thus DuPont is more aware of the overall budget to construct MADC5. The cost plus fee contract allows any savings on the project to be directed back to the owner. Another benefit is that since the owner is responsible for any changes beyond the contract cost, the building will be constructed exactly to the owner's satisfaction.

As for the subcontractor contracts, Holder is contractually responsible for the subcontractors and holds all contracts. All of the contracts are lump sum, with the exception of the mechanical and electrical trades. For the lump sum contracts, the subcontractors were hard-bided and carried an allowance if the scope was somewhat unclear. As for the mechanical and electrical trades, a GMP contract was chosen because the trades are responsible for a majority of the project cost, there is a great chance of changes to be made to the systems, and a GMP provided better fees, making it a win-win for DuPont and Holder. A qualification interview took place with the mechanical and electrical trades, which required the subcontractors to submit a general conditions estimate and fee proposal. Once selected, the contract would state that the subcontractor had accepted based on a GMP that was to be determined.

The previously mentioned contracts seem appropriate for the CM-at-Risk delivery method. Holder is an extremely experienced contractor, one of the top CM-at-Risk contractors according to ENR, which is able to manage several contracts. In addition, the excellent rapport between DuPont and Holder allows for DuPont to fully trust in their contractor and know that whatever Holder decides to do will be in the owner's best interest.

Bonds and Insurance

DuPont does not require bonding for the MADC5 project.

Unlike most projects where all subcontractors are required to carry their own insurance, the subcontractors on MADC5 have been enrolled in a Contractor Controlled Insurance Program (CCIP). Holder buys the insurance policy for the entire job which includes Worker's Compensation/Employers Liability, General Liability, and Excess Liability. This program was chosen because it is a cost savings for the owner since the insurance costs are covered in one fee and there are not fees for each contractor and Holder's modifier rate is much lower compared to the individual subcontractors. In the end, it is a win-win situation.

However, there is additional insurance that is not encompassed by the CCIP but required by all subcontractors including Automobile Liability, Off-site Worker's Compensation/Employer's Liability, Off-site General Liability, and Contractor's Equipment.

Key Contacts

Owner

DuPont Fabros Technology | Bob Berlinsky (Sr. Vice President of Construction)

Architect

Donnally, Vujcic, & Associates, LLC | Ron Runnion (Project Manager)

Engineers

CCG Facilities Integration, Inc | Tom Breard (Project Manager)
Rathgeber/Goss Associates | Mike Goss (Structural Engineer/Project Manager)

CM @ Risk

Holder Construction Company | Blake Edwards (Project Manager)

Key Consultants

EBL Fire Engineering | Fire Protection Consultant
EMO Energy Solutions, LLC | LEED Consultant
Hood, Patterson, and Dewar Incorporated | Commissioning Agent

Organizational Chart

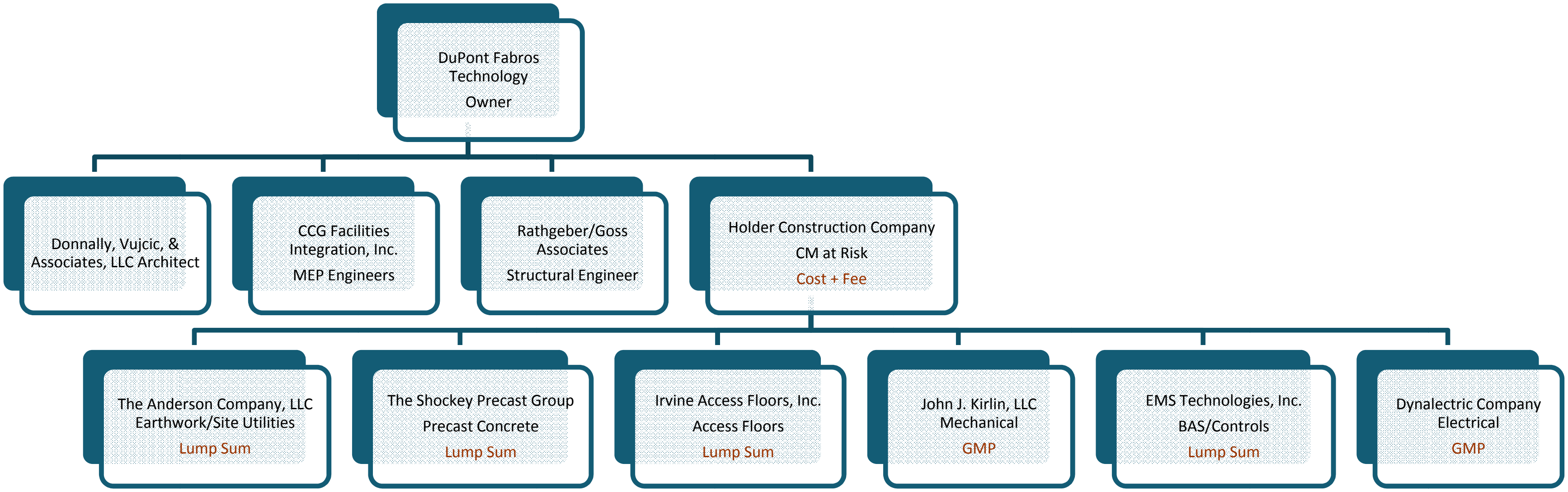


Figure 1 - Project Organizational Chart

PROJECT MANAGEMENT

Holder Construction Company consistently provides expertise in both project management and supervision to every project. Each staff is strategically selected based upon the size, complexity, and duration of the project at hand. Typically, the project will have a Vice President assigned to the project that overlooks the entire process, but is rarely on site. A Project Manager directs the project management staff, while a Superintendant will administer the field supervising staff. Despite a slight existence of a hierarchy, there is an abundant feeling of equality and respect that creates a team atmosphere for the entire job. Each member of the team has their own trade responsibilities, but constantly works together to successfully complete the project.

The MADC5 project, however, required a slightly different staffing plan due to its involvement with other projects. MADC5 is one of three data centers being constructed for DuPont Fabros at the same time, but in different locations. The owner refers to the projects as one overall project entitled, “Project Seven.” As a result, the overall project staff for MADC5 has a larger staff and a couple prominent management positions to oversee the project. Project Seven has a Senior Project Manager to oversee management and a Regional General Superintendant to oversee field supervision.

As for MADC5, the project is led by a Project Manager and Superintendant. The management side includes a Senior Engineer, MEP Coordinator, two Project Engineers, two Office Engineers, a Field Office Processor, and an Administrative Assistant. In the field, there is a Safety Coordinator, Assistant Superintendant, Senior Field Coordinator, and a Field Coordinator.

Team Member Descriptions

Rick Morgan | Sr. VP – Responsible for all data center projects
Tom Shumaker | VP – Responsible for all Mid Atlantic operations/business development
Gavin Kalley | Sr. Project Mgr. – Sr. leadership for all Project Seven (MADC5, NEDC, NWDC)
Blake Edwards | Project Mgr. – Project Manager for ACC4, MADC5, BLU, & BL2
Chris Brogdon | Reg. Gen. Superintendant – Field leadership for all Mid Atlantic projects
Joe Ubario | Superintendent – MADC5 Project Superintendant
Mark Maska | Sr. Field Coordinator – MADC5 Field Supervision
Tyler Antil | Field Coordinator – MADC5 Field Supervision
Paul Jorgensen | MEP Coordinator – MEP Management
Mark Bacus | Sr. Project Engineer – Cost & MEP Management
Jonathan Galvin | Project Engineer – BIM Coordination & trade management
Greg Smith | Project Engineer – LEED Coordination & trade management
Aaron Martens | Office Engineer – Trade management
Angel Holthus | Office Engineer – Trade management
Monjia Belizaire | Office Engineer – Trade management

Please see Figure 2 - Project Team Staffing Plan on the following page.

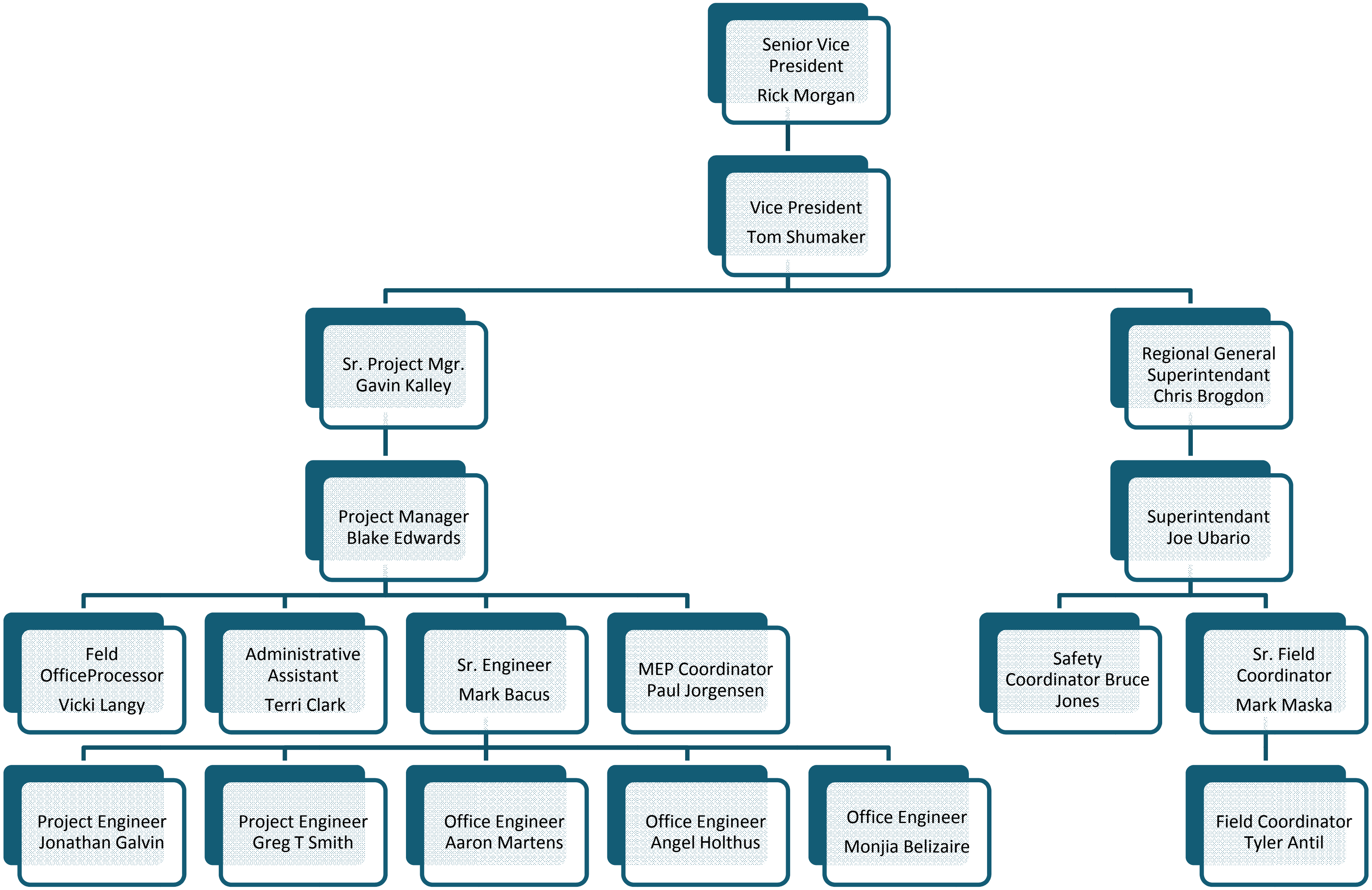


Figure 2 - Project Team Staffing Plan

DESIGN AND CONSTRUCTION OVERVIEW

BUILDING SYSTEMS

EXCAVATION

Overall, the job site did not require any significant excavations, aside from the sump pits and fuel oil tanks. A standard lay back method at 1:1 was utilized for any area requiring excavation. Trench boxes were used for the installation of deep underground electrical conduit. For Phase 2 fuel oil tanks excavation, a sheeting and shoring method was employed. The shoring was driven 23'-0" into the ground for the 18'-0" pit.

Fortunately, the groundwater was located well below the initial job site excavation, thus not requiring a dewatering system. Several months into the project, a few precast columns and caissons had shifted (reason unknown) and required the remaining caissons along that line to be removed and better supported. This excavation came upon water about 12'-0" below grade and was removed via pumps to dry the pits and place the footings and piers.

PRECAST CONCRETE

The building envelope and structure consist primarily of precast pre-stressed concrete columns, beams, insulated exterior spandrels, shear walls, and pre-stressed double tees. There is grout in all open spaces, keyways, connections, and joints to provide as a sealant. Precast members have typical connections using anchor bolts, bearing pads, steel plates, and field welding. See Table 1 below for strength and size information for all precast members.

Table 1 - Precast Concrete Strengths

Type	Strength	Size
Pre-stressed Column	5000 psi	24" x 24"
Inverted Tee Beams	5000 psi	3'-4"W x 4'-0"D
Ledger Beams	8000 psi	2'-0"W x 4'-0"D
Spandrels	8000 psi	8"T x 12'-0"W x 8'-5"H 8"T x 12'-0"W x 11'-5"H
Double Tees	5000 psi	12'-0"W x 32" D

Precast members are manufactured by The Shockey Precast Group located in Winchester, Virginia. In order to erect the precast pieces, Shockey utilized two Manitowoc Model 2250 Series 3 cranes. The cranes can carry a 66,000lb load at 120'-0" radius on jib. One crane was set up to place members between column lines A-D for the entire length of the building, while the other team was to place members between column lines D-G. Please see Appendix B for a more detailed precast erection plan.

CAST-IN-PLACE CONCRETE

MADC5 incorporated cast-in-place concrete for caissons, spread and strip footings, foundation walls, slab on grade, and topping slab. The following table provides a summary of the mentioned concrete structures. See Table 2 below for a breakdown of the various concrete utilized on the job.

Table 2 - CIP Concrete Details

Type	Formwork	Reinforcing	Strength	Placement
Caissons ***(31) 30" dia.*** ***(139) 48" dia.*** ***(39) 60" diam.***	Earth (typ.) Steel Casings (few)	Vertical: #7,10,11 Ties: #3 @ 14" OC #4 @ 18" OC	3000 psi	Pump
Footings	Stick Built	#4 Bars (typ.)	3000 psi	Pump
Foundation Walls	Stick Built	#5 Bars (typ.)	3000 psi	Pump
Slab on Grade ***6"***	Stick Built	10 ga. WWM 6x6 W4.0xW4.0	3000 psi (inside) 3500 psi (outside)	Belt
Topping Slab ***3"***	Pour Stops	4 ga. WWM 10x10 W6.0xW6.0	5000 psi	Crane & Bucket

MECHANICAL SYSTEM

Adequate air conditioning and humidity control are two vital processes that must be maintained within a data center; therefore this center has implemented a system with N+1 redundancy. MADC5 has two chiller plants located in the north-central area of the building, with each plant servicing half of the building. The plants operate independently of one another, however in case of emergency there is an automated interconnection valve allowing one plant to support the other with up to three chillers. This condenser water and primary/secondary chilled water system is comprised of (16) chillers, (16) cooling towers, (16) condenser water pumps, (32) chilled water pumps, and (2) thermal energy storage (TES) tanks. The TES tank is a 500,000 gal chilled water storage tank housing chilled water and emergency makeup water. It is designed to provide emergency make up water without exhausting storage for the chilled water. The piping for this system within the computer rooms is located in the trenches below the raised floor. This provides more underfloor and overhead room for other MEP equipment.

Air handling equipment with chilled water cooling coils provide for the air conditioning system. There are approximately 480 computer room air handlers (CRAH) that supply cool air to the computer rooms, UPS rooms, and electric rooms. Within the computer rooms, the cool air is supplied through the raised floor plenum and is distributed to the computer equipment via grates within the access floor. In the office area, there is one variable air volume (VAV) central station air handling unit (AHU) per floor. In addition, each chiller plant has one constant volume central AHU.

The heating system consists of four 1670Mbh input/1369Mbh output gas fired finned tube boilers, two for each half of the building, that are size to support peak loads at N+N redundancy. The remaining heating loads are supplied by electric heating.

ELECTRICAL SYSTEM

Total utility power will service the data center at 34.5kV in two locations. Both locations will house a 34.5kV, 1200A medium voltage switchgear which will feed power into one of (16) 5MVA pad-mounted transformers. Each pad-mounted transformer steps down the utility power to 345/600V, 3-phase, 4-wire power and feeds its own electrical room which includes two switchboards, MxA and MxB. The switchboards contain a 3000A main breaker servicing the essential bus at 600V, 3-phase/3-wire and the uninterruptible power supply (UPS) bypass and an emergency main breaker served by backup engine-generators. Each electrical room is assigned two engine-generators rated at 2500kW, which are located directly above on the second floor, to backup its system. The Rotary UPS system, one dedicated to each switchboard, is supplied with a flywheel energy storage system capable of supporting the starting of the system's backup engine-generator for at least ten seconds. Electrical rooms also feed four distribution panels, two for critical power loads and two for essential A/C loads, in each adjacent computer room. Computer room capacity is configured for a power density of 200W/SF with the ability to grow to 232W/SF. Operating at this load puts the system at N redundancy, meaning no spare system capacity in the computer room power distribution panels. The entire electrical system is protected by a high-resistance grounding that limits the maximum ground fault current to 15A.

Overall, the electrical system is configured into an Iso-Parallel system with an N+2 redundancy. This system allows all UPS units to share the loads equally via a ring-bus. A system connected to the ring-bus will automatically support the failure of another system connected the ring-bus without adversely affecting any other system, thus isolated.

CURTAIN WALL SYSTEM

The curtain wall system accounts for only a small portion of the building envelope. This façade is located on the southwest corner of the office area, which is on the south-central side of the building, and spans the full height, two floors. The curtain wall is intended to add aesthetic appeal to a rather mundane building by differentiating the office area from the rest of the data center. It creates a more pleasing view for the main entry of the building.

Like most curtain wall designs, this system was designed by a specialty contractor, Vistawall Architectural Products, who requires that the architect approves the shop drawings and information. The system includes an aluminum wall system for 1" glazing, storefront framing for ¼" glazing, and medium style doors for ¼" glazing. Another supplier provides the glazing to be used with the system, which consists of coated vision glass, spandrel glass, and bullet resistant glass outside of the conference rooms. Other materials required by this system are sealants, steel clips and anchors, fasteners, gaskets, and aluminum cladding. It is a typical installation for the Vistawall curtain wall.

FIRE PROTECTION

FIRE ALARM SYSTEM

Fire alarm panels and electronic detection systems create the fire alarm system for MADC5. Located within each computer room near the main exit there is an emergency response kiosk. The kiosk contains a fire alarm control panel for all devices in the room, underfloor/above floor annunciator panel, a fire extinguisher, a tile puller for the access floor, a phone, and a flashlight.

The electronic detection system includes photoelectronic smoke detectors which are mainly located in the computer rooms, both underfloor and above floor. These detectors are capable of determining the exact location of a possible fire situation within a room.

SUPPRESSION SYSTEMS

There are four systems utilized within MADC5, including preaction sprinklers, wet-pipe sprinklers, dry system, and portable fire extinguishers. The preaction sprinkler system, 27 zones in the building, is provided in the switchboard rooms, computer rooms, generator rooms, and other rooms deemed critical. This system consists of double interlocked, electric/pneumatic release valves supplied from an air compressor loop. Valves, which are located within preaction closets within each zone, are double interlocked to avoid a charging of the pipes without a fire emergency. The wet-pipe sprinkler system, total of 7 zones, is provided in all remaining, non-critical areas including corridors, administration rooms, offices, and chiller plants. Valves for this system are located within the sprinkler room. A dry system is only in effect in the loading dock area.

LOCAL CONDITIONS

The site is in Ashburn, Virginia approximately 7 miles north of Washington Dulles International Airport along VA State Highway 28. Ashburn is presently a rural area, thus there is little site congestion and constricted roads for trucks to travel. Aside from the small residential community to the northwest, the area is predominantly commercial creating minimal pedestrian traffic near the site. The project's exact location is within the Ashburn Corporate Center which currently includes three completed data centers built for DuPont Fabros. All three data centers are similar in nature and approximately the same overall height. Following the completion of MADC5, a proposed MADC6 is to be built within the same site adjacent to MADC5. Currently, the construction team is utilizing the MADC6 location as a laydown and parking location. A brief site plan can be viewed in Figure 3 below. For a more detailed existing conditions site plan, please see Appendix A.

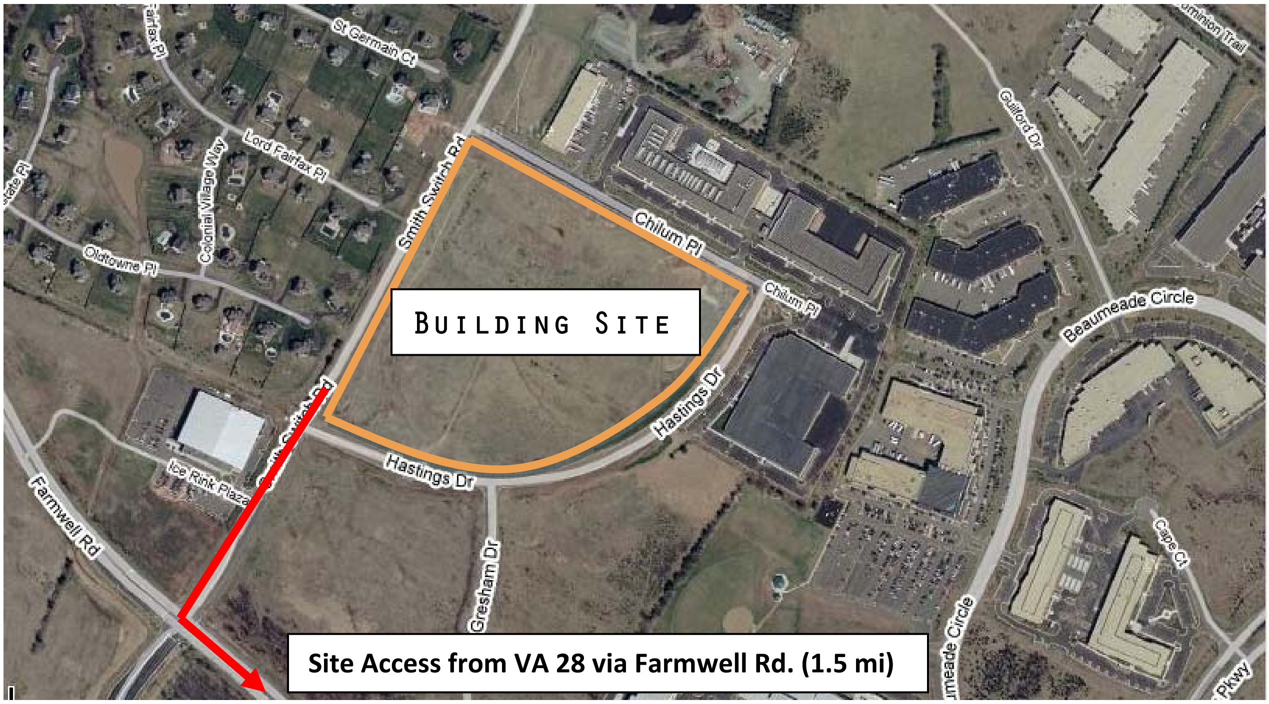


Figure 3 - MADC5 Site Overview

SITE PLAN OF EXISTING CONDITIONS

MADC5 is located on a 33 acre site in Loudoun County, VA approximately 30 miles west of Washington, D.C. Unlike the D.C. Metro area, there are not many preferred construction methods for Loudoun County. As a result, the building uses precast concrete shear walls, cast in place concrete, and glazing for its design.

The actual site location in Ashburn is bounded by Hastings Dr. to the south, Smith Switch Rd. to the northwest, and Chilum Place to the northeast. The large site is beneficial for the construction process for several reasons. First, a majority of the soil can be stock piled onsite to be reused in other areas. Secondly, most materials can be stored on site including precast concrete panels, double tees, conduit, piping, etc. Another important benefit is that there is a decent amount of space for job site trailers (Owner, Engineer, Contractor, and most of the Subcontractors). This allows for easier lines of communication between the project teams. On both sides of the trailers there are parking spaces available for the construction team staff. The workers, however, are to park their vehicles along Hastings Dr. and Chilum Place.

RECYCLING AND TIPPING FEES

Recycling for MADC5 is somewhat of a unique process and highly necessary since the project is pursuing LEED Gold certification. All parties involved with the project throw their trash and recycling into three dumpsters, one for trash and construction waste and two for concrete. If necessary, a steel bin can be brought onsite, however there has yet to be enough steel waste to have a dedicated dumpster. The recycling service, IDS, then comes to the site, removes the dumpsters, and hauls all of the trash back to their recycling center to separate everything. This process allows for the recycling to be thoroughly separated. As a result, the job site has a 98% recycling rate, which qualifies for two credits under MR 2.1 and MR 2.2.

The tipping fees for IDS are as follows:

Mixed Bins:	\$300/4 tons (\$53/ton extra for amount over the 4 tons)
Concrete Bins:	\$210/20 yards

*No rental fees or fuel surcharges

SOIL TYPE

The natural soils within the proposed project area primarily consist of residual clayey or silty soils with minor amounts of fine sand. Generally, as the depth increase, the residual soils become more granular and rock fragments become more abundant. Overall, as seen in Table 3 below, the soils tend to have a fair to very poor potential for general site development.

Table 3 - Soil Type Characteristics, Loudoun County

Soil Group	Typical Terrain	Parent Rock	Problems/ Limiting Factors	Soil Class
Ashburn Silt Loam	Sloping Landscapes	Siltstones	Wetness, Low Bearing Capacities	II
Dulles Silt Loam	Nearly Level Landscapes	Siltstones and Shales	Low Soil Strength and Prolonged Perched Water Table	IV
Albano Silt Loam	Drainage Swales	Siltstones and Shales	Seasonal Perched Water Table	IV

SUBSURFACE CONDITIONS

According to the soils survey, all boring locations indicated 0-6 inches of topsoil. The layers beneath the top soil consisted of the natural residual soils mentioned above. As the auger penetrated deeper, the soil became denser. Refusal depths ranged from 2.5’-8.6’ below the existing ground surface. Shallow weathered siltstone bedrock was reached between 1’-0” to 7’-0” below the ground surface.

GROUNDWATER CONDITIONS

While drilling the boring holes, groundwater did not flow into the bore holes, which determines the groundwater position. As a result, the only groundwater conditions on the site will only be influenced by rainfall and surface water runoff.

SITE LAYOUT PLANNING

As mentioned in the previous section, the project site is quite large allowing for plenty of room to maneuver within the site. As a result, the site logistics were quite identical throughout the main construction phases – excavation, erection, and interior work. Laydown, material storage, and contractor parking remained in the same location, the future site for ACC6, for the duration of the project. Likewise, the jobsite trailers, dumpsters, project gates (six), and traffic flow pattern all remained the same.

For more detailed site layout plans, please see Appendix A.

EXCAVATION SITE LAYOUT

Excavation for this project was extensive in the amount of land that needed to be cleared and graded; however, deep excavation was not truly an issue. The only locations of deep excavation were the caissons, sump pits, UPS Rooms, and retention ponds. The remaining areas were shallow excavation mainly for underground MEP conduit.

ERECTION SITE LAYOUT

Crane locations and paths are the two main differences with the erection site layout plan. There are two paths within the building footprint corresponding to two Manitowoc cranes utilized for precast concrete erection. The crane to the north, crew 1, started slightly ahead of the second crane in order to avoid collision.

INTERIORS SITE LAYOUT

The remaining site layout plan depicts the site plan that would be nearly identical to the finished product. One key feature for this layout is the location of the loading docks within the new building, which is centrally located on the project-east side of the office building. Loading docks and scissor lifts can be employed to unload equipment into the building for installation.

PROJECT LOGISTICS

MILESTONE SCHEDULE

MADC5 is a two-phase construction project which began preconstruction in early July 2007. It is a unique phasing plan since the entire building core and shell will actually be built with only the interior portion of the building being phased.

The project's preconstruction and design phases lasted for eight months. The weather at this time is much more favorable for construction since the winter months finish just as the site work was scheduled to begin. Construction mobilization was initiated in early February 2008, which is a slight overlap of the preconstruction/design phase, followed immediately by sitework and foundations.

Precast erection began in early May 2008, just as the foundation work was finishing, and lasted approximately 4 months, making it the longest construction duration for the project. The precast was sequenced using two crews that were spaced about a week apart. Crew 1 placed precast members between column lines A-D, while Crew 2 placed members between D-G. Please see Appendix B for a complete detail of the erection plan.

Unlike most typical building schedules, the interior work begins prior to being watertight. This is mainly due to the fact that the project is on such a tight schedule. If the project had to wait until the building was watertight, then the project duration would be extended at least 4 months. Instead, the installation of MEP overhead, fire protection, interior partitions, MEP equipment, access floors, and doors and hardware can occur once there is enough slab-on-grade poured. Overall, the interior work is diligently completed as a parade of trades within each room progressing from west to east.

Please see Appendix B for the summary Gantt chart for MADC5.

DETAILED SCHEDULE

OVERVIEW

Construction for MADC5 began in early February 2008. The project is scheduled to finish in early March 2009, just over 13 months of construction. Being that the building is approximately 360,000 SF, a detailed construction schedule is vital to successfully completing such a large-scale project in a short amount of time. Appropriate phasing and sequencing was utilized throughout the project to facilitate the process.

PHASING

The overall duration is somewhat devious due to the way the project was phased. Thirteen months to complete a large project is quite impressive, however, the building will not be fully built out during that period. Interior work for MADC5 is phased, while the entire building shell, foundations, MEP underground, and slab-on-grade will be constructed as one entity. Phase 1 and Phase 2 evenly split the building with the office portion considered Phase 1 construction. Each phase has fourteen computer rooms, eight UPS rooms, eight engine-generator rooms, one medium voltage room, and one chiller plant. Phase 2 construction will be held until released by the owner.

Figure 4 depicts the overall floor plan, first level on top and the mezzanine level on the bottom, for MADC5. The light blue section on the west side of the building is considered Phase 1. Phase 2 is the area shown as the dark blue section on the east.

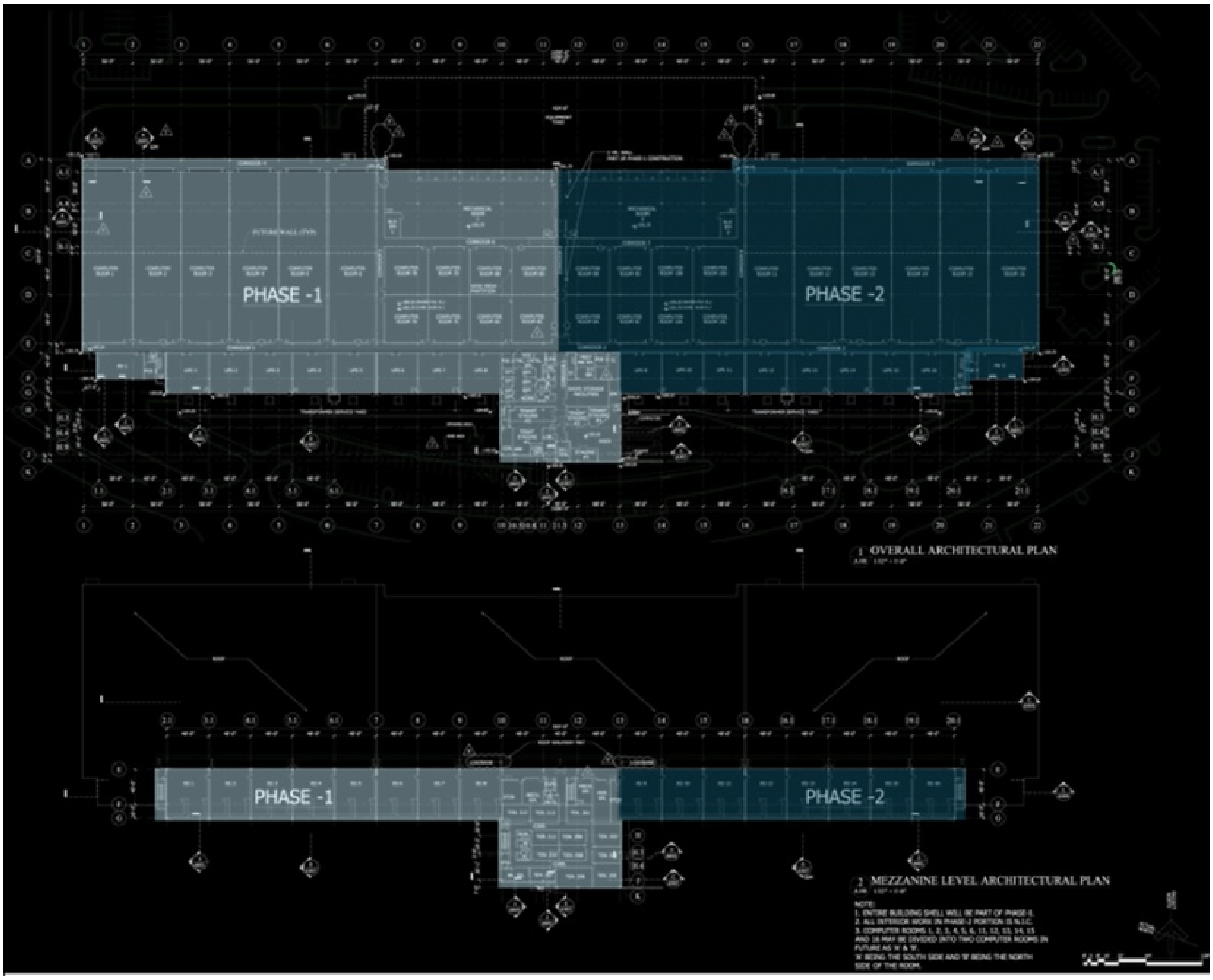


Figure 4 - Overall plan showing the two phases.

Please see Appendix B for the detailed Gantt chart for MADC5.

Sequencing

The nature of the building is directly responsible for the way that the project was sequenced. First and foremost, there are 21 subcontractors with approximately 500 workers on site, which causes severe congestion and delays if left unorganized. To remedy this, the construction manager has developed a specific sequence where work progresses as a parade of trades, beginning on the west and advancing to the east. As soon as a trade has finished work in a given area, the next trade follows immediately in order to meet the tight schedule. Site work, foundations, underground MEP, and precast erection initiate the parade. Approximately two weeks after precast starts, slab-on-grade work begins for the computer rooms, UPS rooms, and engine-generator rooms and follows in the same direction. Likewise, once the concrete has cured enough and the concrete contractors have advanced, interior work on the aforementioned rooms ensues. Unlike most cases where a building is completely enclosed prior to interior work, interior construction begins as soon as the immediately surrounding area is watertight. For example, finishes are installed in the first computer room on the west side while the entire east side of the building is exposed to the elements. This sequencing plan continues for the duration of the project.

The following three tables, Table 4, Table 5, and Table 6, illustrate the typical room sequences for computer rooms, UPS rooms, and engine-generator rooms:

Table 4 - Computer Room Sequence

Computer Room Sequence		Duration
Activity	Seal Concrete Floors	2d
	MEP Overhead/Pull Wire	10d
	Fire Protection	5d
	Below Floor Chilled Water Pipe	15d
	Paint Precast Tees	5d
	Interior Partitions	5d
	MEP Rough In Partitions	5d
	Prime Paint	5d
	Lighting Buss /Fixtures/Fire Alarm Devices	10d
	Install EPO Kiosk	5d
	Set D Boards/Terminate	5d
	Insulate Chilled Water Piping	5d
	Pipe/Insulate CRAH's	5d
	Underfloor Fire Alarm	5d
	Set CRAH Stands/CRAH Units	10d
	Incipient Detection	10d
	Finish Paint	5d
	Grounding Grid	5d
	Access Flooring	5d
	Doors/Hardware	5d
	Base	2d
	Superclean	4d
	Final Clean	5d

Table 5 - UPS Room Sequence

UPS Room Sequence		Duration
Activity	Seal Concrete Floors	1d
	Pull Cable	10d
	MEP Overhead	15d
	Interior Partitions	10d
	Paint Precast Tees	2d
	"Set Switchgear (M's, C's) "	5d
	Fire Protection	5d
	MEP Rough In Partitions	5d
	Prime Paint	1d
	Set CRAH Unit/Terminate/Pipe	10d
	Install Overhead Buss	5d
	Terminate Switchgear	5d
	Set Piller Unit	5d
	Lighting	15d
	Doors/Hardware	5d
	Set IP	5d
	Terminate Piller/IP Units	10d
	Finish Paint	3d
	Base	2d
	Final Clean	5d

Table 6 - Engine-Generator Room Sequence

Engine-Generator Room Sequence		Duration
Activity	Install Louvers/Attenuation/Dampers/Plenums North Wall	15d
	MEP Overhead	5d
	Pour Concrete Fuel Curbs	2d
	Fire Protection	3d
	Interior Partitions	5d
	Set/Pipe Day Tanks EG 1A and 1B	15d
	MEP Rough In Partitions	5d
	Epoxy Membrane in Fuel Containment Curbs	2d
	Paint Precast Tees	2d
	Prime Paint	2d
	Lighting	15d
	Install Exhaust Supports and Mufflers/SCR's	15d
	Set EG 1A and 1B	5d
	Final Muffler Connections	2d
	Install Louvers/Attenuation/Dampers/Plenums South Wall	10d
	Pull Cable/Terminate EG 1A and 1B	20d
	Install Plenum From Radiator to Louvers	2d
	Finish Paint	3d
	Epoxy Generator RM Floors	5d
	Install Unit Heaters	5d
	Doors/Hardware	3d
	Complete Pneumatics	3d
	Base	1d
	Final Clean	5d

Project Cost Summary

Table 7 - Project Cost Breakdown

	Cost	Cost/SF
	Overall Costs	
Actual Building Construction Cost	$ 148,720,000	$ 414
Total Project Cost	$ 170,916,000	$ 475
	Building Systems Costs	
Building Concrete	$ 8,957,000	$ 25
Structural Precast	$ 1,696,000	$ 5
Access Floor	$ 2,110,000	$ 6
Fire Protection	$ 1,308,000	$ 4
Mechanical	$ 33,232,000	$ 93
Electrical	$ 47,087,000	$ 131
Security	$ 1,150,000	$ 4
Mechanical Controls	$ 3,100,000	$ 9
Mechanical Equipment	$ 4,406,000	$ 13
Electrical Equipment	$ 26,798,000	$ 75

Square Foot Estimate

Total Building Area: 360,000 SF
Total Building Perimeter: 3,646 LF
Story Height: 23’-6” FT
RS Means Value: $137.50/SF

Story Height Adjustment: Negligible
Perimeter Adjustment: Negligible
Time Adjustment: Current time – No adjustment needed.
Location Factor: 0.92 (Fairfax, VA is closest location to Ashburn)

Final RS Means Value: $126.50/SF
Project Total Cost: $45,540,000

As shown above in Table 7, the RS Means Square Foot Estimate is not even close to the actual cost of the building. MADC5 is an extremely large data center that cannot be accounted for using RS Means, which only sizes up to 40,000SF and 800LF whereas MADC5 is 360,000SF and 3,646LF. Any adjustments to the story height and perimeter would have a negligible effect on the square foot value since the values decrease as the size of the building increases and the differences between the values is so extreme. In addition, the building estimate does not account for the $33 million of MEP controls and equipment involved with the data center. Please see Appendix C for the detailed RS Means Square Foot analysis.

PARAMETRIC ESTIMATE

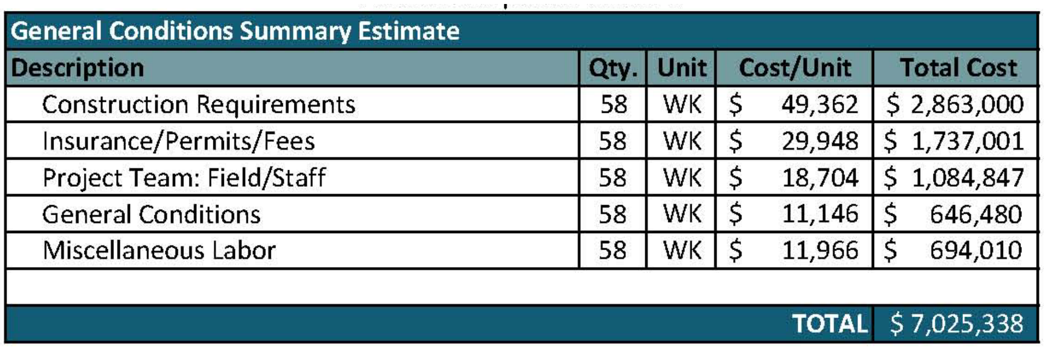
Total Project Cost:	$19,579,868	$55/SF
Total Building Cost:	$18,179,868	$51/SF

Unfortunately, the D4Cost Estimate software does not have a data base for anything similar to a data center. This is more likely attributed to the fact that data centers are more of a “new” design in comparison to the typical commercial buildings featured in the software. Therefore, the D4Cost software is inappropriate to use for estimating. To illustrate this, an estimate has been developed based off an industrial building, Siemens Westinghouse Fuel Cell Facility, with sized at 190,000SF. As shown above, the total project cost is approximately $150 million short of the true estimate. Please see Appendix C for the detailed D4Cost Parametric analysis.

GENERAL CONDITIONS ESTIMATE SUMMARY

MADC5 had a combination of construction requirements, insurance and permits, general conditions, and labor falling within the general conditions that generates an estimate amount of **$7,025,338**, as shown in Table 8 below. In comparison to the overall project cost, this number is approximately **4.1%** of the overall budget. The value may be slightly low then the average percent and could be attributed to the fact that the construction contingency was not included as well as differing staffing costs.

Table 8 - General Conditions Summary



General Conditions Summary Estimate

Description	Qty.	Unit	Cost/Unit	Total Cost
Construction Requirements	58	WK	$ 49,362	$ 2,863,000
Insurance/Permits/Fees	58	WK	$ 29,948	$ 1,737,001
Project Team: Field/Staff	58	WK	$ 18,704	$ 1,084,847
General Conditions	58	WK	$ 11,146	$ 646,480
Miscellaneous Labor	58	WK	$ 11,966	$ 694,010
			TOTAL	$ 7,025,338

Please see Appendix C for a detailed breakdown of the General Conditions estimate.

The following assumptions were made throughout the estimate process:

- Cost Data provided by RS Means 2008 and Holder Construction Company. The numbers from Holder were provided as estimates based on their historical data and RS Means. These values were derived by myself and project team members.
- RS Means 2008 was utilized to derive individual staffing salaries for the job.
- Where staff salaries were not available in RS Means, a logical 10% increase was used for each respective level.
- Values provided from Holder were lump sum amounts, not a unit cost. Thus, the total cost was divided by the project duration to derive a cost/unit value. This value will be beneficial for a future analysis.
- Construction Durations: **13 months** or **58 weeks**
    - Non-working days and holidays are not accounted for, rather based off of the standard calendar

- Staffing durations are based off of start dates on the job. (Information received from Holder)
- All staff is assumed to be on the job through completion since the project team is unsure of status of Phase 2.

DETAILED STRUCTURAL SYSTEMS ESTIMATE SUMMARY

All take-off calculations for the structural estimate were performed by hand based off of the construction documents and precast shop drawings. As previously mentioned, the data center portion of the building is symmetrical; therefore, the take-off needed to only be prepared for half of the building and simply multiplied by a factor of two to account for the other half. A complete take-off had to be done for both floors of the office building since this portion was not symmetrical.

The following assumptions were made throughout the take-off:

- All concrete is pumped.
- Formwork was added as an allowance value provided by the contractor (who uses RS means and historical data) due to sporadic use throughout the project.
- Open Shop labor
- Fairfax, VA was used as the location factor (0.92). It was the closest city to Ashburn; however, the cost may be higher due to a slightly higher cost of living in Fairfax. The calculations include this factor within the unit costs.
- Overhead and profit are omitted from the cost estimate
- RS Means 2008 Online and average unit cost estimates from the precast subcontractor (The Shockey Precast Group) were utilized for the cost calculations.

Please see Table 9 below for a summary of the structural systems. A complete detailed estimate can be found in Appendix C.

Table 9 - Structural Systems Summary Estimate

Structural Systems Summary Estimate		
Division	*Description*	*Total Cost*
02465	Caissons	$ 161,716
03210	Rebar	$ 436,486
03220	Welded Wire Fabric	$ 260,850
03310	Normal Weight Concrete	$ 2,051,131
03310	Formwork Allowance	$ 270,000
03310	Concrete Placement	$ 403,763
03310	CIP – Piers	$ 267,630
03310	CIP – Spread Footing	$ 344,501
03310	CIP – Continuous Footing	$ 126,055
03310	CIP – Slab on Grade	$ 1,821,380
03310	CIP – Topping Slab	$ 1,242,534
03310	CIP – Stairs	$ 3,063
03410	Precast Concrete	$ 9,219,840
	TOTAL	**$16,608,949**

The estimate total for MADC5 is $16,608,949. In comparison to the Technical Assignment 1 assignment, this number is much lower with a percent difference of 25.12%. However, the values utilized for Tech. 1 were based off of preliminary values for the project. A more recent estimate involving the schedule of values for the structural systems provides a much stronger estimate to compare. Please see Table 10 below for the comparison.

Table 10 - Structural Systems Cost Comparison

System	Tech 1	Tech 2	System	SOV	Tech 2
Precast Concrete	$11,695,484	$9,219,840	Precast Concrete	$9,706,654	$9,219,840
CIP Concrete	$8,956,928	$7,227,393	CIP Concrete	$7,204,000	$7,227,393
Caissons	$728,079	$161,716	Caissons	$493,044	$161,716
Total	$21,380,491	$16,608,949	Total	$17,403,698	$16,608,949
% Difference	***25.12%***		***% Difference***	***4.67%***	

Differences between the Tech. 1, the schedule of values, and Tech. 2 values can be attributed to several items. Closeout costs, change orders, mobilization/demobilization, and shipping are not accounted for within the precast concrete value. Initially, the large discrepancy between the CIP concrete estimates is due to inclusion of closeout, change orders, contingency, contractor's fee, construction requirements, and excavation costs. As for the caisson estimate, entities such as mobilization/demobilization, bonds, layout, extra reinforcement, and closeout are responsible for the cost gap. Overall, differing unit prices between RS Means and contractor/subcontractor values all influence the 4.67% differential. For a better comparison of the materials and labor, the above mentioned entities have all been removed from of the original estimate.

ANALYSIS I | INDUSTRY AND THE ECONOMY

BACKGROUND

The construction industry has been affected by the current economic recession. Jobs are suspended, shut down, or not even starting and companies have to downsize. Companies are having trouble securing loans and allocating funds. Unfortunately, it is not likely that the recession will end anytime soon. In fact, "according to economists across the country, nonresidential spending is expected to drop by 3 to 9 percent in 2009, and labor costs will rise 3 to 4.5percent. " (Hale, 2009)

As of August 2008, DuPont Fabros became one of the companies that was having trouble securing loans and was forced to begin suspending its current job, Project Seven, until further notice. As mentioned in the Client Information section, Project Seven includes three projects – Mid-Atlantic Data Center 5 (MADC5) in Ashburn, VA, Northeast Data Center (NEDC) in Piscataway, NJ, and Northwest Data Center (NWDC) in Santa Clara, CA. NEDC and MADC5 followed suit and were suspended in October 2008 and November 2008, respectively.

Fortunately, unlike most companies affected by the economy, DuPont Fabros has several completely leased data centers in full operation that are producing steady revenue.

GOAL

The goal of this research is to develop a project execution plan that would be utilized in a down market environment, allowing the owner to evenly allocate funds throughout the job's entirety. The research will focus on an evaluation of the industry issues discussed in the background information, the immediate need for all three data centers, project cost projections, and company revenue.

METHODOLOGY

1. Research the current status of the US economy and its effect on the construction industry by reading articles and literature focused on this topic.
2. Evaluate the planning of Project Seven, such as:
    a. Projects in new markets
    b. Constructing three projects almost simultaneously
3. Create a cost projection spreadsheet detailing the owner's cash flow throughout the duration of Project Seven
4. Develop a project execution plan for future use in a down market economy by utilizing the spreadsheet.
5. Form conclusions and recommendations.

RESOURCES

- Current Events and Literature
- DuPont Fabros Technology, contact– Faran Kaplan
- Holder Construction onsite staff –Ashburn, VA (MADC5); Piscataway, NJ (NEDC); Santa Clara, CA (NWDC)

INDUSTRY ANALYSIS

ECONOMY'S EFFECT ON CONSTRUCTION

Similar to every other industry, the construction industry has been significantly impacted by the U.S. economy descending into a recession. Beginning in the fall 2007, the economy slowly declined until year's end when the economy temporarily halted. Since then, the economy has been on a continual decrease and finally declared a recession in the fall 2008.

Several sources have stated that two key causes of this recession include, but not limited to, the credit crunch and the Federal Reserve's response to a tightening of available capital. The credit crunch is the idea that the banks become more averse to offer loans for business investments. Moreover, firms are required to present additional information to lenders detailing an ability to maintain a decent credit line and repay the loans (Belman, 2008).

Unlike most industries, however, the construction industry was not immediately affected, but rather experienced a delayed impact. This was due to the fact that most projects currently under construction were based off of previous loans and financial status as opposed to the current situation. Any projects in the early stages of construction or pre-development planning experienced immediate impacts of the economy, resulting in suspensions or complete shut-down. Furthermore, projects within the private commercial construction sector suffered the most since such projects operate on rolling over short term loans for financing (Haughey, 2009).

According to Haughey, "The value of starts in October 2008 plunged 44% from September 2008 for the sum of hotel, office, retail and warehouse. Projects ready to start were held up to redo financing and/or wait for a clearer view of the scale of the recession." Unfortunately, this environment is projected to be an issue well into 2009.

Illustrated below in Table 11, is a projection of commercial construction growth and activity for 2009.

Table 11 - Commercial Construction Growth

Market Segment	2008	2009
	Commercial/Industrial	
Hotels	5.1%	-3.1%
Office Buildings	1.7%	-3.7%
Industrial Facilities	-3.8%	0.4%
Retail	-5.7%	-3.6%
	Institutional	
Healthcare Facilities	5.6%	3.6%
Education	5.5%	-0.1%
Public Safety	3.5%	0.4%
Amusement/Recreation	1.4%	-2.6%
Religious	-1.0%	4.0%

Source: (DiLouie, 2008)

EVALUATION OF THE PLANNING OF PROJECT SEVEN

PROJECTS IN NEW MARKETS

When a company is looking to develop, a key concept it considers is the market which it desires to enter, for this is typically the reason why businesses fail. In most cases, especially with a slowing economy, a company would forgo entering a new market due to the unfamiliarity with that region. DuPont Fabros, however, opted against the standard and chose to initiate Project Seven, a job which would develop one data center in a familiar region and two data centers in completely unfamiliar territory. All three regions, Northern Virginia, Piscataway, NJ, and Santa Clara, CA in Silicon Valley, are premium markets for data center development primarily due to being center's for technology near reasonably priced power, major population hubs, and significant fiber optic networks. In fact, according to an article from MarketWatch:

> *"Silicon Valley, New York and Washington are still the country's top centers for high-tech employment. Metro New York was the U.S.'s top tech employer, with 316,500 of the roughly 5.8 million U.S. tech workers, based on 2006 figures, the report said. Washington, D.C., was second, with 295,800, and the San Jose/Silicon Valley area of Northern California, with 225,300."* (Pimentel, 2008)

The table on the following page, Table 12, includes information pertaining to the three markets that the Owner developed Project Seven.

Although it still may seem that expanding into a "new" region at such a time would likely cause trouble for a company, the table clearly illustrates that all three regions are more than perfect for developing data centers.

Table 12 - Market Information for VA, NJ, and CA

Region	Information
Northern Virginia	"Techtopia--as some local boosters call the new-economy belt around Washington. If software center Seattle is the new economy's brain and chipmaking Silicon Valley is its heart, then Washington is its central nervous system. Spread along, around and mostly under Techtopia's main drag, the Dulles Toll Road, are the vital electronic pathways--wires, cables and fiber-optic lines--that carry more than half of all traffic on the Internet. The region is home to more telecom and satellite companies than any other place on earth. It's not a coincidence that Virginia license plates recently got a new slogan: THE INTERNET CAPITAL OF THE WORLD." (Donnelly & Zagorin, 2000)
	"The region contains the Internet Society, and used to contain the mainframe that houses the master list of all Internet domain names." (Dulles Technology Corridor, 2008)
	"Washington, D.C., was the leader in computer systems design and similar services and in engineering services." (Pimentel, 2008)
Piscataway, NJ	"Metro New York was prominent in the tech-service category, with many of its workers in telecommunications, Internet services, R&D and testing labs, and computer training services." (Pimentel, 2008)
Santa Clara, CA (Silicon Valley)	"Silicon Valley is generally considered to have been the center of the dot-com bubble which started from the mid-1990s and collapsed after the NASDAQ stock market began to decline dramatically in April 2000. Even after the dot-com crash, Silicon Valley continues to maintain its status as one of the top research and development centers in the world. Thousands of high technology companies are headquartered in Silicon Valley." (Silicon Valley, 2009)
	"San Jose/Silicon Valley also was the dominant area for technology manufacturing." (Pimentel, 2008)

CONSTRUCTING THREE PROJECTS ALMOST SIMULTANEOUSLY

The idea of expanding and constructing three new data centers, especially given the locations, is a great concept for a growing company in a growing economy. These locations have proven to be more than suitable for success. The problem lies in the timing of the projects, granted at the start of construction the economy was more stable, but definitely slowing down.

According to the plan, Mid-Atlantic Data Center 5 was to begin February 2008 and finish April 2009. The construction of Northeast Data Center would follow relatively quickly by starting in May 2008 and finishing in May 2009. Two months later, June 2008, construction on Northwest Data Center was to initiate and be completed by October 2009. All in all, the Owner was anticipating spending approximately $520 million within 20 months.

In hindsight, as discussed with an owner's representative, the construction schedules should have progressed in a much different manner. At the very most, the job should have been constructed in the same order as three individual projects occurring sequentially, as opposed to overlapping. In doing so, in the off chance that the market rapidly declines, it is much more financially feasible to construct and complete one data center rather than three at the same time.

PROJECT SEVEN SCHEDULE AND COST ANALYSIS

By evaluating Project Seven's construction expenditures and existing revenue, it was possible to create a cost projection which would detail the cash flow for the job's entirety. The cost projection includes the monthly construction expenditures for MADC5, NEDC, and NWC, as well as the revenue from DuPont Fabros' five existing data centers. Please reference Appendix D for a breakdown of the schedule and cost projections for this section and the following section titled "Project Execution Plan".

The following assumptions were made when developing the cost projection spreadsheets:

- Someone foresighted that the economy was going to rapidly decline like it has done. ("worst case scenario" idea)
- Starting point is $0 at the beginning of construction. This is done as a means of simply evaluating the cash flow during the construction process. As a result, a majority of the values are negative.
- The lease rate is based off of numbers provided by the owner, but is not exact due to confidentiality reasons.
- Assumed the suspension point based on Project Seven's cash flow value the month prior to the suspension of MADC5. At that point, the owner believed it could no longer continue with any projects.
- Income includes revenue from leased space in MADC2, MADC3, MADC4, VA3, VA4, and CH1.
- Per research and conversations with the owner, MADC2, MADC3, MADC4, VA3, VA4 are 100% leased; CH1 is 20% leased for entire duration of Project Seven. The percent of leased space for MADC5, NEDC, and NWDC begins one month prior to construction completion of each respective project. Once completed, leased spaces increase at a rate of two computer rooms per month.
- Cash flow schedule is not per the actual construction schedule, so it begins earlier and may end later. This is a result of costs pertaining to mostly planning, purchasing, preconstruction, logistics, and some equipment progress payments.
- Cash flow for NEDC is the same as MADC5 since values received for NEDC were based off of the job being suspended. (Values provided for MADC5 and NWDC were pre-suspension)

ORIGINAL SCHEDULE AND CASH FLOW

Schedule

Project Seven's original schedule had an intended duration of 20 months, starting in February 2008 and finishing in September 2009. MADC5 was the first project to begin, lasting 15 months. NEDC followed

MADC5 three months later and lasted 13 months. NWDC was the final project, which began two months after NEDC and continued for 15 months. Given DuPont Fabros' past success with data center development, this plan seemed highly viable with one stipulation, optimal economy and market conditions. See Table 13 for a summary of the original Project Seven schedule.

Table 13 - Original Project Schedule

Project	Start	Finish	Orig. Duration (months)	Overlap (months)
MADC5	Feb 2008	Apr 2009	15	-
NEDC	May 2008	May 2009	13	11
NWDC	July 2008	Sept 2009	15	10
Total	**Feb 2008**	**Sept 2009**	**20**	**-**

Cash Flow

As illustrated in Figure 5 below, the first four months of Project Seven experienced a positive cash flow as the construction costs are significantly less than the incoming revenue. Immediately there is a significant increase in constructions costs causing a drastic decrease in the cash flow until NEDC is complete. At this point, despite both MADC5 and NEDC having leased a couple computer rooms, to provide additional revenue for the remainder of the job, Project Seven is at an ultimate low net income of -$298.9 million. In fact, aside from the first four months, the job remains to be in the negative for the entire duration.

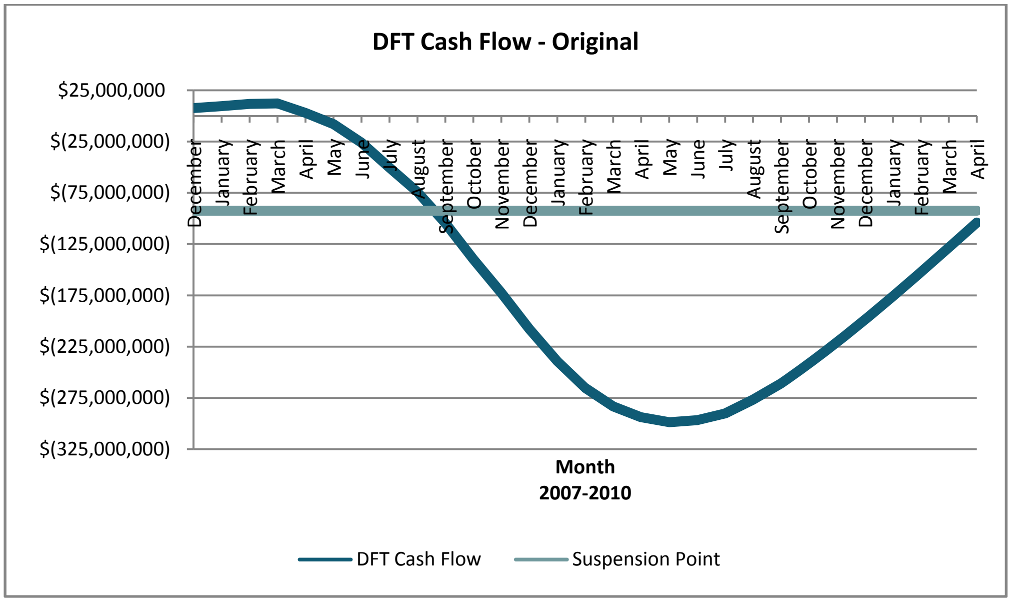


Figure 5 - Original Project Cash Flow

ACTUAL SCHEDULE AND CASH FLOW

Schedule

Previously mentioned above, DuPont Fabros decided to begin suspending Project Seven in August 2008 with NWDC. Of the three projects, NWDC was the newest project under construction and was still dealing with sitework and excavation, thus the most obvious choice for the first suspension. Project Seven continued in hopes of being able to complete both NEDC and MADC5 with the existing funding. Since the banks began to tighten their loaning capabilities, two months later NEDC was unable to continue with construction. With MADC5 the furthest in construction and having clients on board, the Owner chose not to suspend the project. It seemed feasible to finish this project since construction and financial progress was frozen on the other two projects. Unfortunately, with the economy continuing downward in the recession and banks making it extremely difficult to borrow loans, DuPont Fabros was forced to suspend the remaining project.

Fortunately, all three data center projects were only suspended and will be completed as the Owner's revenue from existing properties continues to increase, providing a great chance to secure loans for construction. In fact, MADC5 remobilized in March 2009 and it is hopeful that NEDC will remobilize in August 2009 and NWDC in May 2010. Table 14 below provides a summary of the actual schedule.

Table 14 - Actual Project Schedule

Project	Start	Suspended	Finish	Orig. Duration (months)	Suspension (months)	Total Duration (months)
MADC5	Feb 2008	Aug 2008	July 09	15	3	18
NEDC	May 2008	Oct 2008	Mar 10	13	10	23
NWDC	July 2008	Nov 2008	Apr 10	15	20	35
TOTAL	**Feb 2008**	**-**	**Apr 10**	**-**	**-**	**40**

Cash Flow

The actual schedule follows a similar flow, shown below in Figure 6, as the original schedule from the start of Project Seven until the first suspension, NWDC, at a net income of -$50.4 million. This suspension allowed the remaining two projects to continue for a couple months until it became harder to secure a loan. At the time of NEDC's suspension, the net income was -$87.9 million. Finally, at MADC5's suspension, the net income was at the lowest point of -$92.5 million, which was a value at which the owner believed it could no longer continue with any project. As such, in all evaluations of the cost projections, -$92.5 million is the suspension value and should not be crossed in order to successfully finish Project Seven.

Fortunately, the purpose behind suspending the projects was strictly a result of the struggle to secure a loan for construction and not bankruptcy. DuPont Fabros utilized the suspension to allow the revenue from their assets to steadily increase to a point where the company could illustrate, to the bank, a positive cash flow, which would result in a loan. It was vital that such point is considered "safe" enough such that the projects could have an uninterrupted completion.

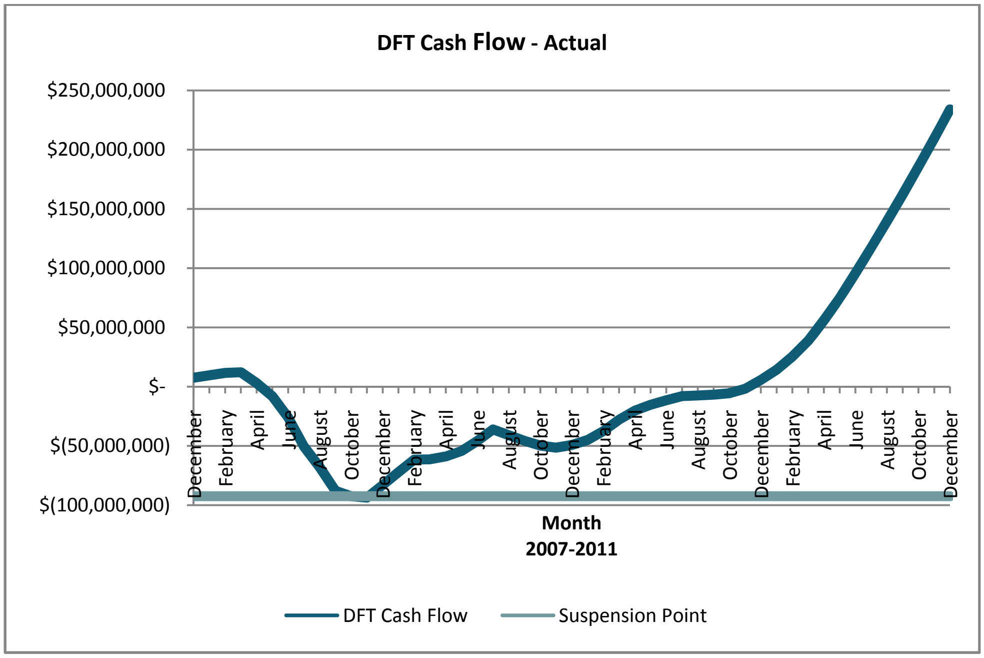


Figure 6 - Actual Project Cash Flow

PROJECT EXECUTION PLAN

The purpose of this project execution plan is to provide a better route for the owner to successfully complete Project Seven, given the time and nature of the economy, as opposed to pushing the typical fast paced construction in order to obtain tenants and future revenue. Through this plan, the owner would base the completion of the project more heavily on current revenue than on the payback of future revenue from Project Seven.

Successful completion of all three projects within Project Seven could occur by following any of the following three options:

1. Prolong each project schedule.
2. Maintain durations and sequence projects with a finish-to-start relationship.
3. Maintain durations with less of an overlap than the original plan.

For further breakdown of the cost projection spreadsheets and schedules, please reference Appendix D.

1. PROLONG PROJECTS

Schedule

The first option involves prolonging each individual project schedule. To accomplish this schedule, a decrease in the amount of work performed each month would occur which would push the remaining work to following month, thus extend the project schedule. Unfortunately, due to confidentiality issues, a complete cost breakdown of the work performed each month was unavailable; therefore an exact final date of this plan cannot be determined. It can be assumed, however, that this option would significantly lengthen the overall project duration, which is not an ideal duration for data center construction.

Cash Flow

Several assumed conclusions can be determined about the cash flow of this option by evaluating the schedule. In general, increasing the duration of each project would result in a cost increase in equipment rental, labor, general conditions, and overhead and profit. Combining these additional costs for all three projects produces a significant cost increase for Project Seven. Another concept is the idea that prolonging each schedule would delay the possibility of receiving income from each project due to leased spaces. Thus, it limits the amount of overlap between each project without having additional revenue to sustain further construction. Lastly, as a result of earning less income than the potential, the overall project could be delayed even more in order to remain above the suspension point.

2. MAINTAIN DURATIONS WITH SEQUENTIAL PROJECTS

Schedule

The second option establishes the extreme case by maintaining the original schedule durations, but scheduling the projects sequentially with a finish-to-start relationship. This option is the standard method of constructing buildings for any owner, as DuPont Fabros has previously developed its data centers this way. A key concept for this approach is maintaining the original project schedules. Since it is vital for data centers to be immediately functional, both a 13 and 15-month schedule is optimal for construction. In total, Project Seven's duration with this option is 43 months, which is only three months longer than the actual schedule. Please see Table 15 below.

Table 15 - Option 1 Project Schedule

Project	Start	Finish	Orig. Duration (months)
MADC5	Feb 2008	Apr 2009	15
NEDC	May 2009	May 2010	13
NWDC	June 2009	Aug 2011	15
Total	**Feb 2008**	**Aug 2011**	**43**

Cash Flow

As illustrated in Figure 7 on the following page, it is easy to conclude that utilizing a finish-to-start relationship would allow all three projects to be completed without any suspensions. Without any overlap, Project Seven remains considerably above the suspension point. Similar to the first option, a major disadvantage to this approach is that delaying the start of each project delays the point at which the owner could earn income from leased spaces of each respective project.

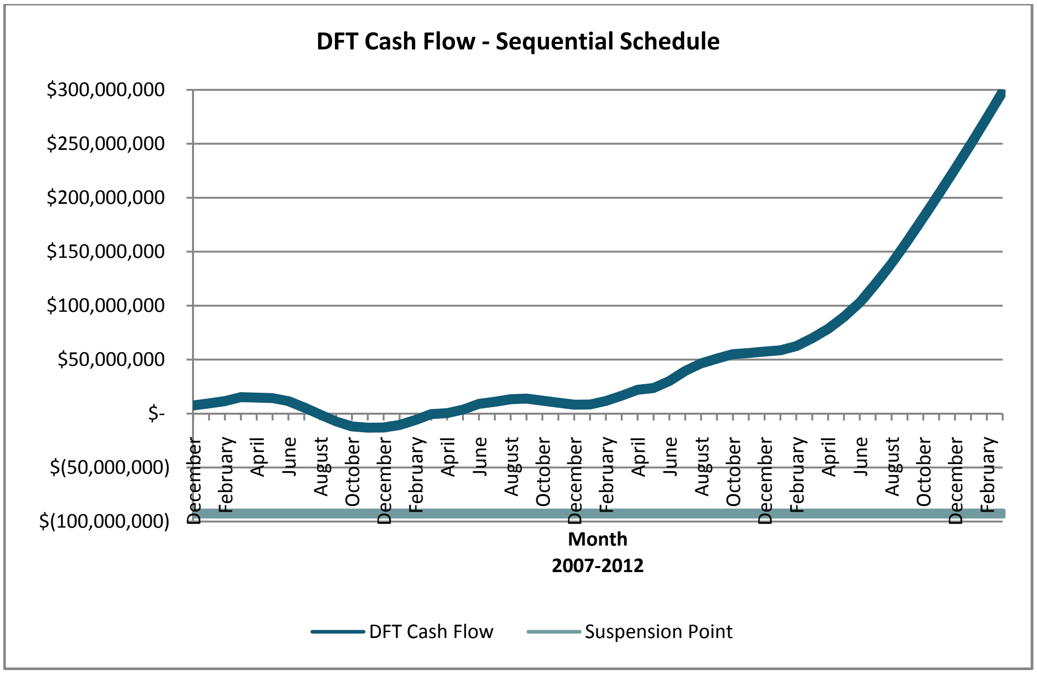


Figure 7 - Option 2 Project Cash Flow

3. MAINTAIN DURATIONS WITH LESS OVERLAP

Schedule

The third option consists of maintaining the original schedule durations and utilizing an overlap as in the original schedule, but not as extreme. In comparison, the overlaps within the original schedule were 11 months for NEDC and 10 months for NWDC, whereas, shown in Table 16below, the overlaps for this schedule are 5 months and 2 months, respectively. The overall duration of this project would be 34 months, which is six months less than the actual schedule. Not only does this option provide the fastest individual project schedules, but also the fastest overall project schedule. Most importantly, discussed in the following section, despite a shorter schedule and utilizing overlaps, it is feasible to successfully complete all three projects.

Table 16 - Option 3 Project Schedule

Project	Start	Finish	Orig. Duration (months)	Overlap (months)
MADC5	Feb 2008	Apr 2009	15	-
NEDC	Nov 2008	Nov 2009	13	5
NWDC	Sept 2009	Nov 2010	15	2
Total	**Feb 2008**	**Nov 2010**	**34**	**-**

Cash Flow

Similar to the first two options, by maintaining the schedules and having a slight overlap, all three projects would be constructed without any added cost and suspensions, as shown below in Figure 8. Project Seven nears the suspension point during completion of NEDC and start-up of NWDC; however it never crosses due to the additional revenue obtained from leased spaces in MADC5 and NEDC. As a result of showing steady and even increased revenue throughout the duration of Project Seven, the owner would have an easier time securing a loan for the duration of the project. Additionally, the end of the schedule depicts a drastic increase in cash flow, which would illustrate to the bank that the owner has the potential to pay off the loan sooner.

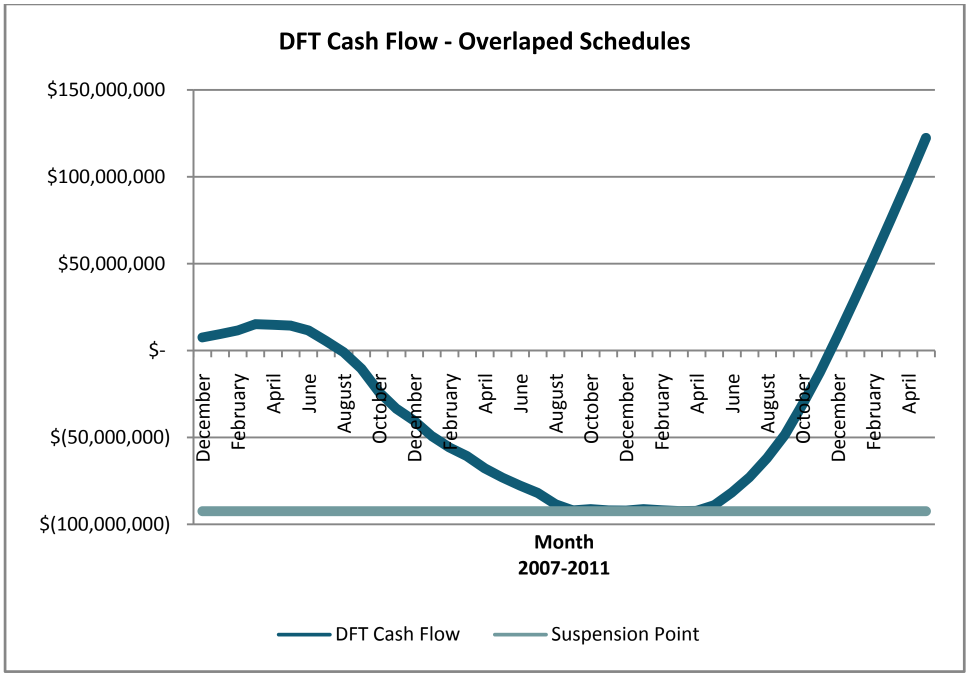


Figure 8 - Option 3 Project Cash Flow

Upon developing this option, a trial was performed to determine an additional benefit of utilizing this method, which is to determine if another project could commence based off of the given cost projection in a poor economy. DuPont Fabros has a desire, assuming the data center market continues to prosper, to eventually proceed with their development pipeline that includes four data centers within the same three regions as Project Seven (Development Pipeline, 2009). Further analysis concluded that with this option it is highly feasible to continue the pipeline within a down economy while remaining above the suspension point.

Table 17 - Additional Project Schedule

Project	Start	Finish	Orig. Duration (months)	Overlap (months)
MADC5	Feb 2008	Apr 2009	15	-
NEDC	Nov 2008	Nov 2009	13	5
NWDC	Sept 2009	Nov 2010	15	2
Add'l Project	Aug 2010	Oct 2011	15	3
Total	**Feb 2008**	**Oct 2011**	**45**	**-**

As demonstrated in above, the additional project would have the same duration as MADC5 and begin three months prior to the completion of NWDC. The total construction duration for all four projects would be 45 months, which is actually only five months longer than the actual schedule. Furthermore, exemplified in Figure 9 below, constructing a fourth project would never cross the suspension point while still maintaining an increased cash flow and eventually providing additional revenue.

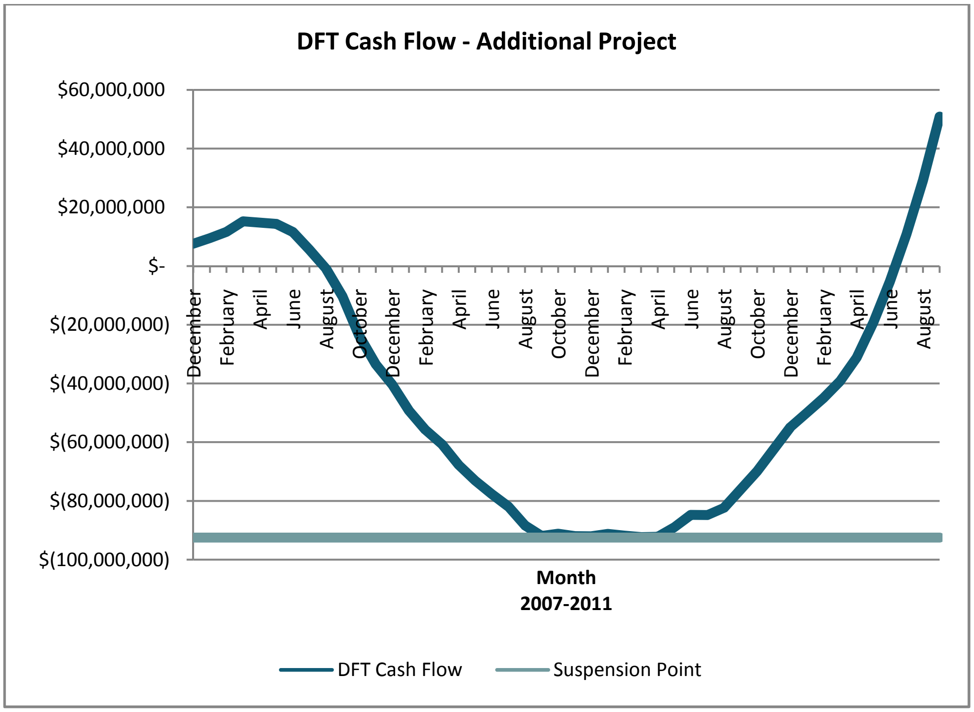


Figure 9 - Additional Project Cash Flow

Conclusions and Recommendations

Given the economic times and the original plan for Project Seven, the possibility of successfully constructing all three projects is nonexistent. By adjusting and creating a plan to correspond to poor market conditions, Project Seven could be completed without any suspensions.

Table 18 - Summary of all Project Schedules

Option	Start	Finish	Orig. Duration (months)	Income at Nov 2010	Add'l Revenue
Actual Project Duration	Feb 2008	May 2011	40	$452,599,560	$0
1. Prolong Projects	Feb 2008	?	?	-	-
2. Maintain Duration with Sequential Projects	Feb 2008	Aug 2011	43	$457,185,960	$4,586,400
3. Maintain Durations with Less Overlap	Feb 2008	Nov 2010	34	$485,850,960	$33,251,400

After a thorough analysis of the owner's construction expenditures, construction schedule, and existing revenue, as summarized in Table 18 above and Figure 10 below, it is recommended that the third option, maintaining schedule durations with less of an overlap than the original plan, of the project execution plan be utilized to develop such a project given a poor economical conditions. Overall, this option provides a shorter construction schedule, **6 months**, and provides the owner with the most additional revenue, **$33,251,400**, while remaining above the suspension point. Most importantly, it provides an opportunity to continue with future development.

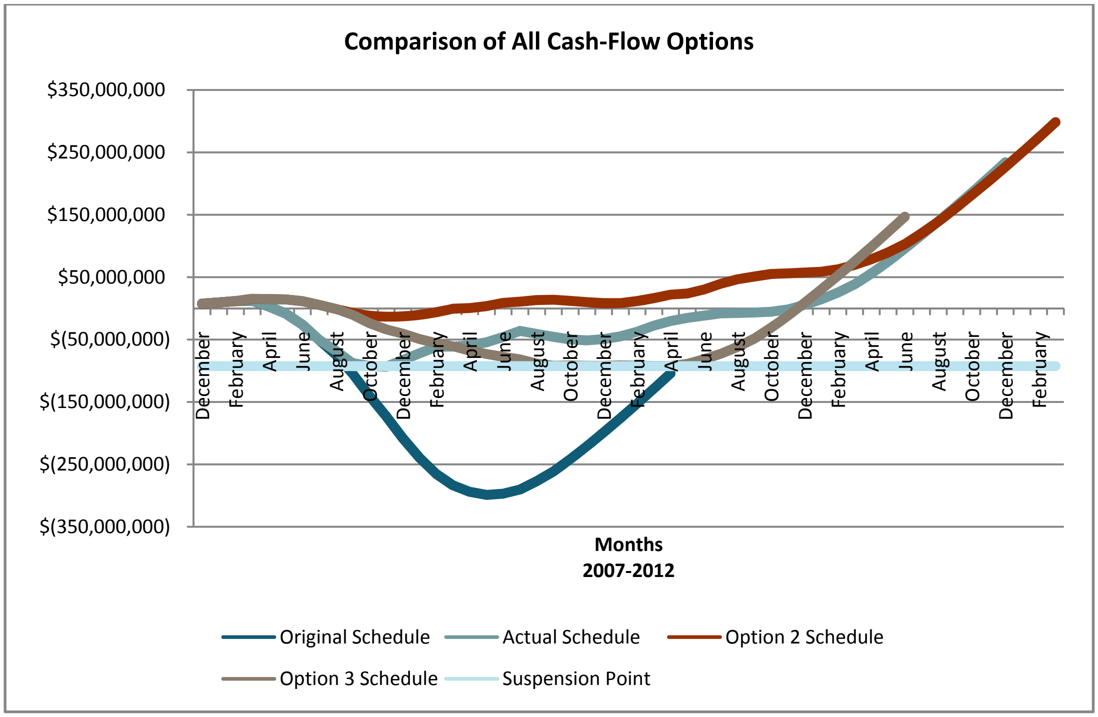


Figure 10 - Cash Flow of all Possible Project Scenarios

ANALYSIS II | ALTERNATIVE CONCRETE CONSTRUCTION PROCESS

BACKGROUND

The concrete construction process has large implications on the successful progression of any project, especially a data center since there is such a complex construction schedule in very little time. All construction trades rely on the completion of concrete slab-on-grade in order to begin any interior installation work. Thus, it is imperative that the concrete subcontractor works as quickly and efficiently as possible.

Overall, the data center's existing use of concrete was quite typical, which involved foundations, equipment pits, slab-on-grade (SOG), trenches within the computer and mechanical rooms, raised slabs for engine-generator rooms (EG) and administration office area, and topping slabs on the roof. Since the building was predominately single-story, the SOG comprised of a majority of the work, covering medium voltage (MV) rooms, uninterruptible power supply (UPS) rooms, mechanical rooms, computer rooms, and the administration office area.

A key difference from typical SOG concrete designs involved large mechanical trenches along the computer room walls (See Figure 11 to the right). These trenches house mechanical main feeds that connect computer room air handlers (CRAH's) with the mechanical equipment in the mechanical rooms. Trenches were utilized to contain spills from the pipes, lower the piping so the access floor can easily clear the pipes, and provide ample underfloor space for other conduit, such as fire alarm and security.

Figure 11 - View of the SOG with Trenches

From start to finish, the concrete subcontractor was on-site from May 28, 2008 until October 28, 2008, totaling 110 days. The cost for this amount of work was approximately $7.2 million, not including overhead and profit, contingency, and other contractual costs.

GOAL

The overall goal of this analysis focuses on reducing the amount of time that the concrete subcontractor is on-site, thus having a ripple effect on subsequent trades and the overall project duration. This analysis involves evaluating a redesign of the slab to be a continuous SOG in lieu of a SOG with trenches and its effect on the underfloor MEP layout. Other areas to evaluate include changing the UPS equipment pits from cast-in-place concrete to precast concrete and SOG pour sequences for UPS rooms, computer rooms, and transformer yard. The benefits of the new design, layout, and sequencing will be researched, including constructability impacts, schedule impacts, and the reduction of materials and cost savings.

METHODOLOGY

1. Review and analyze the current design.
2. Evaluate the constructability of the new design.
3. Perform take-offs associated with the new design to determine material, labor, and equipment savings.
4. Evaluate both the schedule and cost effects of the new design on the concrete subcontractor contract and the overall project contract.
5. Form conclusions and recommendations.

RESOURCES

- DuPont Fabros Technology, contact– Joe Ambrogio
- Holder Construction on-site staff –Ashburn, VA (MADC5) and Chicago, IL (MWDC)
- EYP Mission Critical Facilities/Hill Mechanical, contact – Andrew Syrios
- RS Means 2008 Online
- Case Study of DuPont's Midwest Data Center

CONSTRUCTABILITY ANALYSIS

First and foremost, since the design has been altered a thorough constructability analysis must occur to determine the design feasibility. Two significant alterations to be evaluated are the continuous SOG and precast UPS pits.

CONTINUOUS SOG

As mentioned in the Background and Goal sections above, the existing floor design involves a 6" continuous SOG with trenches located along the walls of the computer rooms. These trenches are typically 3'-0" deep and range from 3'-0" – 7'-0" wide throughout the computer rooms. The trenches house chilled water piping, ranging from 8" – 30" diameter, from the CRAH's to the chillers. Leak containment and providing additional room below the access floor are the two main reasons for utilizing trenches.

Case Study: Midwest Data Center, Elk Grove Village, IL

The idea for a complete continuous SOG originated from DuPont's Midwest Data Center (MWDC), which was constructed throughout 2007. In fact, the original design for MWDC included trenches with the continuous SOG. However, shortly into the design it was determined that the trenches would be removed as a result of value engineering. According to an owner's representative, "Labor costs for certain trades in Chicago were in some cases almost double what they are in Ashburn. The construction team was asked for ideas on how to trim costs and this one was accepted." Furthermore, MWDC was an existing building and trenches would have pushed the electrical ductbanks and underground plumbing another 4'-0" – 6'-0" lower than the actual installation elevation. Doing so would have created a tremendous amount of haul-off, thus very costly.

MWDC and MADC5 are both extremely large buildings, 425,000 SF and 360,000 SF respectively, with a similar interior design concepts. Since a building has been successfully constructed without trenches, it is obvious that the design is possible. Nevertheless, the design still needs to be evaluated based on the given circumstances of the Mid-Atlantic Data Center 5, especially since the MADC5 piping is much larger and the room layouts are completely different.

The new floor design maintains the continuous SOG for the entire building, removing the trenches within the computer rooms. In doing so, there is a significant decrease in the concrete contractor's scope, which ultimately saves materials, time, and money on the entire project, especially since there are fewer obstacles with making deliveries and setting equipment. As far as constructability is concerned for the concrete, pouring a continuous SOG is not only feasible but much easier than having to deal with trenches too. In contrast, making such a modification will cause a ripple effect on other trades, thus requiring a thorough analysis to be certain that such a design is viable.

Underground Conduits

A disadvantage of the trench design is that all trenches have to be coordinated with the underground electrical system, underground plumbing system, storm lines, and sanitary lines. Any lines that run perpendicular to the trenches must be lower than the bottom elevation of the trench, which creates added excavation. This takes time and money to draft and review with all parties. By removing the trenches, the overall underground coordination process is significantly less since the trenches are no longer in the way. In addition, the conduit does not have to be buried as deep which could reduce excavation haul-off. Lastly, plumbing drain lines would not be run as deep, thus allowing the possibility of eliminating lift stations. All of these constructability issues presented with the trenches would no longer be an issue with the flat slab.

Chilled Water Piping

Figure 12 - Chilled water piping

Figure 12 to the left demonstrates the support mechanism for the chilled water piping within the trenches. Steel beams are required to support the piping. By removing the trenches, this steel is no longer necessary to hold up the piping. The piping is merely resting on slab mounted tube steel, which is less laborious to install. The figure also clearly illustrates the tight space available to install the piping, requiring more labor due to the difficulty.

Despite seeming like the perfect choice, resting the chilled water piping on the slab does have its constructible issues to take into consideration. As mentioned above, the pipes must be lifted off of the slab and rest on slab mounted tube steel. Fortunately, since the system is pressurized, there is no need to slope the piping. Another issue involves crossing pipes over each other. With a 42" underfloor space to work with, some design tweaking and further coordination may need to occur when the larger mains must cross over each other. One possible solution is to have the crossovers in the corners of the rooms or at least out of the way of any airflow.

Lastly, the most important constructability issue involves leak containment. An extremely important advantage to the existing design is the inherent leak containment provided by the trenches. Should there ever be a leak, the trenches could contain a large volume of water, 3-4 feet versus 6 inches, and the leak would not affect any other major equipment within the rooms, especially electrical wiring and equipment. As such, the owner and tenants are much more at ease knowing that in an emergency situation, their equipment and business would be protected. On the other hand, the flat slab design added design ingenuity to protect against a leak. Six inch steel angles, which were non-corrosive to moisture due to air humidity from the CRAH's, must be fastened and caulked to the slab surrounding all water filled pipes and coils. Additionally, it was even more vital that floor flatness and levelness were maintained to prevent water from ponding near major equipment. Most of all, the drywall around the computer rooms need to be waterproof in order to contain any water leaks as well.

Access Floor

Access floor installation is greatly affected by altering the concrete floor design. With the existing design the trenches pose an issue with the placement of pedestals for the access floor. Steel or aluminum channels must bridge the trenches to provide support for the pedestals. This requires a large amount of steel to cover all trenches since the trenches are much wider than the actual piping. In turn, such work requires more coordination and labor. Additionally, once tenants move into the space, the power distribution unit (PDU) layout may occur over the trench, requiring additional steel channels to support the PDU stands. This underfloor area, above the trenches and below the access floor, becomes quite cluttered with the abundance of steel and aluminum.

Unfortunately, after much research, the new design experiences similar problems clearing the piping. The maximum size access floor tile is 24"x24" where the piping on this job ranges from 8"-30" plus insulation. It is obvious that the tile and pedestals will not be able to clear all of the piping. Therefore, similar metal channels must be used to bridge the piping. However, as shown in Figure 13 to the right, less bridging is required since it just barely spans the piping as opposed to having to span the entire trench. Further, it is easier and quicker to install the access floor on a continuous surface because there are fewer worries about falling into a trench or having to carefully maneuver around the trenches.

Figure 13 - Bridging over the chilled water pipes

Precast UPS Pits

According to the original design, all UPS pits were to be cast-in-place (CIP) concrete pits (see Figure 15 on the following page). As the construction began on the Phase I UPS rooms 1-8, it was determined that the UPS pits would be changed from CIP to precast (see Figure 14 on the following page) for Phase II UPS rooms 9-16. Therefore, the proposed design includes substituting CIP pits to precast pits for all UPS rooms at the beginning of the design process.

Figure 14 - Precast UPS pits

Figure 15 - Cast-in-place UPS pits

Fortunately, the constructability of precast UPS pits is quite straightforward and requires less arduous labor for the workers. There are two options when installing precast pits, which are pre-coordination or post-coordination. Pre-coordination involves gathering the MEP trades and the precast trade prior to fabrication in order to coordinate all underground MEP rough-ins on the pits. It is highly important that the conduit and pits are exactly aligned to ensure a proper installation. On the other hand, post-coordination, which occurred in the actual design for UPS rooms 9-16, requires core-drilling into the precast pits and sealing around the conduit once it has been placed. Both options are quite viable; however, according to the superintendent, the optimum choice would be to coordinate all pit and conduit locations prior to fabricating the pits.

SCHEDULE ANALYSIS

In analyzing the original schedule, every concrete sequence, except for the EG rooms, mechanical room 1, and equipment yard, could be altered to allow the subcontractor to be onsite for a much shorter duration. The biggest change in the schedule, however, was the ability to bring the subcontractor onsite later, June 18, 2008, since the sequences were tighter and moved smoother. The original schedule required that the subcontractor begin May 28, 2008 in the computer rooms because that was the earliest opportunity to work following precast. However, since the precast dictated the schedule, the concrete pours occurred sporadic throughout the project depending on when certain precast pieces were erected and out of the way. Starting later allows for the precast to get ahead enough so that the concrete does not catch up and can work continuously. [Note: All other underground MEP work began as soon as possible.]

As previously mentioned, several sequences could altered to produce a short schedule, such as computer room, UPS room, mechanical room 2, administration office area, Phase II SOG, topping slab, and transformer yard. The following is a breakdown of the changes made to the original schedule. Please see Appendix B for the original schedule and Appendix E for the revised schedule.

- Computer Rooms
  - Overall duration for computer room sequence was lengthened due to starting the prep/pour activities later while the underground MEP work began as soon as possible.
  - The prep/pour sequence changed from 13 days to 5 days by removing the trenches.

  - Able to overlap prep/pour and establish a start-start relationship after completing half of the previous prep/pour sequence. (5 day prep/pour = SS+2 days…10 day prep/pour = SS+5 days)
  - Duration Comparison:
    - Original = 5/28/08 – 8/15/08 (50 days)
    - New = 7/2/08 – 8/6/08 (26 days)
- UPS Rooms
  - UPS pits changed from cast-in-place concrete to precast concrete because it is a faster and easier installation. As a result, the only concrete work was the SOG. (Phase II was changed after initial design and work had begun on Phase I)
  - Able to pour 2 rooms at the same time because the crew was available.
  - Duration Comparison:
    - Original = 6/12/08 – 8/15/08 (47 days)
    - New = 6/23/08 – 8/1/08 (30 days)
- Mechanical Room 2(Phase 2)
  - Changed the SOG and trench prep/pour sequence to a finish-start relationship with Plumbing/Electrical underground. There is no need for a lag between these activities.
  - Duration Comparison:
    - Original = 8/1/08 – 8/22/08 (16 days)
    - New = 8/1/08 – 8/14/08 (10 days)
- Administration Office Area
  - All of the above changes pushed this area back by a few days, but has no ultimate effect on the overall project.
  - The slight time savings results from moving the prep/pour sequence to a finish-start relationship with Electrical R/I. Again, the previously scheduled lag is unnecessary.
  - Duration Comparison:
    - Original: 8/4/08 – 9/16/08 (32 days)
    - New: 8/13/08 – 9/19/08 (28 days)
- Phase II SOG
  - Includes computer rooms, UPS rooms, EG rooms, MV2, and some small miscellaneous areas (everything else was done with Phase I).
  - Durations affected the same way as Phase I. Additional time savings for these sequences because more man power is available to attend to the areas.
  - Duration Comparison:
    - Original: 9/11/08 – 2/10/09 (109 days)
    - New: 9/18/08 – 12/2/08 (54 days)
- Topping Slabs
  - In the original schedule, topping slabs were waiting on precast, thus creating a large amount of idle time between pours. After discussions with the superintendent, it is possible to prep/pour all topping slab sequences one after another with a finish-start relationship.

  - Delayed the start time of the prep/pours sequence to not catch up to the precast.
  - Building would still be watertight because CM had its own concrete crew seal all joints between precast pieces enough to be watertight.
  - Duration Comparison:
    - Original: 6/4/08 – 10/14/08 (95 days)
    - New: 8/14/08 – 10/14/08 (44 days)
- Transformer Yard
  - Original schedule had an extremely large lag between precast and underground electrical installation. Precast was done with the first section in Phase II (EG 9 and 10) when underground work started in Phase I. It was discovered and realized that underground work could start much sooner, when precast was finished with Phase I (EG 7 and 8).
  - Starting the underground electrical work earlier results in all subsequent activities starting earlier, especially the turndown footings & SOG.
  - Duration Comparison:
    - Original: 10/17/08 – 10/28/08 (8 days)
    - New: 8/28/08 – 9/8/08 (8 days)

As to be expected, several other activities were equally affected by the new concrete sequencing. In fact, no trade will be waiting on concrete per the new schedule. For example, the all of the computer rooms will be done much earlier, which allows for additional time, should it be needed, without delaying other activities.

- Sealing Concrete
  - Concrete SOGs could be sealed sooner, which affects computer rooms, UPS rooms, mechanical rooms, and MV rooms. (The EG rooms have epoxy floors and the administration offices have carpet or ceramic tile.)
- Access Floor
  - There is a shorter installation time, 5 days to 4 days, since the crew has less difficulty bridging the trenches as opposed to bridging the piping.
- Chilled Water Piping and Insulate Chilled Water Piping
  - There is a shorter installation time without the trenches since there is more room to maneuver. The install duration changes from 15 days to 12 days to 10 days and the insulation duration changes from 5 days to 4 days to 3 days, which is a result of the learning curve after the first room.
- Medium Voltage 1
  - The medium voltage equipment for the MV1 room can be installed earlier as well since the room is done sooner. As a result, Level 3 commissioning can begin sooner since it cannot begin until MV1 has been installed.
- Set CRAH Stands/Units
  - All delivery dates could be sooner due to the rooms being ready earlier.
- CRAH Testing

  - In the existing schedule, access floor held up the CRAH tester from performing any tests. CRAH testing depends on computer rooms being dried in, complete, and having power. Per the new schedule, the CRAH tester will be waiting for power instead of room readiness. In addition, since computer rooms will be done faster than the original schedule, the CRAH tester will be able to work much faster and not be held up waiting for rooms to finish. Overall, the new schedule provides for an easier Level 3 process.

Upon evaluating and altering the overall project schedule accordingly, it has been determined that the concrete subcontractor can save **65 days** off of his schedule, which significantly reduces his time on the jobsite. Furthermore, the overall project duration has been reduced by 15 days. There is an obvious discrepancy between 15 days and 65 days, however, this can be accounted for due to critical path items and other trade sequences. For example, the computer room construction can be completed earlier; however, since it is not on the critical path, the overall project duration has not been largely impacted. There is a slight impact because Level 3 testing can begin earlier and there is now some “fluff” time for testing the CRAH’s depending on power. Likewise, having computer rooms done earlier could allow for a larger manpower shift over to more critical path items such as UPS rooms, but since UPS rooms are so small, adding a large amount of people will only crowd the area and there would be a limited reduction or adverse effect on the overall project schedule.

COST ANALYSIS

The following assumptions were made throughout the take-off:

- Cost breakdown values provided by RS Means 2008 Online.
- Fairfax, VA was used as the location factor (0.92). It was the closest city to Ashburn; however, the cost may be higher due to a slightly higher cost of living in Fairfax. The calculations include this factor within the unit costs.
- Overhead and profit are omitted from the cost estimate
- Rebar cost derived by applying a factor to the original value.
  - A ratio of the amount of concrete used on the trenches versus the total amount of concrete used on the project [Ratio = (1405 CY)/ (9790 CY) = 0.14].
- Formwork unit cost provided by Superintendent.
- Open Shop labor
- Trench fall protection value provided by concrete subcontractor.
- All concrete is pumped.

By implementing precast UPS equipment pits and removing the mechanical trenches, the concrete subcontractor has saved **$627,828**, which is a 9**% reduction** in price. This savings value includes materials, labor, equipment, and trench fall protection. Several other cost savings can be also be attributed to the concrete contractor finishing earlier, such as overhead and profit, personnel, and a reduction in contractual fees. However, due to confidentiality issues, an actual amount could not be derived. Please see Table 19 below for a comparison of the two processes. Likewise, please refer to Appendix E for a further cost breakdown.

Table 19 - Existing and New Design Cost Comparison

	Material	Labor	Equipment	Total
Original Process	$ 5,488,661	$ 1,142,884	$ 325,848	$ 7,227,393
Alternative Process	$ 5,140,523	$ 1,096,322	$ 316,720	$ 6,599,565
% Savings	**6%**	**4%**	**3%**	**9%**

In addition to evaluating the cost effect of removing the trenches for the concrete subcontractor, it is necessary to assess other trades that may be financially affected. The two most effected trades are access floor and mechanical. Initially it was assumed that there may be a cost additive for the access floor since the piping is quite large and would require either customized flooring or a unique design layout. Fortunately, after discussions with an access floor subcontractor, it was concluded that having to bridge the piping would not have any cost effect on the access floor budget because the steel channels used to bridge the trenches would be used to bridge the piping. Likewise, for the mechanical subcontractor there is also minimal to no cost effect. It is difficult to estimate the exact amount since it is merely dependent on labor. Installing piping on a flat slab would be much easier and take less time than installing within a trench, however that saved time could be allotted to another activity.

In addition to evaluating the cost effect of removing the trenches for the concrete subcontractor, it is not only necessary to assess other trades that may be financially affected, but also the overall general conditions cost savings for the owner.

The two most effected trades are access floor and mechanical. Initially it was assumed that there may be a cost additive for the access floor since the piping is quite large and would require either customized flooring or a unique design layout. Fortunately, after discussions with an access floor subcontractor, it was concluded that having to bridge the piping would not have any cost effect on the access floor budget because the steel channels used to bridge the trenches would be used to bridge the piping. Likewise, for the mechanical subcontractor there is also minimal to no cost effect. It is difficult to estimate the exact amount since it is merely dependent on labor. Installing piping on a flat slab would be much easier and take less time than installing within a trench, however that saved time could be allotted to another activity.

For the owner, it is important to look at the general conditions for the three main contracts and evaluate the effects of the alternative concrete process. As mentioned in the schedule analysis, by altering the slab design and resequencing, the overall schedule has been shortened by 3 weeks. Though it is not a large change, it does still have significant implications. The total savings amounts to **$543,000**, which is a **3% savings** on the construction manager contract and a **5% savings** on both the electrical and mechanical contractor contracts. Please see Table 20 on the following page for the savings breakdown.

Table 20 - General Conditions Cost Savings

Company	Total Cost	Duration (wk)	Unit Cost ($/wk)	Savings (wk)	Savings ($)
Holder Construction *Construction Manager*	$ 7,025,338	58	$ 121,000	3.0	$ 363,000
Dynalectric (Dyna) *Electrical Contractor*	$ 1,756,335	58	$ 30,000	3.0	$ 90,000
John J. Kirlin (JJK) *Mechanical Contractor*	$ 1,756,335	58	$ 30,000	3.0	$ 90,000
				TOTAL	$ 543,000
				HCC % Savings	**3%**
				Dyna % Savings	**5%**
				JJK % Savings	**5%**

**Dyna and JJK total GC value is approximately 25% of HCC's value (per HCC estimate)*

Overall, the new design remains to be strictly a cost savings for everyone involved. Taken as a whole, the owner has the ability to save **$1,170,828.**

CONCLUSIONS AND RECOMMENDATIONS

Though the existing design of a continuous slab with trenches holds significant value with leak containment; overall, the continuous slab design is much more beneficial.

- The continuous slab system requires much less coordination efforts than constructing trenches due to a simpler design and less material.
- The construction for the concrete subcontractor is 65 days faster, resulting in significantly less time on the jobsite and less overhead on the contract. The overall construction schedule has also been reduced by 15 days.
- This system saves the owner $1,170,828 in construction costs. Of that amount, there is a $627,828 savings on the concrete contract and a $543,000 savings on the project general conditions.

Based on this analysis of constructability, schedule, and cost, the continuous slab design is the recommended system. Every aspect of this design surpasses the existing design for it is easier to construct, quicker, and it is less expensive for the owner.

ANALYSIS III | ENERGY EFFICIENT TECHNOLOGIES

MAE INFLUENCE

BACKGROUND

Mid-Atlantic Data Center 5 will be a highly green building and much more efficient than most typical data centers. In fact, this building will be one of a handful of data centers that has been certified LEED Gold in the country. Nevertheless, in the big picture, a data center still consumes a great deal of energy and continues to struggle with efficiency issues. Due to escalating energy costs, developers are constantly searching for ways to reduce their energy bills and improve their data center efficiencies.

GOAL

The goal of this analysis is to evaluate state-of-the-art electrical and mechanical technologies that could improve the energy efficiency of Mid-Atlantic Data Center 5. Through research and a thorough analysis, the expectation is to conclude that implementing a thin-film photovoltaic (PV) system and water-side economizers would create a more energy efficient building and reduce the overall energy costs for the owner in the long-run.

METHODOLOGY

Thin-Film Photovoltaic System

1. Research current solar panel systems to determine the most efficient and effective system for MADC5.
2. Analyze the solar PV system and its implementation with the building lighting system. Perform calculations to layout the system, size the wires, and size the conduits.
3. Evaluate the constructability, schedule and cost impacts of the solar PV system.
4. Form conclusions and recommendations.

Economizers

1. Research air-side and water-side economizers and determine which equipment would better suit MADC5.
2. Analyze the existing mechanical system to determine the effects of installing economizers.
3. Develop or redesign the system with the economizers.
4. Evaluate the constructability and cost impacts of improving the efficiency of the existing system.
5. Form conclusions and recommendations.

RESOURCES

- Current Events and Literature
- DuPont Fabros Technology, Inc., contacts – Faran Kaplan and Joe Ambrogio
- CCG Facilities Integration, Inc. (MEP Engineer on the project), contact – Mike Mckenna
- EYP Mission Critical Facilities/Hill Mechanical, contact – Andrew Syrios
- Carlisle Syntec, Inc. – Energy Services Department
- The Morin Company, LLC – Steve Wandishin
- Architectural Engineering 5th Year Students – Jim Gawthrop, Mech. & Courtney Yip, L/E

Thin-Film Photovoltaic System | Electrical Influence

Research

Over the past few years, thin-film technology has become the most efficient solar technology available in the market. As of 2005, 19.5% efficiency was recorded with copper-indium-gallium-selenium (CIGS) photovoltaic cells by a team at the National Renewable Energy Laboratory (Copper indium gallium selenide, 2009). CIGS is a semiconductor light absorbing material that has a specific microstructure allowing the cells to be only a few micrometers thin. As expected, the CIGS thin-film technology has exploded in the solar market and has taken on several forms, including a unique cylindrical shape provided by Solyndra.

Product Selection

Solyndra has utilized the CIGS technology to design, manufacture, and sell cylindrical photovoltaic panels, or tubular solar panels, for low-slope rooftops. Within each panel, sized at 1m x 2m, are (40) – 1 inch diameter cylinders with CIGS thin films rolled inside the cylinders. Contrary to traditional panels (Figure 16 below), the tubular panels are mounted horizontally and laid extremely close to one another, allowing significantly more roof coverage and resulting in a higher production of electricity per rooftop per year (Products, 2009).

Figure 16 - Solyndra panels on left vs. conventional panels on the right.

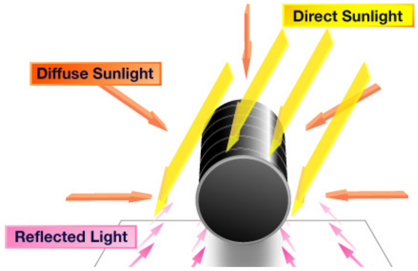


Figure 17 - Solar energy collection of each module.

According to Solyndra, optimum performance can only be achieved when the panels are horizontal to the roof surface.

One of the most unique features of the cylindrical modules is the ability to capture 360-degrees of direct and diffuse sunlight, which allows the system to remain stagnant and not have to track the sun. When combined with a white roof, which reduces building cooling loads, the panels become capable of capturing up to 20% more sunlight from the sunlight that reflects off of the white roof (Solyndra Reveals

Thin-film Solar Tubes, 2008), which in turns produces significantly more electricity per year. Figure 17 to the right depicts the various directions of sunlight that each module can collect.

Figure 18 - Wind design for Solyndra and a conventional system.

Another significant design feature of the tubular panels is its wind performance (Products, 2009). The panels allow wind to blow through the spaces between each module, whereas traditional panels are solid and prohibit wind from passing through the panel. Please see Figure 18 above for an illustration of the two systems. As a result, there is negligible wind loads, both upward and downward, on the roof structure. In fact, the system has significant mass that can sustain up to winds of 130 mph. In addition, this elevated, open configuration optimizes performance for snow loads and other rooftop obstacles.

Design Analysis

Once the solar energy system was chosen, see Appendix F for product data, there were several steps to designing the system for MADC5.

1. Determine the maximum amount of panels that could fit onto the roof, which includes a main roof and a second level mezzanine roof.
    a. Main Roof = 236,000 SF
    b. Mezzanine Roof = 61,000 SF (if necessary)
    c. Panel Size = 6 ft x 3.5 ft = 21 SF

By simple calculations, leaving extra space for roof obstacles and space between panels, it was determined that the main roof could fit about 11,000 panels and the mezzanine could fit 2,800 panels.

2. Determine the amount of panels in each array. See Figure 19 to the right.
    a. Connected in Series (also known as a Series String)
        i. No. of Panels =

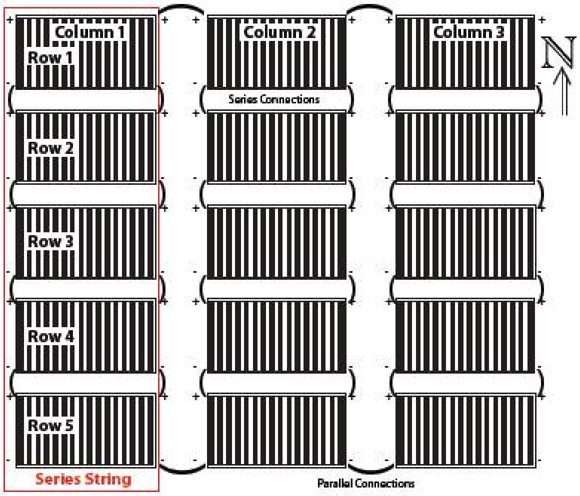


Figure 19 - Series and parallel connections for Solyndra panels

$$\frac{\text{US NEC Rating (V)}}{\text{V}_{\text{OC}}} = \frac{600\text{ V}}{102.5\text{ V}} = 5.85 = \mathbf{5\ panels}$$

   b. Connected in Parallel (Per design guide, up to 3 strings can be placed in parallel.)
      i. $\text{No. of Strings } = \left(\frac{\text{I}_{\text{fault}}}{\text{I}_{\text{SC}}} + 1.25\right)\left(\frac{1}{2.81}\right) = \left(\frac{23\text{ A}}{2.70\text{ A}} + 1.25\right)\left(\frac{1}{2.81}\right) = 3.47 =$ $\mathbf{3\ Stings}$

3. Determine the amount of panels required to power the building lighting load of 508 kW. It is typical to use more panels to ensure that the load is met.
   a. As determined above, each sub-array consists of 15 panels (5x3). Per supplier, it is typical to place 10 sub-arrays in each array.
   b. $\text{No. of Arrays } = \frac{508\text{ kW}}{27.3\frac{\text{kW}}{\text{array}}} = 18.6 = \mathbf{19\ array}$
   c. $\text{No. of Panels } = (19\text{ arrays})\left(150\ \frac{\text{panels}}{\text{array}}\right) = \mathbf{2850\ panels} \ldots \mathbf{518.7\ kW\ power}$
   d. By a comparison to the allowable amount of panels, it can be determined that there is ample room for the panels to power the lighting load.
4. Determine the amount of inverters required for the system.
   a. According to the supplier, this system this size would typically use a 260kW inverter (see Appendix F for product data).
   b. $\text{No. of Inverters} = \frac{518.7\text{ kW}}{260\frac{\text{kW}}{\text{Inverster}}} = 1.995\text{ Inverters}$
   c. For a factor of safety, it is determined that the best option would be to use **3 inverters** to ensure that the system would function properly.
5. Determine the wire and conduit sizes of the conductors connecting the combiner boxes to the inverters.
   a. Please see Appendix F for a complete breakdown of the wire and conduit sizing.

Table 21 - Quantity take-off for DC wires

DC Wires – Combiner Boxes to Inverters				
From Combiner	**To Inverter**	**# of Arrays**	**Cable Size**	**Conduit Size**
AF01	1	10	**300**	**2"**
AF02	1	10	**4/0**	**1-1/2"**
AF03	1	10	**3/0**	**1-1/2"**
AF04	1	10	**2/0**	**1-1/4"**
AF05	1	10	**1**	**1"**
AF06	1	10	**2/0**	**1-1/4"**
AF07	1	10	**4/0**	**1-1/2"**
BF01	2	10	**300**	**2"**
BF02	2	10	**250**	**2"**
BF03	2	10	**4/0**	**1-1/2"**
BF04	2	10	**2/0**	**1-1/4"**
BF05	2	10	**1/0**	**1-1/4"**
BF06	2	10	**3/0**	**1-1/2"**
BF07	2	10	**4/0**	**1-1/2"**
CF01	3	10	**350**	**2"**
CF02	3	10	**300**	**2"**
CF03	3	10	**4/0**	**1-1/2"**
CF04	3	10	**3/0**	**1-1/2"**
CF05	3	10	**2/0**	**1-1/4"**

CONSTRUCTABILITY ANALYSIS

PANEL WEIGHT & MOUNTING

As for the structural design of the system, it is lightweight and self-ballasted. Each panel weighs approximately 70 lbs (Solyndra Reveals Thin-film Solar Tubes, 2008) with a distributed rooftop load of 3.3 lbs/ ft^2 (Products, 2009). Two people can easily lift, carry, and place all the panels while one person makes the electrical connections at the array; however for a job this large it is best to have five people for installation. There are no leak-prone roof penetrations, anchoring, or ballast required to secure the system to the roof. Panels and aluminum frames are simply placed on panel mounts, allowing the panels to be placed over items less than nine inches, and then connected to each other. In comparison to traditional solar panels, the weight and mounting system of the Solyndra system is quite minimal and can be installed without having a significant effect on the existing structure. The simple installation process is depicted below in Figure 20.

Figure 20 - Installation process

WIRING

Panels are prewired for connection with each other, making the installation a fairly simple process. After the panels are mounted, the panels are connected in series and in parallel according to the given configuration. Typical wire size between panels and to the combiner box is #12 AWG. The only extra wire assembly to occur is connecting the combiner boxes to the inverters and the inverters to the panels.

UTILITY CONNECTION REQUIREMENTS

Since this is a significantly large system, it is highly necessary that the local utility company is notified about the installation and use of a solar energy system, as well as to determine if the utility company has any unique requirements. Notification would be sent prior to the installation and connection to the grid.

SAFETY

Solyndra panels, photovoltaic panels in general, are unique equipment in the sense that voltage is present whenever light is present. Therefore, power is constantly on and the panel electrical connects are live wires. It is important that all safety precautions, including local and national electric and building codes, are taken when handling and installing the panels due to the live electricity.

SCHEDULE ANALYSIS

The labor rate for this system with a five man crew is 15 panels/hour. Given there are 2,850 panels, the installation duration is 190 hours, which equates to **24 days** assuming eight-hour work days.

There are two key activities dates to keep in mind when installing the PV system, which are roof completion and Level 3 Commissioning start-up. According to the original schedule, the roof would have been complete by September 12, 2008 and Level 3 Commissioning would have begun in December 2008, creating an available time period of 2.5 months. Since the installation duration is 24 days, the system can be installed with minimal, if any, impact on the schedule.

COST ANALYSIS

FUNDING AND STATE INCENTIVES

FEDERAL

Business Energy Investment Tax Credit (ITC) (Business Energy Investment Tax Credit (ITC))

- This tax credit s is available for systems installed on or before December 31, 2016. For solar energy systems installed, the tax credit equals 30% of expenditures and there is no maximum credit limit.

STATE

Local Option Property Tax Exemption for Solar (Local Option Property Tax Exemption for Solar)

- In the state of Virginia, any residential, commercial, or industrial property with solar energy equipment can be exempt or partially exempt from any county, city, or town property taxes. Solar energy equipment is defined as equipment that is "designed and used primarily for the purpose of providing for the collection and use of incident solar energy for water heating, space heating or cooling or other application which would otherwise require a conventional source of energy."

EQUIPMENT COST

The thin-film photovoltaic system includes the following items:

Table 22 - Cost breakdown of Solyndra system

Description	Cost
System	$3,316,700
Panels (2,850)	
Wiring from Panels to Combiner Boxes	
Combiner Boxes	
Inverter	
Labor	
Monitoring System	$22,900
20-yr Warranty for Inverter/System	$62,000
Permitting	$5,000
Electrical Installation (Conduit & Labor for Combiner Box to Grid)	$320,400
TOTAL INSTALLATION COST	**$3,727,000**
Installation Cost $/W	**$7.19**
Incentives	
Business Energy Investment Tax (30%)	$1,118,100
Local Option Property Tax Exemption for Solar	$0.00
Post Incentive Installation Cost	**$2,608,900**
Installation Cost $/W	**$5.03**

**Costs obtained through discussions with Solyndra installer.*

ENERGY SAVINGS

Table 23 below provides a summary of the energy savings attributed to the Solyndra photovoltaic system.

Table 23 – Solyndra energy savings calculations

PV Avg. Power Output (kWh/yr)	Electricity Cost ($/kWh)	Total Savings	Savings (lbs of CO_2/yr)
687,796	0.068	$46,770	962,914
With Future Proposed Carbon Tax			
687,796	0.1762	$121,190	962,914

- The average power output
- 1.4 lbs of CO_2/kWh (Referenced in Lori Farley's Thesis Report 2008)
- The current electricity rate, as provided by the owner, is $0.068/kWh. However, in order to show an even greater potential savings, an analysis was completed involving the proposed carbon tax on energy. The idea of the carbon tax is to place an environmental tax on carbon dioxide and greenhouse gas emissions. Implementing this tax is a means of slowing the climate change by reducing such emissions and forcing energy companies to produce cleaner energy. It is estimated that a tax between $0.1027-$0.1137/kWh will be placed on electricity produced by coal (for an average of $0.1082) (Carbon Tax, 2009).

PAYBACK

In the case of the Solyndra system the total cost for purchasing and installing is $2,608,900 and the total savings provided by the system is $46,770. Dividing these numbers produces a payback period of **55.8 years**, which is quite unreasonable from a cost perspective for a data center.

As mentioned in the energy savings section above, it is highly probable that a carbon tax will be instituted in the near future. By implementing the carbon tax, the saving for the photovoltaic system increases to $121,190. Such a savings decreases the payback period to **21.5 years**, which is still unreasonable.

ECONOMIZERS | MECHANICAL INFLUENCE

RESEARCH

Economizers are a type of mechanical mechanism that aid in reducing energy consumption by recycling energy produced within a system or utilizing outdoor environment temperature differences (Fontecchio, 2008). In the more recent years, economizers have become more commonly utilized within mechanical systems of data centers on either the chillers or computer room air handling units (CRAHs) due to the ability to save a substantial amount in operating costs.

The typical design of economizers for data centers includes several filters located within the ductwork that connects the outdoor environment to the indoor environment. In order to ensure proper operation of economizers, it is necessary to have good controls, valves, dampers, and maintenance procedures (Economizer, 2009), as well as necessary to monitor the outdoor air conditions to maintain appropriate humidity levels. Otherwise, without proper operation and monitoring, the true savings of the economizers could not be reached.

There are several types of economizers used in the industry; however, data centers typically operate with either air-side economizers and/or water-side economizers. The following sections provide further detail on both the air-side and water-side economizers.

AIR-SIDE ECONOMIZERS

The idea of air-side economizers is to more efficiently prevent overheating of a building space using 100% recirculated air. The cool outdoor air is directly circulated in the building space, while the warm return air is rejected to the outdoors. Figure 21 below provides a diagram of an air-side economizer (Intel Air Side Economization Study, 2008). This process is most efficient when the outdoor air temperature is sufficiently cool and the amount of enthalpy in the air can be reasonably controlled, thus not necessary to additionally condition the air. Mild climates, such as San Francisco, are the optimal geographic region to utilize the economizers and achieve the best reduction in HVAC energy costs. However, temperate climates, such as Chicago, New York City, and Washington, D.C., can also be positively impacted by the economizers.

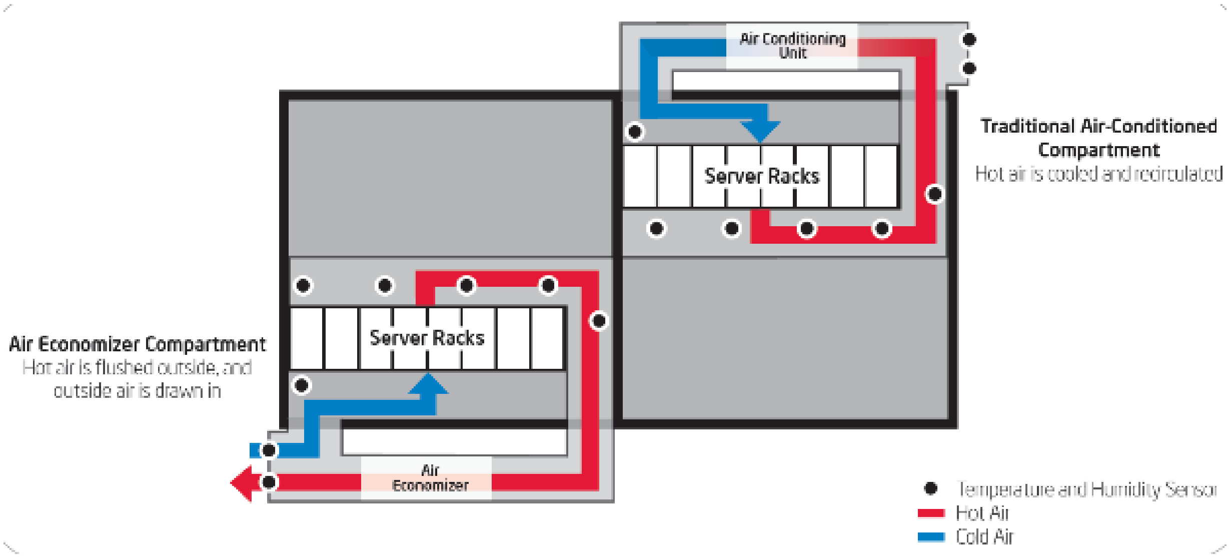


Figure 21 - Air side economizer

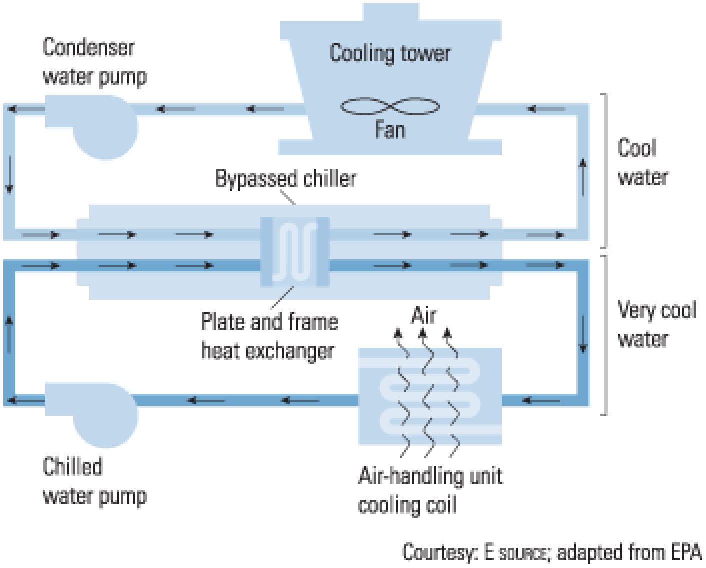
There are several disadvantages to using air-side economizers. First, in comparison to a conventional cooling system, the economizers require additional outdoor air louvers, return duct, and exhaust duct. All of these items require a significant amount of space, especially the louvers, and cost. Second, the controls of this mechanism tend to be quite complex. Lastly, since the economizers have a direct impact on the computer rooms, there is little room for error with the design. (David R. Pickut, 2008)

WATER-SIDE ECONOMIZERS

Water-side economizers, placed on chillers, allow cooling towers to produce chilled water when weather conditions permit. Opposing air-side economizers, this process is most efficient in temperate climates, such as Chicago, New York City, and Washington, D.C., and somewhat efficient in mild climates, such as San Francisco.

Figure 22 - Plate-and-frame heat exchanger

Currently, the most common type of this economizer is the plate-and-frame heat exchanger; see Figure 22 (Plate & Frame Heat Exchangers, 2008) to the right. This type of economizer pre-cools the chilled water prior to flowing into the chiller's evaporator. As long as the outdoor wet-bulb temperature is at least 10°F less than the design return chilled water, there will be a heat transfer from the return chilled water to the condenser water loop from the cooling tower. Therefore, the chiller loading and energy consumption can be reduced as a result of lowering the temperature of the water entering the evaporator. Further, if the wet-bulb temperature decreases low enough, the cooling tower could solely serve the cooling load while the chillers are turned off. Please see Figure 23 below for a diagram of this system. (Heating and Cooling, 2008)



Courtesy: E SOURCE; adapted from EPA

Figure 23 - Water side economizer system

Comparable to an air-side economizer, there are several disadvantages to a water-side economizer. First, this device requires an additional heat exchanger, piping valves, and controls which take up additional space and cost. Further, adding a heat exchanger increases pumping costs due to the added pressure loss. Second, the controls tend to be complex in comparison to a conventional system. Last, water-side economizers can be quite tricky and difficult to operate when the weather conditions are sub-freezing and/or freezing temperatures. (David R. Pickut, 2008)

COMPARISON AND SELECTION

In comparison, air-side and water-side economizers are quite similar in regard to their advantages and disadvantages. Most importantly, in terms of proper climates, both systems could be utilized on MADC5, with water-side being slightly more ideal. However, the most significant difference involves the need for louvers for air-side economizers. Due to the extremely large size of MADC5, the size of louvers required to operate air-side economizers would be too large for the building. On the other hand, in order to utilize water-side economizers, the only requirement would be to purchase plate-and-frame heat exchangers for each of the chillers, a total of eight per phase.

As a result, after talking with several mechanical engineers and evaluating the two devices, it was determined that water-side economizers would best suit MADC5.

CONSTRUCTABILITY ANALYSIS

Fortunately, it is not a difficult task to implement water-side economizers with the existing mechanical design since the economizers can attach to the existing headers with the chillers. One economizer per chiller would be installed in a parallel arrangement to allow the use of either the economizer or chiller at a lower kW depending on the conditions. In order to complete the installation, there is additional material required for connecting and routing pipes, however this does not require a significant amount of extra time, therefore not extending the project schedule. The following page, Figure 24, illustrates a simple schematic drawing of one of the two chiller plants with the water-side economizers.

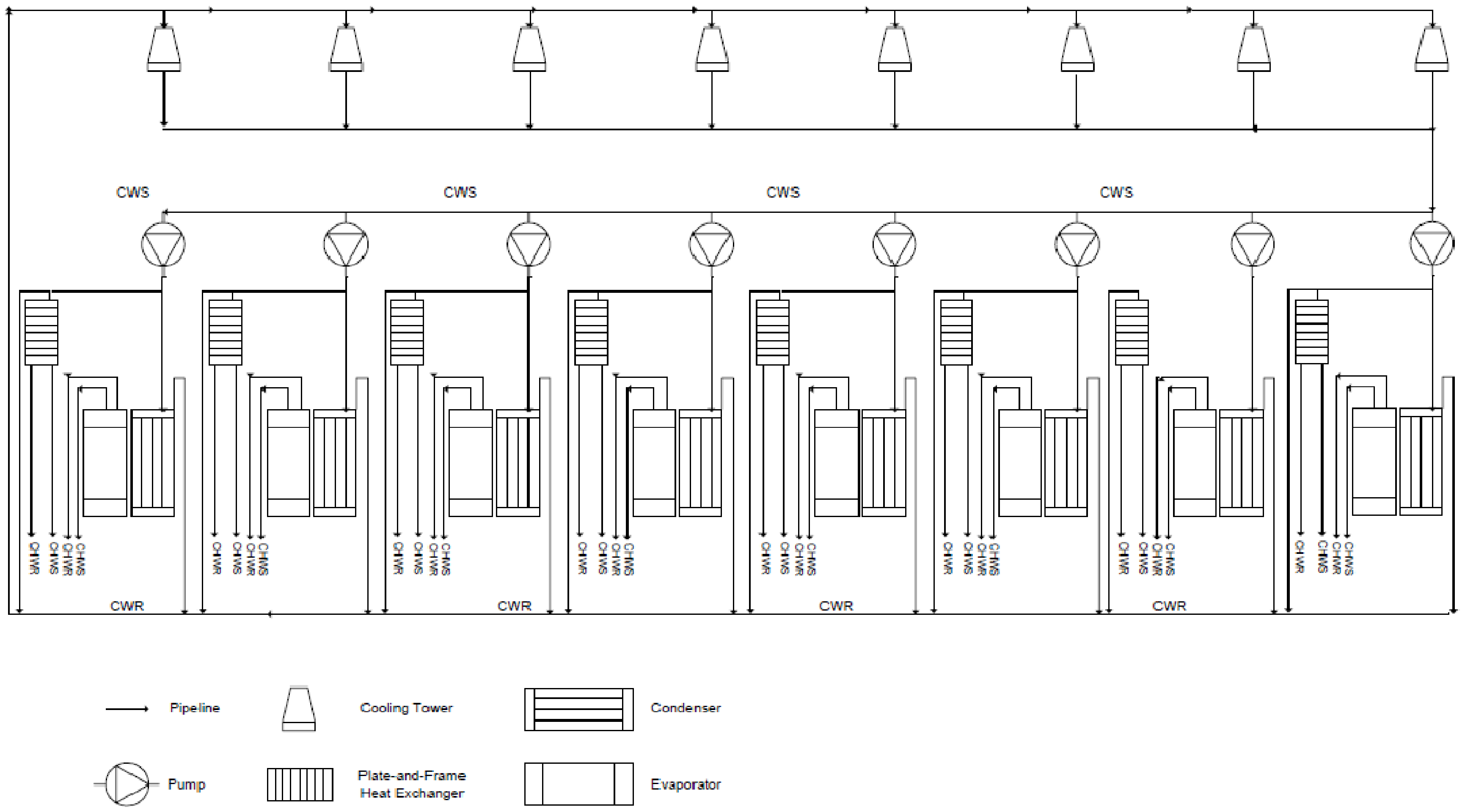


Figure 24 - Schematic of Chiller Plant with water side economizers

COST ANALYSIS

EQUIPMENT SELECTION AND COST

In order to properly size the water-side economizer, or plate-and-frame heat exchanger, it was required to analyze the given parameters for the chilled water pumps and cooling towers. The following performance data assisted with this process:

Table 24 - Water side economizer product data

	Hot Side	Cold Side
Flow Rate (gpm)	2160	3240
Inlet Temperature (°F)	58	43
Outlet Temperature (°F)	46	50.99
Pressure Drop (psi)	3.54	7.78

As a result of analyzing the above data and consulting Steve Wandishin at The Morin Company, LLC, it was determined that the optimal heat exchanger is a Tranter SUPERCHANGER® Plate and Frame Heat Exchanger (cut sheet can be found in Appendix F). The SUPERCHANGER® allows for the separation of hot and cold fluid by a plate which provides the most effect means to transfer heat from one fluid to the other. Fluid travels throughout the devise in a counter-current direction enabling the hot liquid to become cooler and the cold liquid to become warmer, as shown in Figure 25 on the left.

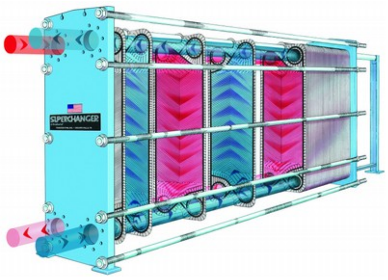


Figure 25 - Tranter SUPERCHANGER® Plate and Frame Heat Exchanger

Each SUPERCHANGER® costs approximately $47,000, plus any additional costs for connection and routing materials. Since there are sixteen chillers for the entire building, it is recommended to ultimately purchase sixteen heat exchangers. However, as the owner has determined to build out Phase 1 of MADC5, it would only be necessary to purchase eight heat exchangers for a total cost of **$376,000**.

ENERGY SAVINGS

According to Michael Kjelgaard, P.E., author of Engineering Weather Data, the energy savings attributed to implementing water-side economizers can be determined by the following formula (Kjelgaard, 2001):

Savings = Cooling Load * Cooling Plant Efficiency * Electricity Cost * Load Hours

**Savings value does not include tower fan and pumping cost. In addition, the cooling load is assumed to be running at 100%.*

Please see Table 24 below for a summary of the energy savings attributed to water-side economizers.

Wet Bulb Temp.	Cooling Load (tons)	Cooling Plant Efficiency (kWh/ton)	Electricity Cost ($/kWh)	Load Hours (h)	Savings per Chiller	Total Savings	Savings (lbs of CO_2/Plant)
24°F	840	0.5	0.068	803	$22,934	$183,472	4,704
With Future Proposed Carbon Tax (+$0.1082** (Carbon Tax, 2009)**)							
24°F	840	0.5	0.1762	803	$59,425	$475,400	4,704

Figure 26 - Water side economizer energy savings data

- For the cooling plant efficiency, since a majority of the savings is directly related to the chillers, the efficiency rating was based on the chiller efficiency of 0.5.
- The current electricity rate, as provided by the owner, is $0.068/kWh. As mentioned in the solar energy system analysis, the carbon tax would be $0.1082.
- Load hours are the number of hours per year when the outside air temperature is below a user defined “economizer on” temperature. When the temperature is below the defined value, the cold outdoor air would be utilized to cool the water as opposed to using mechanically chilled water from the chillers, thus saving electricity costs. For the MADC5 data center, energy savings will be calculated for a wet bulb temperature of 24°F, which is the typical operating temperature. Please see Appendix F for all of the weather data provided by the mechanical engineer.
- 1.4 lbs of CO_2/kWh (Referenced in Lori Farley’s Thesis Report 2008)

Payback

The most important aspect, especially to the owner, of installing a newer, efficient technology is to evaluate the payback period of the device. In the case of the water-side economizer the total cost for purchasing and installing eight is $376,000 whereas the total savings provided by the economizers is $183,472. Dividing these numbers produces a payback period of **2.05 years**, which is quite reasonable.

As mentioned in the energy savings section above, it is highly probable that a carbon tax will be instituted in the near future along with a steady increase in energy costs. By implementing the carbon tax, the saving for eight chillers escalates to $475,400. Such a savings decreases the payback period to only **0.79 years (9.5 months)**.

Conclusions and Recommendations

Thin-Film Photovoltaic System

The push for environmentally-friendly energy sources has created an ever growing market for solar energy systems. Since it is such a new technology and constantly redesigned and improved, the installation cost per Watt is quite high. As a result, the energy savings are much less than owners would hope, creating an extreme payback period. However, solar energy systems are not about the short-term investment, but rather the long-term and how it can help save the environment.

Based on the above analysis, it has been determined that the owner of the project would have to play the deciding role on whether to implement the thin-film photovoltaic system. Data centers are ever-changing buildings and designs that have a relatively short lifespan before being overhauled for something bigger and better. Therefore, due to the volatility of the building and the 55.8 year payback, it would not be a wise investment for the owner. However, in the case of sustainability and protecting the environment, neither time nor money is unreasonable.

WATER-SIDE ECONOMIZER

Implementing water-side economizers are not particularly enticing in today's energy environment due to such low energy costs. In the long-run, economizers provide greater mechanical efficiency and will eventually pay off for themselves, in approximately 2 years as illustrated above. However, with the constantly increasing electricity rates and proposed environmental taxes on existing energy sources producing carbon dioxide emissions, it seems quite logical to utilize economizers within a mechanical design.

Therefore, based on this analysis of constructability and cost, as well as research on escalating energy costs and taxes, it is recommended that water-side economizers be implemented in MADC5. The mechanical devices will ultimately pay for themselves within only 9.5 months to 2 years, which is more than worth the initial investment.

Summary and Conclusions

After a thorough analysis of the owner's construction expenditures, construction schedule, and existing revenue, it is recommended that the project execution plan that involves maintaining schedule durations with less of an overlap be utilized given poor economical conditions. This option provides a 6 month shorter construction schedule and $33,251,400 of additional revenue while remaining above the suspension point. Most importantly, it provides an opportunity to continue with future development.

The recommended alternative concrete construction process involves utilizing the continuous slab system. In comparison to the trench design, it is easier to construct, quicker by 15 days, and saves the owner $1,170,828.

The implementation and use of a thin-film photovoltaic system has both positive and negative aspects of the design.

- Installing the system would cost $2,608,900 with no schedule impact. This system would save $46,770 with a payback period of 55.8 years.
- Not installing the system would save the owner the design costs, but would continue to add carbon emissions into the environment, an ever-growing concern for the earth.

Based on the above analysis, the owner would need to make the ultimate decision depending on what is more important, saving money or reducing the impact of this building on the environment.

Water side economizers are highly recommended as a means of reducing energy consumption within the mechanical system. Though initially costing the owner $376,000, the device would ultimately pay for itself within 2 years, which is worth the initial investment.

In the end, by implementing three* of the four above plans, designs, and systems, it would save the owner $794,828 and 6.5 months of construction. On the other hand, if the owner chose to implement all options it would cost $1,814,072, but would have zero schedule impacts and save 967,618 lbs. of CO_2 annually. Plus, with the additional revenue from the new execution plan, the cost of the PV system is irrelevant. Table 25 found below details the total cost savings to implement all of the systems.

Table 25 - Final Cost Savings

Analysis	Cost Savings	Schedule Savings	Additional Savings
New Execution Plan*	-	6 mo.	$33,251,400 Additional Revenue in 6 months
Continuous Slab Design*	$1,170,828	0.5 mo.	65 days for the concrete subcontractor
Thin-Film PV's	($2,608,900)	No effect	$183,472 in electricity cost & 962,914 lb of CO_2 saved annually
Water side Economizers*	($376,000)	No effect	$46,770 in electricity cost & 4,704 lb of CO_2 saved annually
* Savings - 3 systems	$794,828	6.5 mos.	
Total Savings	(-1,814,072)	6.5 mo.	

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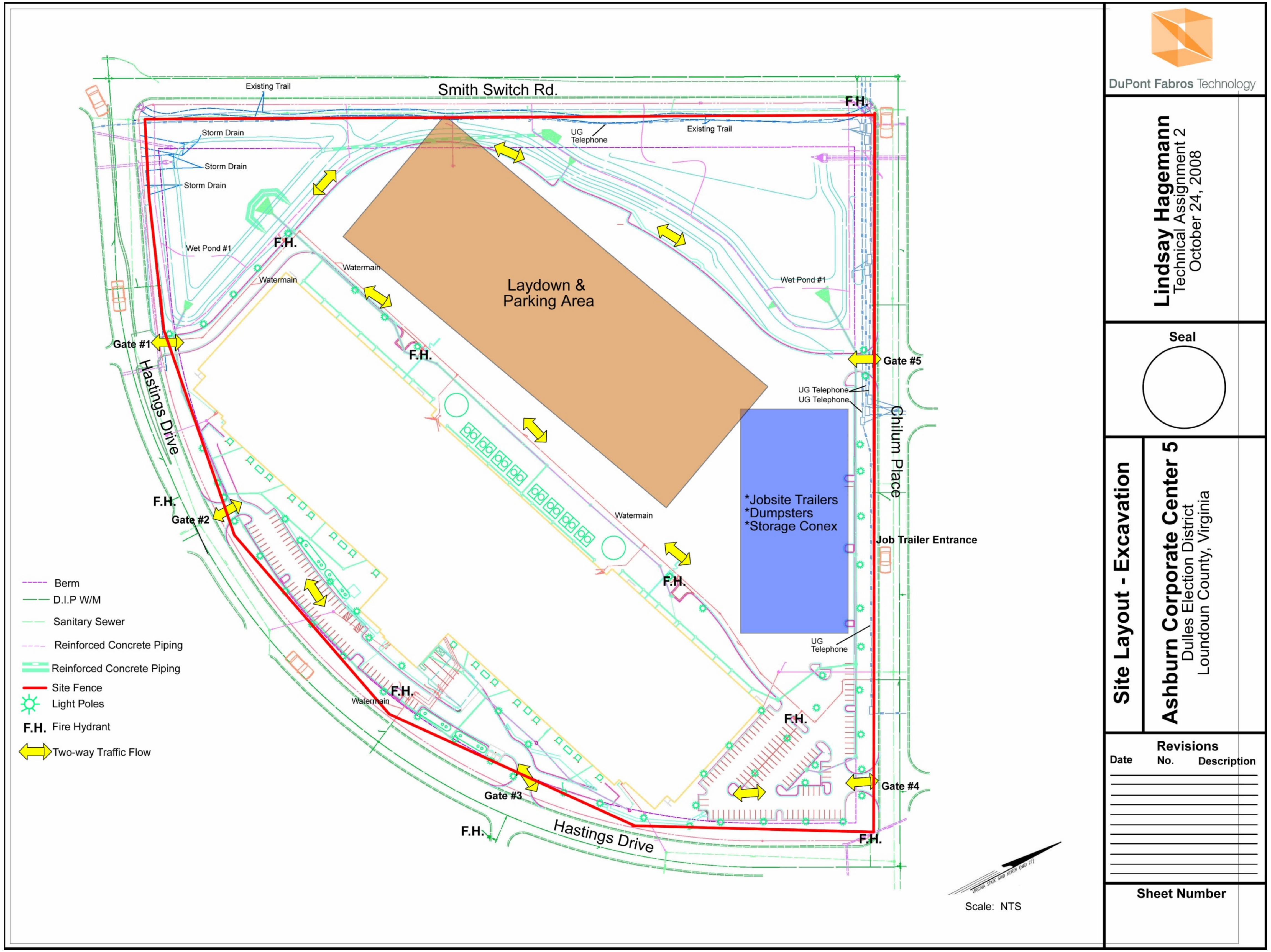
APPENDIX A | SITE LOGISTICS PLANS

SITE PLANS OF EXISTING CONDITIONS, TEMPORARY FACILITIES, AND CRITICAL CONSTRUCTION PHASES CAN BE FOUND ON THE FOLLOWING PAGES.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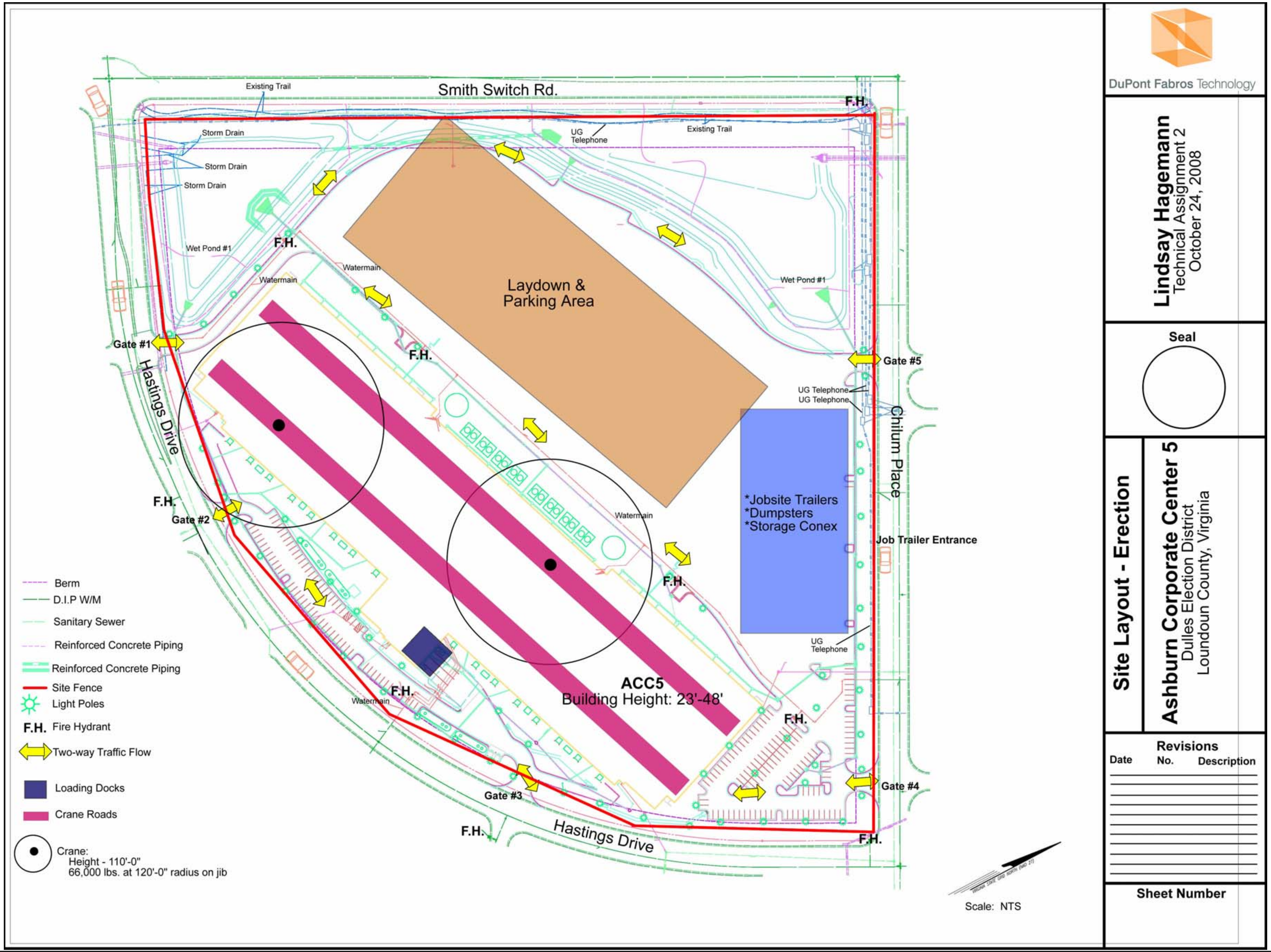
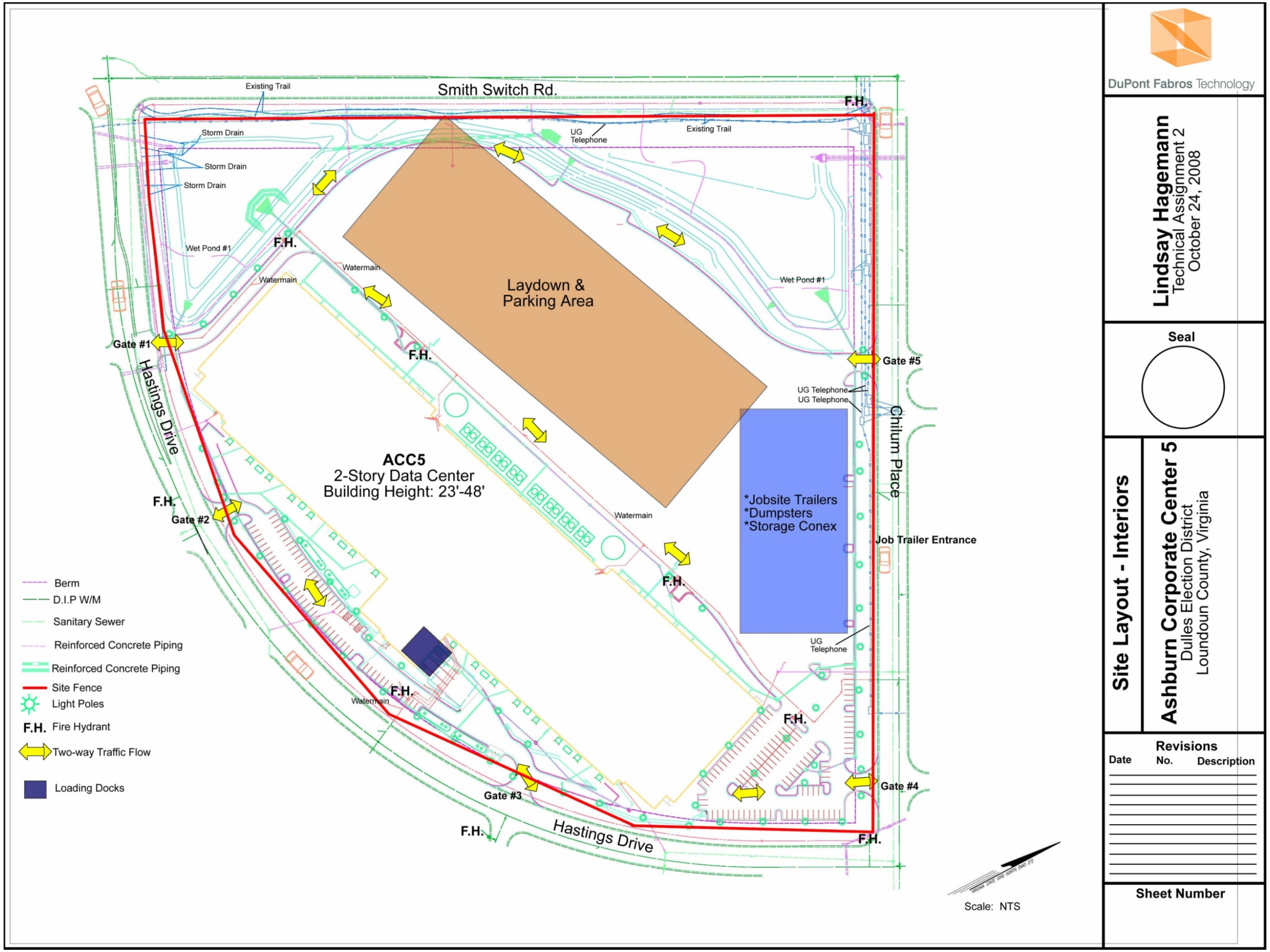
Existing Trail
Storm Drain
Storm Drain
Storm Drain
UG Telephone
Existing Trail
F.H.
Wet Pond #1
Watermain
Watermain
F.H.
Laydown & Parking Area
Wet Pond #1
F.H.
Gate #1
Gate #5
Hastings Drive
UG Telephone
UG Telephone
Chilum Place
*Jobsite Trailers
*Dumpsters
*Storage Conex
Watermain
Job Trailer Entrance
F.H.
Gate #2
F.H.
UG Telephone
F.H.
Watermain
F.H.
Gate #4
Gate #3
F.H.
Hastings Drive
F.H.
Berm
D.I.P W/M
Sanitary Sewer
Reinforced Concrete Piping
Reinforced Concrete Piping
Site Fence
Light Poles
F.H. Fire Hydrant
Two-way Traffic Flow
Scale: NTS
DuPont Fabros Technology
Lindsay Hagemann
Technical Assignment 2
October 24, 2008
Seal
Site Layout - Excavation
Ashburn Corporate Center 5
Dulles Election District
Loundoun County, Virginia
Revisions
Date
No.
Description
Sheet Number

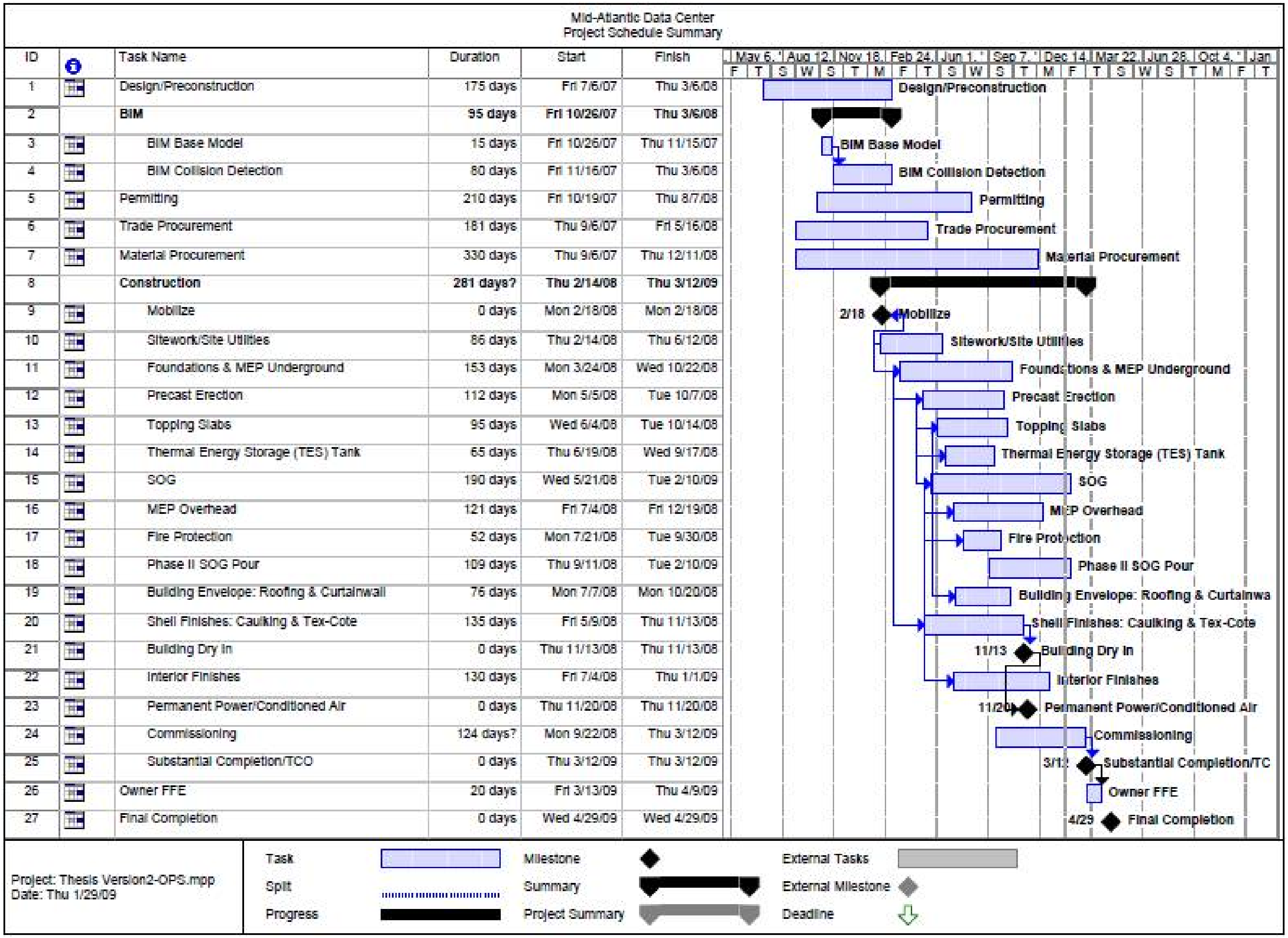

DuPont Fabros Technology
Lindsay Hagemann
Technical Assignment 2
October 24, 2008
Seal
Site Layout - Erection
Ashburn Corporate Center 5
Dulles Election District
Loundoun County, Virginia
Revisions
Date
No.
Description
Sheet Number
Smith Switch Rd.
Existing Trail
F.H.
Storm Drain
Storm Drain
Storm Drain
UG Telephone
Existing Trail
Wet Pond #1
Wet Pond #1
Watermain
Watermain
Laydown & Parking Area
Gate #1
Gate #2
Gate #3
Gate #4
Gate #5
Hastings Drive
Hastings Drive
Chilum Place
UG Telephone
UG Telephone
*Jobsite Trailers
*Dumpsters
*Storage Conex
Job Trailer Entrance
Watermain
UG Telephone
ACC5
Building Height: 23'-48'
Berm
D.I.P W/M
Sanitary Sewer
Reinforced Concrete Piping
Reinforced Concrete Piping
Site Fence
Light Poles
F.H. Fire Hydrant
Two-way Traffic Flow
Loading Docks
Crane Roads
Crane:
Height - 110'-0"
66,000 lbs. at 120'-0" radius on jib
Scale: NTS


Smith Switch Rd.
Existing Trail
Existing Trail
UG Telephone
F.H.
Storm Drain
Storm Drain
Storm Drain
Wet Pond #1
Wet Pond #1
F.H.
Watermain
Watermain
Laydown & Parking Area
Gate #1
Gate #5
F.H.
UG Telephone
UG Telephone
Hastings Drive
Chilum Place
ACC5
2-Story Data Center
Building Height: 23'-48'
F.H.
Gate #2
Watermain
*Jobsite Trailers
*Dumpsters
*Storage Conex
Job Trailer Entrance
F.H.
UG Telephone
F.H.
Watermain
F.H.
Gate #3
Gate #4
F.H.
Hastings Drive
F.H.
Berm
D.I.P W/M
Sanitary Sewer
Reinforced Concrete Piping
Reinforced Concrete Piping
Site Fence
Light Poles
F.H. Fire Hydrant
Two-way Traffic Flow
Loading Docks
Scale: NTS
DuPont Fabros Technology
Lindsay Hagemann
Technical Assignment 2
October 24, 2008
Seal
Site Layout - Interiors
Ashburn Corporate Center 5
Dulles Election District
Loundoun County, Virginia
Revisions
Date
No.
Description
Sheet Number

Appendix B | Project Schedule Summary

A Microsoft Project, Project Schedule and Detailed Project Schedule can be found on the following pages along with the erection plan and sequence.

PROJECT SCHEDULE SUMMARY



Mid-Atlantic Data Center
Project Schedule Summary

ID	Task Name	Duration	Start	Finish
1	Design/Preconstruction	175 days	Fri 7/6/07	Thu 3/6/08
2	**BIM**	**95 days**	**Fri 10/26/07**	**Thu 3/6/08**
3	BIM Base Model	15 days	Fri 10/26/07	Thu 11/15/07
4	BIM Collision Detection	80 days	Fri 11/16/07	Thu 3/6/08
5	Permitting	210 days	Fri 10/19/07	Thu 8/7/08
6	Trade Procurement	181 days	Thu 9/6/07	Fri 5/16/08
7	Material Procurement	330 days	Thu 9/6/07	Thu 12/11/08
8	**Construction**	**281 days?**	**Thu 2/14/08**	**Thu 3/12/09**
9	Mobilize	0 days	Mon 2/18/08	Mon 2/18/08
10	Sitework/Site Utilities	86 days	Thu 2/14/08	Thu 6/12/08
11	Foundations & MEP Underground	153 days	Mon 3/24/08	Wed 10/22/08
12	Precast Erection	112 days	Mon 5/5/08	Tue 10/7/08
13	Topping Slabs	95 days	Wed 6/4/08	Tue 10/14/08
14	Thermal Energy Storage (TES) Tank	65 days	Thu 6/19/08	Wed 9/17/08
15	SOG	190 days	Wed 5/21/08	Tue 2/10/09
16	MEP Overhead	121 days	Fri 7/4/08	Fri 12/19/08
17	Fire Protection	52 days	Mon 7/21/08	Tue 9/30/08
18	Phase II SOG Pour	109 days	Thu 9/11/08	Tue 2/10/09
19	Building Envelope: Roofing & Curtainwall	76 days	Mon 7/7/08	Mon 10/20/08
20	Shell Finishes: Caulking & Tex-Cote	135 days	Fri 5/9/08	Thu 11/13/08
21	Building Dry In	0 days	Thu 11/13/08	Thu 11/13/08
22	Interior Finishes	130 days	Fri 7/4/08	Thu 1/1/09
23	Permanent Power/Conditioned Air	0 days	Thu 11/20/08	Thu 11/20/08
24	Commissioning	124 days?	Mon 9/22/08	Thu 3/12/09
25	Substantial Completion/TCO	0 days	Thu 3/12/09	Thu 3/12/09
26	Owner FFE	20 days	Fri 3/13/09	Thu 4/9/09
27	Final Completion	0 days	Wed 4/29/09	Wed 4/29/09

Project: Thesis Version2-OPS.mpp
Date: Thu 1/29/09

Task	▭	Milestone	◆	External Tasks	▭
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

PRECAST ERECTION PLAN

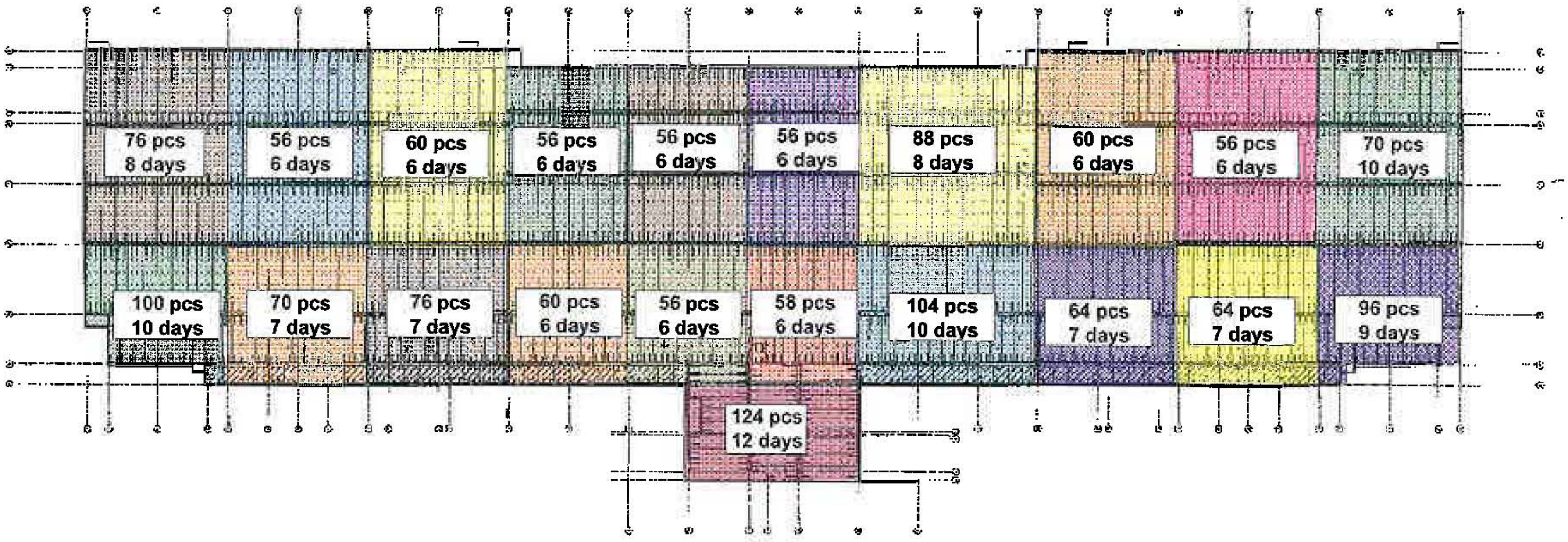


Figure 27 Precast Erection Plan

PRECAST ERECTION SEQUENCE

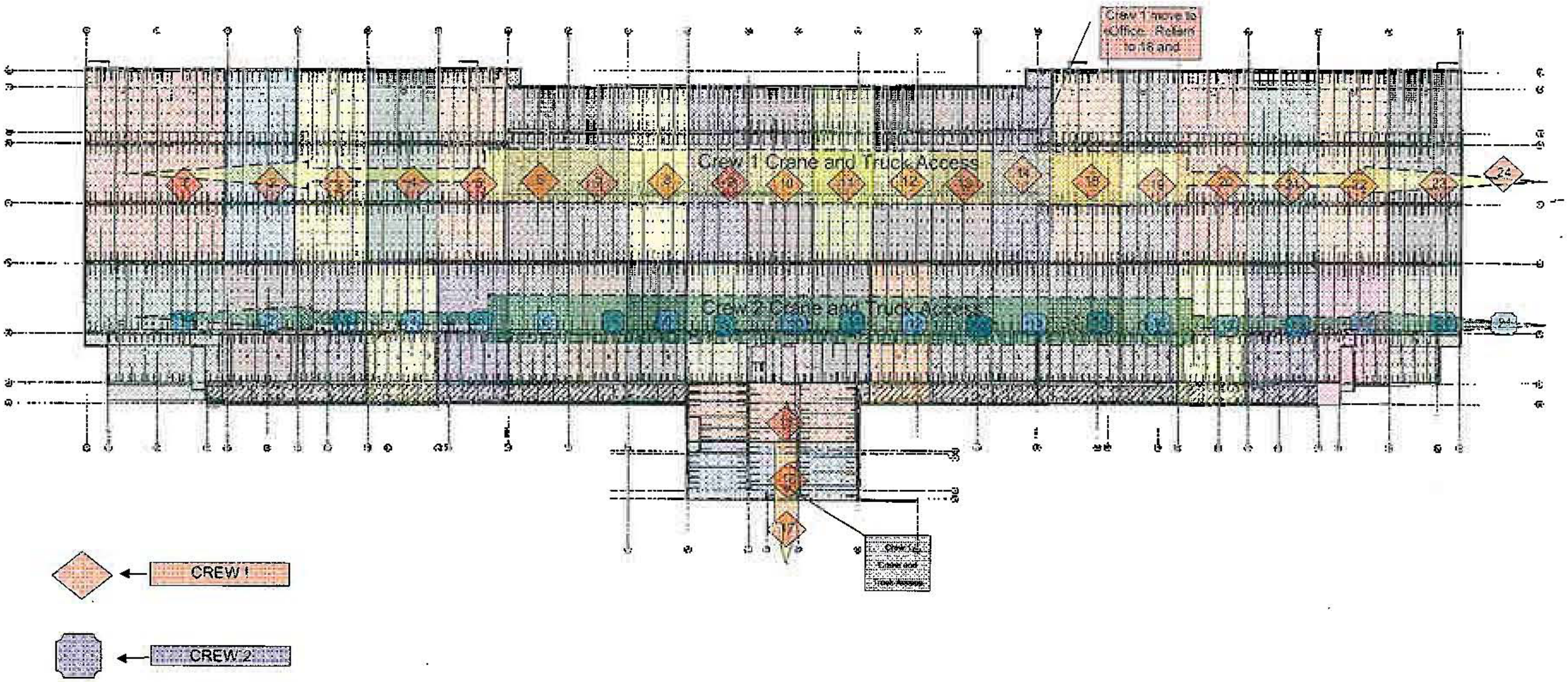
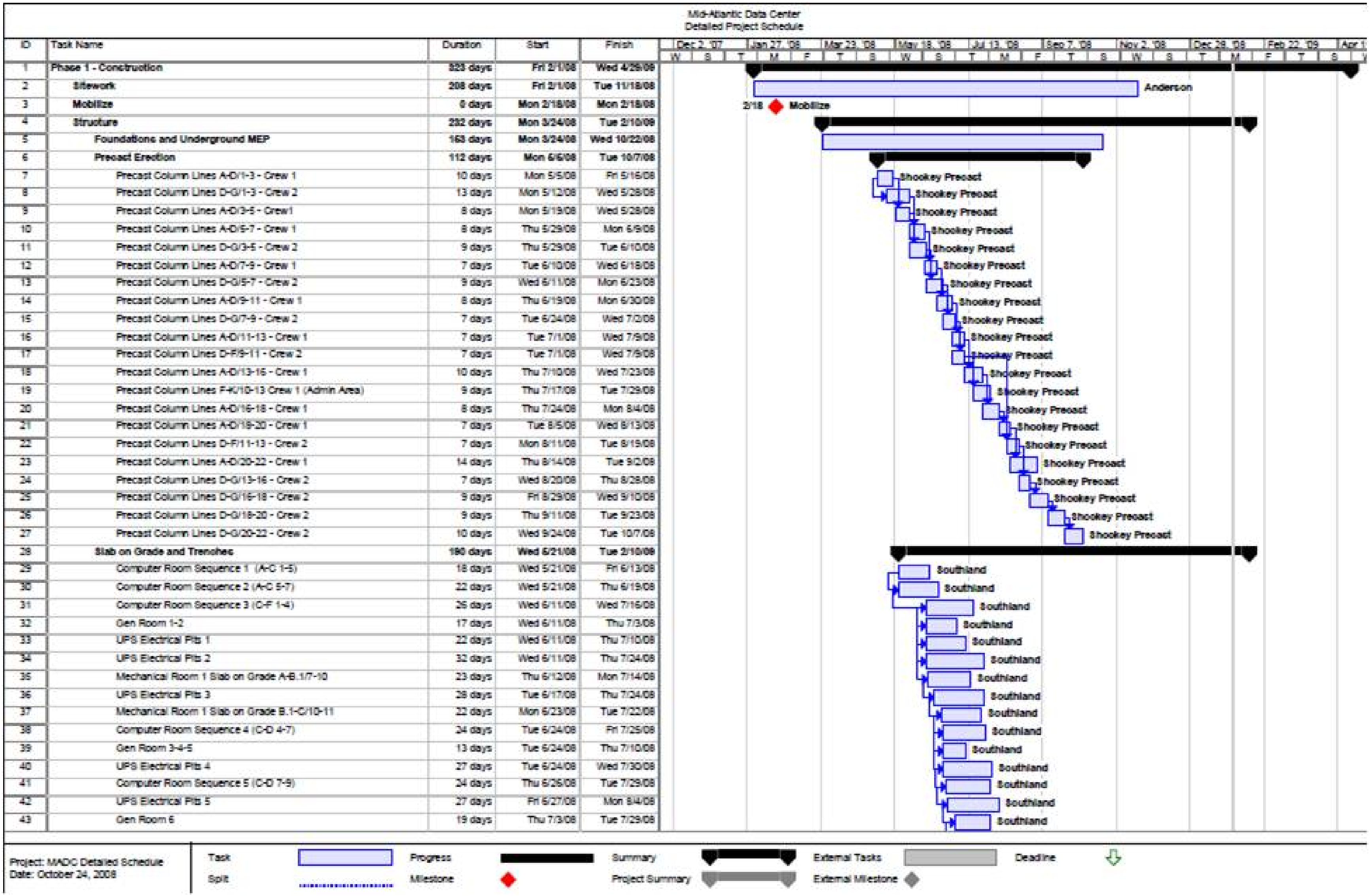


Figure 28 Precast Erection Sequence

DETAILED PROJECT SCHEDULE

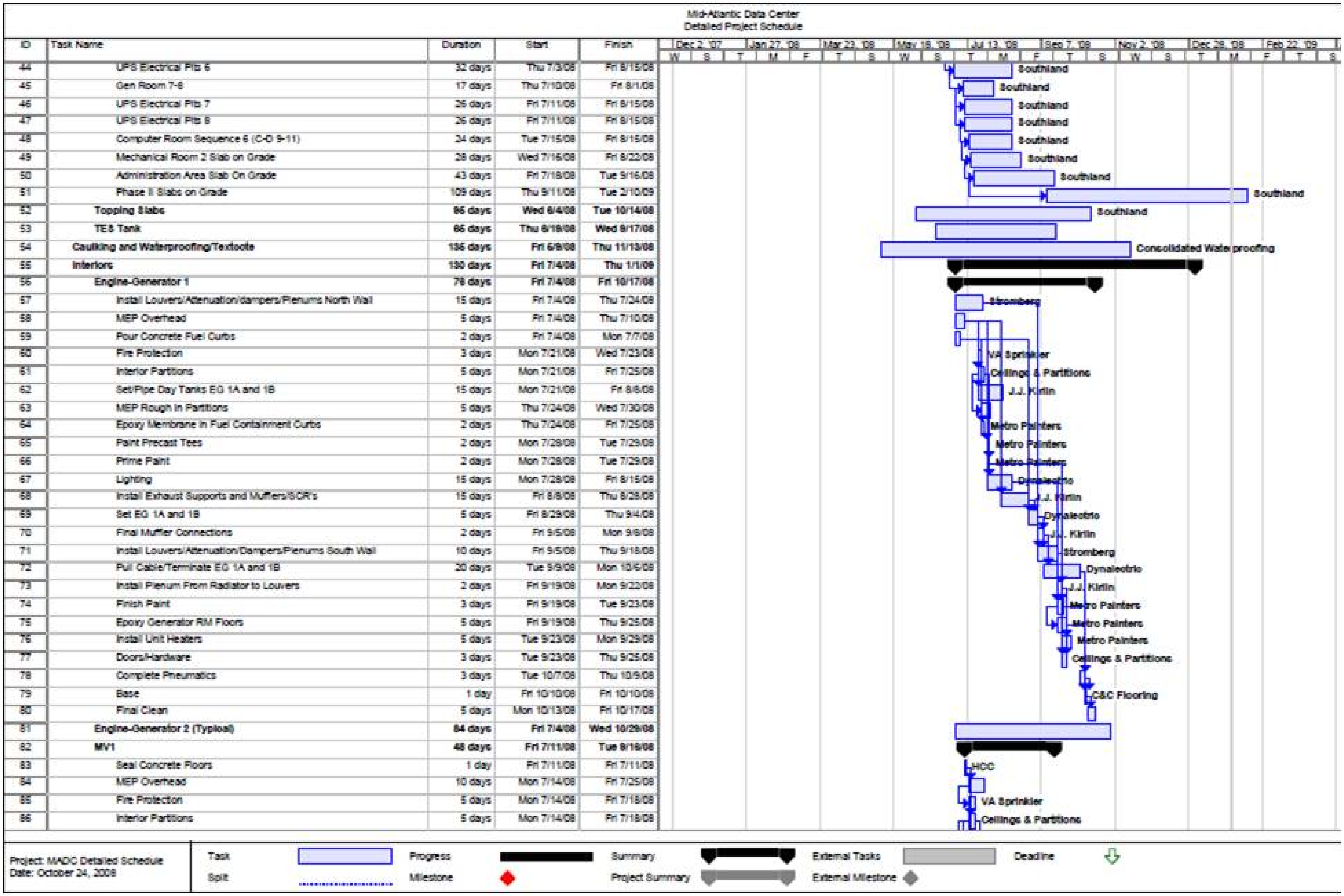


Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Phase 1 - Construction**	**323 days**	**Fri 2/1/08**	**Wed 4/29/09**
2	**Sitework**	**208 days**	**Fri 2/1/08**	**Tue 11/18/08**
3	**Mobilize**	**0 days**	**Mon 2/18/08**	**Mon 2/18/08**
4	**Structure**	**232 days**	**Mon 3/24/08**	**Tue 2/10/09**
5	**Foundations and Underground MEP**	**163 days**	**Mon 3/24/08**	**Wed 10/22/08**
6	**Precast Erection**	**112 days**	**Mon 5/5/08**	**Tue 10/7/08**
7	Precast Column Lines A-D/1-3 - Crew 1	10 days	Mon 5/5/08	Fri 5/16/08
8	Precast Column Lines D-G/1-3 - Crew 2	13 days	Mon 5/12/08	Wed 5/28/08
9	Precast Column Lines A-D/3-5 - Crew1	8 days	Mon 5/19/08	Wed 5/28/08
10	Precast Column Lines A-D/5-7 - Crew 1	8 days	Thu 5/29/08	Mon 6/9/08
11	Precast Column Lines D-G/3-5 - Crew 2	9 days	Thu 5/29/08	Tue 6/10/08
12	Precast Column Lines A-D/7-9 - Crew 1	7 days	Tue 6/10/08	Wed 6/18/08
13	Precast Column Lines D-G/5-7 - Crew 2	9 days	Wed 6/11/08	Mon 6/23/08
14	Precast Column Lines A-D/9-11 - Crew 1	8 days	Thu 6/19/08	Mon 6/30/08
15	Precast Column Lines D-G/7-9 - Crew 2	7 days	Tue 6/24/08	Wed 7/2/08
16	Precast Column Lines A-D/11-13 - Crew 1	7 days	Tue 7/1/08	Wed 7/9/08
17	Precast Column Lines D-F/9-11 - Crew 2	7 days	Tue 7/1/08	Wed 7/9/08
18	Precast Column Lines A-D/13-16 - Crew 1	10 days	Thu 7/10/08	Wed 7/23/08
19	Precast Column Lines F-K/10-13 Crew 1 (Admin Area)	9 days	Thu 7/17/08	Tue 7/29/08
20	Precast Column Lines A-D/16-18 - Crew 1	8 days	Thu 7/24/08	Mon 8/4/08
21	Precast Column Lines A-D/18-20 - Crew 1	7 days	Tue 8/5/08	Wed 8/13/08
22	Precast Column Lines D-F/11-13 - Crew 2	7 days	Mon 8/11/08	Tue 8/19/08
23	Precast Column Lines A-D/20-22 - Crew 1	14 days	Thu 8/14/08	Tue 9/2/08
24	Precast Column Lines D-G/13-16 - Crew 2	7 days	Wed 8/20/08	Thu 8/28/08
25	Precast Column Lines D-G/16-18 - Crew 2	9 days	Fri 8/29/08	Wed 9/10/08
26	Precast Column Lines D-G/18-20 - Crew 2	9 days	Thu 9/11/08	Tue 9/23/08
27	Precast Column Lines D-G/20-22 - Crew 2	10 days	Wed 9/24/08	Tue 10/7/08
28	**Slab on Grade and Trenches**	**190 days**	**Wed 5/21/08**	**Tue 2/10/09**
29	Computer Room Sequence 1 (A-C 1-5)	18 days	Wed 5/21/08	Fri 6/13/08
30	Computer Room Sequence 2 (A-C 5-7)	22 days	Wed 5/21/08	Thu 6/19/08
31	Computer Room Sequence 3 (C-F 1-4)	26 days	Wed 6/11/08	Wed 7/16/08
32	Gen Room 1-2	17 days	Wed 6/11/08	Thu 7/3/08
33	UPS Electrical Pits 1	22 days	Wed 6/11/08	Thu 7/10/08
34	UPS Electrical Pits 2	32 days	Wed 6/11/08	Thu 7/24/08
35	Mechanical Room 1 Slab on Grade A-B.1/7-10	23 days	Thu 6/12/08	Mon 7/14/08
36	UPS Electrical Pits 3	28 days	Tue 6/17/08	Thu 7/24/08
37	Mechanical Room 1 Slab on Grade B.1-C/10-11	22 days	Mon 6/23/08	Tue 7/22/08
38	Computer Room Sequence 4 (C-D 4-7)	24 days	Tue 6/24/08	Fri 7/25/08
39	Gen Room 3-4-5	13 days	Tue 6/24/08	Thu 7/10/08
40	UPS Electrical Pits 4	27 days	Tue 6/24/08	Wed 7/30/08
41	Computer Room Sequence 5 (C-D 7-9)	24 days	Thu 6/26/08	Tue 7/29/08
42	UPS Electrical Pits 5	27 days	Fri 6/27/08	Mon 8/4/08
43	Gen Room 6	19 days	Thu 7/3/08	Tue 7/29/08

Project: MADC Detailed Schedule
Date: October 24, 2008

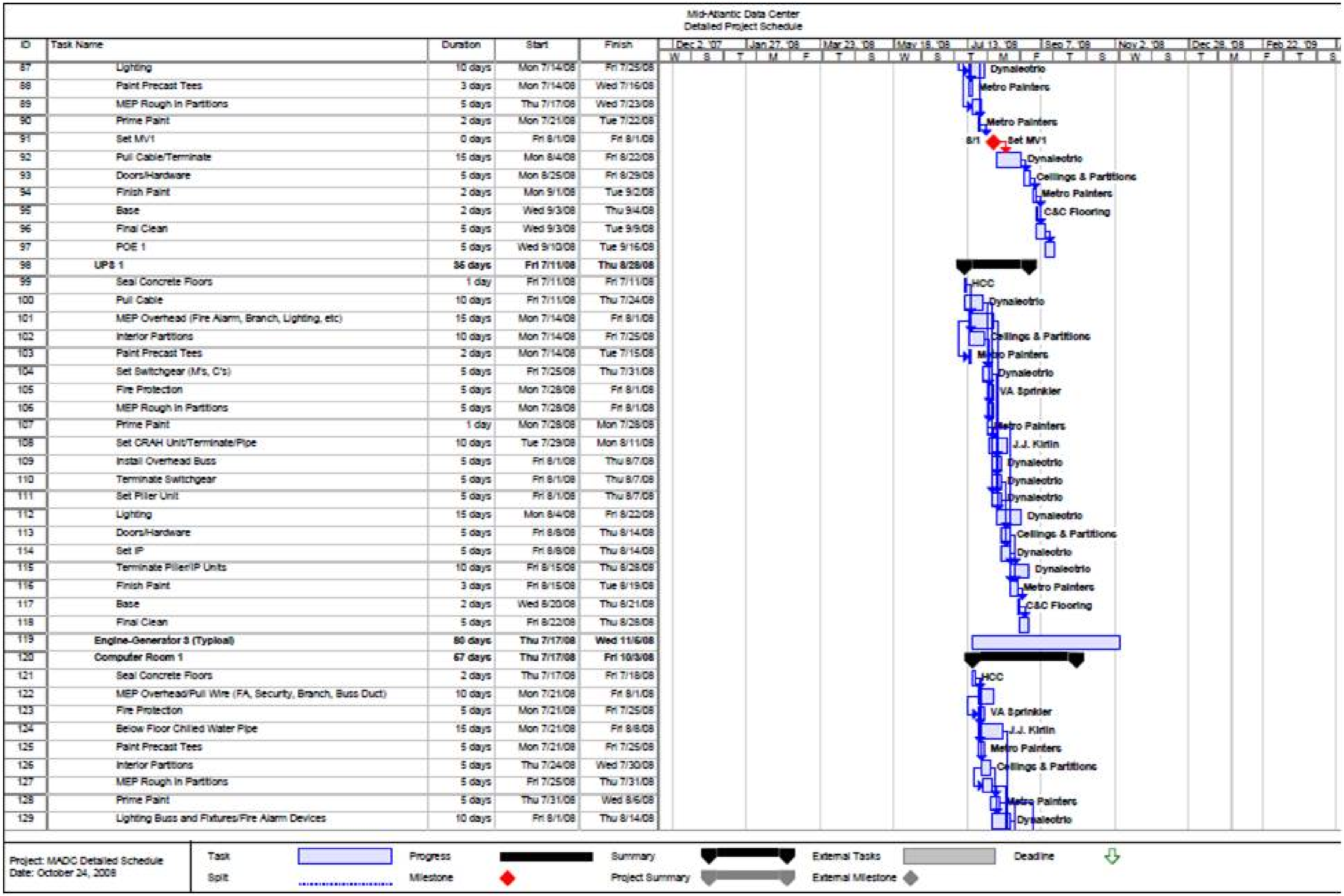
Task	▭	Progress	■	Summary	▼▬▼	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▼▬▼	External Milestone	◆		



Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
44	UPS Electrical Pits 6	32 days	Thu 7/3/08	Fri 8/15/08
45	Gen Room 7-8	17 days	Thu 7/10/08	Fri 8/1/08
46	UPS Electrical Pits 7	26 days	Fri 7/11/08	Fri 8/15/08
47	UPS Electrical Pits 8	26 days	Fri 7/11/08	Fri 8/15/08
48	Computer Room Sequence 6 (C-D 9-11)	24 days	Tue 7/15/08	Fri 8/15/08
49	Mechanical Room 2 Slab on Grade	28 days	Wed 7/16/08	Fri 8/22/08
50	Administration Area Slab On Grade	43 days	Fri 7/18/08	Tue 9/16/08
51	Phase II Slabs on Grade	109 days	Thu 9/11/08	Tue 2/10/09
52	**Topping Slabs**	**96 days**	**Wed 6/4/08**	**Tue 10/14/08**
53	**TES Tank**	**66 days**	**Thu 6/19/08**	**Wed 9/17/08**
54	**Caulking and Waterproofing/Textoote**	**136 days**	**Fri 6/6/08**	**Thu 11/13/08**
55	**Interiors**	**130 days**	**Fri 7/4/08**	**Thu 1/1/09**
56	**Engine-Generator 1**	**76 days**	**Fri 7/4/08**	**Fri 10/17/08**
57	Install Louvers/Attenuation/dampers/Plenums North Wall	15 days	Fri 7/4/08	Thu 7/24/08
58	MEP Overhead	5 days	Fri 7/4/08	Thu 7/10/08
59	Pour Concrete Fuel Curbs	2 days	Fri 7/4/08	Mon 7/7/08
60	Fire Protection	3 days	Mon 7/21/08	Wed 7/23/08
61	Interior Partitions	5 days	Mon 7/21/08	Fri 7/25/08
62	Set/Pipe Day Tanks EG 1A and 1B	15 days	Mon 7/21/08	Fri 8/8/08
63	MEP Rough In Partitions	5 days	Thu 7/24/08	Wed 7/30/08
64	Epoxy Membrane in Fuel Containment Curbs	2 days	Thu 7/24/08	Fri 7/25/08
65	Paint Precast Tees	2 days	Mon 7/28/08	Tue 7/29/08
66	Prime Paint	2 days	Mon 7/28/08	Tue 7/29/08
67	Lighting	15 days	Mon 7/28/08	Fri 8/15/08
68	Install Exhaust Supports and Mufflers/SCR's	15 days	Fri 8/8/08	Thu 8/28/08
69	Set EG 1A and 1B	5 days	Fri 8/29/08	Thu 9/4/08
70	Final Muffler Connections	2 days	Fri 9/5/08	Mon 9/8/08
71	Install Louvers/Attenuation/Dampers/Plenums South Wall	10 days	Fri 9/5/08	Thu 9/18/08
72	Pull Cable/Terminate EG 1A and 1B	20 days	Tue 9/9/08	Mon 10/6/08
73	Install Plenum From Radiator to Louvers	2 days	Fri 9/19/08	Mon 9/22/08
74	Finish Paint	3 days	Fri 9/19/08	Tue 9/23/08
75	Epoxy Generator RM Floors	5 days	Fri 9/19/08	Thu 9/25/08
76	Install Unit Heaters	5 days	Tue 9/23/08	Mon 9/29/08
77	Doors/Hardware	3 days	Tue 9/23/08	Thu 9/25/08
78	Complete Pneumatics	3 days	Tue 10/7/08	Thu 10/9/08
79	Base	1 day	Fri 10/10/08	Fri 10/10/08
80	Final Clean	5 days	Mon 10/13/08	Fri 10/17/08
81	**Engine-Generator 2 (Typical)**	**84 days**	**Fri 7/4/08**	**Wed 10/29/08**
82	**MV1**	**48 days**	**Fri 7/11/08**	**Tue 9/16/08**
83	Seal Concrete Floors	1 day	Fri 7/11/08	Fri 7/11/08
84	MEP Overhead	10 days	Mon 7/14/08	Fri 7/25/08
85	Fire Protection	5 days	Mon 7/14/08	Fri 7/18/08
86	Interior Partitions	5 days	Mon 7/14/08	Fri 7/18/08

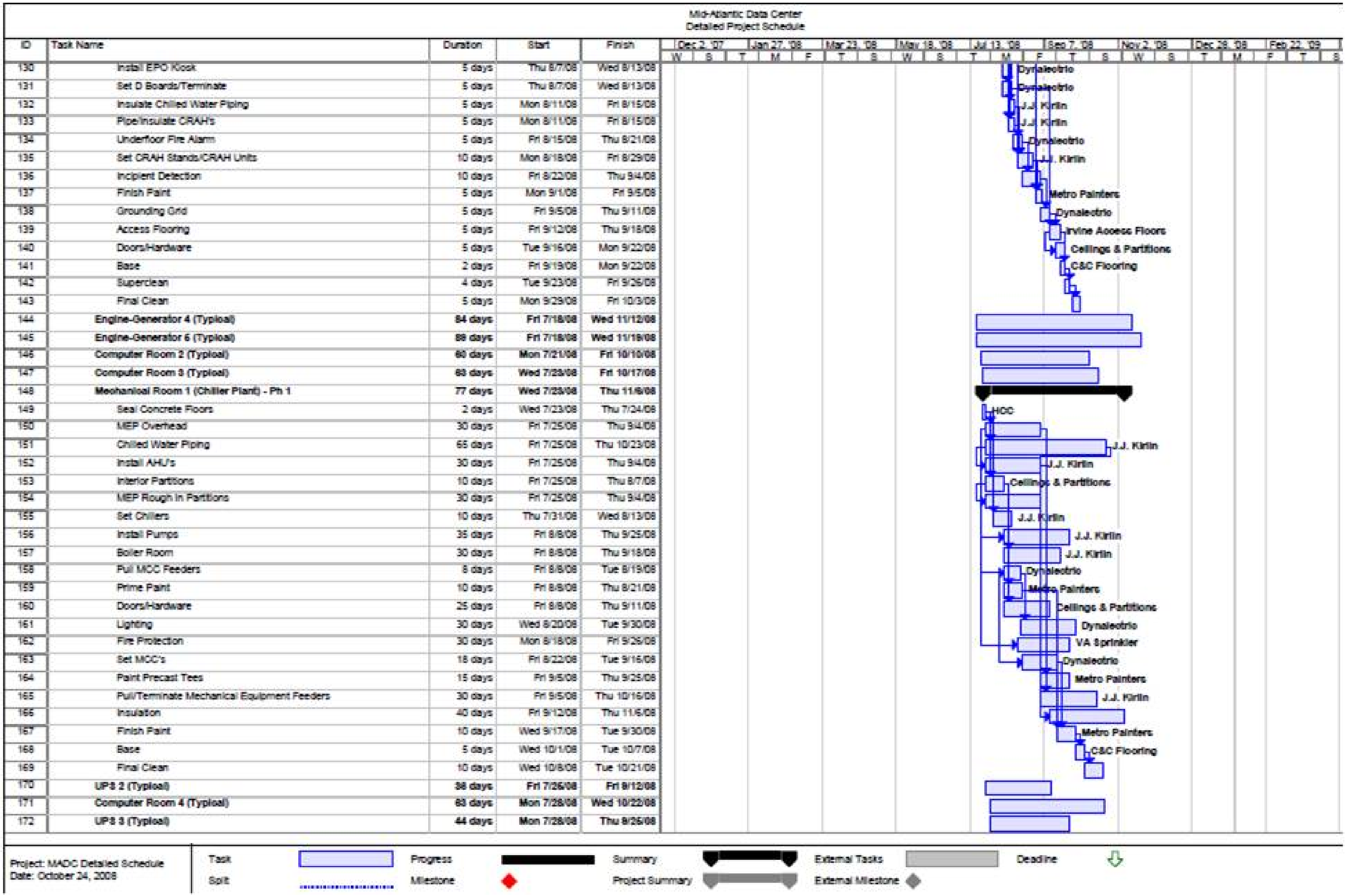
Project: MADC Detailed Schedule
Date: October 24, 2008



Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
87	Lighting	10 days	Mon 7/14/08	Fri 7/25/08
88	Paint Precast Tees	3 days	Mon 7/14/08	Wed 7/16/08
89	MEP Rough In Partitions	5 days	Thu 7/17/08	Wed 7/23/08
90	Prime Paint	2 days	Mon 7/21/08	Tue 7/22/08
91	Set MV1	0 days	Fri 8/1/08	Fri 8/1/08
92	Pull Cable/Terminate	15 days	Mon 8/4/08	Fri 8/22/08
93	Doors/Hardware	5 days	Mon 8/25/08	Fri 8/29/08
94	Finish Paint	2 days	Mon 9/1/08	Tue 9/2/08
95	Base	2 days	Wed 9/3/08	Thu 9/4/08
96	Final Clean	5 days	Wed 9/3/08	Tue 9/9/08
97	POE 1	5 days	Wed 9/10/08	Tue 9/16/08
98	**UPS 1**	**35 days**	**Fri 7/11/08**	**Thu 8/28/08**
99	Seal Concrete Floors	1 day	Fri 7/11/08	Fri 7/11/08
100	Pull Cable	10 days	Fri 7/11/08	Thu 7/24/08
101	MEP Overhead (Fire Alarm, Branch, Lighting, etc)	15 days	Mon 7/14/08	Fri 8/1/08
102	Interior Partitions	10 days	Mon 7/14/08	Fri 7/25/08
103	Paint Precast Tees	2 days	Mon 7/14/08	Tue 7/15/08
104	Set Switchgear (M's, C's)	5 days	Fri 7/25/08	Thu 7/31/08
105	Fire Protection	5 days	Mon 7/28/08	Fri 8/1/08
106	MEP Rough In Partitions	5 days	Mon 7/28/08	Fri 8/1/08
107	Prime Paint	1 day	Mon 7/28/08	Mon 7/28/08
108	Set CRAH Unit/Terminate/Pipe	10 days	Tue 7/29/08	Mon 8/11/08
109	Install Overhead Buss	5 days	Fri 8/1/08	Thu 8/7/08
110	Terminate Switchgear	5 days	Fri 8/1/08	Thu 8/7/08
111	Set Piller Unit	5 days	Fri 8/1/08	Thu 8/7/08
112	Lighting	15 days	Mon 8/4/08	Fri 8/22/08
113	Doors/Hardware	5 days	Fri 8/8/08	Thu 8/14/08
114	Set IP	5 days	Fri 8/8/08	Thu 8/14/08
115	Terminate Piller/IP Units	10 days	Fri 8/15/08	Thu 8/28/08
116	Finish Paint	3 days	Fri 8/15/08	Tue 8/19/08
117	Base	2 days	Wed 8/20/08	Thu 8/21/08
118	Final Clean	5 days	Fri 8/22/08	Thu 8/28/08
119	**Engine-Generator 3 (Typical)**	**80 days**	**Thu 7/17/08**	**Wed 11/5/08**
120	**Computer Room 1**	**57 days**	**Thu 7/17/08**	**Fri 10/3/08**
121	Seal Concrete Floors	2 days	Thu 7/17/08	Fri 7/18/08
122	MEP Overhead/Pull Wire (FA, Security, Branch, Buss Duct)	10 days	Mon 7/21/08	Fri 8/1/08
123	Fire Protection	5 days	Mon 7/21/08	Fri 7/25/08
124	Below Floor Chilled Water Pipe	15 days	Mon 7/21/08	Fri 8/8/08
125	Paint Precast Tees	5 days	Mon 7/21/08	Fri 7/25/08
126	Interior Partitions	5 days	Thu 7/24/08	Wed 7/30/08
127	MEP Rough In Partitions	5 days	Fri 7/25/08	Thu 7/31/08
128	Prime Paint	5 days	Thu 7/31/08	Wed 8/6/08
129	Lighting Buss and Fixtures/Fire Alarm Devices	10 days	Fri 8/1/08	Thu 8/14/08

Project: MADC Detailed Schedule
Date: October 24, 2008

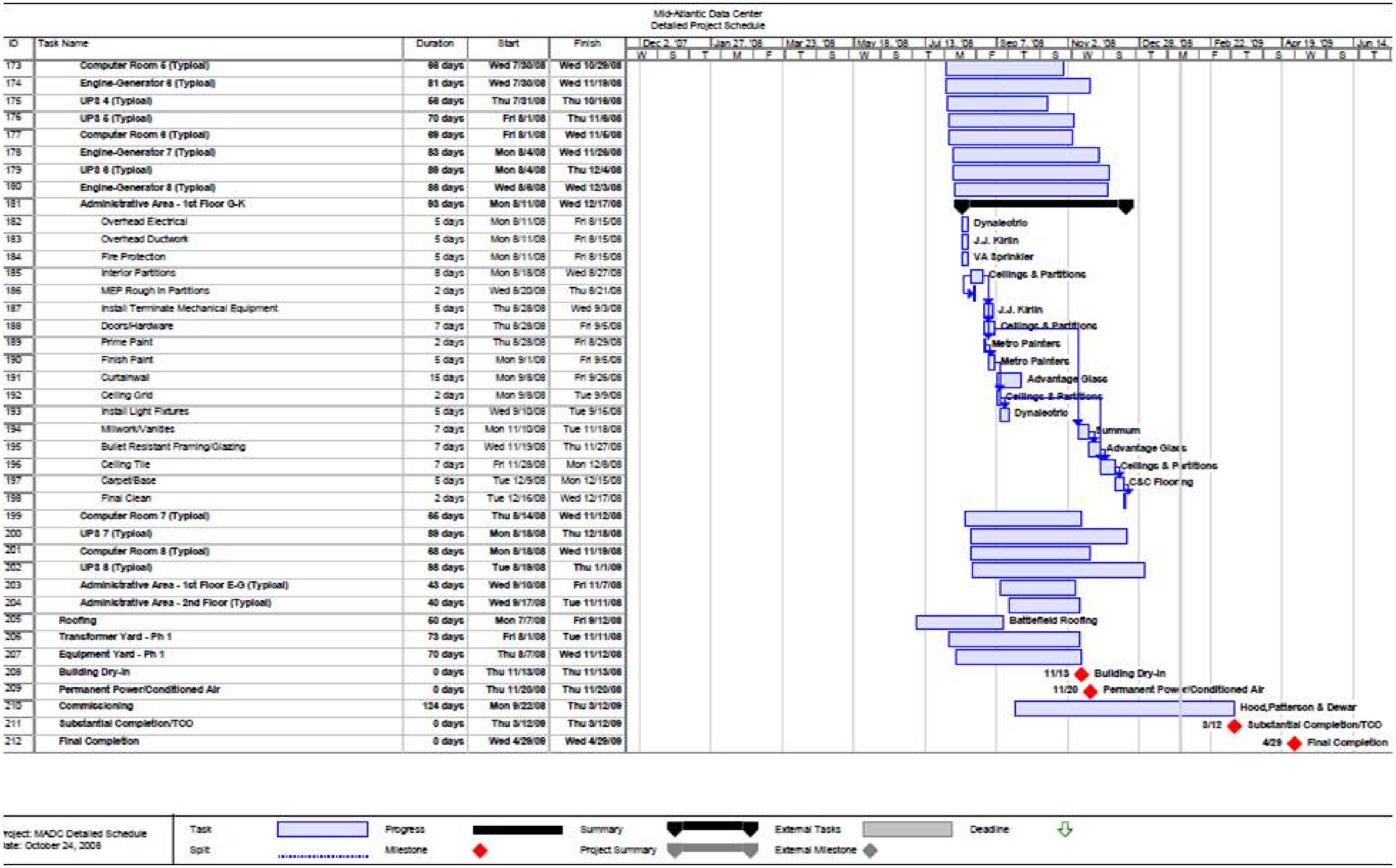


Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
130	Install EPO Kiosk	5 days	Thu 8/7/08	Wed 8/13/08
131	Set D Boards/Terminate	5 days	Thu 8/7/08	Wed 8/13/08
132	Insulate Chilled Water Piping	5 days	Mon 8/11/08	Fri 8/15/08
133	Pipe/Insulate CRAH's	5 days	Mon 8/11/08	Fri 8/15/08
134	Underfloor Fire Alarm	5 days	Fri 8/15/08	Thu 8/21/08
135	Set CRAH Stands/CRAH Units	10 days	Mon 8/18/08	Fri 8/29/08
136	Incipient Detection	10 days	Fri 8/22/08	Thu 9/4/08
137	Finish Paint	5 days	Mon 9/1/08	Fri 9/5/08
138	Grounding Grid	5 days	Fri 9/5/08	Thu 9/11/08
139	Access Flooring	5 days	Fri 9/12/08	Thu 9/18/08
140	Doors/Hardware	5 days	Tue 9/16/08	Mon 9/22/08
141	Base	2 days	Fri 9/19/08	Mon 9/22/08
142	Superclean	4 days	Tue 9/23/08	Fri 9/26/08
143	Final Clean	5 days	Mon 9/29/08	Fri 10/3/08
144	**Engine-Generator 4 (Typical)**	**84 days**	**Fri 7/18/08**	**Wed 11/12/08**
145	**Engine-Generator 6 (Typical)**	**89 days**	**Fri 7/18/08**	**Wed 11/19/08**
146	**Computer Room 2 (Typical)**	**60 days**	**Mon 7/21/08**	**Fri 10/10/08**
147	**Computer Room 3 (Typical)**	**63 days**	**Wed 7/23/08**	**Fri 10/17/08**
148	**Mechanical Room 1 (Chiller Plant) - Ph 1**	**77 days**	**Wed 7/23/08**	**Thu 11/6/08**
149	Seal Concrete Floors	2 days	Wed 7/23/08	Thu 7/24/08
150	MEP Overhead	30 days	Fri 7/25/08	Thu 9/4/08
151	Chilled Water Piping	65 days	Fri 7/25/08	Thu 10/23/08
152	Install AHU's	30 days	Fri 7/25/08	Thu 9/4/08
153	Interior Partitions	10 days	Fri 7/25/08	Thu 8/7/08
154	MEP Rough In Partitions	30 days	Fri 7/25/08	Thu 9/4/08
155	Set Chillers	10 days	Thu 7/31/08	Wed 8/13/08
156	Install Pumps	35 days	Fri 8/8/08	Thu 9/25/08
157	Boiler Room	30 days	Fri 8/8/08	Thu 9/18/08
158	Pull MCC Feeders	8 days	Fri 8/8/08	Tue 8/19/08
159	Prime Paint	10 days	Fri 8/8/08	Thu 8/21/08
160	Doors/Hardware	25 days	Fri 8/8/08	Thu 9/11/08
161	Lighting	30 days	Wed 8/20/08	Tue 9/30/08
162	Fire Protection	30 days	Mon 8/18/08	Fri 9/26/08
163	Set MCC's	18 days	Fri 8/22/08	Tue 9/16/08
164	Paint Precast Tees	15 days	Fri 9/5/08	Thu 9/25/08
165	Pull/Terminate Mechanical Equipment Feeders	30 days	Fri 9/5/08	Thu 10/16/08
166	Insulation	40 days	Fri 9/12/08	Thu 11/6/08
167	Finish Paint	10 days	Wed 9/17/08	Tue 9/30/08
168	Base	5 days	Wed 10/1/08	Tue 10/7/08
169	Final Clean	10 days	Wed 10/8/08	Tue 10/21/08
170	**UPS 2 (Typical)**	**36 days**	**Fri 7/25/08**	**Fri 9/12/08**
171	**Computer Room 4 (Typical)**	**63 days**	**Mon 7/28/08**	**Wed 10/22/08**
172	**UPS 3 (Typical)**	**44 days**	**Mon 7/28/08**	**Thu 9/25/08**

Project: MADC Detailed Schedule
Date: October 24, 2008

Task	▭	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩
Split	┅	Milestone	◆	Project Summary	▬	External Milestone	◆		



Mid-Atlantic Data Center
Detailed Project Schedule

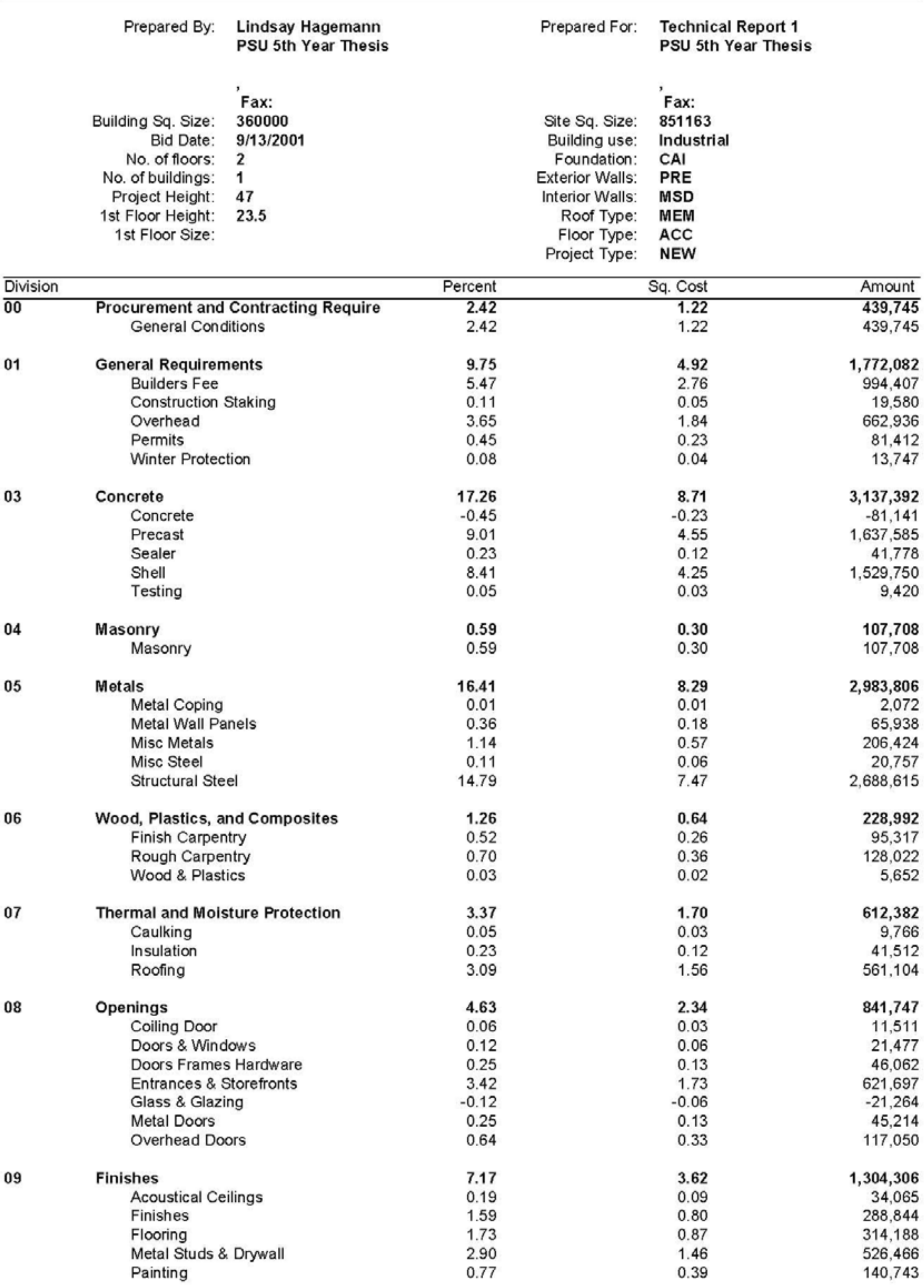
ID	Task Name	Duration	Start	Finish
173	**Computer Room 5 (Typical)**	**66 days**	**Wed 7/30/08**	**Wed 10/29/08**
174	**Engine-Generator 6 (Typical)**	**81 days**	**Wed 7/30/08**	**Wed 11/19/08**
175	**UPS 4 (Typical)**	**58 days**	**Thu 7/31/08**	**Thu 10/16/08**
176	**UPS 5 (Typical)**	**70 days**	**Fri 8/1/08**	**Thu 11/6/08**
177	**Computer Room 6 (Typical)**	**69 days**	**Fri 8/1/08**	**Wed 11/5/08**
178	**Engine-Generator 7 (Typical)**	**83 days**	**Mon 8/4/08**	**Wed 11/26/08**
179	**UPS 6 (Typical)**	**89 days**	**Mon 8/4/08**	**Thu 12/4/08**
180	**Engine-Generator 8 (Typical)**	**86 days**	**Wed 8/6/08**	**Wed 12/3/08**
181	**Administrative Area - 1st Floor G-K**	**93 days**	**Mon 8/11/08**	**Wed 12/17/08**
182	Overhead Electrical	5 days	Mon 8/11/08	Fri 8/15/08
183	Overhead Ductwork	5 days	Mon 8/11/08	Fri 8/15/08
184	Fire Protection	5 days	Mon 8/11/08	Fri 8/15/08
185	Interior Partitions	8 days	Mon 8/18/08	Wed 8/27/08
186	MEP Rough In Partitions	2 days	Wed 8/20/08	Thu 8/21/08
187	Install Terminate Mechanical Equipment	5 days	Thu 8/28/08	Wed 9/3/08
188	Doors/Hardware	7 days	Thu 8/28/08	Fri 9/5/08
189	Prime Paint	2 days	Thu 8/28/08	Fri 8/29/08
190	Finish Paint	5 days	Mon 9/1/08	Fri 9/5/08
191	Curtainwall	15 days	Mon 9/8/08	Fri 9/26/08
192	Ceiling Grid	2 days	Mon 9/8/08	Tue 9/9/08
193	Install Light Fixtures	5 days	Wed 9/10/08	Tue 9/16/08
194	Millwork/Vanities	7 days	Mon 11/10/08	Tue 11/18/08
195	Bullet Resistant Framing/Glazing	7 days	Wed 11/19/08	Thu 11/27/08
196	Ceiling Tile	7 days	Fri 11/28/08	Mon 12/8/08
197	Carpet/Base	5 days	Tue 12/9/08	Mon 12/15/08
198	Final Clean	2 days	Tue 12/16/08	Wed 12/17/08
199	**Computer Room 7 (Typical)**	**66 days**	**Thu 8/14/08**	**Wed 11/12/08**
200	**UPS 7 (Typical)**	**89 days**	**Mon 8/18/08**	**Thu 12/18/08**
201	**Computer Room 8 (Typical)**	**68 days**	**Mon 8/18/08**	**Wed 11/19/08**
202	**UPS 8 (Typical)**	**98 days**	**Tue 8/19/08**	**Thu 1/1/09**
203	**Administrative Area - 1st Floor E-G (Typical)**	**43 days**	**Wed 9/10/08**	**Fri 11/7/08**
204	**Administrative Area - 2nd Floor (Typical)**	**40 days**	**Wed 9/17/08**	**Tue 11/11/08**
205	**Roofing**	**50 days**	**Mon 7/7/08**	**Fri 9/12/08**
206	**Transformer Yard - Ph 1**	**73 days**	**Fri 8/1/08**	**Tue 11/11/08**
207	**Equipment Yard - Ph 1**	**70 days**	**Thu 8/7/08**	**Wed 11/12/08**
208	**Building Dry-In**	**0 days**	**Thu 11/13/08**	**Thu 11/13/08**
209	**Permanent Power/Conditioned Air**	**0 days**	**Thu 11/20/08**	**Thu 11/20/08**
210	**Commissioning**	**124 days**	**Mon 9/22/08**	**Thu 3/12/09**
211	**Substantial Completion/TCO**	**0 days**	**Thu 3/12/09**	**Thu 3/12/09**
212	**Final Completion**	**0 days**	**Wed 4/29/09**	**Wed 4/29/09**

roject: MADC Detailed Schedule
ate: October 24, 2008

Appendix C | Project Cost Evaluation

D4Cost, RS Means Square Foot, General Conditions, and Detailed Structural Systems cost estimate data can be found on the following pages.

D4Cost Estimate



Prepared By:	**Lindsay Hagemann** **PSU 5th Year Thesis**	Prepared For:	**Technical Report 1** **PSU 5th Year Thesis**
	, **Fax:**		**,** **Fax:**
Building Sq. Size:	**360000**	Site Sq. Size:	**851163**
Bid Date:	**9/13/2001**	Building use:	**Industrial**
No. of floors:	**2**	Foundation:	**CAI**
No. of buildings:	**1**	Exterior Walls:	**PRE**
Project Height:	**47**	Interior Walls:	**MSD**
1st Floor Height:	**23.5**	Roof Type:	**MEM**
1st Floor Size:		Floor Type:	**ACC**
		Project Type:	**NEW**

Division		Percent	Sq. Cost	Amount
00	**Procurement and Contracting Require**	**2.42**	**1.22**	**439,745**
	General Conditions	2.42	1.22	439,745
01	**General Requirements**	**9.75**	**4.92**	**1,772,082**
	Builders Fee	5.47	2.76	994,407
	Construction Staking	0.11	0.05	19,580
	Overhead	3.65	1.84	662,936
	Permits	0.45	0.23	81,412
	Winter Protection	0.08	0.04	13,747
03	**Concrete**	**17.26**	**8.71**	**3,137,392**
	Concrete	-0.45	-0.23	-81,141
	Precast	9.01	4.55	1,637,585
	Sealer	0.23	0.12	41,778
	Shell	8.41	4.25	1,529,750
	Testing	0.05	0.03	9,420
04	**Masonry**	**0.59**	**0.30**	**107,708**
	Masonry	0.59	0.30	107,708
05	**Metals**	**16.41**	**8.29**	**2,983,806**
	Metal Coping	0.01	0.01	2,072
	Metal Wall Panels	0.36	0.18	65,938
	Misc Metals	1.14	0.57	206,424
	Misc Steel	0.11	0.06	20,757
	Structural Steel	14.79	7.47	2,688,615
06	**Wood, Plastics, and Composites**	**1.26**	**0.64**	**228,992**
	Finish Carpentry	0.52	0.26	95,317
	Rough Carpentry	0.70	0.36	128,022
	Wood & Plastics	0.03	0.02	5,652
07	**Thermal and Moisture Protection**	**3.37**	**1.70**	**612,382**
	Caulking	0.05	0.03	9,766
	Insulation	0.23	0.12	41,512
	Roofing	3.09	1.56	561,104
08	**Openings**	**4.63**	**2.34**	**841,747**
	Coiling Door	0.06	0.03	11,511
	Doors & Windows	0.12	0.06	21,477
	Doors Frames Hardware	0.25	0.13	46,062
	Entrances & Storefronts	3.42	1.73	621,697
	Glass & Glazing	-0.12	-0.06	-21,264
	Metal Doors	0.25	0.13	45,214
	Overhead Doors	0.64	0.33	117,050
09	**Finishes**	**7.17**	**3.62**	**1,304,306**
	Acoustical Ceilings	0.19	0.09	34,065
	Finishes	1.59	0.80	288,844
	Flooring	1.73	0.87	314,188
	Metal Studs & Drywall	2.90	1.46	526,466
	Painting	0.77	0.39	140,743

10	**Specialties**	**0.43**	**0.22**	**77,597**
	Specialties	0.21	0.11	38,035
	Toilet Partitions & Accessories	0.22	0.11	39,563
11	**Equipment**	**0.02**	**0.01**	**4,374**
	Equipment	0.02	0.01	4,374
14	**Conveying Systems**	**0.33**	**0.16**	**59,108**
	Elevators	0.33	0.16	59,108
21	**Fire Suppression**	**1.63**	**0.82**	**296,229**
	Sprinkler	1.63	0.82	296,229
22	**Plumbing**	**4.44**	**2.24**	**806,680**
	Plumbing	4.44	2.24	806,680
23	**HVAC**	**19.01**	**9.60**	**3,455,731**
	HVAC	19.01	9.60	3,455,731
26	**Electrical**	**11.29**	**5.70**	**2,051,989**
	Electrical	11.29	5.70	2,051,989
Total Building Costs		**100.00**	**50.50**	**18,179,868**
02	**Existing Conditions**	**100.00**	**1.64**	**1,400,000**
	Site Work	100.00	1.64	1,400,000
Total Non-Building Costs		**100.00**	**1.64**	**1,400,000**
Total Project Costs		**--**	**--**	**19,579,868**

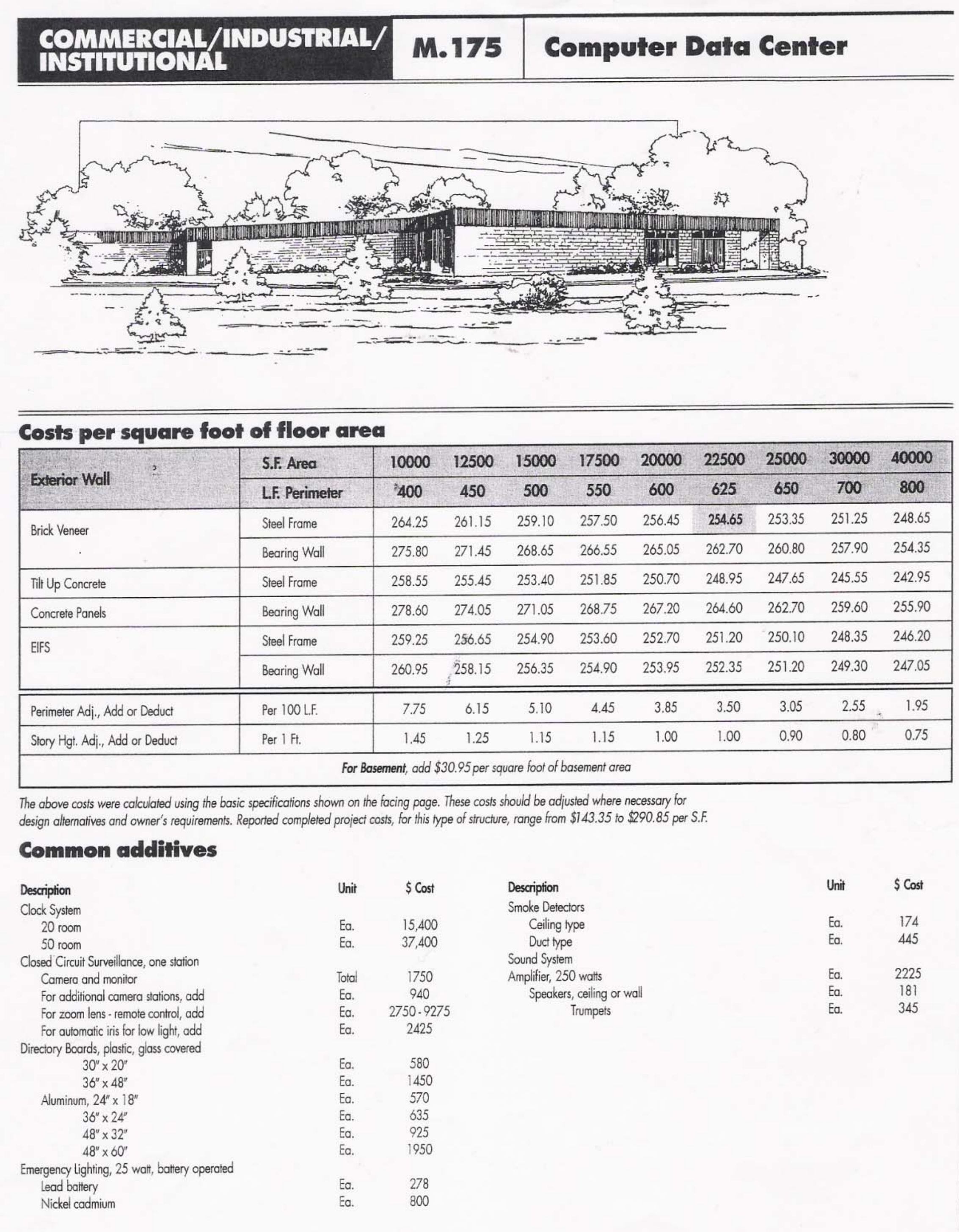
Brief Summary of Siemens Westinghouse Fuel Cell Facility

From the early stages of the project, Siemens embraced the goals of achieving LEED(R) 2.0/2.1 Certification for the entire building, which includes a two-story office and one-story high-bay manufacturing area for a total of 190,000 square feet. Conference rooms, laboratories, cafeteria, restrooms and other support spaces are included in the office wing.

The perimeter walls are 8-inch precast concrete walls with insulation integral to each panel, and are considered as mass walls. The insulated precast wall panels achieve an effective u-value which is 5% more efficient than what is required. The largest energy saving feature of the building's skin is the vertical glazing system. The total glazing area is 19% of the gross wall area, and conducts 16% less heat than the required glazing.

The heating, ventilating, and air conditioning (HVAC) systems serving the building consist of a chilled water plant, hydronic hot water boiler plant, ten constant volume air handling units for air distribution and ventilation in the manufacturing area, and a variable air volume, roof top air handling unit serving the office and laboratory areas.

RS Means Square Foot Estimate



COMMERCIAL/INDUSTRIAL/ INSTITUTIONAL | **M.175** | **Computer Data Center**

Costs per square foot of floor area

Exterior Wall	S.F. Area	10000	12500	15000	17500	20000	22500	25000	30000	40000
	L.F. Perimeter	400	450	500	550	600	625	650	700	800
Brick Veneer	Steel Frame	264.25	261.15	259.10	257.50	256.45	254.65	253.35	251.25	248.65
	Bearing Wall	275.80	271.45	268.65	266.55	265.05	262.70	260.80	257.90	254.35
Tilt Up Concrete	Steel Frame	258.55	255.45	253.40	251.85	250.70	248.95	247.65	245.55	242.95
Concrete Panels	Bearing Wall	278.60	274.05	271.05	268.75	267.20	264.60	262.70	259.60	255.90
EIFS	Steel Frame	259.25	256.65	254.90	253.60	252.70	251.20	250.10	248.35	246.20
	Bearing Wall	260.95	258.15	256.35	254.90	253.95	252.35	251.20	249.30	247.05
Perimeter Adj., Add or Deduct	Per 100 L.F.	7.75	6.15	5.10	4.45	3.85	3.50	3.05	2.55	1.95
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	1.45	1.25	1.15	1.15	1.00	1.00	0.90	0.80	0.75
***For Basement**, add $30.95 per square foot of basement area*										

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements. Reported completed project costs, for this type of structure, range from $143.35 to $290.85 per S.F.

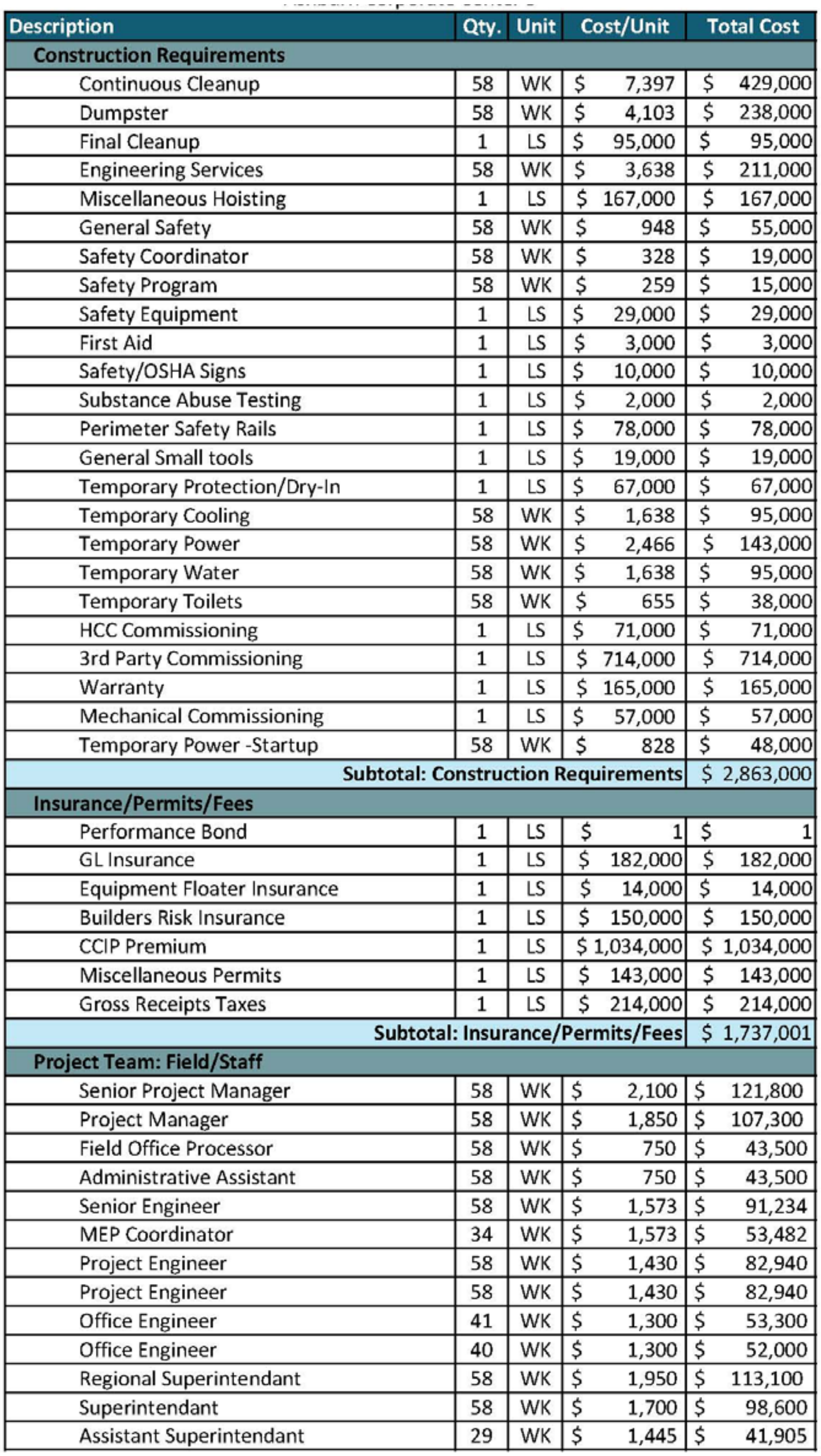
Common additives

Description	**Unit**	**$ Cost**
Clock System		
20 room	Ea.	15,400
50 room	Ea.	37,400
Closed Circuit Surveillance, one station		
Camera and monitor	Total	1750
For additional camera stations, add	Ea.	940
For zoom lens - remote control, add	Ea.	2750 - 9275
For automatic iris for low light, add	Ea.	2425
Directory Boards, plastic, glass covered		
30" x 20"	Ea.	580
36" x 48"	Ea.	1450
Aluminum, 24" x 18"	Ea.	570
36" x 24"	Ea.	635
48" x 32"	Ea.	925
48" x 60"	Ea.	1950
Emergency Lighting, 25 watt, battery operated		
Lead battery	Ea.	278
Nickel cadmium	Ea.	800

Description	**Unit**	**$ Cost**
Smoke Detectors		
Ceiling type	Ea.	174
Duct type	Ea.	445
Sound System		
Amplifier, 250 watts	Ea.	2225
Speakers, ceiling or wall	Ea.	181
Trumpets	Ea.	345

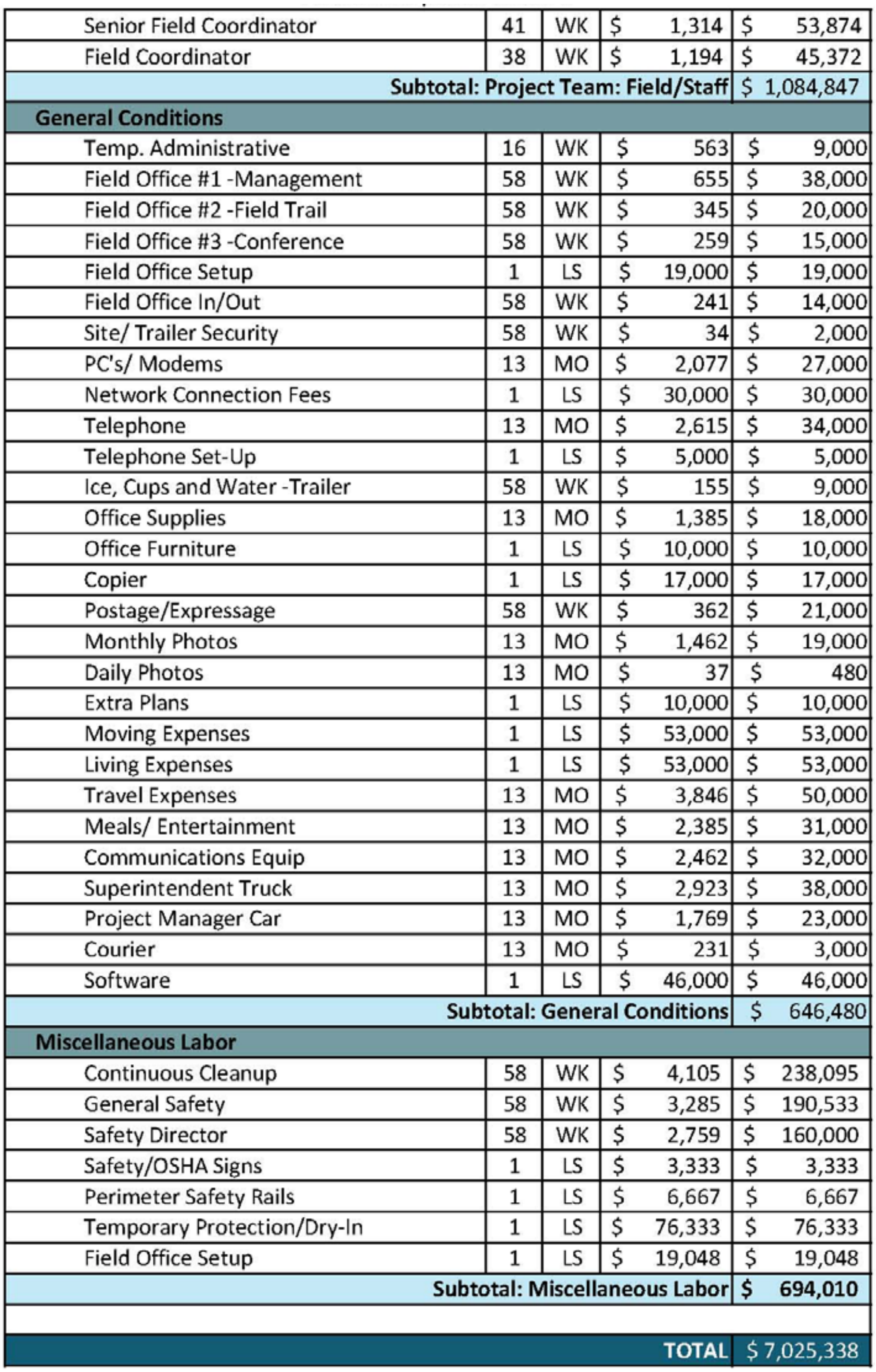
General Conditions Cost Estimate

Table 26 - General Conditions Estimate p.1



Description	Qty.	Unit	Cost/Unit	Total Cost
Construction Requirements				
Continuous Cleanup	58	WK	$ 7,397	$ 429,000
Dumpster	58	WK	$ 4,103	$ 238,000
Final Cleanup	1	LS	$ 95,000	$ 95,000
Engineering Services	58	WK	$ 3,638	$ 211,000
Miscellaneous Hoisting	1	LS	$ 167,000	$ 167,000
General Safety	58	WK	$ 948	$ 55,000
Safety Coordinator	58	WK	$ 328	$ 19,000
Safety Program	58	WK	$ 259	$ 15,000
Safety Equipment	1	LS	$ 29,000	$ 29,000
First Aid	1	LS	$ 3,000	$ 3,000
Safety/OSHA Signs	1	LS	$ 10,000	$ 10,000
Substance Abuse Testing	1	LS	$ 2,000	$ 2,000
Perimeter Safety Rails	1	LS	$ 78,000	$ 78,000
General Small tools	1	LS	$ 19,000	$ 19,000
Temporary Protection/Dry-In	1	LS	$ 67,000	$ 67,000
Temporary Cooling	58	WK	$ 1,638	$ 95,000
Temporary Power	58	WK	$ 2,466	$ 143,000
Temporary Water	58	WK	$ 1,638	$ 95,000
Temporary Toilets	58	WK	$ 655	$ 38,000
HCC Commissioning	1	LS	$ 71,000	$ 71,000
3rd Party Commissioning	1	LS	$ 714,000	$ 714,000
Warranty	1	LS	$ 165,000	$ 165,000
Mechanical Commissioning	1	LS	$ 57,000	$ 57,000
Temporary Power -Startup	58	WK	$ 828	$ 48,000
			Subtotal: Construction Requirements	$ 2,863,000
Insurance/Permits/Fees				
Performance Bond	1	LS	$ 1	$ 1
GL Insurance	1	LS	$ 182,000	$ 182,000
Equipment Floater Insurance	1	LS	$ 14,000	$ 14,000
Builders Risk Insurance	1	LS	$ 150,000	$ 150,000
CCIP Premium	1	LS	$ 1,034,000	$ 1,034,000
Miscellaneous Permits	1	LS	$ 143,000	$ 143,000
Gross Receipts Taxes	1	LS	$ 214,000	$ 214,000
			Subtotal: Insurance/Permits/Fees	$ 1,737,001
Project Team: Field/Staff				
Senior Project Manager	58	WK	$ 2,100	$ 121,800
Project Manager	58	WK	$ 1,850	$ 107,300
Field Office Processor	58	WK	$ 750	$ 43,500
Administrative Assistant	58	WK	$ 750	$ 43,500
Senior Engineer	58	WK	$ 1,573	$ 91,234
MEP Coordinator	34	WK	$ 1,573	$ 53,482
Project Engineer	58	WK	$ 1,430	$ 82,940
Project Engineer	58	WK	$ 1,430	$ 82,940
Office Engineer	41	WK	$ 1,300	$ 53,300
Office Engineer	40	WK	$ 1,300	$ 52,000
Regional Superintendant	58	WK	$ 1,950	$ 113,100
Superintendant	58	WK	$ 1,700	$ 98,600
Assistant Superintendant	29	WK	$ 1,445	$ 41,905

Table 27 - General Conditions Estimate p.2



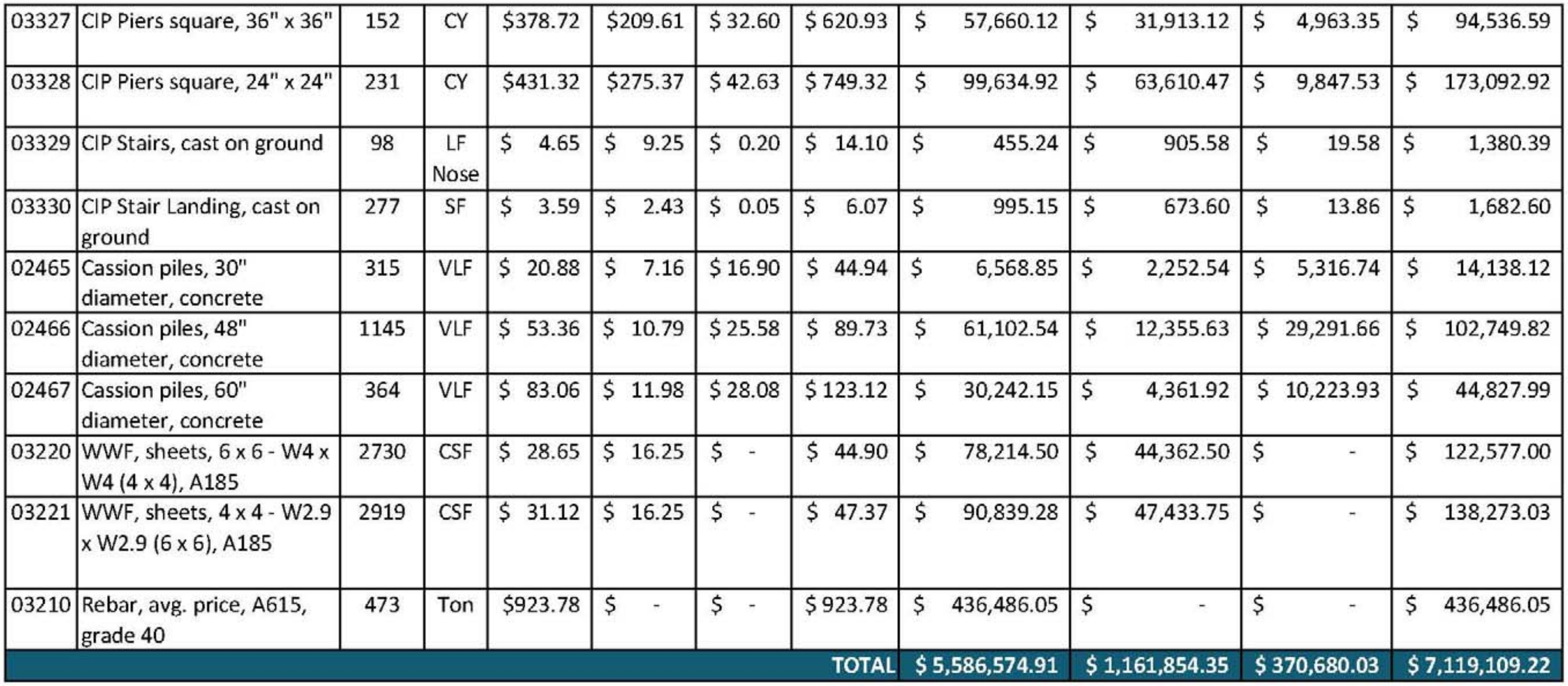
Senior Field Coordinator	41	WK	$ 1,314	$ 53,874
Field Coordinator	38	WK	$ 1,194	$ 45,372
			Subtotal: Project Team: Field/Staff	$ 1,084,847
General Conditions				
Temp. Administrative	16	WK	$ 563	$ 9,000
Field Office #1 -Management	58	WK	$ 655	$ 38,000
Field Office #2 -Field Trail	58	WK	$ 345	$ 20,000
Field Office #3 -Conference	58	WK	$ 259	$ 15,000
Field Office Setup	1	LS	$ 19,000	$ 19,000
Field Office In/Out	58	WK	$ 241	$ 14,000
Site/ Trailer Security	58	WK	$ 34	$ 2,000
PC's/ Modems	13	MO	$ 2,077	$ 27,000
Network Connection Fees	1	LS	$ 30,000	$ 30,000
Telephone	13	MO	$ 2,615	$ 34,000
Telephone Set-Up	1	LS	$ 5,000	$ 5,000
Ice, Cups and Water -Trailer	58	WK	$ 155	$ 9,000
Office Supplies	13	MO	$ 1,385	$ 18,000
Office Furniture	1	LS	$ 10,000	$ 10,000
Copier	1	LS	$ 17,000	$ 17,000
Postage/Expressage	58	WK	$ 362	$ 21,000
Monthly Photos	13	MO	$ 1,462	$ 19,000
Daily Photos	13	MO	$ 37	$ 480
Extra Plans	1	LS	$ 10,000	$ 10,000
Moving Expenses	1	LS	$ 53,000	$ 53,000
Living Expenses	1	LS	$ 53,000	$ 53,000
Travel Expenses	13	MO	$ 3,846	$ 50,000
Meals/ Entertainment	13	MO	$ 2,385	$ 31,000
Communications Equip	13	MO	$ 2,462	$ 32,000
Superintendent Truck	13	MO	$ 2,923	$ 38,000
Project Manager Car	13	MO	$ 1,769	$ 23,000
Courier	13	MO	$ 231	$ 3,000
Software	1	LS	$ 46,000	$ 46,000
			Subtotal: General Conditions	$ 646,480
Miscellaneous Labor				
Continuous Cleanup	58	WK	$ 4,105	$ 238,095
General Safety	58	WK	$ 3,285	$ 190,533
Safety Director	58	WK	$ 2,759	$ 160,000
Safety/OSHA Signs	1	LS	$ 3,333	$ 3,333
Perimeter Safety Rails	1	LS	$ 6,667	$ 6,667
Temporary Protection/Dry-In	1	LS	$ 76,333	$ 76,333
Field Office Setup	1	LS	$ 19,048	$ 19,048
			Subtotal: Miscellaneous Labor	**$ 694,010**
			TOTAL	$ 7,025,338

DETAILED STRUCTURAL SYSTEMS COST ESTIMATE

Table 28 - Caisson & Concrete Estimate – pg 1

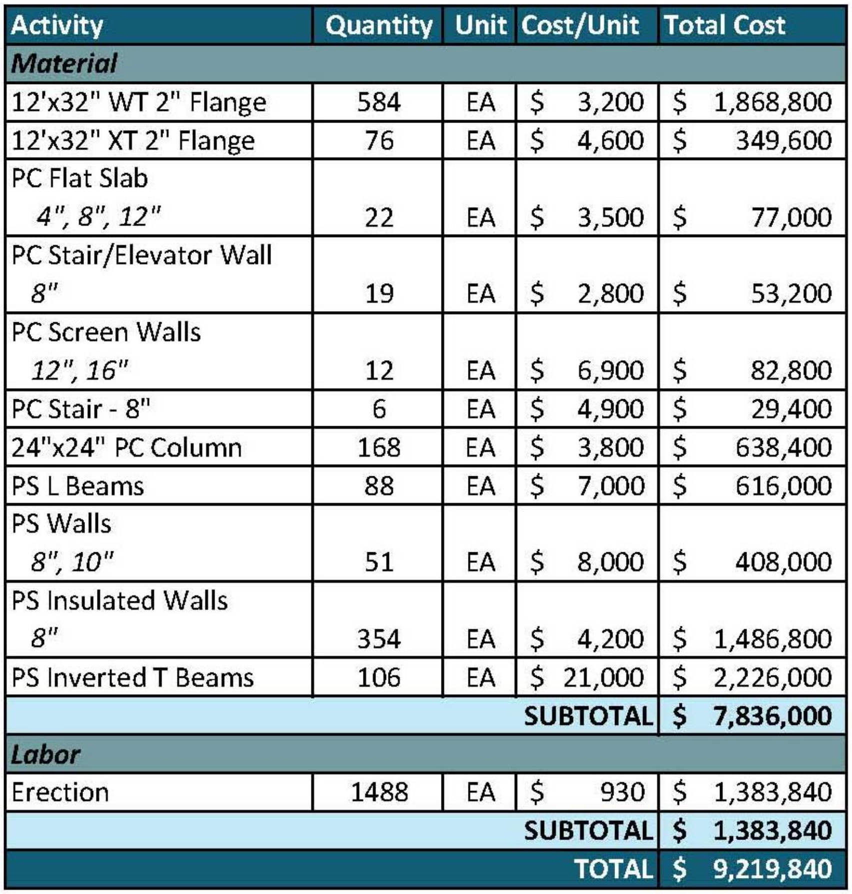
Div.	Description	Qty	Unit	Mat'l	Labor	Equip.	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
03310	3000 psi concrete	9790	CY	$105.20	$ -	$ -	$ 105.20	$ 1,029,855.40	$ -	$ -	$ 1,029,855.40
03311	3500 psi concrete	2167	CY	$108.36	$ -	$ -	$ 108.36	$ 234,761.94	$ -	$ -	$ 234,761.94
03312	4000 psi concrete	674	CY	$111.51	$ -	$ -	$ 111.51	$ 75,129.86	$ -	$ -	$ 75,129.86
03313	5000 psi concrete	6204	CY	$114.67	$ -	$ -	$ 114.67	$ 711,384.01	$ -	$ -	$ 711,384.01
03314	Placing, topping slab, pumped, <6" thick	5343	CY	$ -	$ 9.45	$ 5.57	$ 15.02	$ -	$ 50,488.99	$ 29,759.12	$ 80,248.11
03315	Placing, topping slab, pumped, 6"-10" thick	1594	CY	$ -	$ 8.26	$ 4.87	$ 13.13	$ -	$ 13,168.51	$ 7,764.00	$ 20,932.50
03316	Placing, continuous footing, pumped	648	CY	$ -	$ 8.84	$ 5.22	$ 14.06	$ -	$ 5,723.90	$ 3,379.95	$ 9,103.85
03317	Placing, grade beam, pumped	674	CY	$ -	$ 7.36	$ 4.33	$ 11.69	$ -	$ 4,958.80	$ 2,917.34	$ 7,876.14
03318	Placing, SOG, pumped, up to 6" thick	12143	CY	$ -	$ 10.19	$ 6.02	$ 16.21	$ -	$ 123,739.72	$ 73,102.37	$ 196,842.08
03319	Placing, SOG, pumped, over 6" thick	3442	CY	$ -	$ 7.15	$ 4.21	$ 11.36	$ -	$ 24,612.09	$ 14,491.87	$ 39,103.96
03320	Placing, spread footing, pumped	1526	CY	$ -	$ 20.55	$ 11.99	$ 32.54	$ -	$ 31,359.30	$ 18,296.74	$ 49,656.04
03321	CIP, topping slab, 4" slab	471508	SF	$ 1.43	$ 0.46	$ 0.28	$ 2.17	$ 674,257.08	$ 216,893.89	$ 132,022.37	$ 1,023,173.34
03322	CIP, topping slab, 6" slab	76167	SF	$ 2.13	$ 0.47	$ 0.28	$ 2.88	$ 162,235.71	$ 35,798.49	$ 21,326.76	$ 219,360.96
03323	CIP, spread footing	1308	CY	$201.98	$ 60.83	$ 0.57	$ 263.38	$ 264,189.84	$ 79,565.64	$ 745.56	$ 344,501.04
03324	CIP, continuous strip footing, 24" x 12"	648	CY	$139.92	$ 54.25	$ 0.51	$ 194.68	$ 90,598.20	$ 35,126.88	$ 330.23	$ 126,055.30
03325	CIP, slab on grade, 6" thick	589057	SF	$ 2.05	$ 0.48	$ 0.01	$ 2.54	$ 1,207,567.57	$ 282,747.53	$ 5,890.57	$ 1,496,205.67
03326	CIP, slab on grade, 8" thick	97650	SF	$ 2.81	$ 0.51	$ 0.01	$ 3.33	$ 274,396.50	$ 49,801.50	$ 976.50	$ 325,174.50

Table 29 - Caisson & Concrete Estimate - pg 2



03327	CIP Piers square, 36" x 36"	152	CY	$378.72	$209.61	$ 32.60	$ 620.93	$ 57,660.12	$ 31,913.12	$ 4,963.35	$ 94,536.59
03328	CIP Piers square, 24" x 24"	231	CY	$431.32	$275.37	$ 42.63	$ 749.32	$ 99,634.92	$ 63,610.47	$ 9,847.53	$ 173,092.92
03329	CIP Stairs, cast on ground	98	LF Nose	$ 4.65	$ 9.25	$ 0.20	$ 14.10	$ 455.24	$ 905.58	$ 19.58	$ 1,380.39
03330	CIP Stair Landing, cast on ground	277	SF	$ 3.59	$ 2.43	$ 0.05	$ 6.07	$ 995.15	$ 673.60	$ 13.86	$ 1,682.60
02465	Cassion piles, 30" diameter, concrete	315	VLF	$ 20.88	$ 7.16	$ 16.90	$ 44.94	$ 6,568.85	$ 2,252.54	$ 5,316.74	$ 14,138.12
02466	Cassion piles, 48" diameter, concrete	1145	VLF	$ 53.36	$ 10.79	$ 25.58	$ 89.73	$ 61,102.54	$ 12,355.63	$ 29,291.66	$ 102,749.82
02467	Cassion piles, 60" diameter, concrete	364	VLF	$ 83.06	$ 11.98	$ 28.08	$ 123.12	$ 30,242.15	$ 4,361.92	$ 10,223.93	$ 44,827.99
03220	WWF, sheets, 6 x 6 - W4 x W4 (4 x 4), A185	2730	CSF	$ 28.65	$ 16.25	$ -	$ 44.90	$ 78,214.50	$ 44,362.50	$ -	$ 122,577.00
03221	WWF, sheets, 4 x 4 - W2.9 x W2.9 (6 x 6), A185	2919	CSF	$ 31.12	$ 16.25	$ -	$ 47.37	$ 90,839.28	$ 47,433.75	$ -	$ 138,273.03
03210	Rebar, avg. price, A615, grade 40	473	Ton	$923.78	$ -	$ -	$ 923.78	$ 436,486.05	$ -	$ -	$ 436,486.05
							TOTAL	$ 5,586,574.91	$ 1,161,854.35	$ 370,680.03	$ 7,119,109.22

Table 30 - Precast Estimate



Activity	Quantity	Unit	Cost/Unit	Total Cost
Material				
12'x32" WT 2" Flange	584	EA	$ 3,200	$ 1,868,800
12'x32" XT 2" Flange	76	EA	$ 4,600	$ 349,600
PC Flat Slab *4", 8", 12"*	22	EA	$ 3,500	$ 77,000
PC Stair/Elevator Wall *8"*	19	EA	$ 2,800	$ 53,200
PC Screen Walls *12", 16"*	12	EA	$ 6,900	$ 82,800
PC Stair - 8"	6	EA	$ 4,900	$ 29,400
24"x24" PC Column	168	EA	$ 3,800	$ 638,400
PS L Beams	88	EA	$ 7,000	$ 616,000
PS Walls *8", 10"*	51	EA	$ 8,000	$ 408,000
PS Insulated Walls *8"*	354	EA	$ 4,200	$ 1,486,800
PS Inverted T Beams	106	EA	$ 21,000	$ 2,226,000
			SUBTOTAL	**$ 7,836,000**
Labor				
Erection	1488	EA	$ 930	$ 1,383,840
			SUBTOTAL	**$ 1,383,840**
			TOTAL	**$ 9,219,840**

Appendix D | Analysis I Information

Cost Projection Spreadsheets for the Critical Industry Analysis can be found on the following pages.

DFT INCOME PER MONTH

Building	Power (MW)	Lease Rate ($/mo/KW)	% Leased	Total ($/mo)
Complete				
VA3	10	$ 126.00	100%	$ 1,260,000
VA4	12	$ 126.00	100%	$ 1,512,000
MADC2	10	$ 126.00	100%	$ 1,260,000
MADC3	13	$ 126.00	100%	$ 1,638,000
MADC4	36.4	$ 126.00	100%	$ 4,586,400
CH1	18.2	$ 126.00	20%	$ 458,640
			SUBTOTAL	$ 10,715,040
Construction				
MADC5	36.4	$ 126.00	100%	$ 4,586,400
NEDC	36.4	$ 126.00	100%	$ 4,586,400
NWDC	36.4	$ 126.00	100%	$ 4,586,400
			SUBTOTAL	$ 13,759,200

Original Project - Cost Projection

Total: Dec 07 - Apr 10	**2007**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**
Const: Feb 08 - Sept 09	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
MADC5	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)
NJ 1	$ -	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)
NWDC	$ -	$ -	$ -	$ -	$ -	$ (1,959,000)	$ (8,075,000)	$ (7,231,000)	$ (6,176,000)	$ (10,534,000)	$ (13,796,000)	$ (14,602,000)	$ (18,238,000)
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040
DFT Cash Flow	**$ 7,592,040**	**$ 9,503,080**	**$ 11,635,120**	**$ 12,120,160**	**$ 2,887,200**	**$ (8,083,760)**	**$ (26,070,720)**	**$ (50,449,680)**	**$ (74,251,640)**	**$ (104,625,600)**	**$ (139,697,560)**	**$ (172,730,520)**	**$ (207,818,480)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End													
NJ 1 Start/End									*Stop NWDC*		*Stop NEDC*	*Stop MADC5*	
NWDC Start/End													

Total: Dec 07 - Apr 10	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2010**
Const: Feb 08 - Sept 09	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**
MADC5	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ (18,633,000)	$ (18,629,000)	$ (16,123,000)	$ (12,490,000)	$ (11,150,000)	$ (8,829,000)	$ (6,528,000)	$ (3,109,000)	$ (1,795,000)	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 11,288,340	$ 11,861,640	$ 12,434,940	$ 13,581,540	$ 14,728,140	$ 16,448,040	$ 17,594,640	$ 19,314,540	$ 21,034,440	$ 22,181,040	$ 22,754,340
DFT Cash Flow	**$ (239,363,440)**	**$ (265,359,400)**	**$ (283,462,060)**	**$ (294,008,420)**	**$ (298,856,480)**	**$ (296,841,940)**	**$ (290,204,800)**	**$ (276,865,760)**	**$ (261,066,120)**	**$ (241,751,580)**	**$ (220,717,140)**	**$ (198,536,100)**	**$ (175,781,760)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

			MADC5 Leases										
MADC5 Start/End			2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16		
NJ 1 Start/End			0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00
NWDC Start/End				NEDC Leases									
				2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16	
				0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00
								NWDC Leases					
								2:16	2:16	4:16	6:16	8:16	10:16
								0.125	0.125	0.25	0.375	0.5	0.625

ACTUAL PROJECT - COST PROJECTION

Total: Dec 07 - Dec 11	2007	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2009
Const: Feb 08 - May 11	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**
MADC5	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ -	$ -
NJ 1	$ -	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ -	$ (1,959,000)	$ (8,075,000)	$ (7,231,000)	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040
DFT Cash Flow	**$ 7,592,040**	**$ 9,503,080**	**$ 11,635,120**	**$ 12,120,160**	**$ 2,887,200**	**$ (8,083,760)**	**$ (26,070,720)**	**$ (50,449,680)**	**$ (68,075,640)**	**$ (87,915,600)**	**$ (92,472,560)**	**$ (93,706,520)**	**$ (82,991,480)**	**$ (72,276,440)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End														
NJ 1 Start/End									*Stop NWDC*		*Stop NEDC*	*Stop MADC5*		
NWDC Start/End									$ (50,449,680)		$ (87,915,600)	$ (97,472,560)		

Total: Dec 07 - Dec 11	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2010	2010	2010
Const: Feb 08 - May 11	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**
MADC5	$ -	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 11,288,340	$ 11,288,340	$ 11,861,640	$ 12,434,940	$ 13,008,240	$ 13,581,540	$ 14,154,840	$ 14,728,140	$ 15,874,740	$ 15,874,740
DFT Cash Flow	**$ (61,561,400)**	**$ (61,376,360)**	**$ (59,016,320)**	**$ (54,434,280)**	**$ (45,883,940)**	**$ (36,158,600)**	**$ (41,015,960)**	**$ (45,778,020)**	**$ (49,804,780)**	**$ (51,495,240)**	**$ (49,289,400)**	**$ (45,091,260)**	**$ (37,571,520)**	**$ (27,829,780)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

					MADC5 Leases									
MADC5 Start/End					2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16	
NJ 1 Start/End					0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00
NWDC Start/End													NEDC Leases	
													2:16	2:16
													0.125	0.125

Total: Dec 07 - Dec 11	2010	2010	2010	2010	2010	2010	2010	2010	2010	2011	2011	2011	2011	2011
Const: Feb 08 - May 11	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ (6,176,000)	$ (10,534,000)	$ (13,796,000)	$ (14,602,000)	$ (18,238,000)	$ (18,633,000)	$ (18,629,000)	$ (16,123,000)	$ (12,490,000)	$ (11,150,000)	$ (8,829,000)	$ (6,528,000)	$ (3,109,000)	$ (1,795,000)
Income	$ 16,448,040	$ 17,021,340	$ 17,594,640	$ 18,167,940	$ 18,741,240	$ 19,314,540	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 20,461,140	$ 20,461,140
DFT Cash Flow	**$ (20,295,740)**	**$ (15,371,400)**	**$ (11,572,760)**	**$ (8,006,820)**	**$ (7,503,580)**	**$ (6,822,040)**	**$ (5,563,200)**	**$ (1,798,360)**	**$ 5,599,480**	**$ 14,337,320**	**$ 25,396,160**	**$ 38,756,000**	**$ 56,108,140**	**$ 74,774,280**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End														
NJ 1 Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NWDC Start/End														
	4:16	6:16	8:16	10:16	12:16	14:16	16:16							
	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
													NWDC Leases	
													2:16	2:16
													0.125	0.125

Total: Dec 07 - Dec 11	2011	2011	2011	2011	2011	2011	2011
Const: Feb 08 - May 11	**June**	**July**	**August**	**September**	**October**	**November**	**December**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 21,034,440	$ 21,607,740	$ 22,181,040	$ 22,754,340	$ 23,327,640	$ 23,900,940	$ 24,474,240
DFT Cash Flow	**$ 95,808,720**	**$ 117,416,460**	**$ 139,597,500**	**$ 162,351,840**	**$ 185,679,480**	**$ 209,580,420**	**$ 234,054,660**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End							
NJ 1 Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NWDC Start/End							
	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	4:16	6:16	8:16	10:16	12:16	14:16	16:16
	0.25	0.375	0.5	0.625	0.75	0.875	1.00

Maintain Durations with Sequential Projects – Cost Projection

Total: Dec 07 - Dec 11	**2007**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**	**2008**
Const: Feb 08 - May 11	**December**	**January**	**February**	**March**	**April**	***May***	**June**	**July**	**August**	**September**	**October**	**November**	**December**
MADC5	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040
DFT Cash Flow	**$ 7,592,040**	**$ 9,503,080**	**$ 11,635,120**	**$ 15,243,160**	**$ 14,814,200**	**$ 14,385,240**	**$ 11,580,280**	**$ 5,576,320**	**$ (905,640)**	**$ (7,225,600)**	**$ (11,782,560)**	**$ (13,016,520)**	**$ (12,831,480)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End													
NJ 1 Start/End									*Stop NWDC*			*Stop NEDC*	*Stop MADC5*
NWDC Start/End													

Total: Dec 07 - Dec 11	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2009**	**2010**
Const: Feb 08 - May 11	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**
MADC5	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 11,288,340	$ 11,288,340	$ 11,861,640	$ 12,434,940	$ 13,008,240	$ 13,581,540	$ 14,154,840	$ 14,728,140	$ 15,301,440	$ 15,301,440	$ 15,301,440
DFT Cash Flow	**$ (10,471,440)**	**$ (5,889,400)**	**$ (462,060)**	**$ 459,280**	**$ 3,737,920**	**$ 9,065,860**	**$ 10,930,100**	**$ 13,367,640**	**$ 14,002,480**	**$ 12,011,620**	**$ 10,116,060**	**$ 8,382,500**	**$ 8,411,940**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End			MADC5 Leases										
NJ 1 Start/End			2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16		
NWDC Start/End			0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00

Total: Dec 07 - Dec 11	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2011**	**2011**
Const: Feb 08 - May 11	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)			$ -	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ (1,959,000)	$ (8,075,000)	$ (7,231,000)	$ (6,176,000)	$ (10,534,000)	$ (13,796,000)	$ (14,602,000)	$ (18,238,000)	$ (18,633,000)	$ (18,629,000)	$ (16,123,000)
Income	$ 15,301,440	$ 15,301,440	$ 15,874,740	$ 15,874,740	$ 16,448,040	$ 17,021,340	$ 17,594,640	$ 18,167,940	$ 18,741,240	$ 19,314,540	$ 19,887,840	$ 19,887,840	$ 19,887,840
DFT Cash Flow	**$ 11,764,380**	**$ 16,535,820**	**$ 22,096,560**	**$ 23,763,300**	**$ 30,242,340**	**$ 39,524,680**	**$ 46,585,320**	**$ 50,957,260**	**$ 55,096,500**	**$ 56,173,040**	**$ 57,427,880**	**$ 58,686,720**	**$ 62,451,560**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End													
NJ 1 Start/End													
NWDC Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			NEDC Leases										
			2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16		
			0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00

Total: Dec 07 - Dec 11	**2011**	**2011**	**2011**	**2011**	**2011**	**2011**	**2011**	**2011**	**2011**	**2011**	**2012**	**2012**	**2012**
Const: Feb 08 - May 11	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ (12,490,000)	$ (11,150,000)	$ (8,829,000)	$ (6,528,000)	$ (3,109,000)	$ (1,795,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 20,461,140	$ 20,461,140	$ 21,034,440	$ 21,607,740	$ 22,181,040	$ 22,754,340	$ 23,327,640	$ 23,900,940	$ 24,474,240
DFT Cash Flow	**$ 69,849,400**	**$ 78,587,240**	**$ 89,646,080**	**$ 103,005,920**	**$ 120,358,060**	**$ 139,024,200**	**$ 160,058,640**	**$ 181,666,380**	**$ 203,847,420**	**$ 226,601,760**	**$ 249,929,400**	**$ 273,830,340**	**$ 298,304,580**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End													
NJ 1 Start/End													
NWDC Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
					NWDC Leases								
					2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16
					0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00

MAINTAIN DURATIONS WITH LESS OVERLAP – COST PROJECTION

	2007	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2009	2009
	December	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**
MADC5	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040
DFT Cash Flow	**$ 7,592,040**	**$ 9,503,080**	**$ 11,635,120**	**$ 15,243,160**	**$ 14,814,200**	**$ 14,385,240**	**$ 11,580,280**	**$ 5,576,320**	**$ (905,640)**	**$ (10,348,600)**	**$ (23,709,560)**	**$ (33,526,520)**	**$ (40,448,480)**	**$ (49,232,440)**	**$ (55,794,400)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End															
NJ 1 Start/End									*Stop NWDC*		*Stop NEDC*	*Stop MADC5*			
NWDC Start/End															

	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2010	2010	2010	2010	2010
	March	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**
MADC5	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ (1,959,000)	$ (8,075,000)	$ (7,231,000)	$ (6,176,000)	$ (10,534,000)	$ (13,796,000)	$ (14,602,000)	$ (18,238,000)	$ (18,633,000)	$ (18,629,000)	$ (16,123,000)
Income	$ 11,288,340	$ 11,288,340	$ 11,861,640	$ 12,434,940	$ 13,008,240	$ 13,581,540	$ 14,154,840	$ 15,301,440	$ 15,874,740	$ 16,448,040	$ 17,021,340	$ 17,594,640	$ 18,167,940	$ 18,741,240	$ 19,314,540
DFT Cash Flow	**$ (60,764,060)**	**$ (67,757,720)**	**$ (73,093,080)**	**$ (77,693,140)**	**$ (81,915,900)**	**$ (88,358,360)**	**$ (91,964,520)**	**$ (91,194,080)**	**$ (91,986,340)**	**$ (92,072,300)**	**$ (91,215,960)**	**$ (91,859,320)**	**$ (92,324,380)**	**$ (92,212,140)**	**$ (89,020,600)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End	MADC5 Leases														
NJ 1 Start/End	2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16						
NWDC Start/End	0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00	1.00	1.00	1.00	1.00
								NEDC Leases							
								2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16
								0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875

			2010	2010	2010	2010	2010	2010	2010	2011	2011	2011	2011
	June	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ (12,490,000)	$ (11,150,000)	$ (8,829,000)	$ (6,528,000)	$ (3,109,000)	$ (1,795,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 20,461,140	$ 20,461,140	$ 21,034,440	$ 21,607,740	$ 22,181,040	$ 22,754,340	$ 23,327,640	$ 23,900,940	$ 24,474,240
DFT Cash Flow	**$ (81,622,760)**	**$ (72,884,920)**	**$ (61,826,080)**	**$ (48,466,240)**	**$ (31,114,100)**	**$ (12,447,960)**	**$ 8,586,480**	**$ 30,194,220**	**$ 52,375,260**	**$ 75,129,600**	**$ 98,457,240**	**$ 122,358,180**	**$ 146,832,420**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End													
NJ 1 Start/End													
NWDC Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	16:16												
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
					NWDC Leases								
					2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16
					0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00

Total: Dec 07 - Dec 11
Const: Feb 08 - May 11

Additional Project – Cost Projection

Total: Dec 07 - Oct 11	2007	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2009
Const: Feb 08 - Oct 11	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**
MADC5	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)
NWDC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Additional Project	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040	$ 10,715,040
DFT Cash Flow	**$ 7,592,040**	**$ 9,503,080**	**$ 11,635,120**	**$ 15,243,160**	**$ 14,814,200**	**$ 14,385,240**	**$ 11,580,280**	**$ 5,576,320**	**$ (905,640)**	**$ (10,348,600)**	**$ (23,709,560)**	**$ (33,526,520)**	**$ (40,448,480)**	**$ (49,232,440)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End														
NJ 1 Start/End									*Stop NWDC*		*Stop NEDC*	*Stop MADC5*		
NWDC Start/End														
Add'l Project Start/End														

Total: Dec 07 - Oct 11	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2009	2010	2010	2010
Const: Feb 08 - Oct 11	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**
MADC5	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ -	$ (1,959,000)	$ (8,075,000)	$ (7,231,000)	$ (6,176,000)	$ (10,534,000)	$ (13,796,000)	$ (14,602,000)	$ (18,238,000)	$ (18,633,000)
Additional Project	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income	$ 10,715,040	$ 11,288,340	$ 11,288,340	$ 11,861,640	$ 12,434,940	$ 13,008,240	$ 13,581,540	$ 14,154,840	$ 15,301,440	$ 15,874,740	$ 16,448,040	$ 17,021,340	$ 17,594,640	$ 18,167,940
DFT Cash Flow	**$ (55,794,400)**	**$ (60,764,060)**	**$ (67,757,720)**	**$ (73,093,080)**	**$ (77,693,140)**	**$ (81,915,900)**	**$ (88,358,360)**	**$ (91,964,520)**	**$ (91,194,080)**	**$ (91,986,340)**	**$ (92,072,300)**	**$ (91,215,960)**	**$ (91,859,320)**	**$ (92,324,380)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End		MADC5 Leases												
NJ 1 Start/End		2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16	16:16				
NWDC Start/End		0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.00	1.00	1.00	1.00	1.00
Add'l Project Start/End									NEDC Leases					
									2:16	2:16	4:16	6:16	8:16	10:16
									0.125	0.125	0.25	0.375	0.5	0.625

Total: Dec 07 - Oct 11	2010	2010	2010	2010	2010	2010	2010	2010	2010	2011	2011	2011	2011	2011
Const: Feb 08 - Oct 11	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**
MADC5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NWDC	$ (18,629,000)	$ (16,123,000)	$ (12,490,000)	$ (11,150,000)	$ (8,829,000)	$ (6,528,000)	$ (3,109,000)	$ (1,795,000)	$ -	$ -	$ -	$ -	$ -	$ -
Additional Project	$ -	$ -	$ (3,123,000)	$ (8,804,000)	$ (8,583,000)	$ (7,107,000)	$ (11,144,000)	$ (11,144,000)	$ (13,520,000)	$ (16,719,000)	$ (17,197,000)	$ (17,035,000)	$ (15,272,000)	$ (11,949,000)
Income	$ 18,741,240	$ 19,314,540	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 19,887,840	$ 20,461,140	$ 20,461,140	$ 21,034,440	$ 21,607,740	$ 22,181,040	$ 22,754,340	$ 23,327,640	$ 23,900,940
DFT Cash Flow	**$ (92,212,140)**	**$ (89,020,600)**	**$ (84,745,760)**	**$ (84,811,920)**	**$ (82,336,080)**	**$ (76,083,240)**	**$ (69,875,100)**	**$ (62,352,960)**	**$ (54,838,520)**	**$ (49,949,780)**	**$ (44,965,740)**	**$ (39,246,400)**	**$ (31,190,760)**	**$ (19,238,820)**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End														
NJ 1 Start/End														
NWDC Start/End	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Add'l Project Start/End														
	12:16	14:16	16:16											
	0.75	0.875	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
							NWDC Leases							
							2:16	2:16	4:16	6:16	8:16	10:16	12:16	14:16
							0.125	0.125	0.25	0.375	0.5	0.625	0.75	0.875

Additional Project – Cost Projection Continued…

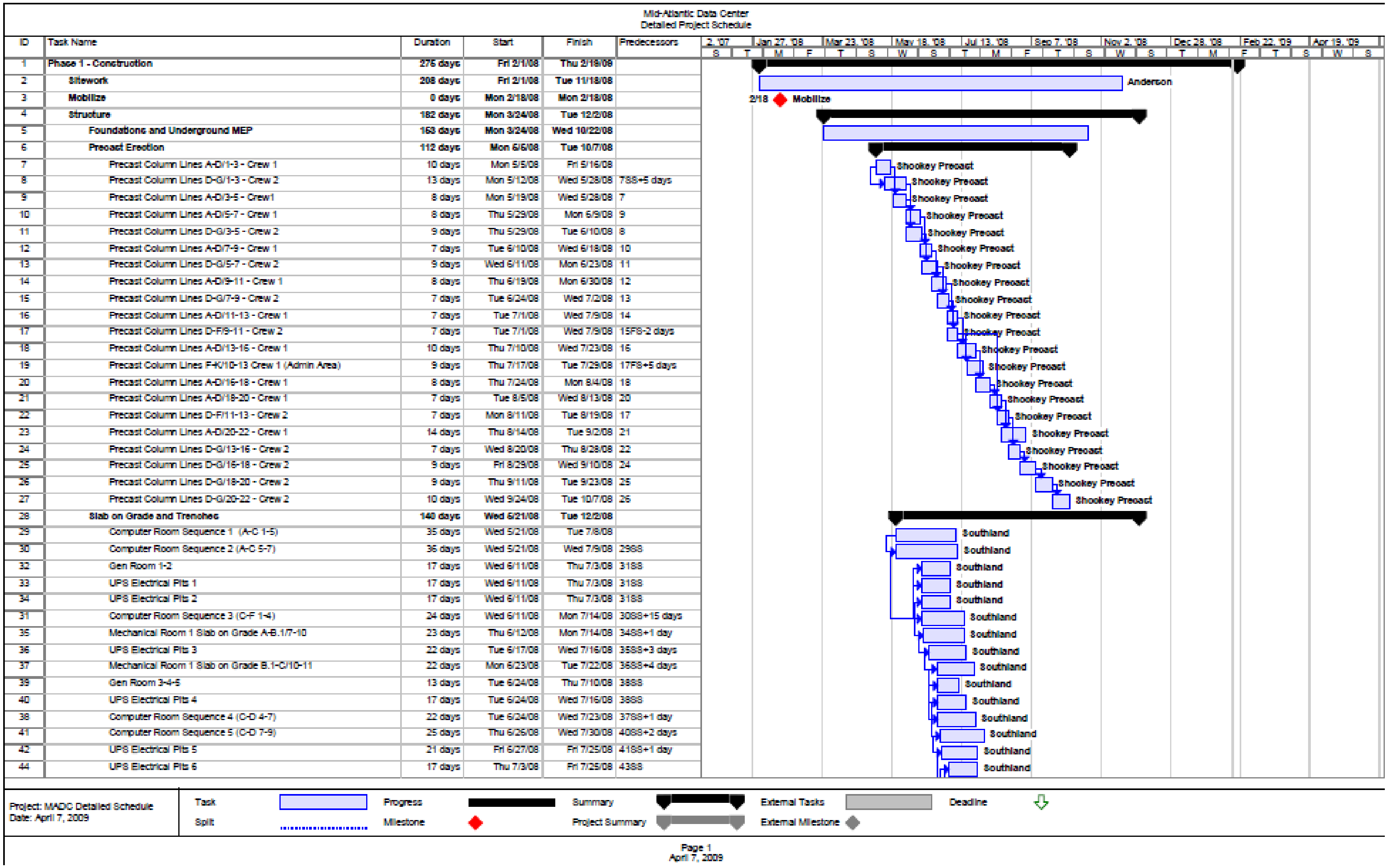
Total: Dec 07 - Oct 11	2011	2011	2011	2011	2011
Const: Feb 08 - Oct 11	**June**	**July**	**August**	**September**	**October**
MADC5	$ -	$ -	$ -	$ -	$ -
NJ 1	$ -	$ -	$ -	$ -	$ -
NWDC	$ -	$ -	$ -	$ -	$ -
Additional Project	$ (10,530,000)	$ (8,355,000)	$ (6,133,000)	$ (2,738,000)	$ (1,563,000)
Income	$ 24,474,240	$ 24,474,240	$ 24,474,240	$ 24,474,240	$ 24,474,240
DFT Cash Flow	**$ (5,294,580)**	**$ 10,824,660**	**$ 29,165,900**	**$ 50,902,140**	**$ 73,813,380**
Suspension Point	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)	$ (92,472,560)

MADC5 Start/End					
NJ 1 Start/End					
NWDC Start/End	1.00	1.00	1.00	1.00	1.00
Add'l Project Start/End					
	1.00	1.00	1.00	1.00	1.00
	16:16				
	1.00	1.00	1.00	1.00	1.00

Appendix E | Analysis II Information

Schedule and Cost Savings Data for the Alternative Concrete Construction Process can be found on the following pages.

Revised Schedule



Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Phase 1 - Construction**	**276 days**	**Fri 2/1/08**	**Thu 2/19/09**	
2	**Sitework**	**208 days**	**Fri 2/1/08**	**Tue 11/18/08**	
3	**Mobilize**	**0 days**	**Mon 2/18/08**	**Mon 2/18/08**	
4	**Structure**	**182 days**	**Mon 3/24/08**	**Tue 12/2/08**	
5	**Foundations and Underground MEP**	**163 days**	**Mon 3/24/08**	**Wed 10/22/08**	
6	**Precast Erection**	**112 days**	**Mon 5/5/08**	**Tue 10/7/08**	
7	Precast Column Lines A-D/1-3 - Crew 1	10 days	Mon 5/5/08	Fri 5/16/08	
8	Precast Column Lines D-G/1-3 - Crew 2	13 days	Mon 5/12/08	Wed 5/28/08	7SS+5 days
9	Precast Column Lines A-D/3-5 - Crew1	8 days	Mon 5/19/08	Wed 5/28/08	7
10	Precast Column Lines A-D/5-7 - Crew 1	8 days	Thu 5/29/08	Mon 6/9/08	9
11	Precast Column Lines D-G/3-5 - Crew 2	9 days	Thu 5/29/08	Tue 6/10/08	8
12	Precast Column Lines A-D/7-9 - Crew 1	7 days	Tue 6/10/08	Wed 6/18/08	10
13	Precast Column Lines D-G/5-7 - Crew 2	9 days	Wed 6/11/08	Mon 6/23/08	11
14	Precast Column Lines A-D/9-11 - Crew 1	8 days	Thu 6/19/08	Mon 6/30/08	12
15	Precast Column Lines D-G/7-9 - Crew 2	7 days	Tue 6/24/08	Wed 7/2/08	13
16	Precast Column Lines A-D/11-13 - Crew 1	7 days	Tue 7/1/08	Wed 7/9/08	14
17	Precast Column Lines D-F/9-11 - Crew 2	7 days	Tue 7/1/08	Wed 7/9/08	15FS-2 days
18	Precast Column Lines A-D/13-16 - Crew 1	10 days	Thu 7/10/08	Wed 7/23/08	16
19	Precast Column Lines F-K/10-13 Crew 1 (Admin Area)	9 days	Thu 7/17/08	Tue 7/29/08	17FS+5 days
20	Precast Column Lines A-D/16-18 - Crew 1	8 days	Thu 7/24/08	Mon 8/4/08	18
21	Precast Column Lines A-D/18-20 - Crew 1	7 days	Tue 8/5/08	Wed 8/13/08	20
22	Precast Column Lines D-F/11-13 - Crew 2	7 days	Mon 8/11/08	Tue 8/19/08	17
23	Precast Column Lines A-D/20-22 - Crew 1	14 days	Thu 8/14/08	Tue 9/2/08	21
24	Precast Column Lines D-G/13-16 - Crew 2	7 days	Wed 8/20/08	Thu 8/28/08	22
25	Precast Column Lines D-G/16-18 - Crew 2	9 days	Fri 8/29/08	Wed 9/10/08	24
26	Precast Column Lines D-G/18-20 - Crew 2	9 days	Thu 9/11/08	Tue 9/23/08	25
27	Precast Column Lines D-G/20-22 - Crew 2	10 days	Wed 9/24/08	Tue 10/7/08	26
28	**Slab on Grade and Trenches**	**140 days**	**Wed 5/21/08**	**Tue 12/2/08**	
29	Computer Room Sequence 1 (A-C 1-5)	35 days	Wed 5/21/08	Tue 7/8/08	
30	Computer Room Sequence 2 (A-C 5-7)	36 days	Wed 5/21/08	Wed 7/9/08	29SS
32	Gen Room 1-2	17 days	Wed 6/11/08	Thu 7/3/08	31SS
33	UPS Electrical Pits 1	17 days	Wed 6/11/08	Thu 7/3/08	31SS
34	UPS Electrical Pits 2	17 days	Wed 6/11/08	Thu 7/3/08	31SS
31	Computer Room Sequence 3 (C-F 1-4)	24 days	Wed 6/11/08	Mon 7/14/08	30SS+15 days
35	Mechanical Room 1 Slab on Grade A-B.1/7-10	23 days	Thu 6/12/08	Mon 7/14/08	34SS+1 day
36	UPS Electrical Pits 3	22 days	Tue 6/17/08	Wed 7/16/08	35SS+3 days
37	Mechanical Room 1 Slab on Grade B.1-C/10-11	22 days	Mon 6/23/08	Tue 7/22/08	36SS+4 days
39	Gen Room 3-4-5	13 days	Tue 6/24/08	Thu 7/10/08	38SS
40	UPS Electrical Pits 4	17 days	Tue 6/24/08	Wed 7/16/08	38SS
38	Computer Room Sequence 4 (C-D 4-7)	22 days	Tue 6/24/08	Wed 7/23/08	37SS+1 day
41	Computer Room Sequence 5 (C-D 7-9)	25 days	Thu 6/26/08	Wed 7/30/08	40SS+2 days
42	UPS Electrical Pits 5	21 days	Fri 6/27/08	Fri 7/25/08	41SS+1 day
44	UPS Electrical Pits 6	17 days	Thu 7/3/08	Fri 7/25/08	43SS

Project: MADC Detailed Schedule
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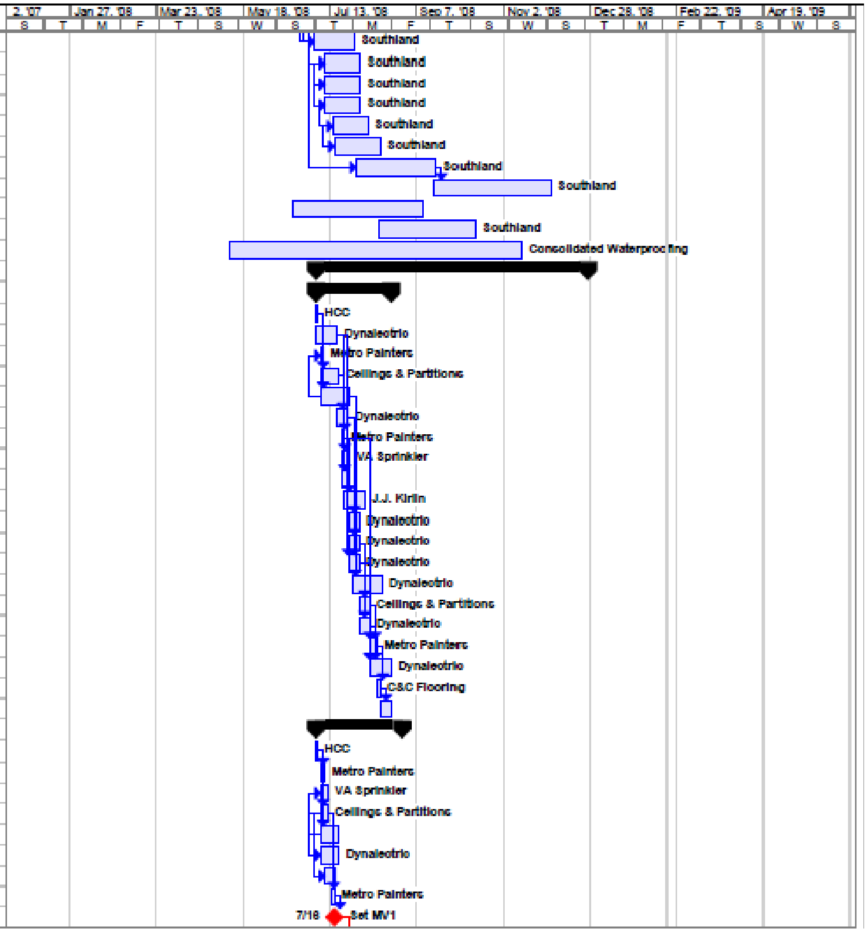
Figure 29 - Revised Overall Detailed Project Schedule

Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
43	Gen Room 6	18 days	Thu 7/3/08	Mon 7/28/08	42SS+4 days
45	Gen Room 7-8	17 days	Thu 7/10/08	Fri 8/1/08	44SS+5 days
46	UPS Electrical Pits 7	17 days	Thu 7/10/08	Fri 8/1/08	45SS
47	UPS Electrical Pits 8	17 days	Thu 7/10/08	Fri 8/1/08	46SS
48	Computer Room Sequence 6 (C-D 9-11)	17 days	Tue 7/15/08	Wed 8/6/08	47SS+3 days
49	Mechanical Room 2 Slab on Grade	22 days	Wed 7/16/08	Thu 8/14/08	48SS+1 day
50	Administration Area Slab On Grade	38 days	Wed 7/30/08	Fri 9/19/08	44SS+19 days
51	Phase II Slabs on Grade	54 days	Thu 9/18/08	Tue 12/2/08	50FS-2 days
53	**TES Tank**	**61 days**	**Thu 6/19/08**	**Thu 9/11/08**	
52	**Topping Slabs**	**44 days**	**Thu 8/14/08**	**Tue 10/14/08**	
54	**Caulking and Waterproofing/Textcote**	**135 days**	**Fri 5/9/08**	**Thu 11/13/08**	
55	**Interiors**	**128 days**	**Fri 7/4/08**	**Fri 12/26/08**	
98	**UPS 1**	**35 days**	**Fri 7/4/08**	**Thu 8/21/08**	
99	Seal Concrete Floors	1 day	Fri 7/4/08	Fri 7/4/08	
100	Pull Cable	10 days	Fri 7/4/08	Thu 7/17/08	
103	Paint Precast Tees	2 days	Mon 7/7/08	Tue 7/8/08	101SS
102	Interior Partitions	10 days	Mon 7/7/08	Fri 7/18/08	99
101	MEP Overhead (Fire Alarm, Branch, Lighting, etc)	15 days	Mon 7/7/08	Fri 7/25/08	99
104	Set Switchgear (M's, C's)	5 days	Fri 7/18/08	Thu 7/24/08	100
107	Prime Paint	1 day	Mon 7/21/08	Mon 7/21/08	102
105	Fire Protection	5 days	Mon 7/21/08	Fri 7/25/08	102
106	MEP Rough In Partitions	5 days	Mon 7/21/08	Fri 7/25/08	102
108	Set CRAH Unit/Terminate/Pipe	10 days	Tue 7/22/08	Mon 8/4/08	107
109	Install Overhead Buss	5 days	Fri 7/25/08	Thu 7/31/08	104
110	Terminate Switchgear	5 days	Fri 7/25/08	Thu 7/31/08	104
111	Set Piller Unit	5 days	Fri 7/25/08	Thu 7/31/08	100,104
112	Lighting	15 days	Mon 7/28/08	Fri 8/15/08	101
113	Doors/Hardware	5 days	Fri 8/1/08	Thu 8/7/08	110
114	Set IP	5 days	Fri 8/1/08	Thu 8/7/08	111
116	Finish Paint	3 days	Fri 8/8/08	Tue 8/12/08	107,113
115	Terminate Piller/IP Units	10 days	Fri 8/8/08	Thu 8/21/08	111,114
117	Base	2 days	Wed 8/13/08	Thu 8/14/08	116
118	Final Clean	5 days	Fri 8/15/08	Thu 8/21/08	117
82	**MV1**	**40 days**	**Fri 7/4/08**	**Thu 8/28/08**	
83	Seal Concrete Floors	1 day	Fri 7/4/08	Fri 7/4/08	
88	Paint Precast Tees	3 days	Mon 7/7/08	Wed 7/9/08	83
85	Fire Protection	5 days	Mon 7/7/08	Fri 7/11/08	84SS
86	Interior Partitions	5 days	Mon 7/7/08	Fri 7/11/08	83
84	MEP Overhead	10 days	Mon 7/7/08	Fri 7/18/08	83
87	Lighting	10 days	Mon 7/7/08	Fri 7/18/08	86SS
89	MEP Rough In Partitions	5 days	Thu 7/10/08	Wed 7/16/08	86SS+3 days
90	Prime Paint	2 days	Mon 7/14/08	Tue 7/15/08	86
91	Set MV1	0 days	Wed 7/16/08	Wed 7/16/08	90



Project: MADC Detailed Schedule
Date: April 7, 2009

Task	▭	Progress	▬	Summary	▬	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆		

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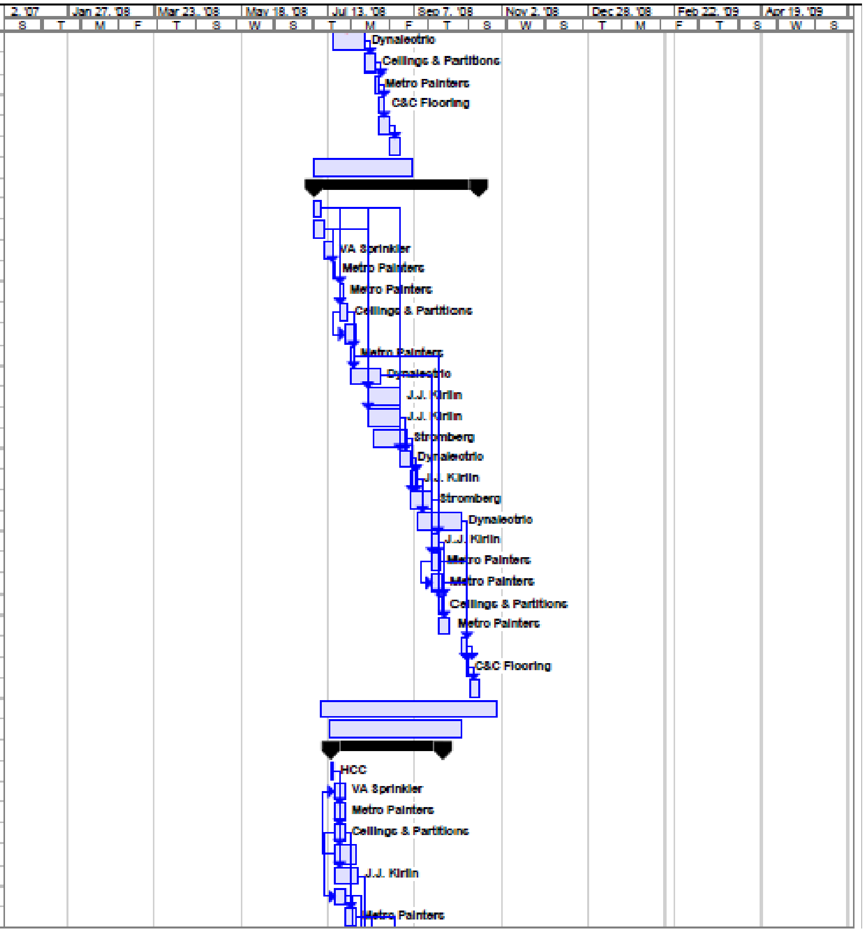
Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
92	Pull Cable/Terminate	15 days	Wed 7/16/08	Tue 8/5/08	91
93	Doors/Hardware	5 days	Wed 8/6/08	Tue 8/12/08	92
94	Finish Paint	2 days	Wed 8/13/08	Thu 8/14/08	93
95	Base	2 days	Fri 8/15/08	Mon 8/18/08	94
96	Final Clean	5 days	Fri 8/15/08	Thu 8/21/08	94
97	POE 1	5 days	Fri 8/22/08	Thu 8/28/08	96
170	**UPS 2 (Typical)**	**48 days**	**Fri 7/4/08**	**Fri 9/5/08**	
56	**Engine-Generator 1**	**76 days**	**Fri 7/4/08**	**Fri 10/17/08**	
59	Pour Concrete Fuel Curbs	2 days	Fri 7/4/08	Mon 7/7/08	
58	MEP Overhead	5 days	Fri 7/4/08	Thu 7/10/08	
60	Fire Protection	3 days	Fri 7/11/08	Tue 7/15/08	
65	Paint Precast Tees	2 days	Wed 7/16/08	Thu 7/17/08	58FS+3 days
64	Epoxy Membrane in Fuel Containment Curbs	2 days	Mon 7/21/08	Tue 7/22/08	59FS+9 days
61	Interior Partitions	5 days	Mon 7/21/08	Fri 7/25/08	58FS+6 days
63	MEP Rough In Partitions	5 days	Thu 7/24/08	Wed 7/30/08	61SS+3 days
66	Prime Paint	2 days	Mon 7/28/08	Tue 7/29/08	61
67	Lighting	15 days	Mon 7/28/08	Fri 8/15/08	61
62	Set/Pipe Day Tanks EG 1A and 1B	15 days	Fri 8/8/08	Thu 8/28/08	59FS+23 days
68	Install Exhaust Supports and Mufflers/SCR's	15 days	Fri 8/8/08	Thu 8/28/08	58FS-2 days
57	Install Louvers/Attenuation/dampers/Plenums North Wall	15 days	Tue 8/12/08	Mon 9/1/08	
69	Set EG 1A and 1B	5 days	Fri 8/29/08	Thu 9/4/08	59,68
70	Final Muffler Connections	2 days	Fri 9/5/08	Mon 9/8/08	69
71	Install Louvers/Attenuation/Dampers/Plenums South Wall	10 days	Fri 9/5/08	Thu 9/18/08	57FS-5 days,69
72	Pull Cable/Terminate EG 1A and 1B	20 days	Tue 9/9/08	Mon 10/6/08	70
73	Install Plenum From Radiator to Louvers	2 days	Fri 9/19/08	Mon 9/22/08	71
74	Finish Paint	3 days	Fri 9/19/08	Tue 9/23/08	71,67
75	Epoxy Generator RM Floors	5 days	Fri 9/19/08	Thu 9/25/08	74SS
77	Doors/Hardware	3 days	Tue 9/23/08	Thu 9/25/08	66,73
76	Install Unit Heaters	5 days	Tue 9/23/08	Mon 9/29/08	73
78	Complete Pneumatics	3 days	Tue 10/7/08	Thu 10/9/08	72
79	Base	1 day	Fri 10/10/08	Fri 10/10/08	74,75,78
80	Final Clean	5 days	Mon 10/13/08	Fri 10/17/08	79
81	**Engine-Generator 2 (Typical)**	**82 days**	**Tue 7/8/08**	**Wed 10/29/08**	
205	**Restroom 138**	**61 days**	**Mon 7/14/08**	**Mon 10/6/08**	
120	**Computer Room 1**	**53 days**	**Tue 7/15/08**	**Thu 9/25/08**	
121	Seal Concrete Floors	2 days	Tue 7/15/08	Wed 7/16/08	
123	Fire Protection	5 days	Thu 7/17/08	Wed 7/23/08	122SS
125	Paint Precast Tees	5 days	Thu 7/17/08	Wed 7/23/08	121
126	Interior Partitions	5 days	Thu 7/17/08	Wed 7/23/08	121
122	MEP Overhead/Pull Wire (FA, Security, Branch, Buss Duct)	10 days	Thu 7/17/08	Wed 7/30/08	121
124	Chilled Water Pipe	12 days	Thu 7/17/08	Fri 8/1/08	121
127	MEP Rough In Partitions	5 days	Fri 7/18/08	Thu 7/24/08	126SS+1 day
128	Prime Paint	5 days	Thu 7/24/08	Wed 7/30/08	126



Project: MADC Detailed Schedule
Date: April 7, 2009

Task	▭	Progress	▬	Summary	▬	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆		

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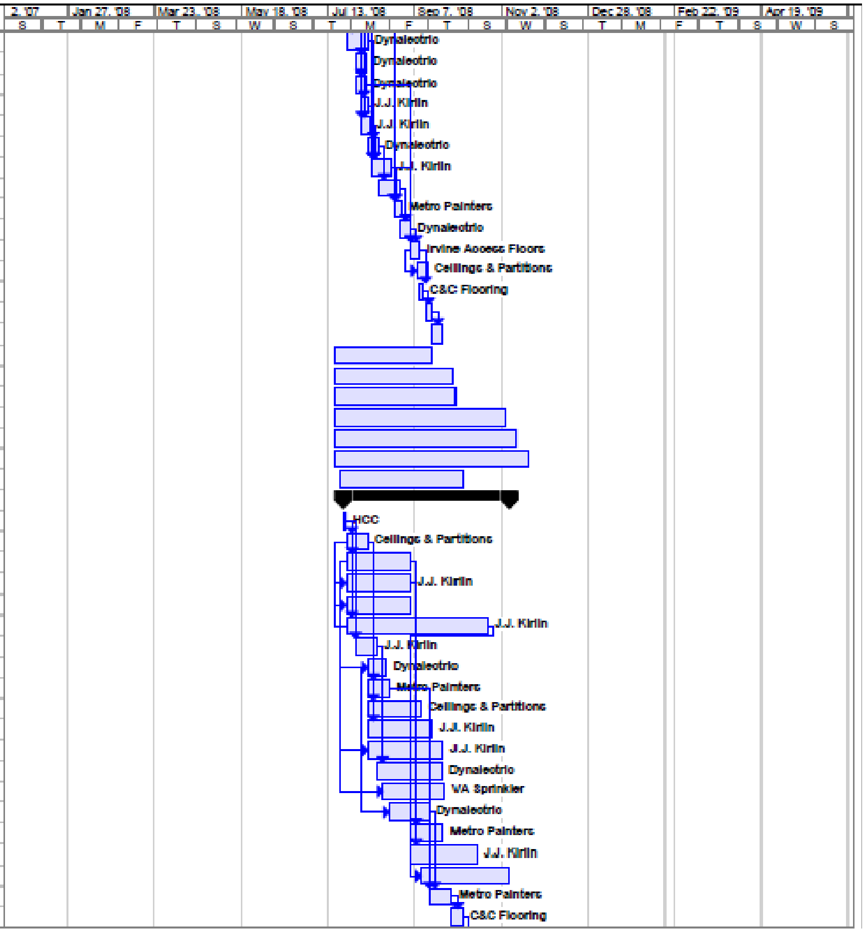
Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
129	Lighting Buss and Fixtures/Fire Alarm Devices	10 days	Fri 7/25/08	Thu 8/7/08	127
130	Install EPO Kiosk	5 days	Thu 7/31/08	Wed 8/6/08	128
131	Set D Boards/Terminate	5 days	Thu 7/31/08	Wed 8/6/08	128
132	Insulate Chilled Water Piping	4 days	Mon 8/4/08	Thu 8/7/08	124
133	Pipe/Insulate CRAH's	5 days	Mon 8/4/08	Fri 8/8/08	124,127
134	Underfloor Fire Alarm	5 days	Fri 8/8/08	Thu 8/14/08	129
135	Set CRAH Stands/CRAH Units	10 days	Mon 8/11/08	Fri 8/22/08	128,132,133
136	Incipient Detection	10 days	Fri 8/15/08	Thu 8/28/08	134
137	Finish Paint	5 days	Mon 8/25/08	Fri 8/29/08	128,131,135
138	Grounding Grid	5 days	Fri 8/29/08	Thu 9/4/08	136
139	Access Flooring	4 days	Fri 9/5/08	Wed 9/10/08	131,135,138
140	Doors/Hardware	5 days	Tue 9/9/08	Mon 9/15/08	139SS+2 days
141	Base	2 days	Thu 9/11/08	Fri 9/12/08	139
142	Superclean	4 days	Mon 9/15/08	Thu 9/18/08	141
143	Final Clean	5 days	Fri 9/19/08	Thu 9/25/08	142
172	**UPS 3 (Typical)**	**48 days**	**Thu 7/17/08**	**Thu 9/18/08**	
146	**Computer Room 2 (Typical)**	**55 days**	**Thu 7/17/08**	**Wed 10/1/08**	
175	**UPS 4 (Typical)**	**58 days**	**Thu 7/17/08**	**Thu 10/2/08**	
119	**Engine-Generator 3 (Typical)**	**79 days**	**Thu 7/17/08**	**Tue 11/4/08**	
144	**Engine-Generator 4 (Typical)**	**84 days**	**Thu 7/17/08**	**Tue 11/11/08**	
145	**Engine-Generator 5 (Typical)**	**89 days**	**Thu 7/17/08**	**Tue 11/18/08**	
147	**Computer Room 3 (Typical)**	**57 days**	**Mon 7/21/08**	**Tue 10/7/08**	
148	**Mechanical Room 1 (Chiller Plant) - Ph 1**	**77 days**	**Wed 7/23/08**	**Thu 11/6/08**	
149	Seal Concrete Floors	2 days	Wed 7/23/08	Thu 7/24/08	
153	Interior Partitions	10 days	Fri 7/25/08	Thu 8/7/08	149
150	MEP Overhead	30 days	Fri 7/25/08	Thu 9/4/08	149
152	Install AHU's	30 days	Fri 7/25/08	Thu 9/4/08	151SS
154	MEP Rough In Partitions	30 days	Fri 7/25/08	Thu 9/4/08	153SS
151	Chilled Water Piping	65 days	Fri 7/25/08	Thu 10/23/08	149
155	Set Chillers	10 days	Thu 7/31/08	Wed 8/13/08	149
158	Pull MCC Feeders	8 days	Fri 8/8/08	Tue 8/19/08	154SS+10 days
159	Prime Paint	10 days	Fri 8/8/08	Thu 8/21/08	153
160	Doors/Hardware	25 days	Fri 8/8/08	Thu 9/11/08	153
157	Boiler Room	30 days	Fri 8/8/08	Thu 9/18/08	153
156	Install Pumps	35 days	Fri 8/8/08	Thu 9/25/08	151SS+10 days
161	Lighting	30 days	Thu 8/14/08	Wed 9/24/08	155
162	Fire Protection	30 days	Mon 8/18/08	Fri 9/26/08	150SS+16 days
163	Set MCC's	18 days	Fri 8/22/08	Tue 9/16/08	158SS+10 days
164	Paint Precast Tees	15 days	Fri 9/5/08	Thu 9/25/08	150
165	Pull/Terminate Mechanical Equipment Feeders	30 days	Fri 9/5/08	Thu 10/16/08	152
166	Insulation	40 days	Fri 9/12/08	Thu 11/6/08	151FS-30 days
167	Finish Paint	10 days	Wed 9/17/08	Tue 9/30/08	159,163
168	Base	5 days	Wed 10/1/08	Tue 10/7/08	167



Project: MADC Detailed Schedule
Date: April 7, 2009

Task	▭	Progress	▬	Summary	▼▬▼	External Tasks	▭	Deadline	⇩
Split	┈┈┈	Milestone	◆	Project Summary	▼▬▼	External Milestone	◆		

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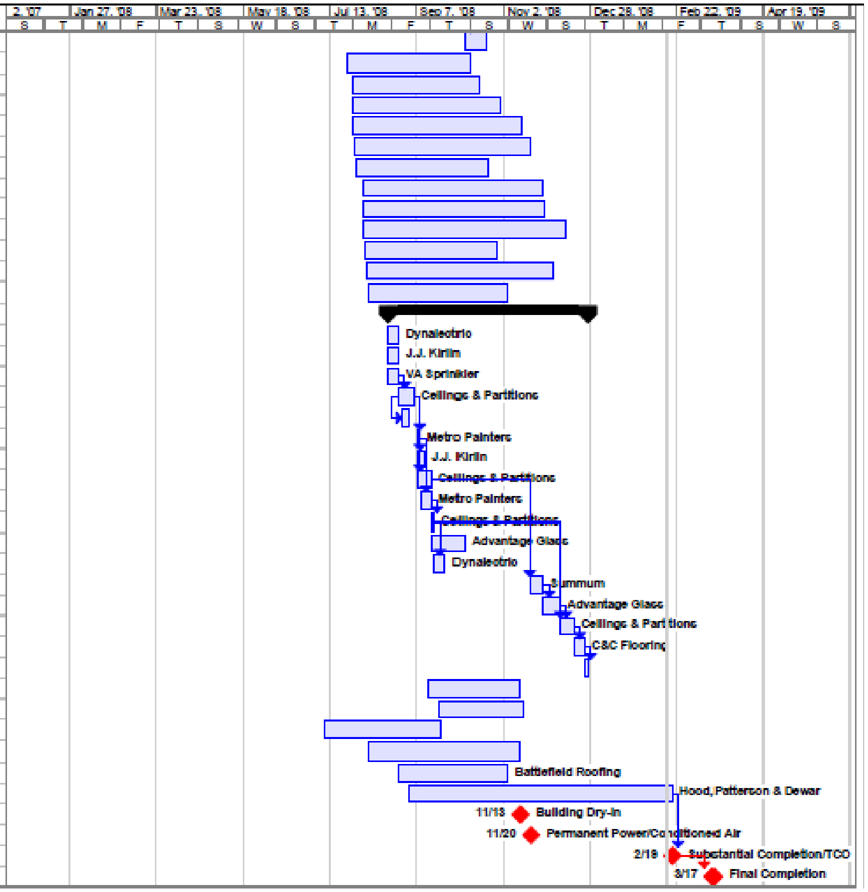
Mid-Atlantic Data Center
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
169	Final Clean	10 days	Wed 10/8/08	Tue 10/21/08	168
171	**Computer Room 4 (Typical)**	**57 days**	**Thu 7/24/08**	**Fri 10/10/08**	
173	**Computer Room 5 (Typical)**	**59 days**	**Mon 7/28/08**	**Thu 10/16/08**	
175	**UPS 5 (Typical)**	**69 days**	**Mon 7/28/08**	**Thu 10/30/08**	
179	**UPS 6 (Typical)**	**79 days**	**Mon 7/28/08**	**Thu 11/13/08**	
174	**Engine-Generator 6 (Typical)**	**82 days**	**Tue 7/29/08**	**Wed 11/19/08**	
177	**Computer Room 6 (Typical)**	**61 days**	**Wed 7/30/08**	**Wed 10/22/08**	
178	**Engine-Generator 7 (Typical)**	**83 days**	**Mon 8/4/08**	**Wed 11/26/08**	
200	**UPS 7 (Typical)**	**85 days**	**Mon 8/4/08**	**Fri 11/28/08**	
202	**UPS 8 (Typical)**	**94 days**	**Mon 8/4/08**	**Thu 12/11/08**	
199	**Computer Room 7 (Typical)**	**61 days**	**Tue 8/5/08**	**Tue 10/28/08**	
180	**Engine-Generator 8 (Typical)**	**86 days**	**Wed 8/6/08**	**Wed 12/3/08**	
201	**Computer Room 8 (Typical)**	**63 days**	**Thu 8/7/08**	**Mon 11/3/08**	
181	**Administrative Area - 1st Floor G-K**	**93 days**	**Wed 8/20/08**	**Fri 12/26/08**	
182	Overhead Electrical	5 days	Wed 8/20/08	Tue 8/26/08	
183	Overhead Ductwork	5 days	Wed 8/20/08	Tue 8/26/08	
184	Fire Protection	5 days	Wed 8/20/08	Tue 8/26/08	
185	Interior Partitions	8 days	Wed 8/27/08	Fri 9/5/08	184
186	MEP Rough In Partitions	2 days	Fri 8/29/08	Mon 9/1/08	185SS+2 days
189	Prime Paint	2 days	Mon 9/8/08	Tue 9/9/08	185
187	Install Terminate Mechanical Equipment	5 days	Mon 9/8/08	Fri 9/12/08	185
188	Doors/Hardware	7 days	Mon 9/8/08	Tue 9/16/08	185
190	Finish Paint	5 days	Wed 9/10/08	Tue 9/16/08	189
192	Ceiling Grid	2 days	Wed 9/17/08	Thu 9/18/08	190
191	Curtainwall	15 days	Wed 9/17/08	Tue 10/7/08	
193	Install Light Fixtures	5 days	Fri 9/19/08	Thu 9/25/08	192
194	Millwork/Vanities	7 days	Wed 11/19/08	Thu 11/27/08	188FS+45 days
195	Bullet Resistant Framing/Glazing	7 days	Fri 11/28/08	Mon 12/8/08	194
196	Ceiling Tile	7 days	Tue 12/9/08	Wed 12/17/08	192,195
197	Carpet/Base	5 days	Thu 12/18/08	Wed 12/24/08	196
198	Final Clean	2 days	Thu 12/25/08	Fri 12/26/08	197
203	**Administrative Area - 1st Floor E-G (Typical)**	**43 days**	**Mon 9/15/08**	**Wed 11/12/08**	
204	**Administrative Area - 2nd Floor (Typical)**	**40 days**	**Mon 9/22/08**	**Fri 11/14/08**	
207	**Transformer Yard - Ph 1**	**53 days**	**Thu 7/10/08**	**Mon 9/22/08**	
208	**Equipment Yard - Ph 1**	**70 days**	**Thu 8/7/08**	**Wed 11/12/08**	
206	**Roofing**	**50 days**	**Wed 8/27/08**	**Tue 11/4/08**	
211	**Commissioning**	**122 days**	**Wed 9/3/08**	**Thu 2/19/09**	
209	**Building Dry-In**	**0 days**	**Thu 11/13/08**	**Thu 11/13/08**	
210	**Permanent Power/Conditioned Air**	**0 days**	**Thu 11/20/08**	**Thu 11/20/08**	
212	**Substantial Completion/TCO**	**0 days**	**Thu 2/19/09**	**Thu 2/19/09**	211
213	**Final Completion**	**0 days**	**Tue 3/17/09**	**Tue 3/17/09**	212FS+18 days



Project: MADC Detailed Schedule
Date: April 7, 2009

Task	▭	Progress	▬	Summary	▼▬▼	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▼▬▼	External Milestone	◆		

Page 5
April 7, 2009

Cost Savings Data

Table 31 – New Design: Formwork Unit Cost Savings Estimate

Description	Qty	Unit	# Rooms	Unit Price	Total
UPS Pits	4	Bundles/Pit	8	4000	$ 128,000
Computer Room Trenches	0.625	Bundles/Rm	16	4000	$ 40,000
				Total	$ 168,000

Table 32 – New Design: Concrete Unit Cost Savings Estimate

Div.	Description	Qty	Unit	Material	Labor	Equip	Total
03310	3000 psi concrete	1,405	CY	$147,771	$0	$0	$147,771
03318	Placing, SOG, pumped, up to 6" thick	1,405	CY	$0	$14,314	$8,456	$22,770
03325	CIP, slab on grade, 6" thick	67,183	SF	$137,725	$32,248	$672	$170,645
03210	Rebar, avg. price, A615, grade 40	68	Ton	$62,642	$0	$0	$62,642
	Formwork	1	LS	$0	$0	$0	$168,000
	Trench Fall Protection	1	LS	$0	$0	$0	$56,000
			TOTAL	$348,138	$46,562	$9,128	$627,828

Table 33 - Existing Design: Unit Cost Estimate

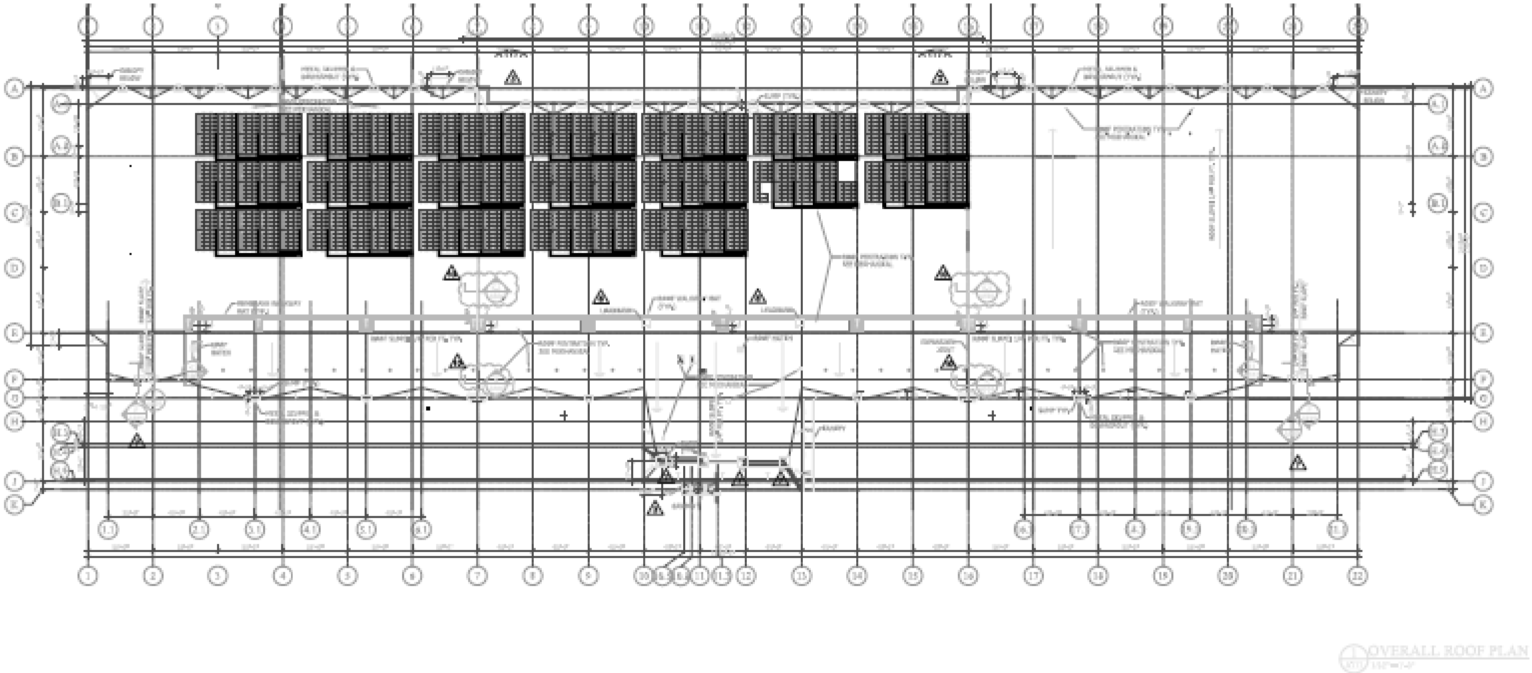
Div.	Description	Qty	Unit	Material	Labor	Equip	Total
03310	3000 psi concrete	9,790	CY	$1,029,855	$0	$0	$1,029,855
03311	3500 psi concrete	2,167	CY	$234,762	$0	$0	$234,762
03312	4000 psi concrete	674	CY	$75,130	$0	$0	$75,130
03313	5000 psi concrete	6,204	CY	$711,384	$0	$0	$711,384
03314	Placing, topping slab, pumped, <6" thick	5,343	CY	$0	$50,489	$29,759	$80,248
03315	Placing, topping slab, pumped, 6"-10" thick	1,594	CY	$0	$13,169	$7,764	$20,933
03316	Placing, continuous footing, pumped	648	CY	$0	$5,724	$3,380	$9,104
03317	Placing, grade beam, pumped	674	CY	$0	$4,959	$2,917	$7,876
03318	Placing, SOG, pumped, up to 6" thick	12,143	CY	$0	$123,740	$73,102	$196,842

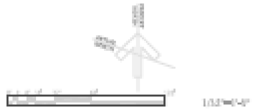
03319	Placing, SOG, pumped, over 6" thick	3,442	CY	$0	$24,612	$14,492	$39,104
03320	Placing, spread footing, pumped	1,526	CY	$0	$31,359	$18,297	$49,656
03321	CIP, topping slab, 4" slab	471,508	SF	$674,257	$216,894	$132,022	$1,023,173
03322	CIP, topping slab, 6" slab	76,167	SF	$162,236	$35,798	$21,327	$219,361
03323	CIP, spread footing	1,308	CY	$264,190	$79,566	$746	$344,501
03324	CIP, continuous strip footing, 24" x 12"	648	CY	$90,598	$35,127	$330	$126,055
03325	CIP, slab on grade, 6" thick	589,057	SF	$1,207,568	$282,748	$5,891	$1,496,206
03326	CIP, slab on grade, 8" thick	97,650	SF	$274,397	$49,802	$977	$325,175
03327	CIP Piers square, 36" x 36"	152	CY	$57,660	$31,913	$4,963	$94,537
03328	CIP Piers square, 24" x 24"	231	CY	$99,635	$63,610	$9,848	$173,093
03329	CIP Stairs, cast on ground	98	LF Nose	$455	$906	$20	$1,380
03330	CIP Stair Landing, cast on ground	277	SF	$995	$674	$14	$1,683
03220	WWF, sheets, 6 x 6 - W4 x W4 (4 x 4), A185	2,730	CSF	$78,215	$44,363	$0	$122,577
03221	WWF, sheets, 4 x 4 - W2.9 x W2.9 (6 x 6), A185	2,919	CSF	$90,839	$47,434	$0	$138,273
03210	Rebar, avg. price, A615, grade 40	473	Ton	$436,486	$0	$0	$436,486
	Formwork	1	LS	$0	$0	$0	$270,000
TOTAL				**$5,488,661**	**$1,142,884**	**$325,848**	**$7,227,393**

APPENDIX F | ANALYSIS III INFORMATION

SOLAR LAYOUT, WIRE/CONDUIT SIZING, PRODUCT, AND WEATHER DATA FOR THE ENERGY EFFICIENT TECHNOLOGY ANALYSIS CAN BE FOUND ON THE FOLLOWING PAGES.

Solar Panel Layout





Wire and Conduit Sizing Data Sheet

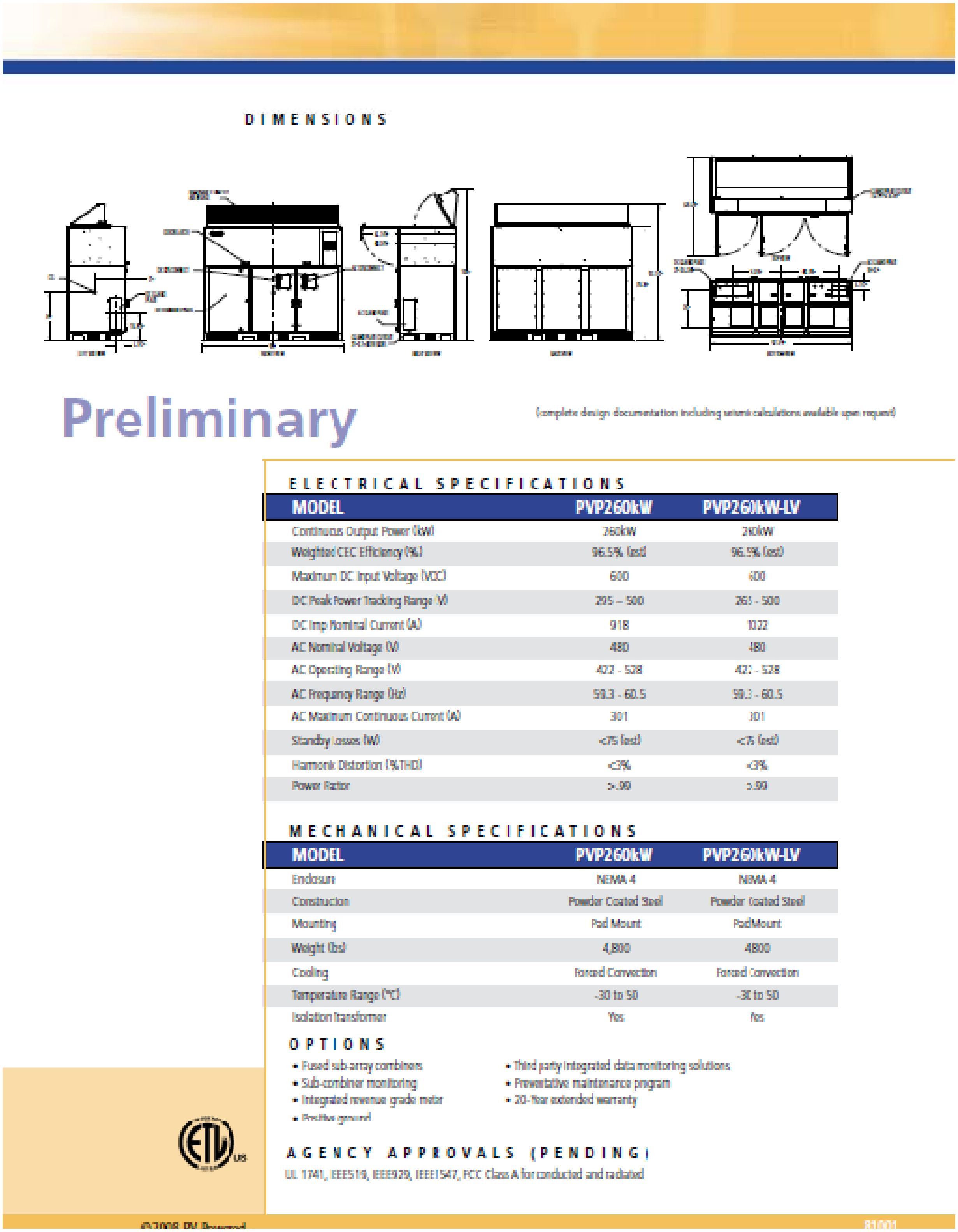
DC Wires - Combiner Boxes to Inverters

From Combiner	To Inverter	# of Arrays	Amps	Volts	Distance of Run	Total Cable Length (DC+ & DC-)	Total Cable Resistance	Cable Size	Diameter (in.)	Area of Cable Size (sq. in.)	No. of Cables	Area of #4 AWG Ground	Max Total Diameter	Total Area	Conduit Size
AF01	1	10	74	370	515	1030	0.0485	**300**	0.630	0.312	2	0.042	1.492	0.666	**2"**
AF02	1	10	74	370	410	820	0.0610	**4/0**	0.528	0.219	2	0.042	1.288	0.480	**1-1/2"**
AF03	1	10	74	370	310	620	0.0806	**3/0**	0.470	0.173	2	0.042	1.172	0.388	**1-1/2"**
AF04	1	10	74	370	210	420	0.1190	**2/0**	0.418	0.137	2	0.042	1.068	0.316	**1-1/4"**
AF05	1	10	74	370	160	320	0.1563	**1**	0.332	0.087	2	0.042	0.896	0.216	**1"**
AF06	1	10	74	370	230	460	0.1087	**2/0**	0.418	0.137	2	0.042	1.068	0.316	**1-1/4"**
AF07	1	10	74	370	330	660	0.0758	**4/0**	0.528	0.219	2	0.042	1.288	0.480	**1-1/2"**
BF01	2	10	74	370	550	1100	0.0455	**300**	0.630	0.312	2	0.042	1.492	0.666	**2"**
BF02	2	10	74	370	450	900	0.0556	**250**	0.575	0.260	2	0.042	1.382	0.562	**2"**
BF03	2	10	74	370	350	700	0.0714	**4/0**	0.528	0.219	2	0.042	1.288	0.480	**1-1/2"**
BF04	2	10	74	370	250	500	0.1000	**2/0**	0.418	0.137	2	0.042	1.068	0.316	**1-1/4"**
BF05	2	10	74	370	200	400	0.1250	**1/0**	0.372	0.109	2	0.042	0.976	0.260	**1-1/4"**
BF06	2	10	74	370	270	540	0.0926	**3/0**	0.470	0.173	2	0.042	1.172	0.388	**1-1/2"**
BF07	2	10	74	370	370	740	0.0676	**4/0**	0.528	0.219	2	0.042	1.288	0.480	**1-1/2"**
CF01	3	10	74	370	590	1180	0.0424	**350**	0.681	0.364	2	0.042	1.594	0.770	**2"**
CF02	3	10	74	370	490	980	0.0510	**300**	0.630	0.312	2	0.042	1.492	0.666	**2"**
CF03	3	10	74	370	390	780	0.0641	**4/0**	0.528	0.219	2	0.042	1.288	0.480	**1-1/2"**
CF04	3	10	74	370	290	580	0.0862	**3/0**	0.470	0.173	2	0.042	1.172	0.388	**1-1/2"**
CF05	3	10	74	370	240	480	0.1042	**2/0**	0.418	0.137	2	0.042	1.068	0.316	**1-1/4"**

Conduit Standards

Size	Diameter (in.)	Area (sq. in.)	Area less 40%	LF of Conduit
1"	1.049	0.86	0.52	160
1-1/4"	1.380	1.50	0.90	1130
1-1/2"	1.610	2.04	1.22	2720
2"	2.067	3.36	2.02	2595

INVERTER PRODUCT DATA



DIMENSIONS

Preliminary

(complete design documentation including seismic calculations available upon request)

ELECTRICAL SPECIFICATIONS

MODEL	PVP260kW	PVP260kW-LV
Continuous Output Power (kW)	260kW	260kW
Weighted CEC Efficiency (%)	96.5% (est)	96.5% (est)
Maximum DC Input Voltage (VDC)	600	600
DC Peak Power Tracking Range (V)	295 – 500	265 - 500
DC Imp Nominal Current (A)	918	1022
AC Nominal Voltage (V)	480	480
AC Operating Range (V)	422 - 528	422 - 528
AC Frequency Range (Hz)	59.3 - 60.5	59.3 - 60.5
AC Maximum Continuous Current (A)	301	301
Standby Losses (W)	<75 (est)	<75 (est)
Harmonic Distortion (%THD)	<3%	<3%
Power Factor	>.99	>.99

MECHANICAL SPECIFICATIONS

MODEL	PVP260kW	PVP260kW-LV
Enclosure	NEMA 4	NEMA 4
Construction	Powder Coated Steel	Powder Coated Steel
Mounting	Pad Mount	Pad Mount
Weight (lbs)	4,800	4800
Cooling	Forced Convection	Forced Convection
Temperature Range (°C)	-30 to 50	-30 to 50
Isolation Transformer	Yes	Yes

OPTIONS

- Fused sub-array combiners
- Sub-combiner monitoring
- Integrated revenue grade meter
- Positive ground
- Third party integrated data monitoring solutions
- Preventative maintenance program
- 20-Year extended warranty

AGENCY APPROVALS (PENDING)

UL 1741, IEEE519, IEEE929, IEEE1547, FCC Class A for conducted and radiated

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NEC HANDBOOK – CONDUCTOR PROPERTIES CHART

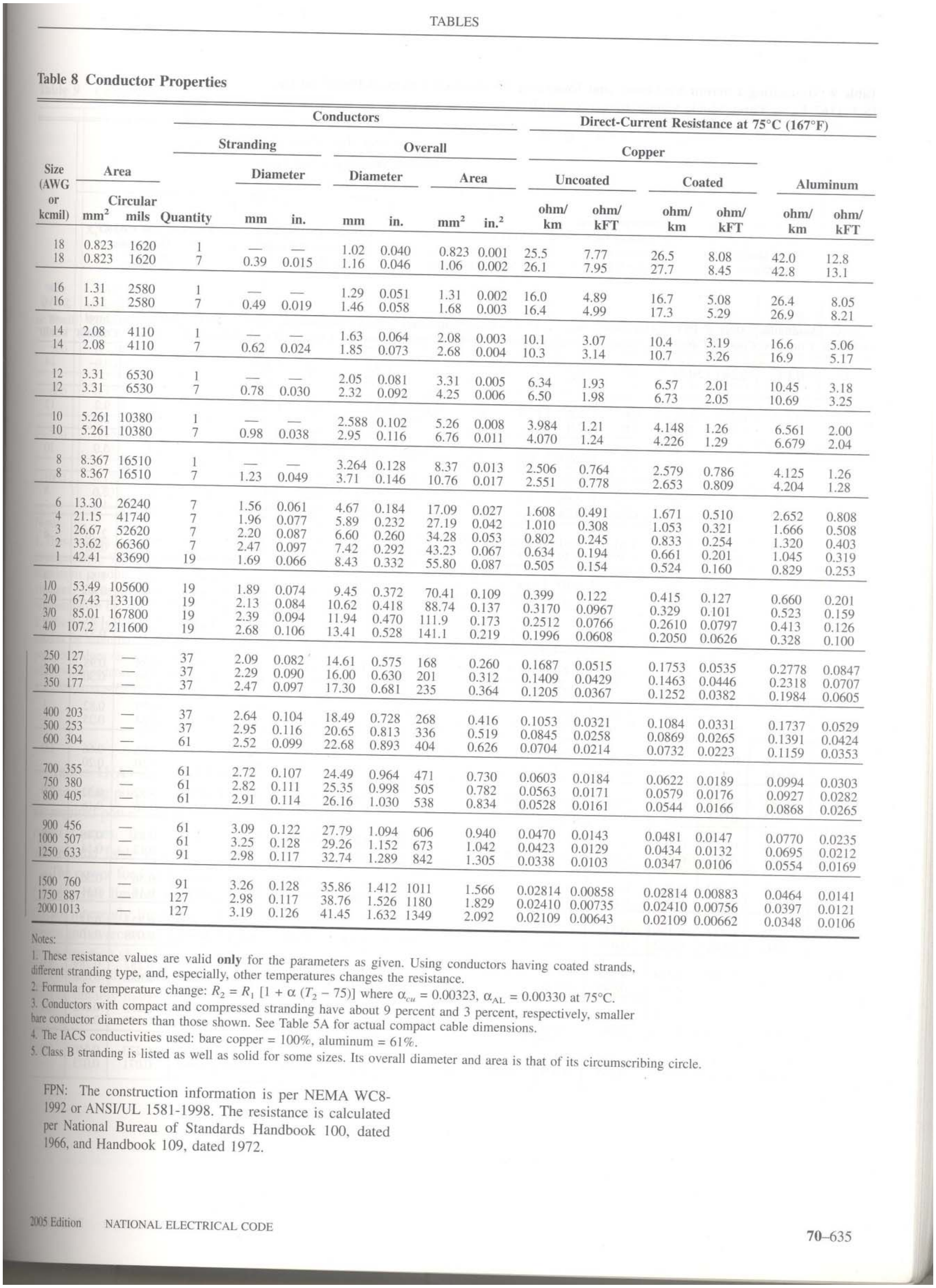


Table 8 Conductor Properties

			Conductors							Direct-Current Resistance at 75°C (167°F)					
				Stranding		Overall				Copper					
	Area			Diameter		Diameter		Area		Uncoated		Coated		Aluminum	
Size (AWG or kcmil)	mm^2	Circular mils	Quantity	mm	in.	mm	in.	mm^2	in.^{2}	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100
250	127	—	37	2.09	0.082	14.61	0.575	168	0.260	0.1687	0.0515	0.1753	0.0535	0.2778	0.0847
300	152	—	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
350	177	—	37	2.47	0.097	17.30	0.681	235	0.364	0.1205	0.0367	0.1252	0.0382	0.1984	0.0605
400	203	—	37	2.64	0.104	18.49	0.728	268	0.416	0.1053	0.0321	0.1084	0.0331	0.1737	0.0529
500	253	—	37	2.95	0.116	20.65	0.813	336	0.519	0.0845	0.0258	0.0869	0.0265	0.1391	0.0424
600	304	—	61	2.52	0.099	22.68	0.893	404	0.626	0.0704	0.0214	0.0732	0.0223	0.1159	0.0353
700	355	—	61	2.72	0.107	24.49	0.964	471	0.730	0.0603	0.0184	0.0622	0.0189	0.0994	0.0303
750	380	—	61	2.82	0.111	25.35	0.998	505	0.782	0.0563	0.0171	0.0579	0.0176	0.0927	0.0282
800	405	—	61	2.91	0.114	26.16	1.030	538	0.834	0.0528	0.0161	0.0544	0.0166	0.0868	0.0265
900	456	—	61	3.09	0.122	27.79	1.094	606	0.940	0.0470	0.0143	0.0481	0.0147	0.0770	0.0235
1000	507	—	61	3.25	0.128	29.26	1.152	673	1.042	0.0423	0.0129	0.0434	0.0132	0.0695	0.0212
1250	633	—	91	2.98	0.117	32.74	1.289	842	1.305	0.0338	0.0103	0.0347	0.0106	0.0554	0.0169
1500	760	—	91	3.26	0.128	35.86	1.412	1011	1.566	0.02814	0.00858	0.02814	0.00883	0.0464	0.0141
1750	887	—	127	2.98	0.117	38.76	1.526	1180	1.829	0.02410	0.00735	0.02410	0.00756	0.0397	0.0121
2000	1013	—	127	3.19	0.126	41.45	1.632	1349	2.092	0.02109	0.00643	0.02109	0.00662	0.0348	0.0106

Notes:

1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. Formula for temperature change: $R_2 = R_1 [1 + \alpha (T_2 - 75)]$ where $\alpha_{cu} = 0.00323$, $\alpha_{AL} = 0.00330$ at 75°C.
3. Conductors with compact and compressed stranding have about 9 percent and 3 percent, respectively, smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.
4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.
5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area is that of its circumscribing circle.

FPN: The construction information is per NEMA WC8-1992 or ANSI/UL 1581-1998. The resistance is calculated per National Bureau of Standards Handbook 100, dated 1966, and Handbook 109, dated 1972.

NEC Handbook – Conductor Conduit Sizing Chart

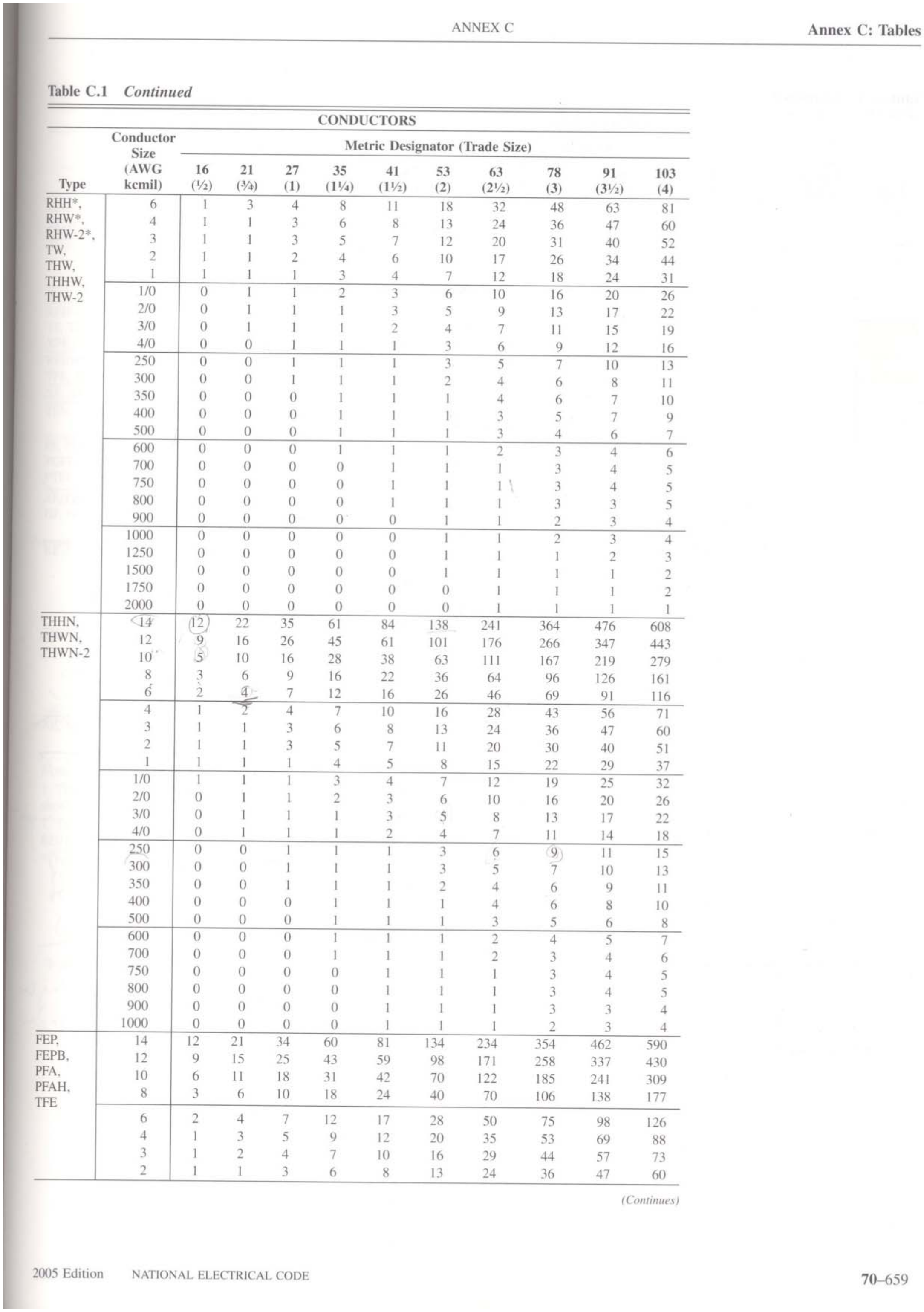
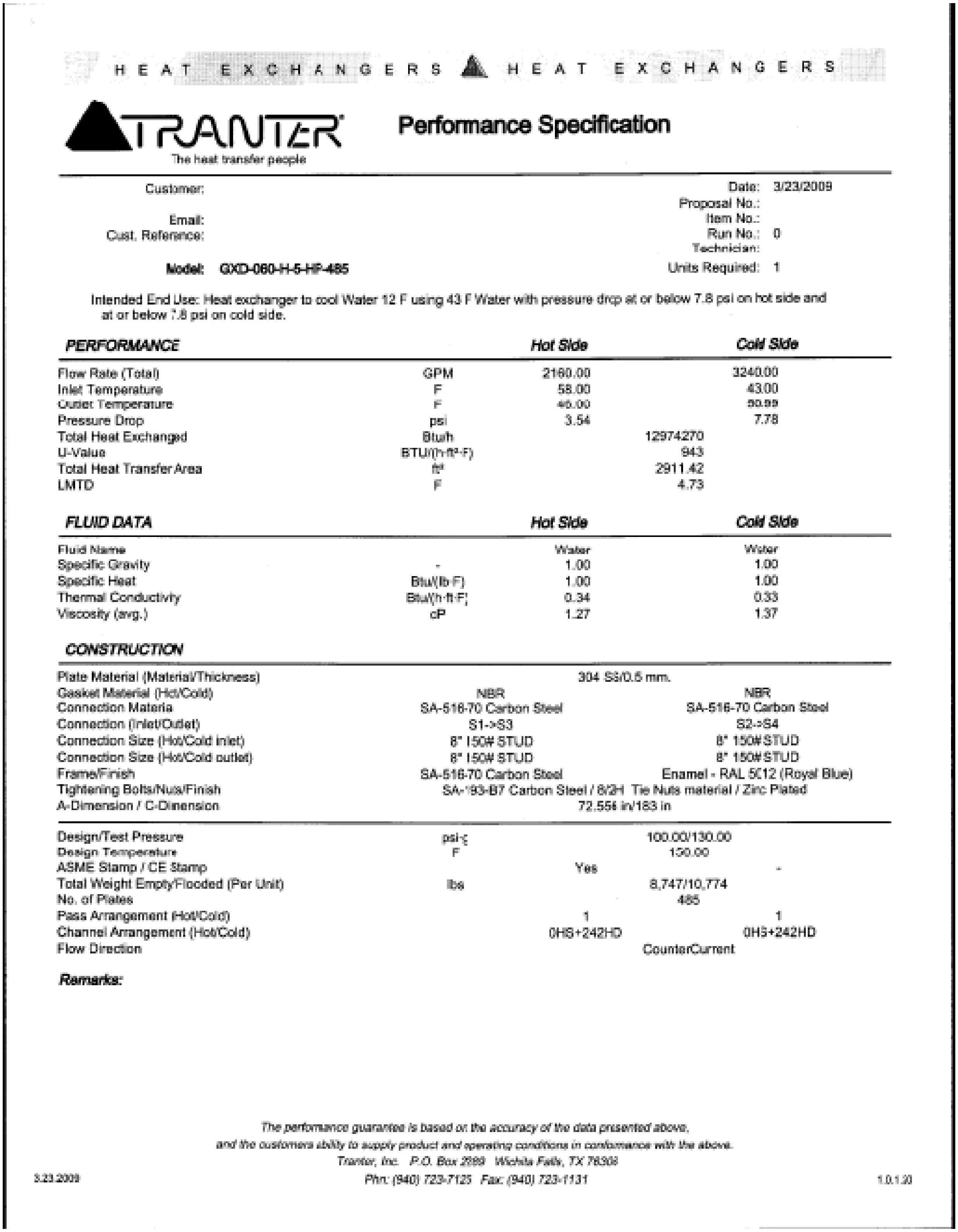


Table C.1 *Continued*

		CONDUCTORS									
	Conductor Size	Metric Designator (Trade Size)									
Type	(AWG kcmil)	16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)
RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2	6	1	3	4	8	11	18	32	48	63	81
	4	1	1	3	6	8	13	24	36	47	60
	3	1	1	3	5	7	12	20	31	40	52
	2	1	1	2	4	6	10	17	26	34	44
	1	1	1	1	3	4	7	12	18	24	31
	1/0	0	1	1	2	3	6	10	16	20	26
	2/0	0	1	1	1	3	5	9	13	17	22
	3/0	0	1	1	1	2	4	7	11	15	19
	4/0	0	0	1	1	1	3	6	9	12	16
	250	0	0	1	1	1	3	5	7	10	13
	300	0	0	1	1	1	2	4	6	8	11
	350	0	0	0	1	1	1	4	6	7	10
	400	0	0	0	1	1	1	3	5	7	9
	500	0	0	0	1	1	1	3	4	6	7
	600	0	0	0	1	1	1	2	3	4	6
	700	0	0	0	0	1	1	1	3	4	5
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	3	5
	900	0	0	0	0	0	1	1	2	3	4
	1000	0	0	0	0	0	1	1	2	3	4
	1250	0	0	0	0	0	1	1	1	2	3
	1500	0	0	0	0	0	1	1	1	1	2
	1750	0	0	0	0	0	0	1	1	1	2
	2000	0	0	0	0	0	0	1	1	1	1
THHN, THWN, THWN-2	14	12	22	35	61	84	138	241	364	476	608
	12	9	16	26	45	61	101	176	266	347	443
	10	5	10	16	28	38	63	111	167	219	279
	8	3	6	9	16	22	36	64	96	126	161
	6	2	4	7	12	16	26	46	69	91	116
	4	1	2	4	7	10	16	28	43	56	71
	3	1	1	3	6	8	13	24	36	47	60
	2	1	1	3	5	7	11	20	30	40	51
	1	1	1	1	4	5	8	15	22	29	37
	1/0	1	1	1	3	4	7	12	19	25	32
	2/0	0	1	1	2	3	6	10	16	20	26
	3/0	0	1	1	1	3	5	8	13	17	22
	4/0	0	1	1	1	2	4	7	11	14	18
	250	0	0	1	1	1	3	6	9	11	15
	300	0	0	1	1	1	3	5	7	10	13
	350	0	0	1	1	1	2	4	6	9	11
	400	0	0	0	1	1	1	4	6	8	10
	500	0	0	0	1	1	1	3	5	6	8
	600	0	0	0	1	1	1	2	4	5	7
	700	0	0	0	1	1	1	2	3	4	6
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	4	5
	900	0	0	0	0	1	1	1	3	3	4
	1000	0	0	0	0	1	1	1	2	3	4
FEP, FEPB, PFA, PFAH, TFE	14	12	21	34	60	81	134	234	354	462	590
	12	9	15	25	43	59	98	171	258	337	430
	10	6	11	18	31	42	70	122	185	241	309
	8	3	6	10	18	24	40	70	106	138	177
	6	2	4	7	12	17	28	50	75	98	126
	4	1	3	5	9	12	20	35	53	69	88
	3	1	2	4	7	10	16	29	44	57	73
	2	1	1	3	6	8	13	24	36	47	60

(Continues)

TRANTER SUPERCHANGER® PLATE AND FRAME HEAT EXCHANGER



HEAT EXCHANGERS HEAT EXCHANGERS

TRANTER®
The heat transfer people

Performance Specification

Customer:
Email:
Cust. Reference:
Model: GXD-060-H-5-HP-485

Date: 3/23/2009
Proposal No.:
Item No.:
Run No.: 0
Technician:
Units Required: 1

Intended End Use: Heat exchanger to cool Water 12 F using 43 F Water with pressure drop at or below 7.8 psi on hot side and at or below 7.8 psi on cold side.

PERFORMANCE		*Hot Side*		*Cold Side*
Flow Rate (Total)	GPM	2160.00		3240.00
Inlet Temperature	F	58.00		43.00
Outlet Temperature	F	46.00		50.99
Pressure Drop	psi	3.54		7.78
Total Heat Exchanged	Btu/h		12974270	
U-Value	BTU/(h·ft²·F)		943	
Total Heat Transfer Area	ft²		2911.42	
LMTD	F		4.73	

FLUID DATA		*Hot Side*	*Cold Side*
Fluid Name		Water	Water
Specific Gravity	-	1.00	1.00
Specific Heat	Btu/(lb·F)	1.00	1.00
Thermal Conductivity	Btu/(h·ft·F)	0.34	0.33
Viscosity (avg.)	cP	1.27	1.37

CONSTRUCTION			
Plate Material (Material/Thickness)		304 SS/0.5 mm.	
Gasket Material (Hot/Cold)	NBR		NBR
Connection Materia	SA-516-70 Carbon Steel		SA-516-70 Carbon Steel
Connection (Inlet/Outlet)	S1->S3		S2->S4
Connection Size (Hot/Cold inlet)	8" 150# STUD		8" 150# STUD
Connection Size (Hot/Cold outlet)	8" 150# STUD		8" 150# STUD
Frame/Finish	SA-516-70 Carbon Steel		Enamel - RAL 5012 (Royal Blue)
Tightening Bolts/Nuts/Finish	SA-193-B7 Carbon Steel / 8/2H Tie Nuts material / Zinc Plated		
A-Dimension / C-Dimension		72.554 in/183 in	

Design/Test Pressure	psi-g		100.00/130.00	
Design Temperature	F		130.00	
ASME Stamp / CE Stamp		Yes		-
Total Weight Empty/Flooded (Per Unit)	lbs		8,747/10,774	
No. of Plates			485	
Pass Arrangement (Hot/Cold)		1		1
Channel Arrangement (Hot/Cold)		0HS+242HD		0HS+242HD
Flow Direction			CounterCurrent	

Remarks:

The performance guarantee is based on the accuracy of the data presented above,
and the customers ability to supply product and operating conditions in conformance with the above.
Tranter, Inc. P.O. Box 2289 Wichita Falls, TX 76308
Phn: (940) 723-7125 Fax: (940) 723-1131

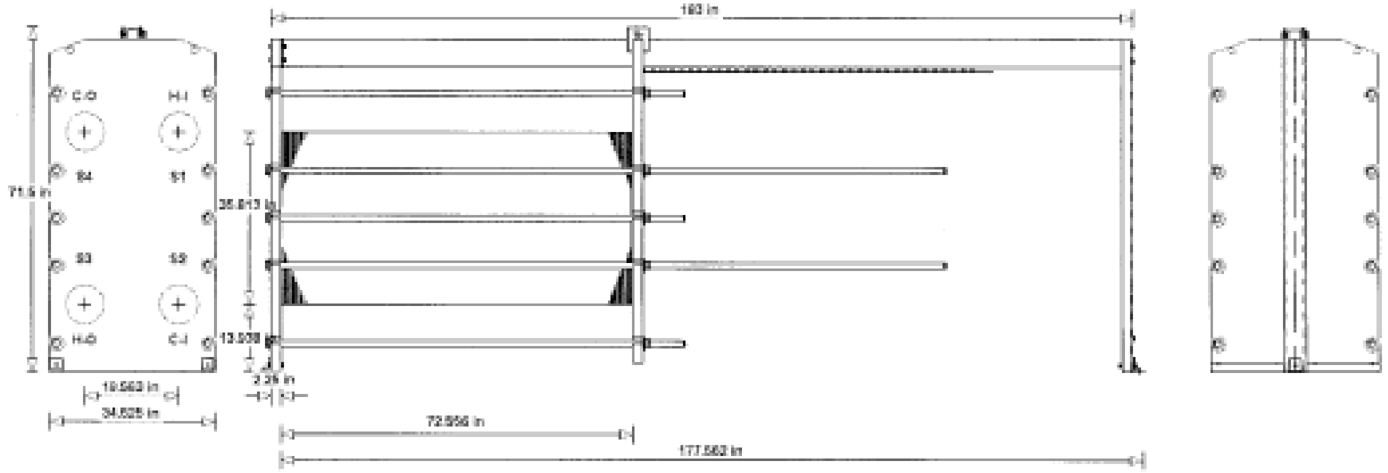
3.23.2009

1.0.1.30

TRANTER®
The heat transfer people

SUPERCHANGER ASSEMBLY
GXD-060-H-5-HP-485

Sizing Number:
000000



Dimensions are for reference purposes only and are not to be used for construction.

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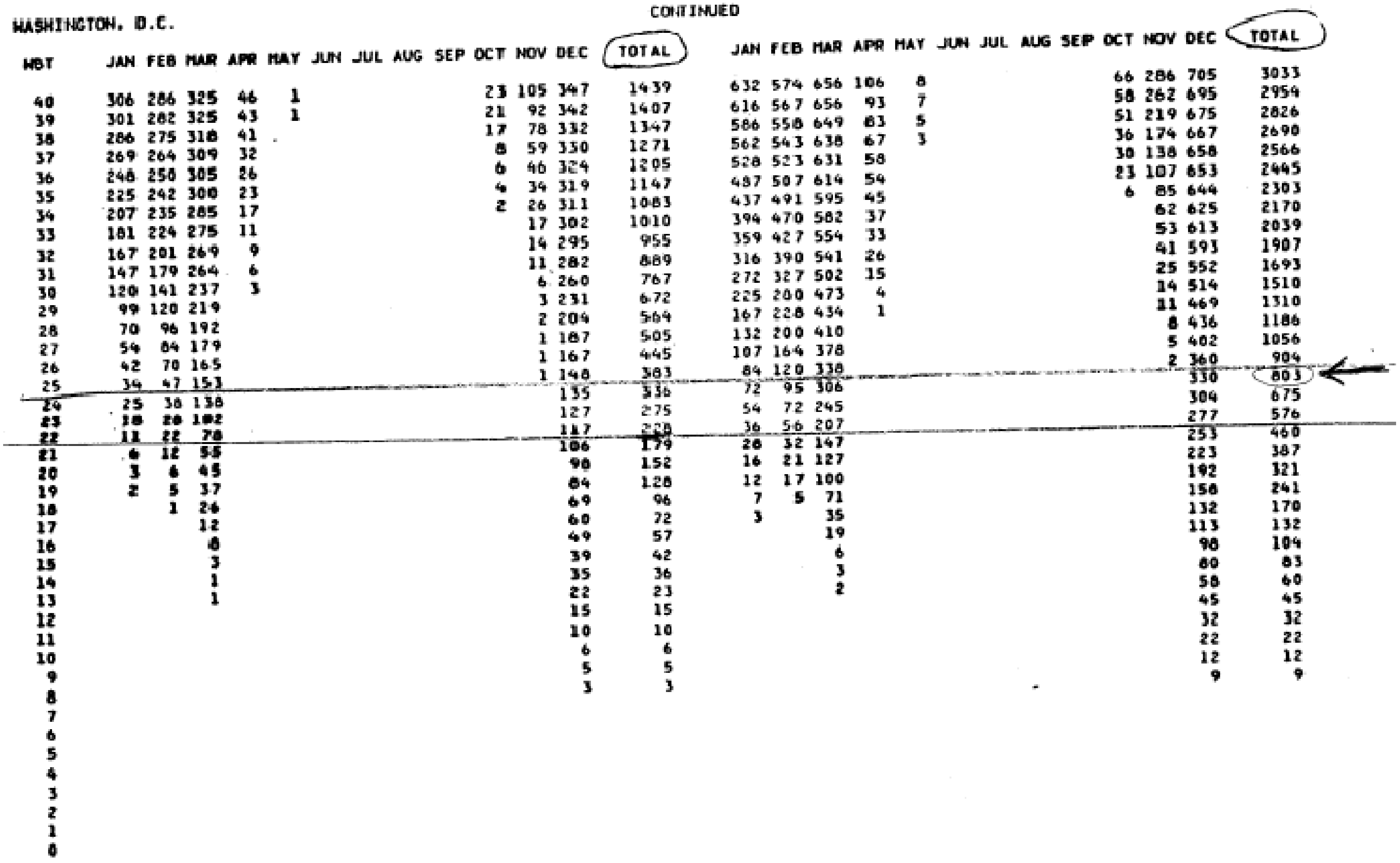
WEATHER DATA



WASHINGTON, D.C.

WBT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
40	306	286	325	46	1					23	105	347	1439
39	301	282	325	43	1					21	92	342	1407
38	286	275	318	41						17	78	332	1347
37	269	264	309	32						8	59	330	1271
36	248	258	305	26						6	46	324	1205
35	225	242	300	23						4	34	319	1147
34	207	235	285	17						2	26	311	1083
33	181	224	275	11							17	302	1010
32	167	201	269	9							14	295	955
31	147	179	264	6							11	282	889
30	120	141	237	3							6	260	767
29	99	120	219								3	231	672
28	70	96	192								2	204	564
27	54	84	179								1	187	505
26	42	70	165								1	167	445
25	34	47	153								1	148	383
24	25	38	138									135	336
23	18	20	102									127	275
22	11	22	78									117	228
21	6	12	55									106	179
20	3	6	45									90	152
19	2	5	37									84	128
18		1	24									69	96
17			12									60	72
16			8									49	57
15			3									39	42
14			1									35	36
13			1									22	23
12												15	15
11												10	10
10												6	6
9												5	5
8												3	3
7													
6													
5													
4													
3													
2													
1													
0													

CONTINUED

WBT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
40	632	574	656	106	8					66	286	705	3033
39	616	567	656	93	7					58	262	695	2954
38	586	558	649	83	5					51	219	675	2826
37	562	543	638	67	3					36	174	667	2690
36	528	523	631	58						30	138	658	2566
35	487	507	614	54						21	107	653	2445
34	437	491	595	45						6	85	644	2303
33	394	470	582	37							62	625	2170
32	359	427	554	33							53	613	2039
31	316	390	541	26							41	593	1907
30	272	327	502	15							25	552	1693
29	225	280	473	4							14	514	1510
28	167	228	434	1							11	469	1310
27	132	200	410								8	436	1186
26	107	164	378								5	402	1056
25	84	120	338								2	360	904
24	72	95	306									330	803
23	54	72	245									304	675
22	36	56	207									277	576
21	28	32	147									253	460
20	16	21	127									223	387
19	12	17	100									192	321
18	7	5	71									158	241
17	3		35									132	170
16			19									113	132
15			6									98	104
14			3									80	83
13			2									58	60
12												45	45
11												32	32
10												22	22
9												12	12
8												9	9