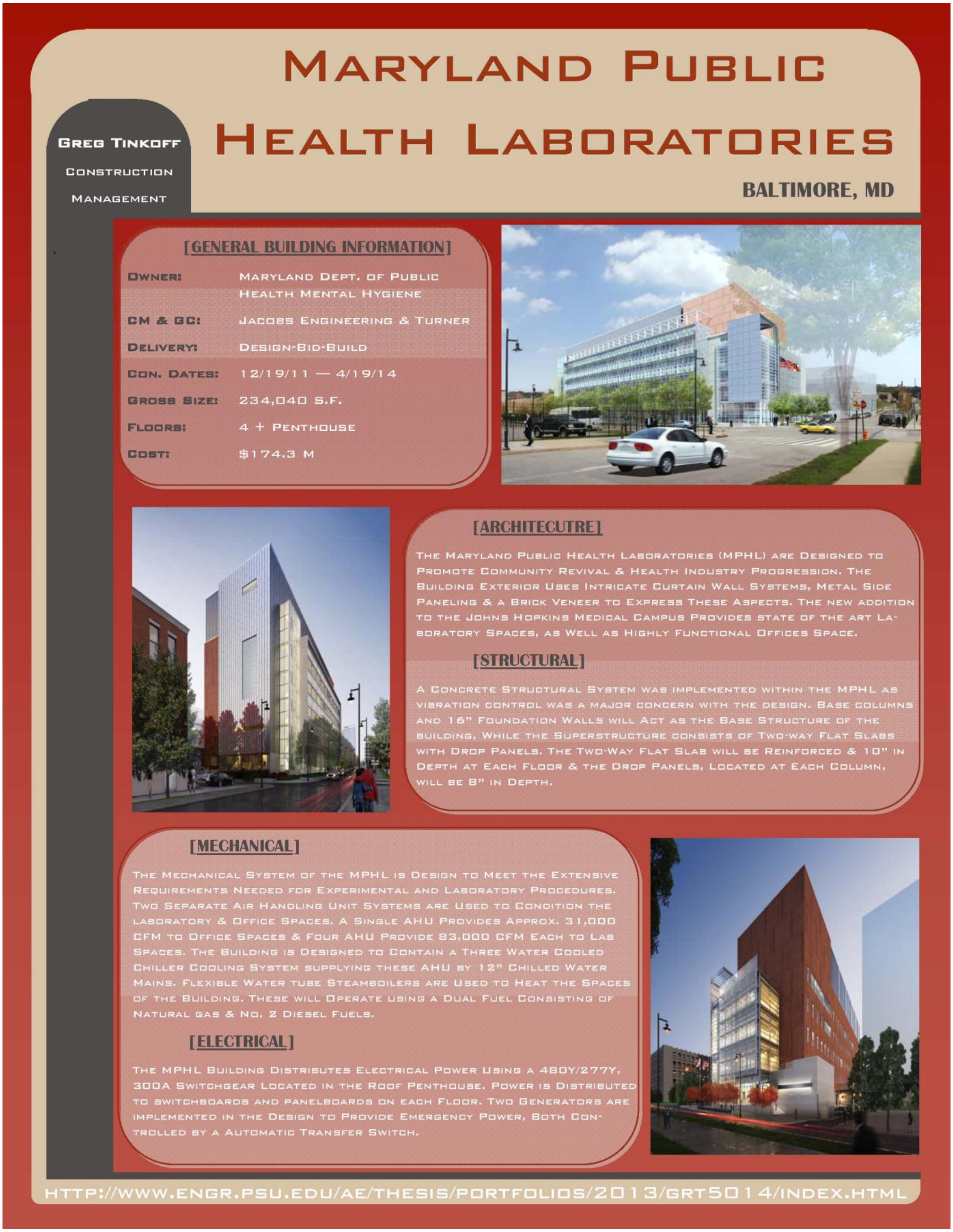
Senior Thesis Final Report

Greg Tinkoff

Maryland Public Health Laboratories | Baltimore MD

Construction Management

April 3, 2013



Maryland Public Health Laboratories

Baltimore, MD

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[GENERAL BUILDING INFORMATION]

Owner:	Maryland Dept. of Public Health Mental Hygiene
CM & GC:	Jacobs Engineering & Turner
Delivery:	Design-Bid-Build
Con. Dates:	12/19/11 — 4/19/14
Gross Size:	234,040 S.F.
Floors:	4 + Penthouse
Cost:	$174.3 M

[ARCHITECUTRE]

The Maryland Public Health Laboratories (MPHL) are Designed to Promote Community Revival & Health Industry Progression. The Building Exterior Uses Intricate Curtain Wall Systems, Metal Side Paneling & a Brick Veneer to Express These Aspects. The new addition to the Johns Hopkins Medical Campus Provides state of the art Laboratory Spaces, as Well as Highly Functional Offices Space.

[STRUCTURAL]

A Concrete Structural System was implemented within the MPHL as vibration control was a major concern with the design. Base columns and 16" Foundation Walls will Act as the Base Structure of the building, While the Superstructure consists of Two-way Flat Slabs with Drop Panels. The Two-Way Flat Slab will be Reinforced & 10" in Depth at Each Floor & the Drop Panels, Located at Each Column, will be 8" in Depth.

[MECHANICAL]

The Mechanical System of the MPHL is Design to Meet the Extensive Requirements Needed for Experimental and Laboratory Procedures. Two Separate Air Handling Unit Systems are Used to Condition the laboratory & Office Spaces. A Single AHU Provides Approx. 31,000 CFM to Office Spaces & Four AHU Provide 83,000 CFM Each to Lab Spaces. The Building is Designed to Contain a Three Water Cooled Chiller Cooling System supplying these AHU by 12" Chilled Water Mains. Flexible Water tube Steamboilers are Used to Heat the Spaces of the Building. These will Operate using a Dual Fuel Consisting of Natural gas & No. 2 Diesel Fuels.

[ELECTRICAL]

The MPHL Building Distributes Electrical Power Using a 480Y/277Y, 300A Switchgear Located in the Roof Penthouse. Power is Distributed to switchboards and panelboards on each Floor. Two Generators are implemented in the Design to Provide Emergency Power, Both Controlled by a Automatic Transfer Switch.

http://www.engr.psu.edu/ae/thesis/portfolios/2013/grt5014/index.html

Executive Summary

The following document provides four comprehensive analyses of the construction process of the Maryland Public Health Laboratories. Areas of the building project were investigated and innovative construction techniques and procedures were implemented to stimulate significant cost and schedule savings. The current project owned by MEDCO will be located on the Johns Hopkin's Science & Technology campus in East Baltimore, MD. This facility is to host the occupants, The Maryland Department of Health and Mental Hygiene, who will be using the facility to conduct medical research. The 234,000 S.F. project is comprised of several research laboratories and office space. It has been mandated by both the city of Baltimore and state of Maryland that this facility achieve a LEED Certification of no less than LEED Silver as this facility is to meet all requirements of the urban renewal project implemented within the community.

Technical Analysis #1: Precast Concrete Structural System

The first technical analysis in the report is focused on the idea of precast construction. Implementing a precast structural system would be a method to accelerate project schedule, as structural members are prefabricated during construction and are erected in short time duration. A structural analysis is introduced in this section to provide assurance that these precast members can resist loading that has been originally designed for a cast in place concrete system. In conclusion to scheduling and cost analyses it has been determined that a precast structural system could accelerate the schedule by 3.4 weeks and eliminate the need for a six day work week, without additional costs to the building project.

Technical Analysis #2: Virtual Mock-ups for Façade Systems

The second technical analysis researches the virtual mock-ups and the potential benefits the technology can produce. Research was mostly conducted through industry professional interviews and case study comparisons. Information has indicated that virtual mock-ups have great effects on the quality and efficiency of construction. This is in turns reduces the amount of change orders due to installation error and could potentially save time on building projects. If such technology were to be implemented on the Maryland Public Health Laboratories project cost savings of approximately of $94,710 could be achieved with little expenditures.

Technical Analysis #3: Implementation of Dewatering System

The third technical analysis was a thorough investigation and re-design of the projects dewatering system. A significant amount of time and money has been lost due to an unanticipated high groundwater table. A mechanical breadth is introduced in this section as a selecting, sizing and mapping of a deep well dewatering system is performed to effectively service the site under the given conditions. Cost analyses and schedule impact analysis have indicated that the lost 2 months of the current project would be save from a dewatering system implemented prior to excavation and a total of greater than $1.4 million could be saved.

Technical Analysis #4: Stormwater Harvesting System

The fourth and final analysis explores the opportunities for owner cost savings and sustainability improvements with the use of a proposed stormwater harvesting system. It is a goal of both the owner and project teams to acquire an additional two LEED credit points to achieve Gold certification. Unfortunately, due to the building system water load demand the implementation of solely a harvesting system will achieve these points. Water run-off reduction and water consumption have reduced producing an annual savings of $455,630, but would pay off for the installation cost after 2.6 years of building operation.

Acknowledgements

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Turner Construction Company

HDR, Inc.

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Corretta Bennett – Turner Construction Co.

Justin Beaver – Griffin Dewatering Co.

Andreas Phelps – Balfour Beatty plc.

Mitch Cormelius – Mortenson Construction Co.

Reno Russell – Bigge Crane and Rigging Co.

Joe Hockberger – Mersino Dewatering

Jordan Kahlenberg – Contech Engineering Solutions

Ken Dombroski – Contech Engineering Solutions

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Project Description

The Maryland Public Health Laboratories project is a 234,000 medical research project that has been under construction since December 19, 2011. Partners, East Baltimore Development, Inc. and Forest City – New East Baltimore Partnership, have developed the area of East Baltimore and have commissioned for a new facility to be constructed on the Science & Technology Park at Johns Hopkins University. The owner MEDCO has financed the building and holds contracts with the majority of the parties involved with the design and construction of the project.

The building that is currently being constructed will be occupied by the Maryland Department of Health and Mental Hygiene, who has requested that they require a facility of at least 225,000 gross square feet to perform necessary research in their field. The Maryland Public Health Laboratories has been designed at a total of 234,040 gross square feet and will consist of seven stories. Two of these stories include a 40 foot mechanical penthouse that will host all HVAC units. The project has been priced at approximately $111,400,000 and is to be completed by expected date of April 19, 24.

The current project teams that area involved with the design and construction of the project are HDR, Inc., Jacobs Engineering, and Turner Construction Company. HDR, Inc. is the project designers, who are in charge of all building architectural and engineering designs. HDR has designed the facility as such to not only support the current functions and research performed by the Maryland Department of Health and Mental Hygiene, but was required to meet the needs for future growth of the science and technologies of public health.

Jacobs who has been awards the Lump Sum CMc contract, is the project manager for the Maryland Public Health Laboratories. They are to oversee and manage all project progressions and facilitate issues that arise between the owner and construction. Both HDR and Jacobs hold contracts with owners MEDCO and deal directly with consultants from both MEDCO and the Maryland Department of Health and Mental Hygiene. Turner Construction holds a contract with Jacobs as the general contractors on the job. Turner is responsible for the budgeting of subcontractor work and noting construction progress through the duration of the project.

The current project has been mandated by Baltimore and the state of Maryland that the building achieve a LEED certification of LEED Silver. There has been a strong effort has been demonstrated to revitalize the community of East Baltimore, as this was once an unfavorable are of the city. The building has been required to express the ideas of innovation and progress through its looks, sustainability, and practices. The Maryland Public Laboratories is to be an iconic building within the East Baltimore community, revitalizing the surrounding neighborhood and its residents.

Figure 1: The Maryland Public Health Laboratories (image provided by HDR, Inc.)

Client Information

Building Owners

The building owners, who've financed the project and are building a facility to house future occupants, the Maryland Department of Health & Mental Hygiene, are a highly respected health care company. This American based company currently serves more than 65 million citizens across the United States.

Their main area of focus is pharmaceuticals, as they service private and public employers. Other markets that the company currently services are health plans, labor unions, government agencies, and also provide individual services. As a 2011 Fortune 500 it is a well-respected company in the healthcare industry. MEDCO was able to earn the number one rank in the Healthcare: Pharmacy and Other Services category in the Fortune's World's Most Admired Companies.

MEDCO is hoping to expand their company and technology by financing the construction of complex medical research facility, which is currently known as the Maryland Public Health Laboratories. The occupants of the facility are researchers whose goal is to advance the medical industry with the research they produce. The hope is the current building will provide the environment to do so.

Building Occupants

The Maryland Department of Health & Mental Hygiene, located in Baltimore, MD, is a government department that provides a multitude of services and conducts research related the health field. They strive to be at the forefront of medical research. To do so they have requested to have new state of the art health laboratory constructed to replace the existing laboratories.

The occupants have expressed its desire to enhance the local community by adding to the renowned Johns Hopkins Science and Technology Park. This area of Baltimore has been in a revival process and the Maryland Department of Health & Mental Hygiene has decided to be involved in improving the community and habitants within. Also, a request of the building occupants is to implement a design that will promote functionality and flexibility, in hopes to enhance collaboration of the occupants who will work and conduct research within the facility. In the eyes of the owner a dynamic expression must be provided from the build, demonstrating science of public health, as well as environmental sustainability.

Sustainability is a feature requested by the occupants, as the State of Maryland has mandated the facility to be designed in such a way that it achieves LEED Silver.

In the end the Maryland Department of Health & Mental Hygiene wants to receive a functional building of quality work. It should demonstrate the progress of public health and the importance to strive for enhancement in the field. This state of the art laboratory is designed to express such aspects sought out by the building occupants.

Project Delivery

The project delivery system chosen for the Maryland Public Health Laboratories was a design-bid-build system with a lump sum GC contract. This type of system provided the best fit due to the type of building being constructed. Specific codes and requirements are necessary and must be in compliance with when designing a facility of such difficulty. The design must have met these requirements before any phase of construction could have been initiated as requested by the owner. HDR, an architecture and engineering group, was selected to design all aspects of the building.

The bidding for construction management began with a prequalification process, which was issued to all bidding companies. The objective of the owner was to create a qualifying shortlist of competent companies for the job. Companies that were selected to the shortlist were issued bid documents to price. To award the contract, a final selection was chosen based on a “best value” of the project. Jacob’s Engineering Construction Services was awarded the project with Turner Construction as their general contracting group. Other companies were also issued portions of project including commissioning, material testing and inspection, and testing and balancing, which are all contracted to MEDCO.

Jacobs Management team upholds contracts with only Turner, assuming responsible for the work provided by them, and the owner, MEDCO. Turner in turn hold contracts with the subcontractors used on the project. HDR and Jacobs do not contractual agreements with one another, but do work together to execute the designs in the field. Contracts pertaining building designs are held solely between the owner, MEDCO, and architectural and engineering firm, HDR. The chart indicates all major companies involved in the project and their relationships with one another. General contractual agreements will be indicated within the chart.

To provide security for the project, insurance and bonding was purchased by both Jacobs and Turner. Contractor controlled insurance program was implemented in the project. This means Turner has taken responsibility and has provided insurance coverage over all subcontracted and contracted work, rather than the owner of the project. This policy virtually covers all working parties on the project, providing protection if there is an issue regarding lack of performance, quality work or damages that occur during the project.

Along with the contractor controlled insurance program, a payment and performance (P&P) bond has been agreed upon for this project. This is a contractual agreement that the contractor, Turner, ensures completion of all work specified in their scope or will face penalties. Failure to complete the work will result in no pay and the surety company who created the bond will have to locate another contracting group to perform the remaining work.

Project Team Staffing Plan

Jacobs's Construction Services has assembled their team in such a way to encourage efficiency managing this project. Project managers, Brian Temme and Ahmad Hamid, are located on site and deal heavily with owner relations and are involved with Turner in the construction planning as well. They supervise project schedules, attend to cost budgeting, note progression of construction and establish reports to provide to there in house team, who then in turn can establish schedules, costs estimates, quality inspections, and more.

Within the Arlington, VA office, Jacobs has developed an in house project team of various divisions. These divisions include Safety Management, Project Controls, Scheduler, Contract Manager, Project Accounting, Cost Estimating, Design Reviews, and MTT Project Controls. The divisions collectively provide cost analyses, task scheduling, quality checks, safety programs/data, procurement/contractual information, and other various services.

To better understand the Jacob's organizational strategies an organizational chart is provided in figures below. **Figure 2** represents the staffing plan during the pre-design/ design/ and bidding phases of the building project. **Figure 3** represents the organizational plans during the construction of the project. This chart displays how the project managers are associated with groups and members involved in the project. Also, it shows how the home office support is linked into the project and the numerous divisions that consist of the in house team.

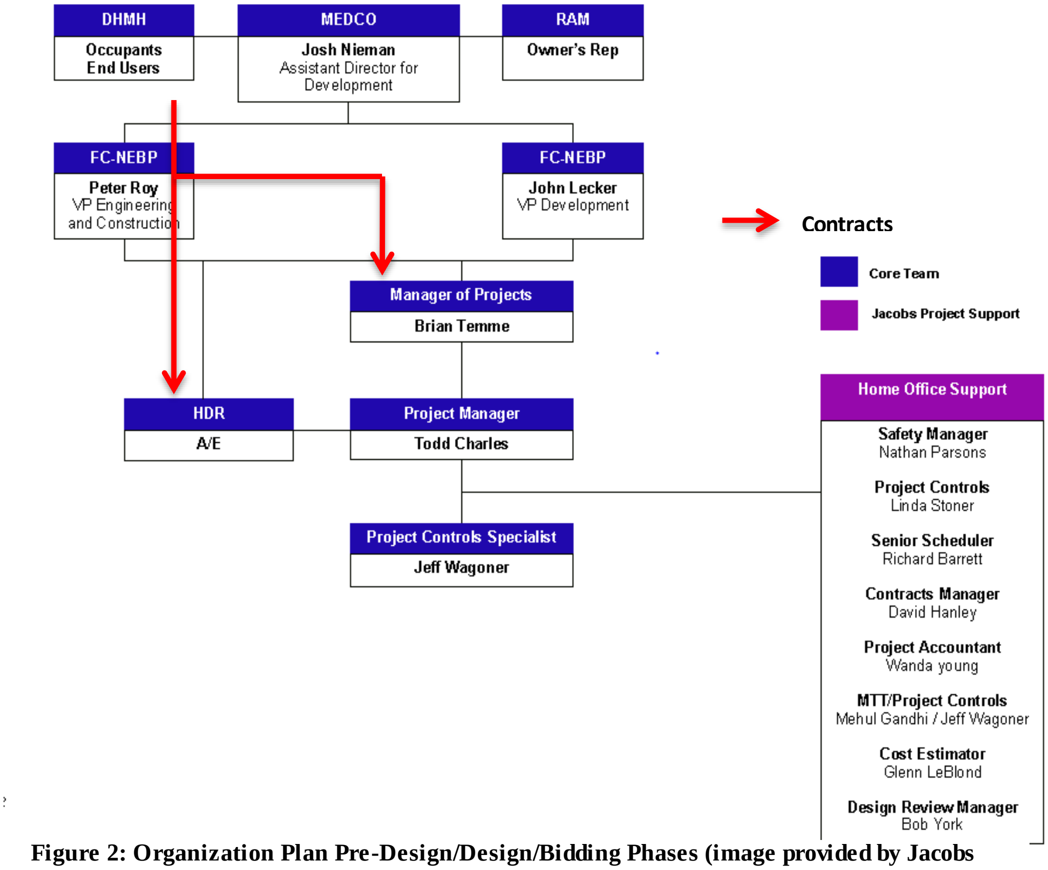


Figure 2: Organization Plan Pre-Design/Design/Bidding Phases (image provided by Jacobs Engineering)

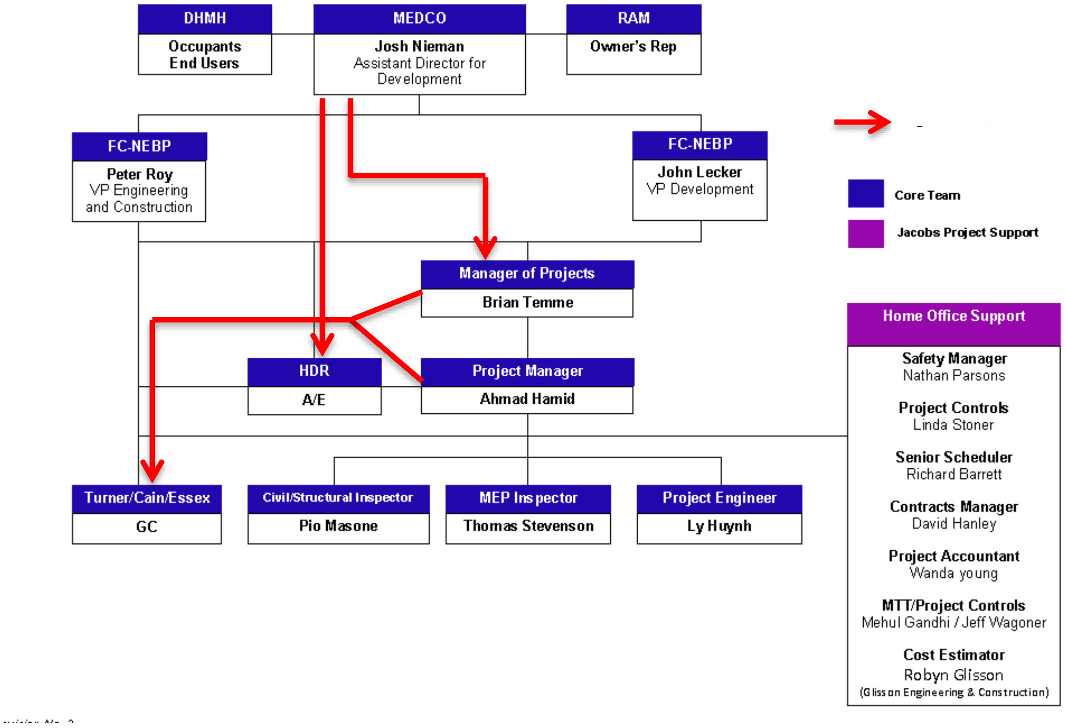


Figure 3: Organization Plan Construction Phase (image provided by Jacobs Engineering)

Building Systems Summary

The Building Systems Checklist provided below indicates the building systems existing within the Maryland Public Health Laboratory project. Provided shortly afterwards are building system summaries that briefly explain the details of each system design of the project.

Yes	No	Work Scope
X		Demolition Required
X		Structural Steel Frame
X		Cast in Place Concrete
	X	Precast Concrete
X		Mechanical System
X		Electrical System
X		Masonry
X		Curtain Wall
X		Support of Excavation

Table 1: Building Systems Checklist

Demolition

The project requires demolition as the building footprint is located on an existing parking lot. The demolition isn't very substantial, but the removal of existing pavement, pathways, and foliage is necessary before excavation can begin. Roughly 50,000 sq. ft. of pavement and pathway needs to be removed along with 22 surrounding trees in the surrounding area.

Structural Steel System

Little structural steel framing is used throughout the project, but can be located in areas including the 5th Floor Terrace and Mechanical Equipment Support Dunnage Room. Steel framing for the terrace is designed to support loading of a green roof and pavers. The mechanical room uses structural steel to support mechanical and electrical equipment housed in the area. In addition to the structural steel used in these rooms, structural steel is used to in façade support connections. Used to support the curtain walls around the east and south facades, spandrel beams are introduced, connected to concrete columns of the buildings structure.

Cast in Place Concrete

Foundation

The foundation of the Maryland Public Laboratories uses spread footings that will bear at a nominal depth below the lowest floor level and are designed for an allowable net bearing capacity of 8 ksf. Footings located in the northwest corner of the building footprint are designed for 4 ksf. These footings located in this corner are lowered up to 17' below the lower level slab to reach competent bearing of approximately 8ksf. Foundation that is adjacent to footings that is located on top of soft soils are lowered such that the higher footing is no more than 1.5H:1V above the lower footing per the geotechnical report.

Foundation walls within the basement are 16” thick, and contain an average reinforcing weight of 150 lbs. /c.y. All foundation walls are supported by continuous wall footings. These footings are 3’ wide and 18” deeps. These walls are also designed with drainage to alleviate hydrostatic pressure onto the wall.

The lower level slab-on-grade is 5” thick and is normal weight concrete reinforced with 6x6-W2.0x2.0 welded wire mesh. Areas that are sensitive to vibration and are required to meet higher levels of vibration requirements are designed with a 6” thick reinforced slab on grade.

All slabs are designed to be placed on specified waterproofing, which will also be placed on top of an unreinforced mud mat. This will then lie on a 4” compacted drainage course and a properly proof-rolled sub-base. Under slab drainage is also provided to alleviate hydrostatic pressure on the slab on grade.

Superstructure

The Maryland Public Laboratories uses a concrete structural system of two-way conventionally reinforced flat slabs with drop panels. These slabs are 10” thick using 8” deep drop panels at each column. They are designed as such to meet an allowable vibration velocity of 4000 micro-inches/second at the mid-point of the bay.

The building is designs consist of two mechanical penthouses, the first with a similar structural two-way reinforced flat slab with drop panels of the typical building floors and the second using one-way slabs and concrete beams. The concrete beams provide support of one-story columns on the east and south sides of the roof.

Lastly to resist lateral loads imposed onto the building a 12” thick concrete shear wall is designed for all floors, excluding the penthouse level 2 and penthouse roof. These shear walls are designed using reinforcing of approximately 120 lbs./c.y. and will match the strength of the total column strength of each floor. In the penthouse moment frames are used to resist lateral loads.

Mechanical System

Supply Air System

The Maryland Public Laboratories’ supply air system is divided into two air handling systems, the first conditioning the laboratories and high-density occupant areas and the second for the office areas. The office area air handling system will contain a supply fan with a 60 HP motor and return motor of 30HP. The office AHU supplies approximately 31,000 CFM and will return air from the offices on the ground floor and the offices on the second fifth floors. The offices are positively pressurized with respects to the adjacent lab spaces.

Laboratory spaces will be served by an additional four AHUs that will provide approximately 79,000 CFM, using 100% outdoor air. The supply fans used within each of the four AHUs will be a 200 HP motor. All AHUs will be in active use.

The main air handling systems will be variable volume distributed with a variable frequency drive of the supply. This will maintain constant air pressure within all zones of the supply air distribution system. Throughout the entire year air delivered to these zones will be at a constant 55°F.

Exhaust Air Systems

Within the Maryland Public Health Laboratories there will be several dedicated specialized exhaust systems and a general laboratory exhaust systems that will all be provided with standby power. The General Laboratory exhaust systems consist of four 83,000 CFM single width, single inlet centrifugal exhaust fans with motor starters. These are located on the roof within a screened area and will be manifolded together. Each fan will be approximately 125 HP. Exhaust air passes 30% pre-filters and an energy recovery wheel prior to exhaustion. All four fans within the system will operate with a flow rate of 62,000 came. each.

Exhaust systems of specialized labs will not be discussed as requested by the building's owner.

Cooling System

There is three water cooled chillers located within the mechanical penthouse of the facility that will provide a total cooling load of approximately 2100 tons and a design flow of 4200 gpm. AHU's will receive the cooled water by means of chilled water mains that are 12" in diameter. These coolers will operate with a supply design temperature of 44°F and a return temperature of 56°F. The components that comprise this system include an expansion tank, air separator; three dual cell roof mounted cooling towers using a 25 HP motor, a waterside economizer, four chilled water pumps sized at 1,500 gpm., and four condenser water containing 2,250 gpm. VFDs.

A process-chilled water system is designed to provide cooling to condensated waste from the steam sterilizers. The purpose of this system is to reduce the amount of domestic water wasted to drain and cool the sterilizer condensate more effectively. This system will contain two centrifugal pumps sized for 50% capacity, 130 gpm. with VFDs, as well as a 500 gallon storage tank used to reduce chilled water temperature fluctuation.

Process Steam, Heating and Humidification Systems

The laboratory will be served by three dual fuel, natural gas, and no. 2 diesel fuel, flexible watertube steam boilers. These boilers are located in the boiler room within the mechanical penthouse. Each boiler will be used to serve one third of the building load. The steam boiler is designed to operate at 100 psig and provides steam for the tissue digesters. Used within the system are two 1/3-2/3 pressure reducing valve stations. These stations function by reducing the steam pressure down to 80 psi for the process load and 15 psi for the humidifiers.

A packaged condensate return unit with pressure powered pumps is used to return low pressure condensate back to the deaerator. The deaerator is used to remove dissolved gasses from the boiler feedwater. A surge tank is designed to accept a slug of condensate return from the condensate return unit.

The systems designed for the Maryland Public Health Laboratories will provide a load of 8,400 MBH and a design flow of 420 gpm. using 6" hot water piping mains. The heating needs are served by four 3,000 MBH, duel fuel, natural gas and no. 2 diesel fuel high efficiency, direct vent, condensing boilers. These boilers will also be located in the boiler room within the mechanical penthouse and each will serve one third of the buildings heating load. There will also be a fourth redundant boiler. These boilers will operate with a supply design temperature of 140°F and return temperature of 100°F. The system will be comprised of an expansion tank, air separator, and three pumps sized for 300 gpm, with a VFD.

Electrical System

The building's primary electrical distribution includes a 480Y/277Y, 3000 amp main switchgear that will be provided power by 2500kVA, 480Y/277V utility transformers. The main switchgear and circuit breaker is located in a main electrical room within the penthouse of the building. Electrical power is then distributed to life safety electric closets, containing emergency electric panels and transformers. These are located in the penthouse and basement and serve to power life safety lighting, fire control room, and specialty lighting, in case of emergency. Also, distribution will occur to floor electric closest located among each floor. These contain normal utility and standby power electric panel boards and transformer.

Located within mechanical/electrical penthouse will be two generators and generator paralleling switchgears. These generators are designed to be controlled by the Automatic Transfer Switches, which are required for emergency and legally required power. They are designed provide the necessary amount of power to meet all emergency, legally required, and optional standby electric loads.

Lastly on each floor there will be two 480Y/277V switchboard and one 208Y/120V receptacle panelboard, provided power from the main panel board in the mechanical penthouse. The two 480Y/277V are designed to serve both the lighting and small equipment present on the respected floor. The 208Y/120V receptacle panelboards also have a power transformer associated with it.

Masonry

A brick veneer on structural steel framing will be used on the east, west, and north elevations. A random pattern will be implemented with the use of two separate color range "blocks." They will be set in a way to incorporate the recessed and contrasting vertical bands used to tie control joints and window edges.

Curtain Wall

There will be a curtain wall system implemented on the east and south facades. The stick built system will include integrated steel supports to allow for the designed sunscreen and catwalk systems that will be included with the curtain wall design. The south façade will include integrated panelized sun shades supported by an internal steel support systems connected to the curtain wall.

Support for Excavation

In order to construct the building, foundation was needed to be installed. As the site boundaries are very constricting, certain measures had to be taken. Adjacent roadways and structures had prevented simple excavation to occur. The process of driving H-piles into the soil and the use of sheeting, tie-backs, and whalers was the choice of supporting the excavated areas. Excavation and supports began on the west end and continued east until all sides were fully supported. A portion was left unattended as this was used as an access ramp, providing vehicle and personnel access to the center of the excavated area.

Project Cost Evaluation

To successfully evaluate the cost associated with the construction of the Maryland Public Health Laboratories several cost analyses had to be conducted. These analyses included building cost overview, building system cost overviews, building square floor estimates, and system assembly's estimates. Project and Construction cost values are provided in the Project Cost Overview **Table 2**. The table provides actual building construction costs, as well as construction costs per square foot. Construction costs include approximately a General Conditions cost of 11% by the General Contractor. Also included within the table is the Total Project cost, which includes non-construction related costs (e.g. sitework, insurance, bonding, utilities etc.)

Project Cost Overview

	Actual Cost	Cost per SF
Construction Cost	$111,400,000	$474/SF
Total Project Cost	$174,3231,174	$529/SF

Table 2: Project Cost Overview

As depicted above the cost of construction is approximately $111M. There is an additional $63M added to construction costs creating a total project cost of approximately $174M. The additional costs included in the project are:

- Permit and Bonding
- Utility Connection Fee/Costs
- Equipment & Furnishing
- Testing & Inspections
- Consultants & Specialty Consultants
- Insurances
- Architectures & Engineering Services
- Financing
- Development Management
- Owner Contingency

The second costs analysis provides cost data regarding the building systems of the project. These systems include Sitework, Structural Steel, Cast-in-Place Concrete, Masonry, Fire Protection, Radiation Protection, HVAC/Plumbing, & Electrical systems. This information is provided in **Table 3**. Each system will be divided into a total valued cost and a cost per square foot as well. This will provide insight how the costs of each system compare to one another and how expensive it is to build a design of such complexity.

Building Assemblies Cost Overview		
	Actual Cost	**Cost per SF**
Sitework	$3,298,846	$15/S.F.
Structural Steel	$2,300,000	$10/S.F.
Cast-in-Place Concrete	$8,242,200	$37/S.F.
Masonry	$1,290,000	$6/S.F.
Fire Protection	$510,000	$3/S.F.
HVAC/Plumbing	$23,615,000	$105/S.F.
Electrical	$14,110,000	$63/S.F.

Table 3: Building Assemblies Cost Overview

The second table indicates that the most costly systems within the designed building are the HVAC/Plumbing and Electrical systems. This is usually typical in buildings such as these, as intricate designs are needed to meet the extensive requirements of laboratory facilities.

The next cost analysis performed was a square foot cost of the building. Cost data was collect from "RSMeans Square Foot Costs" manual to establish a rough cost estimate for the laboratories. The value calculated using this method is inaccurate in comparison to the previously established building cost because many of the building's details are neglected in the research. The rough estimate of the laboratories was approximately a$55M difference from the projected total cost. This is due to the fact that medical or biological laboratories are not provided by RSMeans. A 4-8 story hospital had to be used to develop the cost data as this building type is the most similar to a laboratory. Also details including unique building systems, building structure, exterior envelope design, and other aspect are lost from the cost calculations. Provided in the table below, **Table 4**, are the total cost value of the square foot cost estimate performed and the cost per square foot.

Square Foot Cost Estimate		
	Estimated Cost	**Cost per SF**
Construction Cost	$54,558,000	$273/SF

Table 4: Square Foot Cost Estimate

The final cost analysis conducted was an assembly's cost estimate. These costs were based off the mechanical, electrical, fire protection, and plumbing systems. General cost data of particular items included in these systems was chosen and collected together to form a general cost for the entire system. This provides a rough cost estimate for the MEP system within the facility. **Table 5** below shows all cost estimates for specific systems within the building. Assumptions were made when establishing these values such as this building is assumed to be a medical facility as laboratory data isn't provided. Many of the complex systems within the design aren't provided by RSMeans so systems and items chosen are the most similar to that of the intended design. Costs aren't adjusted to the area nor the year with assemblies cost.

Building Assemblies Cost Estimate		
	Estimated Cost	**Cost per SF**
Mechanical	$21,53,250	$10/S.F.
Electrical	$271,305	$1.2/S.F.
Fire Protection	$2,493,0000	$11/S.F.
Plumbing	$86,265	$0.34/S.F.

Table 5: Building Assemblies Cost Estimate

After both cost analyses were conducted there are very few similarities between the costs of systems in the overview versus those in the cost estimate. The only system that shares any sort of resemblance is the mechanical system once combined with the plumbing system, as referred to in the assemblies cost overview table above. Again the difference in cost values derives from the lack of data provided by "RSMeans Assemblies Cost Data" manual. Many significant components of each MEP system design couldn't be located within the book. This created the need to establish assumptions. All collected data was based on its similarities to the system specifications and components. Using RSMeans to create a cost estimate can only provide a rough estimate of a system and isn't used to determine an accurate cost of a building project and its systems.

Existing Conditions

The Maryland Public Health Laboratory project is located within the New East Baltimore Community (NEBC) PUD, a community that is joined together by the Johns Hopkins Medical Campus and the Middle East neighborhood. As this project resides in an urban settlement, the area is currently developed with existing structures, roadways, and utility lines that are adjacent to the site. These conditions pose as key factors as the management team and the general contractor coordinate plans for construction. Construction must be planned to suit the area, complying with state and city requirements. Concerns for the local public must be taken into consideration as the project is located adjacent to neighborhoods and work facilities. ***Figure 4*** provides an aerial view of the project site.

These constricting conditions serve as a hindrance when excavating the site, as excavation will be necessary to implement the building design. Because of existing structure a typical set-back excavation cannot be achieved. A support system is most likely going to be implemented on the project.

Figure 4: Site Aerial View (image provided by Bing.com)

As seen in the provided picture the site is located between three existing roadways, Ashland Ave., Barnes St., and N. Rutland Ave., creating logistical issues as the already developed area provides little room to stage equipment and conduct work. Existing utilities associated with the adjacent roadways include sanitary, storm, gas, water, concrete encased duct, and Comcast Coax lines. Specific utility lines do pass beneath through the building project boundary and must be tended to during the demolitions and excavation phases. Both designers HDR and construction teams Jacobs Engineering and Turner Construction plan to improve some of the existing utility lines that will directly feed from the building project. This has been requested by the city and state.

It has been also been requested by the state that the contractor awarded the project would newly install and improve existing utility lines. On the west side of the site is a 3-story masonry block building and to the north a 4-story building. A proposed plan to create an alley between the laboratory and the east masonry building is indicated within the scope of the project.

Along with surrounding conditions it is also worthy to note that the site boundaries are located on an existing parking lot. Lamp posts, planters, trees and pathways existed within the area and all were needed to be removed to proceed with construction. Provided within **Appendix A** will be an existing conditions plan depicting site boundaries, adjacent structures/roadways, and other significant conditions.

Site Layout Planning

A major concern when involved with construction in an urban development is the minimal area provided as well as the surrounding conditions. The Maryland Public Health laboratories site lies between three streets and another structure. Coordination of work, safety, and staging of materials becomes difficult when working in such tight spaces. Fortunately, the city of Baltimore allowed the use of the adjacent parking lot for a trailer compound and employee parking. Also, there is a strong need of focus on incoming and outgoing traffic from the site. Traffic control must be coordinated in such a way that promote steady flow and will not cause vehicular traffic. Traffic can delay material deliveries and in turn delay the work being performed on site. The project site uses six gates located on all corners of the site perimeter. It is beneficial and necessary to document a logistics plan, strategizing how to handle such issues that are present with a site similar to this.

The three stages of construction that will be focused on are the Excavation of the site, the erection of the Superstructure, and Finishes being done within the enclosed building. Each requires certain attention as they possess dissimilar aspects of one another. For instance a crane is needed during the Superstructure phase, as in the excavation phase dewatering systems may need to be implemented. There are several similarities of each phase site plan that include trailer compound area, site boundary fencing, temporary power distribution station, areas of egress, and staging areas. Some maybe subject to move at certain period, but generally remain constant throughout construction. Brief site layout descriptions are provided of each of the three stages, as well as a site layout plan located in **Appendix B, C, & D.**

Excavation

The excavation plan depicts the events and activities taking place while excavation occurs. In the site plan provided in **Appendix B** there are several key elements that are enforced. These include excavation boundaries, tie-back areas, dewatering lines/pump, and an access ramp. It is necessary to note the excavation boundaries on a plan because it notifies areas that can be used for alternative means. The excavated area indicated on the plan is located near the site fencing along Ashland Ave. and N Rutland Ave. It extends in a rectangular fashion from west to east as most of the excavation occurs east. Tie-backs are included on the drawing indicating where they are in use. A dewatering system is provided as the project experienced flooding as excavation continued deeper. A dewater line runes around the perimeter of the excavated site and is operated by a dewatering pump in the north end of the site. An access ramp is shown, providing a mean of access for personnel and vehicles working within the excavated area.

Superstructure

The superstructure plan provides a visualization of the operations that exist during the erection of the building's structural system. **Appendix C** provides a logistics plan of the phase, depicting key activities and elements present during this period. A crane is placed in the south center of the building footprint, as there is little room to use a crane able to perform work for this project along the edges of the site. Crawler/mobile cranes could not reach areas and they would need to travel to certain areas to perform work. This would prove inefficient compared to that of a tower crane. Also provided in the plan is scaffolding used by the trades to complete the building envelope. The scaffolding will move west to east as indicated on the drawing as the erection of the concrete structural system is progresses from west to east. Concrete trucks are located near the trailer complex in the northeast section of the site. Concrete and material deliveries enter the site via Ashland Ave. and will exit either up Rutland Ave. or back through Ashland Ave.

Finishes

The finishes phase of construction is the period of construction after the building has been dried-in and interior work is in progress. The logistic plan located in **Appendix D** shows significant features of this phase and how they are lain out across the site. Material/personnel hoist are depict along the north façade of the building providing temporary transportation until the elevators are active within the structure. Dumpsters and recycling are located near the trailer complex and are used to dispose of waste accumulated on site. Lastly a materials laydown area is located along the north fence line. Materials staged here will be brought into the building via the hoists and used for finishes construction.

Local Conditions

As the new Maryland Public Health Laboratories are being constructed in a previously developed area there are several local conditions to consider regarding the design and construction of the building. To begin, local requirements and codes must be in compliance with as the project resides on a medical campus and adjacent to local Baltimore neighborhoods. These local neighborhoods have been constructed under an urban renewal plan that the design and construction of the building must abide by. These guidelines were established to promote a rebirth of once an unfavorable area. The city expects the building to be designed in such that it's aesthetically pleasing, expressing a progressive appeal, but standing harmoniously with the surrounding building within the Johns Hopkins campus it resides. Other ordinances enacted by city council have shaped the design of the building, surrounding streetscape, and process of construction used on the project.

As the area is a medical campus and open to the public, noise codes must be taken into consideration while constructing. Heavy construction can't exceed past a certain time of day because such activity produces noise that disturbs local residents. Also vehicular and pedestrian traffic remains constantly present within the area and must be attend to. This assures safety of local pedestrians in the area and promotes work efficiency.

The city of Baltimore has allowed construction teams to assemble adjacent to the site in the existing parking lot. This has proved beneficial because local conditions would have prevented the trailer site and parking to be in proximity to the building. This would have created inefficiency in construction as delays from site to the working trailers would consume valuable time in a work day.

Along with the requirements the project must follow mandated by the State of Maryland and City of Baltimore the site possesses geological issues that were attended to throughout excavation. The main issue was that excavation proceeded past the local water table. The water table in the area lies approximately 15 ft. below grade. Because excavation continues deeper than the water table line the project inevitably experienced flooding within the excavated area. Measures were taken to pump the excess water out from the excavation area by means of a water pump and line.

Detailed Project Schedule

On any given construction project there are several schedules that are the driving force of task progression and completion. These schedules are continuously revised to ensure accuracy, factoring any change in the construction process. A detailed project schedule contains the specific individual tasks performed throughout the duration of an entire project. These tasks define the steps to complete a larger portion of work, allowing other forms of work to begin or continue.

Another use for detailed schedules is to provide specific work sequencing of individual tasks. It can be easily noted whether certain tasks can work simultaneously without causing delays of other tasks being performed on site.

The Maryland Public Health Laboratories is currently run on a strict schedule that has been provided by Jacobs Engineering. The notice to proceed was issued for January 1, 2012 and the project completion date is set at April 19, 2014. Between these two dates are thousands of individual task necessary to complete the project. To simplify the many task of this schedule, it was sub-categorized into major components of the design/construction. This provided an idea of what tasks and assemblies are necessary to be complete d to successful complete certain construction phases. Jacobs also used their schedule to indicate the sequencing of work zones as project tasks are seen being performed from the west end of the building to the east end. This is one of several ways Jacobs ensured work progress efficiency as multiple tasks can be performed at once.

Schedule Description

The detailed project schedule developed has been divided into several key sub-categories that depict the major assemblies and phases consisted within the project. These categories include Site work, Foundations, Slab on Grade, Concrete Superstructure, Structural Steel, Stairs, MEP Risers, Building Envelope, Elevators, Interiors, Commissioning, and Close-Out. Each are important steps of the construction process and will continue to be further discussed. A detailed schedule is provided in ***Appendix E*** of the report.

Sitework

The sitework portion of the schedule pertains to the preparation period and excavation necessary to begin the construction of the building structure itself. Mobilization, soil testing and site demolition were a few of the first task performed on site. Excavation of the site began several months afterwards due to proceeding foundation tasks that were necessary to begin excavation intended for sitework. The few tasks that were included with sitework excavation were the excavation of the north retaining footing/wall and the installation of underground utilities around the building perimeter.

Foundation

The foundation phase of the schedule is one of the first phases experienced on site. The site is located in a confined, developed area and specific procedures of going about excavation for foundations needed to be considered. This portion of the schedule depicts the excavation process necessary to place the foundation. Foundation construction was able to proceed, while excavation was continuing as work was sequenced from west to east. The tower crane construction concludes the end of this schedule as this phase approximately lasted for 4 weeks.

Slab on Grade

It was essential to place the slab on grade at a specific date if the construction was going to run along its intended critical path. The slab on grade allows for the superstructure to proceed. This section of the schedule lasts for approximately 2 months as underslab utility installation, preparation for pour, and SOG pour are the primary tasks performed within the scheduled dates.

Concrete Superstructure

The concrete superstructure is the part of the schedule when structural members are being constructed. As this is a concrete structural system, tasks being performed include installing reinforcing steel, MEP sleeves, pouring elevated slabs and columns, and curing the concrete. The schedule is broken down by floor as the schedule progress as the construction of floors move upwards. Because of the limited amount of line items allowed to create this schedule, it was difficult to indicate that this process also was performed from west to east. To conclude this portion of the schedule structural steel installation within the penthouse was also provided.

Stairs/MEP Risers

Construction of stairs and MEP risers are provided within the schedule. These sections have been divided into the locations they were installed or constructed.

Building Envelope

One of the most intricate systems of the building project and a large portion of the detail schedule is the building envelope. The envelope schedule has been divided into exterior framing, façade construction and roofing. The building envelope again divided by floor as each floor takes roughly 20 days to complete. Each façade scheduled duration as certain elevation contains a multitude of exterior systems or more complex exterior systems. Systems that are provided within this portion of the schedule include precast band, brick veneer, metal panel, curtain wall, and storefront installation. This is a major component of the detailed schedule as many tasks are performed to dry-in the building. The duration of this period is approximately 10 months.

Interiors

The longest experienced portion of the schedule is the interiors. This includes all MEP work performed amongst all floors of the building, floor construction tasks, and interior finishes of each floor. The schedule is divided by each floor. The penthouse is the most detailed of all floors because it contains major mechanical components. These components take several months to install, connect to mechanical distribution systems, and power.

Each floor is scheduled as such to show MEP rough-ins and trim-outs of both overhead mains and branches. Along, with performed tasks regarding MEP, interior construction and finishes of each floor are provided within the detailed schedule. Again, because of limited line items there wasn't the ability to show the sequencing of interior work from west to east. This is the largest portion of the detailed schedule as interior tasks last approximately a year and a half.

Commissioning & Close-out

The final section of the detailed schedule is commissioning & close-out. This is the phase dedicated to testing the systems within the building. It is used evaluate each system and note any problems a system might experience. This part of the schedule is broken down into its commissioning phase, endurance phase and followed by the final completion of the building.

The Maryland Public Health Laboratories project follows a stringent schedule lasting two years and 4 months. The scheduled provided in ***Appendix E*** narrows Jacobs provided schedule, representing in detail the major task performed at each phase of construction.

Technical Analysis #1: Precast Concrete Structural System

Problem Identification

Prior to erection of the building's structural system, the Maryland Public Health Laboratories project experienced significant time losses to the schedule. These unforeseen conditions have led to a great amount of money tacked onto the project budget as additional time has been counteracted with added manpower. It is imperative to find procedures or construction techniques that would absolve the time loss. To do so investigations within areas of building design and construction will exploit the possibilities.

The general design of this building is a rectangular building consisting of 6 stories and is constructed using cast in place concrete. Introducing a precast concrete design in the early stages of construction is an idea that could greatly reduce the schedule of the project, which would have mitigated the loss of time and money currently suffered on the project.

Research Plan & Objectives

The idea for this research analysis was produced after attending and listening to the topic of modularization and precast units in construction at the PACE Roundtable conference. It was chosen as a critical industry issue because this type of construction is proving to very imminent in today's industry, as owners and contractors want to produce buildings with extremely shortened schedules. There are various ways to implement precast and modularized construction within a project. The most logical method for the Maryland Public Health Laboratories is to use a precast structural system as the linear and mostly rectangular shape of the building allows for ability to create pieces that can easily build together. This eliminates costs for formwork and reduces scaffolding needed to build cast in place concrete units. Also, the ability to sequence the erection of these pieces becomes easier and due to the fact they are pre-casted, work fronts become accessible earlier in the project schedule.

To properly analyze this topic of research there are numerous areas that must be considered. A breakdown of the building's structural design, using both project design documents and column/beam schedules, must be conducted to acquire the information need to produce member sizes and quantities. Research regarding crane sizing is necessary, as the crane used to pick and install these pieces must counteract the weight of each member. Logistical research will provide information regarding the delivery process and installation of the members. Sequencing of the structural members will remain similar to sequencing of the cast in place concrete. Cost and scheduling impacts is the final area of research that will prove the feasibility of the study and indicate if the use of a precast structural system will reduce the project schedule.

To obtain the necessary information within each area of the analysis discussions from industry professionals will be conducted. Online research will help establish the best way to execute a precast concrete structural system on the given project. The phases from procurement to installation will be scrutinized throughout the entirety of the analysis to properly establish the feasibility of such an idea.

Application Methodology

To effectively research the analysis topic of the implementation of a precast concrete structural system, the following steps must be taken:

1. Breakdown of the building's elevated slab plans and column/beam schedules.
2. Determine sizing and quantity of specific structural members designed for the building.
3. Conduct interviews with industry professionals regarding precast systems and how they are implemented within building projects.
4. Research and size crane with the ability to handle specified loads produced by designed precast structural members.
5. Analyze site conditions to produce site logistical plans required for structural member deliveries, picks, and installation.
6. Consider and produce sequencing plans to understand the work fronts that will be available for laborers to begin their work.
7. An overall cost analysis will be perform to understand the earnings and expenditures associated with the precast structural system in comparison to the original cast in place concrete method.
8. Schedule impact analysis will indicate the dates when the beginning of the construction of precast concrete member will occur and when installation will occur in the overall schedule.
9. Lastly, an overall feasibility analysis will be conducted, considering all aspects that are involved with precast concrete structural systems used on this project.

System Overview

Precast concrete structural systems is a fairly new concept in the building industry that has been applied to reduce overall schedules of a project. Concrete members such as beams and columns, as well as elevated slabs are created offsite and typically delivered to the project the date they are to be installed. These members are prestressed at the location they are produced to assure they meet loading requirements.

The use of precast concrete structural systems has its benefits as it reduces a significant amount materials needed to create members. The elimination of formwork from a project site is one of many benefits exhibited when precast systems are used. As all members are produced off site, reusable formwork is used at these production locations to create numerous members. Material waste is greatly reduced as precision is easily attained at these controlled work environments. The quality of the structural members produced is also greater for similar reasoning as the reduction of material waste. Also, these members can be safely made as many hazards are eliminated in the controlled production locations rather than casting the concrete on site.

Because these precast structural members are cast offsite, the production of each can begin prior to when they need to be installed. This allows from the majority of the structural system to be created prior to the erection of the buildings structure. Also, as these members don't cure on-site work fronts are accessible earlier, allowing for additional work to occur earlier throughout the schedule. The sequencing and installation of these members is greatly quicker, as there is no need to install scaffolding, formwork, set reinforcing, and pump or place the concrete into the designated forms. This reduces schedule significantly and can potential reduce the costs of construction.

Figure 5: Hollow Core Planks (image provided by Bethlehem Construction Inc.)

Figure 6: Precast Column Erection (image provided by timesunion.com)

Building Structural Break-Down

To begin the topic precast structural system analysis a total breakdown of the Maryland Public Health Laboratories structural design was conducted. This breakdown encompasses the elevated slabs, columns, and beams designed for the building. Shear walls, foundation construction, slab on grade, and structural steel weren't considered in the precast structural analysis. It is uncommon for the slab on grade of a building to be precast and delivered for installation. Also, the structural steel within the design of this building is small and isn't incorporated with the majority of the structure.

The first structural system taken off from the design documents were the elevated slabs. The design documents used to take off the slabs were Floor Slab Layouts, which are provided in **Appendix F**. It is typical for precast slabs to be designed using hollow core planks. It was mentioned by an industry professional that the sizing of these planks are on average 32' x 4' feet in dimension. These units will be 8" in depth as this is the design of the original structure system to meet vibration requirements of laboratories. A 2" topping will be placed over the hollow core slab. Nitterhouse construction, located in Chambersburg, PA, produces hollow core planks of a minimum compressive strength of 5,000 psi which supersedes the building's slab designed compressive strength of 4,000 psi. Nitterhouse's hollow core specifications are provided in **Appendix G.** All these specifications allow for the use of 32' x 4' x 8" hollow core planks topping as the elevated slab system of the Maryland Public Health Laboratories.

The floor slab layout was divided into units of 32' x 4' to scale, as shown in **Figure 7**. Certain members were elongated to dimensions of 36' x 4' to meet adequate connection. Hollow core planks can span lengths of up to 40', which allows the ability to use 36' spans. Each member is placed adjacent to one another horizontally as they are to be grouted together along a key way provided in the precast design. Along the shorter ends, cylindrical voids within the slab are aligned between slabs and then are grouted together. Because the slab design of the building isn't perfectly rectangular, adjustments were made to fit the angular design in certain areas of the slab. This can be done because these planks can be cut at angles to fit angular shapes. Approximations were made in these areas these cuts were purely based off the drawings and aren't precise cuts made on-site. In addition to angular cuts, planks can be cut to shorten the member and used where there are long gaps between plank connections.

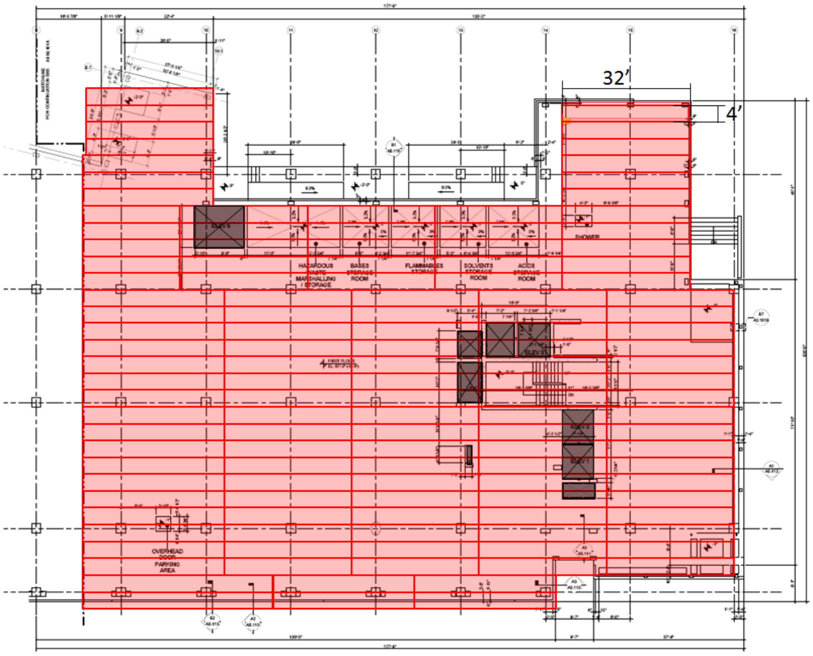


Figure 7: Hollow Core Plank Breakdown of First Floor West End (plans provided by HDR, Inc.)

Differences in slab layout between floors were considered as the first floor slab was larger than those of the above 5 slabs. The upper level penthouse level's slab is significantly smaller than all the others and was need to be taken into consideration to assure an accurate assessment of the quantity of hollow core planks needed for the project. The quantities of hollow core planks need for the slabs of each floor are graphically represented in **Table 6** below.

Table 6: Hollow core Plank Quantities per Floor

Level	Quantity
Floor 1	275
Floor 2	256
Floor 3	256
Floor 4	256
Floor 5	256
Lower Level Penthouse	218
Upper Level Penthouse	100
Roof	216
TOTAL	**11833**

The next portion of the building's structural system design breakdown is a take-off of structural columns. This quantity was established using the column schedule provided within the design documents. This schedule is provided in **Appendix H**. Precast concrete structural columns are typically produced in heights, ranging from 2-3 stories. The precast columns designed for this building range in various heights depending on the original design. Each column is spliced at specific floor heights and is connected using anchor bolts and baseplates, specifically designed for each designated splice. The reasoning for the column splicing is to accelerate the production process and erection process of the precast design. Larger units can be erected at more accelerated rates as there are less of them to place. These splices will occur on floors 3 and 6. The majority of the columns are designed spanning from the basement floor to the top of the third floor, the third floor to the top of the fifth floor, and the entirety of the mechanical penthouse space. 5,000 psi structural grout designed to resist shrinkage is placed between each column splice connection. A graphical representation of the splicing is provided in **Figure 8**. The anchor bolts fasten into the baseplate is to assure stability and rigidity of the splice connection.

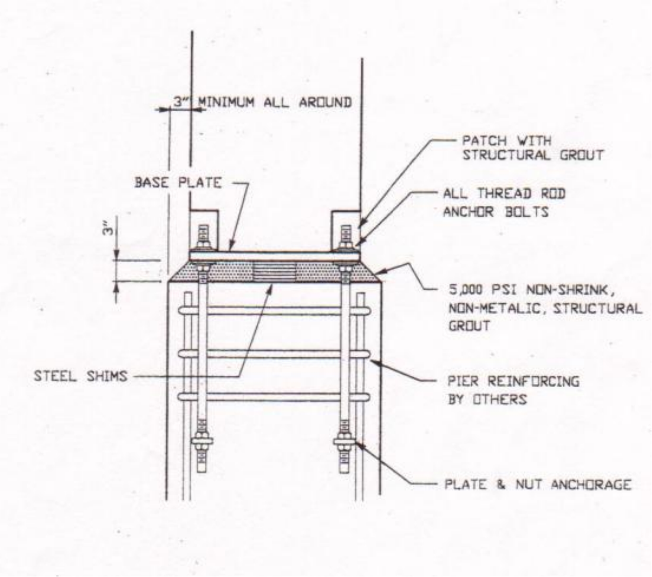


Figure 8: Concrete Column Splice Connection (image provided by Nitterhouse Concrete Products)

Every column taken off and combined to other building columns from the original drawings, to form those reaching 2-3 stories, never exceed 55'. This height was established after speaking to industry professionals as it would be too cumbersome and heavy to control during a critical crane pick of the larger members. Also, consideration in flatbed truck length was taken to assure every column could safely fit on the flatbed during deliveries. The longest flatbed extension of a truck by requirement can be 54'. The tallest precast column size designed for the Maryland Public Health Laboratories is 54', which is adequate with the flatbed truck requirements.

When combining columns of specific stories, considerations to column dimensions and original height were made. The subgrade portion of the building is 20'. The ground floor is 18' in height, floors 2-5 are each 16' in height and both penthouse levels are 20'. Whenever possible the subgrade and first two floor columns were combined for a total column height of approximately 54'. The following three building floors were combined for a total height of 48'. Lastly, the penthouse columns were combined for a total column height of 40'.

Unfortunately, there were many places where columns at specific column-line locations wouldn't extend the entirety of the building. Columns that only reached a single story or were located only at certain floors of the building were noted. In **Appendix I** a table is provided representing the designed precast concrete columns based off the original structural design documents. This table provides the column designation, dimensions, height, and reinforcement type and size of the column. It is important to note that all original reinforcement design within these members will remain the same. No changes to the reinforcement were done because it was mentioned that at the production plant reinforcement can be applied as shown in the original drawings without exceptions.

The last take off performed in the building's structural breakdown was the structural beams. These beams weren't indicated in the structural drawings in the Floor Framing Layout's so to obtain the quantity of beams need for the precast structural system design the quantity of concrete used within the 95% accurate bid was used. A total of 1,035 cubic yards or 27,945 cubic feet of concrete was used solely for beam design in the original design documents. Using the beam schedule within in the drawings, which is provided in **Appendix J**, a total of 394 beams were accounted for in the design of this building. Dividing 27,945 cubic feet of concrete by 394 beams, an average size for each beam in the building is 72 cubic feet. Because of the lack of information provided in the drawings there is uncertainty in the length of each member. The lengths of each structural member is established by the dimensions of specific members, provided by the column schedule, in association to the average column size of 72 cu. ft. established above. This value is based off the Turners budgeted amount of concrete specifically for concrete beams on the project. The amount procured for concrete beams was approximately 711 cubic yards of concrete. The breakdown of beams per floor is provided in **Table 7** below.

Table 7: Structural Beam Quantities per Floor

Level	Quantity
Floor 1	59
Floor 2	70
Floor 3	45
Floor 4	45
Floor 5	50
Lower Level Penthouse	70
Upper Level Penthouse	30
Roof	26
TOTAL	**394**

After the completion of the structural system breakdown into adequate sized members for precast design costs and sequencing can be established. This breakdown accounted for the slab, which is designed using precast hollow core planks, columns, and beams.

Crane Specification

The crane is an essential piece of equipment when placing precast structural members. Because these members are typically large and weigh a great amount a crane that can withstand such a load must be used to effectively implement the structural design.

Currently on the Maryland Public Health Laboratories project the Peiner SK 415 Hammerhead Tower Crane is being rented (complete specification provided in **Appendix K**). This crane's lifting capacity is approximately 22,025-44,050 lbs. (10-20 tons). Unfortunately, the precast design of the largest member, a 54' column at 32.75" x 28", weighs 48,432 lbs. This weight doesn't include the reinforcement, but is significantly greater than the lifting capacity of the crane that the reinforcement weight doesn't need to be taken into consideration. To implement a precast structural system there will need to be an increase in the crane size. The Peiner SK 565 is more suitable for the precast system conditions.

The Peiner SK 565 Hammerhead Tower Crane has the ability to lift up to 70,600 lbs. or 32 tons. (Complete crane specification provided in **Appendix K**) This lifting capacity is well over any weight produced by any of the designed precast members. Also, this mast difference between cranes 45', as the SK 565 reaches a maximum height of 260'. This height is suitable for lifting these members into place and the additional height provided room to efficiently move larger members without issues concerning lift height.

Figure 9: Hammerhead Tower Crane (image provided by Biggie Crane and Rigging)

Unfortunately, due to the increase in crane size, there is an increased cost associated. This will be discussed in the Precast Cost Analysis section.

Site Logistical Planning

The Maryland Public Health Laboratories project is located in an established part of Baltimore. There is existing features on all sides of the project boundaries that must be taken into consideration. **Figure 10** shows a satellite image of the current site. Because precast structural members are designed offsite and are delivered to the project when they are ready to be installed, planning for the delivers is necessary. Currently Jacob's and Turner, who are the responsible parties on the current project for logistical issues, are directing concrete trucks from N. Wolfe St., a block east of the site, down Ashland Ave. These trucks station adjacent to the tower crane located in the middle of the south side of the excavated boundary. Once each of these concrete trucks have provided all there delivered concrete to the site they are properly washed through a Neptune Truck Washing Machine approximately 100 feet down Ashland Ave. This is required by the city

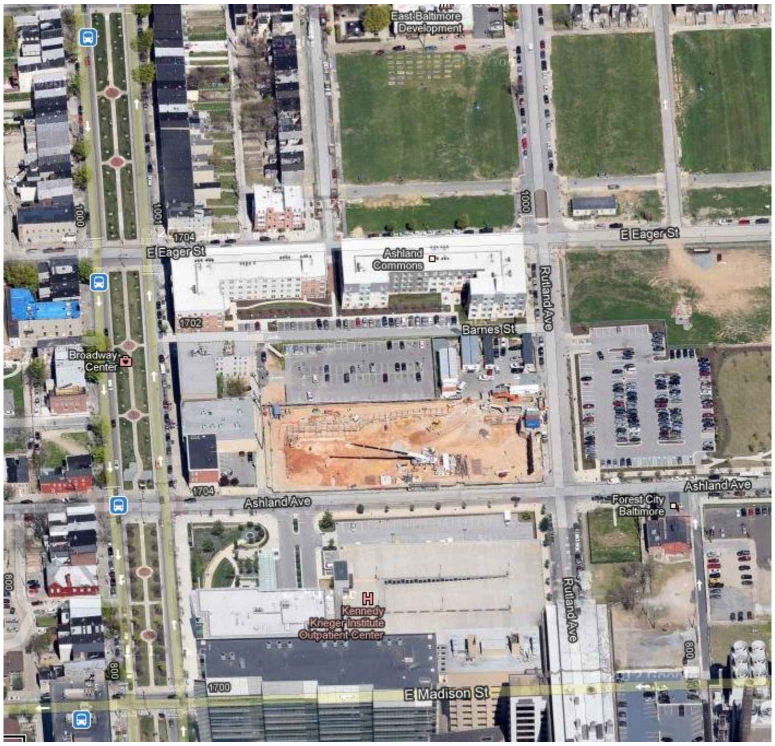


Figure 5: Satellite Image of Site (image provided by Google Maps)

and project as this ensures all concrete trucks leaving the area don't accidently leave debris and wet concrete on the streets and property of Baltimore.

With the use of precast units there won't be a need for this truck washing machine. The use of already cured concrete will eliminate any possibility for leaving wet concrete on the city streets. But, because grouting will be necessary to establish the precast member connections this machine will remain in place. These grouting pump trucks are required to be cleaned, similar to concrete trucks, as they do provide material of a cementitious nature. **Figure 11** is an image of grout being pumped from a delivery truck into a designated location.

Figure 11: Grout Delivery Truck and Pump (image provided by all-concrete-cement.com)

A similar logistics plan would occur with the precast member deliveries. As the project teams have already established clearance to use the streets mentioned above for concrete delivery, this will be the same route used for the precast deliveries. Flatbed trucks of dimensions of 98" width and 54' length will approach the site via N. Wolfe St and turn onto Ashland Ave. They will stage themselves in the designated zoned off area for crane picks. This zone has been approved by the city as staging area for concrete trucks therefor it will be used to stage flatbed delivery trucks and grout delivery trucks/pumps.

To assure efficiency in the precast member picks and grout pumping, project superintendents will direct the two individual trucks in such to reduce congestion. As grout pumps have a restricted reach they will be stationed along Ashland Ave. to effectively reach there designated grouting connections at the time. The precast delivery truck will be close in proximity to the pump truck, but there isn't as great of an importance of its staging position. The delivery trucks will station along Ashland Ave. in a location where the tower crane can effective and safely hoist the member off the flatbed.

Flaggers will assist the trucks and direct pedestrian and vehicular traffic on Ashland Ave. to assure safety to the nearby people and equipment. Because the current site is located in an urban environment it is crucial that flaggers be attentive to the occurring lifts. During member lifts traffic will cease until the member is safely fastened to its designed location. These large members of significant weight can cause property and health damage, so flaggers must prevent all traffic within the crane lifting radius. **Appendix L** depicts a visual representation of the site logistical plan of the delivery process of the precast members.

Precast Member Sequencing

Sequencing is an important constructability concept that must be logically planned to assure effective building. The sequencing of precast structural member installation will be similar to that of the original cast in place plan. After the slab on grade, shear walls, and foundation are installed during the subgrade structural phase, columns will be placed from west to east. These columns will be installed into designated footings along the slab on grade. The connection will consist of the baseplate attached to the bottom of the column face and anchored into the spread footing by means of anchor bolts. Similar to the column splice connection mentioned above, 5,000 psi non-shrink structural grout will be place between the structural connections. The connection detail is provided in **Figure 12.**

Columns will begin being installed at the north most column line E and continue towards the crane to column line A. Columns existing in the main bays will be installed prior to smaller columns being placed.

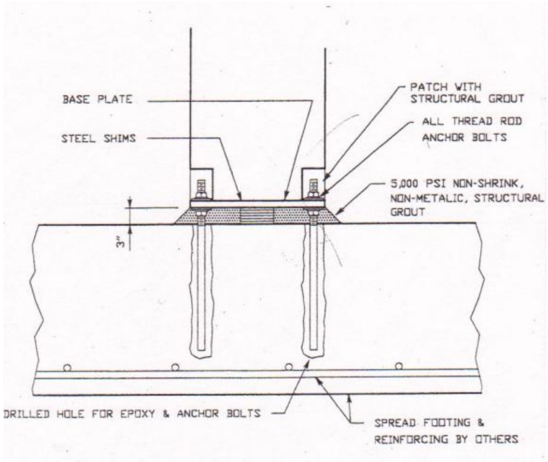


Figure 12: Column to Spread Footing Connection (image provided by Nitterhouse Concrete Products)

Once all columns that exist through the basement and first two floors of the building are installed are installed, beams designed for the first floor will be installed. These beams are connected to column members by grouting them to designed ledges along the precast columns. **Figure 13** depicts the connection of these columns and beams.

After all beams have been safely connected to their respective columns, hollow core planks for the first floor will be installed. These planks, similar to column erection, will be installed from west to east and from north to south. Each plank is fastened along ledger beams located around the perimeter of the building and lie on top of beams installed within the interior of the building. The edges of each plank are grouted into place using 5,000 psi grout on these hunches, or the ledges mentioned above, to assure stability. Hollow core planks are connected to one another by grouting adjacent keyways together. **Figure 14** provides a detail of hollow core plank connections. The a detail of the grouting keyways mentioned above is provided in **Figure 15**

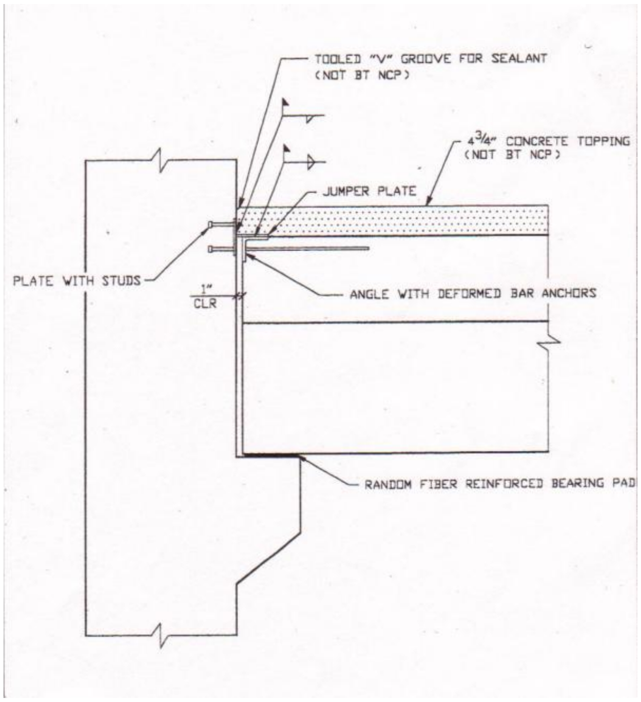


Figure 13: Precast Column to Beam Connection (image provided by Nitterhouse Concrete Products)

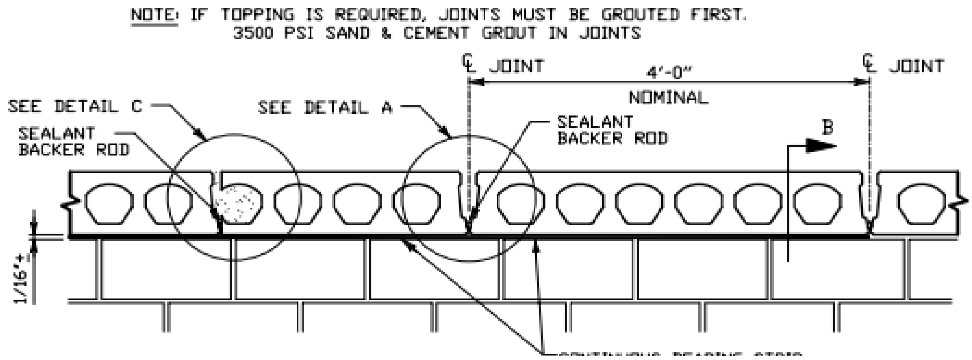


Figure 14: Hollow Core Plank to Plank Connection (image provided by Nitterhouse Concrete Products)

The installation of beams and hollow core planks will continue to occur in a similar process until the first three floors are completely erected. Columns erection will continue, as column splices will allow for the next three floors to be erected. Columns will connect to one another by means of anchor bolts and column shoes as mentioned above. Once all columns between the third to fifth floors are installed, beams then hollow core planks will proceed. This process will continue throughout the entire building, until all precast member have been safely connected to one another. The last of the structural member reside in the roof design and allow for the construction of the buildings envelope to commence.

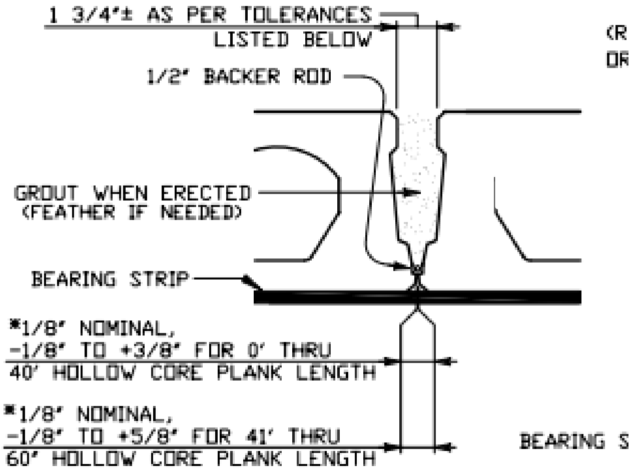


Figure 15: Grouting Keyway Detail (image provided by Nitterhouse Concrete Products)

Scheduling Impacts

The Maryland Public Laboratories has been planned to proceed on a strict schedule with a Notice to Proceed on December 19, 2011 and Completion of Work date of April 19, 2014. Unfortunately the project suffered great set back in the schedule, but the implementation of a precast concrete structural system will significantly reduce the time frame of the structural erection phase.

The original cast in place concrete structural design was proposed to take approximately 116 days to complete (May 25- Sep. 19). Because Jacobs has scheduled the concrete subcontractors, Miller Long & Arnold, to work Saturday shifts, the total duration for the completion of the cast in place structure totals to 97 days or 16.2 weeks. Many tasks involved with the original plan included erecting scaffold framing system, place formwork, pour concrete structural system, cure concrete, and remove scaffolding, formwork, and reshore. Many of these tasks are eliminated or reduced with the implementation of a precast structural system, reducing the time it takes to erect the building's structure. Because structural members are created off-site there is no need for formwork and scaffolding is significantly reduced. Shoring is reduced as well because the concrete doesn't need to undergo a curing process to reach its desired strength.

There are several additional factors to take into account when planning to use a precast structural system that don't apply to a cast in place concrete system. The time to pick and place members must be established, as well as the time it takes to grout and connect members. Columns and beams take approximately 30 minutes to erect, provided by industry professionals. Hollow core planks take roughly 10 minutes to erect and place each. Grouting and fastening connections occur during the member lift preparation and lifting process so doesn't affect the time it takes to lift members. Grout pumps are used to connect members together. The need for significant scaffolding become eliminated from the process and is negligible to the project schedule, according to industry professionals.

With the given lifting, erection and connecting information provided by industry professionals, time calculations are performed to establish the total amount of time it would take to efficiently erect a precast building structure. Using the 30 minutes erection time for beams and columns, a total of 41.6 days (8.3 weeks) will be the time it takes to erect 656 members. In addition, the total time to erect 1617 hollow core planks at 10 minutes per lift would be 38.2 days (7.6 weeks). There is no need to change the hoist block between lifts of different members as the same component can be used to lift each precast member. (It is important to note that all scheduling calculations are based on a 5 day, 8 hour work week.)

Table 8- Precast Member Erection Time

Members	# of Members	Pick Duration	Quantity
Beam/Columns	271 + 394 = 665	30 min.	19950 min. (41.6 days)
Hollow Core Planks	1833	10 min.	18330 min. (38.2 days)
		TOTAL DURATION	**79.8 days ~ 80 days**

The total amount of time it will take to erect a precast structural system will be the summation of both the beams/columns and hollow core planks and that will be approximately 80 days. This is a difference of 17 days or 3.4 weeks from the original cast in place concrete plan. The significant reduction in schedule almost absolves the lost two months in project schedule, due to ground water table issues. Also, because the concrete doesn't need to cure on-site, designated trades can begin work on finished floors as work fronts become available quicker. MEP work can begin 20 days prior to the original project schedule start date. This creates an additional reduction in the schedule that isn't accounted for within this analysis.

Production Duration

Precast units are produced off-site at a controlled production plant and are delivered to the project site at the time they are needed to be installed. Because most of the information about precast structural systems was provided by Nitterhouse Concrete Products that is the selected vendor for the project. It is typical to have approximately 75% of the concrete produced before structural erection occurs on site. With the given amount of precast members used for the Maryland Public Laboratories project, 2498 members must be produced prior to the erection process.

Production information provided by Nitterhouse indicated that 50 hollow core slabs can be created in one work day and 3 columns and beams can be created in a work day. Hollow core planks and beams/columns can be produced simultaneously so the members with the greater duration to complete will be the control time frame. Beam and columns will take a total of 222 work days to produce or 44 weeks (11 months).

To produce precast members in time for the erection process, production must occur on June 25, 2011. This date is approximately 11 months prior to the beginning of concrete structural construction on May 25, 2012, set in the original project schedule. Because Nitterhouse's concrete plant is located approximately 100 miles away from the project site in Baltimore, MD, deliveries can be shipped that day without layovers in designated locations. The expected delivery duration is 1 hours 42 min. according to Google Maps, so this will not ultimately affect the start production date of the precast concrete members. **Figure 16** depicts the intended route precast deliveries will take to reach the project site.

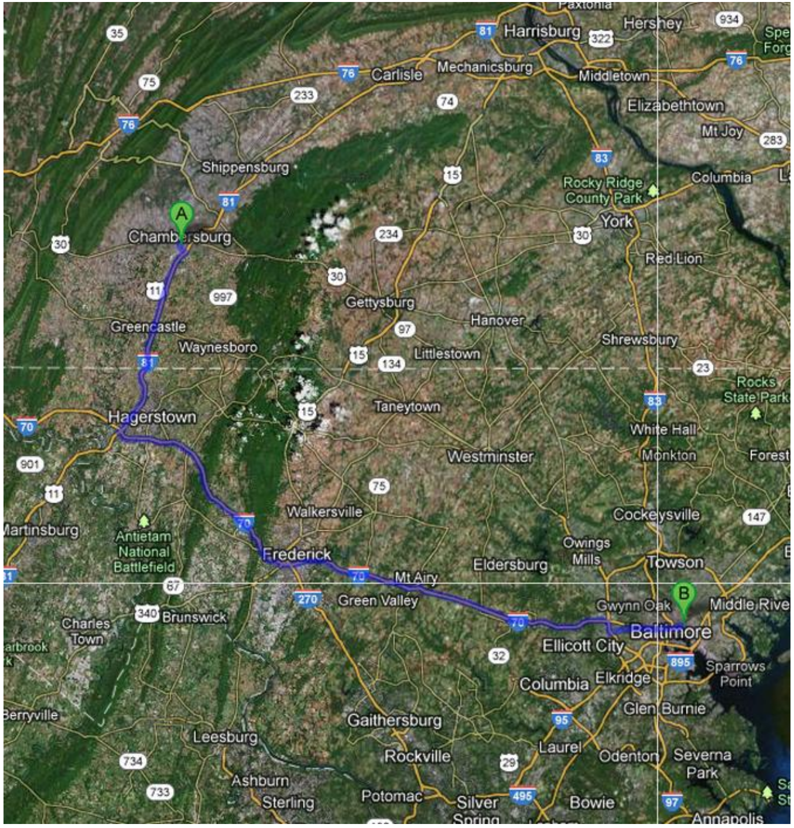


Figure 16: Precast Concrete Delivery Route (image provided by maps.google.com)

Cost Analysis

Typically the implementation of precast structural systems is to significantly reduce project schedule. In certain cases, cost savings can be associated with using precast and prefabricated unit in a design. Employing precast structural units for the superstructure of the Maryland Public Laboratories can save a large sum of money on the project.

In conclusion to discussion with industry professionals at Nitterhouse Concrete Products, cost values were established for the concrete units that would be used on the project. The cost of a hollow core plank, used to create the floor slabs of the building, costs on average $8.00 per square foot. It was mentioned that this price includes the following:

- 6000 psi concrete
- Production cost (labor, formwork, testing, etc.)
- 5000 psi reinforced grout used to fill cylindrical voids and create connections
- Reinforcement based on specification
- Delivery cost (preparation, fuel, driver fee)
- Erection costs (labor costs for 6 person crew)

Precast structural columns are valued at approximately $140 for every foot in height. This price includes:

- 5000 psi concrete
- Production cost (labor, formwork, hunches, testing, etc.)
- 5000 psi reinforced grout used to connect beams to hunches, splicing, and spread footing connections.
- Baseplates, anchor bolts (nuts and washers), steel shims, column reinforcement based on specification.
- Delivery cost (preparation, fuel, driver fee)
- Erection cost (labor costs for 6 person crew)

Lastly, structural beams are approximately $155 for every foot in length. This price includes:

-
- 5000 psi concrete
- Production cost (labor, formwork, testing, etc.)
- 5000 psi reinforced grout for connection to columns and hollow core planks.
- Misc. steel for connections (steel angles, jumper plates, studs, etc.)
- Delivery cost (preparation, fuel, driver fee)
- Erection cost (labor costs for 6 person crew)

Using the given cost values for each precast structural unit and the quantity needed to be produced to fulfill the design, the total cost for the precast structural system can be established. **Table 9** shows the calculated cost values of the hollow core planks, structural columns and beams, based on the costs data provided by a Nitterhouse project executive.

Table 9: Structural Precast Unit Cost (Vendor Pricing)

Precast Structural System Cost Using Vendor Pricing

Structural Unit	Quantity of Members	Calculated Units for Cost	Cost per Unit	Total Cost
8" Hollow Core Plank	1833	208,096 sq. ft.	8.00/ S.F.	$1,889,024.00
Structural Column	271	1373 ft.	140.00/ ft.	$1,655,220.00
Structural Beam	394	2948.29 ft.	155.00/ ft.	$1,880,842.85
		TOTAL COST :		$5,425,086.85

Based off these cost values the structural system totals to approximately $5,201,130.00. It is important to note that this doesn't include structural members such as, structural steel, shear walls, foundation construction, and slab on grade. **Appendix M** provides a cost breakdown estimate of the precast structural system using vendor pricing. To ensure accuracy of the given structural system total, an RS Means Assemblies cost was established.

RS Means Cost data provides costs data for a building system. Systems are broken down by units typically associated with the design and used to produce an overall price for the system. There were five sections used from the RSMeans Assemblies Cost Data 2013 manual that included, "Tied, Concentric Loaded Precast Concrete Columns", "Tied, Eccentric Loaded Precast Concrete Columns", "Rectangular Precast Beams", " 'L' Shaped Precast Beams", and "Precast Plank with No Topping."

The column breakdown and take-off was used to price the system using RSMeans. Columns that were positioned on locations against the building's external walls were considered eccentrically loaded. These columns included those in columns line 1, 15.5, 15.6, 16, A, A.3, E, E.5, B2 columns, columns in column line B in the penthouse, and columns in column line 15 positioned above the first two floors. Once this has been established columns were priced using the section B1010 206 & B1010 207 in RSMeans.

The columns within this section are broken down into the several components that it takes to assemble the precast member. These components include:

- precast column of either 10-12' story height, 5 ksi. concrete
- anchor bolts in set
- steel bearing plates; top, bottom, haunches (haunches at designated floor heights)
- erection crew.

To properly price the columns of the building superstructure each column that was created was priced based off the column size dimensions and vertical height. Most columns were based off a 14' floor height, as this was the largest floor height provided in the manual. The building ranges in floor heights from 16'-20' so 14' was the next best option. To appropriately price columns whose dimensions were two large and weren't indicated within the manual, a trend-line was produced from a graph of all costs versus their respective sizes. The trend line equation was used to calculate the price for size columns that weren't provided in the manual. The total price for each column is based of material and installation costs. The total column cost of the precast columns estimated to be $2,099,601

The structural precast beams were priced using the sections B1010 213 and B1010 215. Beams that were casted along the external walls of the buildings were estimated as "L" shaped precast beams as they are designed with a ledge that the edge of the slab will be grouted. Beams within the upper penthouse level and roof level and existed along the external walls of the building weren't chosen to be "L" shaped precast member as they didn't hold up a floor slab. These beams held up roof materials and there was no need for the ledge to be formed on the beam. Both types of beams are produced prestressed members that are made from 5 ksi. concrete. The difficulty for pricing the beams was that all the beams provided within the drawings spanned lengths that weren't provided specifically in RSMeans. Also, RSMeans provides beams with common dimensions and those within the design varied from those provided. To best calculate prices for precast beams, beams within the drawings were rounded to the nearest span and sizing. Each beam's costs include the price of materials and an installation fee. The total cost estimated for the beams was $2,087,268**.**

Lastly, hollow core planks were priced using the section B1010 229. The 32'x 4' and 36'x 4' planks, both at 8" deep, were priced using 30' span. This was so because the difference in price varied very slightly between span increments. The hollow core plank assembly includes:

- Precast prestressed concrete floor slabs 8" thick, grouted
- Edge forms to 6" high on elevated slab, 4 uses
- Welded wire fabric 6 x 6 – W1.4 x W1.4 (10x10), 21 lb. /csf, 10? Lap
- Concrete, ready mix, regular weight, 3000 psi
- Place and vibrate concrete, elevated less than 6", pumped
- Finishing floor, monolithic steel trowel finish for resilient tile
- Curing with sprayed membrane curing compound

The total cost for each plank, which includes both materials and installation fees, came to be $10.06 per square foot. As there is 1617 units the total cost for the hollow core plank slab system totaled $2,082,179.

The total cost when estimated using RSMeans Cost Assemblies data totals to $7,793,203. This cost significantly exceeds vendors pricing of $5,201,130.00. **Appendix N** provides a cost analysis on the precast structural system using RSMeans Cost Assemblies Data 2013. This can be due to a number of factors. First of all many precast member's dimensions had to be rounded to fit numerical data provided within the manuals. This was mostly performed during the beam estimating. Many beam dimensions within the original drawing didn't match the provided data. These beams had to be rounded and some beams were cut into smaller segments to match dimensions in the manual. This created additional cost as producing a lot of smaller beams is less cost efficient than producing larger beams. Also, columns were priced less expensive the great height their hunches were located or their floor heights. The only floor heights provided were those at 10', 12', and 14', while the lowest floor height was 16' in the Maryland Public Laboratories. Also, larger column dimensions had a greater priced associated with the column.

Vendor pricing was based off a lump sum price that included an average of all components included in the production and installation of the members. Mangers at Nitterhouse explained that their prices included concrete, grout, miscellaneous steel, reinforcement, production costs, installation costs, etc. Unfortunately the prices were given as a single price per square foot or linear foot, which didn't take into account members of greater or smaller dimensions. Also, reinforcement was hidden in the lump sum price, so there wasn't any indication what size reinforcement was used and the weight of reinforcement used for accurate pricing.

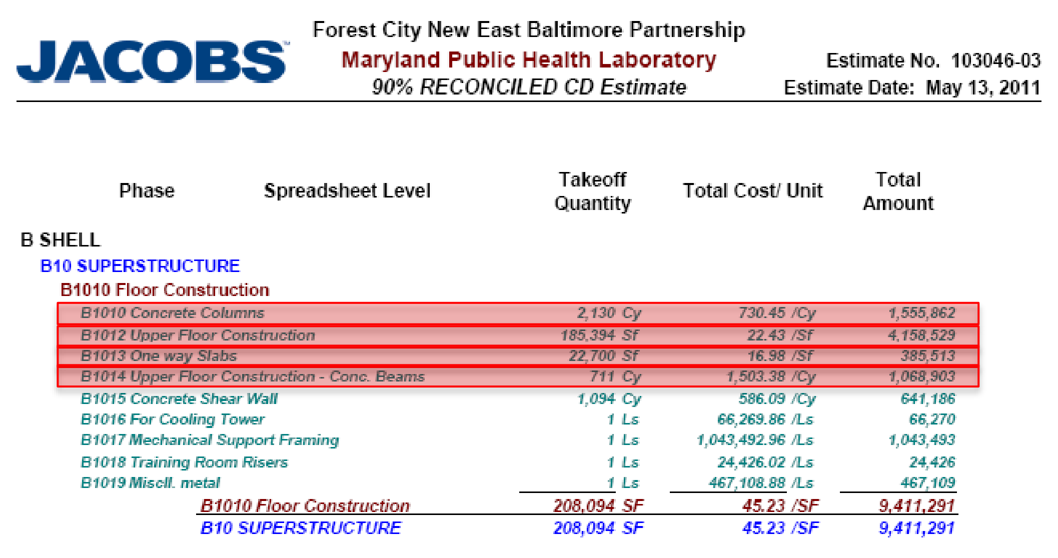
The final costs associated with the precast concrete structural system that hasn't been mentioned is the additional cost associated to the increased crane size. The crane need to lift these large precast members had to be able to lift approximately 48,000 lbs. of weight. The tower crane originally purchased for the site was only able to lift a maximum of 44,000 lbs. A similar crane, but at the next size would be able to carry a maximum of 70,600 lbs. This far exceeds the amount needed to carry the largest precast members. The original crane was budgeted at $50,000 per month and was used for a total of 12 months. This is a total cost of $600,000. After speaking with crane rental vendors, Biggie Crane and Rigging Co., a rental price for the Peiner SK 565 Hammerhead Tower Crane (next size up) would cost an additional $25,000 a month or $75,000 a months. This totals to $900,000 budgeted to the project for a larger crane. This is a significant increase in price as the difference between crane sizes is $300,000.

Feasibility Analysis

To accurately determine the feasibility of the proposed analysis of implementing a precast structural system within the Maryland Public Health Laboratories cost and schedule comparisons must be conducted. The ultimate reason for implementing a precast structural system is accelerate the project schedule, as these members are easier to install and the tasks of creating the formwork onsite, preparing for the concrete pour, finishing the concrete, and curing the concrete is eliminated for the schedule. The production of the concrete members would occur before the construction of the building's superstructure. These members would be casted off-site at a production plant during site preparation, excavation, and foundation phases of construction. The production portion of the precast concrete process would have no effect on the total project schedule.

To successfully install the entire structure, lifting the members off the flatbed trucks, placing into their designated locations, and grouting all member connections would take a calculated 80 days (16 weeks). This duration based on a 5 day work schedule. The projected duration of the original cast in place concrete system was supposed to take approximately 97 days (16.2) to complete. This duration is based off the originally implemented 6 day work schedule. If 5 day work schedule was created this duration would total to 19.4 weeks. This has been indicated in the projects baseline schedule between the dates of May 25, 2012- September 19, 2012. The amount of time saved implementing a precast concrete structural system would be approximately 17 working days or 3.4 weeks based off a 5 day working schedule. This proves that implementing a precast structural system would be highly beneficial toward accelerating the schedule. Not only will the project team save approximately 3.4 weeks from the total project schedule, but project management teams wouldn't have to implement a 6 day work schedule for the concrete subcontractors.

The second comparison is the costs associated with the original cast in place concrete system versus the newly implemented precast structural system. The cost of concrete column, beams, and elevated slab construction for the original cast in place concrete system derives from the 90% CD Reconciled Estimate created by Jacobs Engineering. The Superstructure section of cost estimate is broken down into several categories. The categories of importance include, Concrete Columns, Upper Floor Construction, Upper Floor Construction- Conc. Beams, and One way Slabs. **Figure 17** provides a cost break down for each for the concrete superstructure. The breakdown is only based on those categories that matter to the cost analysis. **Table 10** provides a costs summary of these indicated categories and the total costs of the superstructure.



Forest City New East Baltimore Partnership
Maryland Public Health Laboratory
90% RECONCILED CD Estimate

Estimate No. 103046-03
Estimate Date: May 13, 2011

Phase	Spreadsheet Level	Takeoff Quantity	Total Cost/ Unit	Total Amount
B SHELL				
B10 SUPERSTRUCTURE				
B1010 Floor Construction				
B1010 Concrete Columns		2,130 Cy	730.45 /Cy	1,555,862
B1012 Upper Floor Construction		185,394 Sf	22.43 /Sf	4,158,529
B1013 One way Slabs		22,700 Sf	16.98 /Sf	385,513
B1014 Upper Floor Construction - Conc. Beams		711 Cy	1,503.38 /Cy	1,068,903
B1015 Concrete Shear Wall		1,094 Cy	586.09 /Cy	641,186
B1016 For Cooling Tower		1 Ls	66,269.86 /Ls	66,270
B1017 Mechanical Support Framing		1 Ls	1,043,492.96 /Ls	1,043,493
B1018 Training Room Risers		1 Ls	24,426.02 /Ls	24,426
B1019 Miscll. metal		1 Ls	467,108.88 /Ls	467,109
	B1010 Floor Construction	208,094 SF	45.23 /SF	9,411,291
	B10 SUPERSTRUCTURE	208,094 SF	45.23 /SF	9,411,291

Figure 6: Jacob's Engineering Estimated Superstructure Cost (image provided by Jacobs Engineering)

Table 10: Analysis Cost Totals (information provided by Jacobs Engineering)

Analysis Cost Total for Cast in Place Concrete Superstructure			
Sub-Category	**Takeoff Quantity**	**Total Cost/Unit**	**Total Amount**
Concrete Columns	2,130 C.Y.	730.45/ C.Y.	1,555,862

Upper Floor Construction	185,394 S.F.	22.43/ S.F.	4,158,529
One way Slabs	22,700 S.F.	16.98/ S.F.	385,513
Upper Floor Construction – Concrete Beams	711 C.Y.	1,503.38/ C.Y.	1,068,903
		SUPERSTRUCTURE TOTAL COST:	**$7,168,807**

The total cost of the superstructure being analyzed from Jacobs' estimated costs is $7,168,807. Because this is based off 90% completed CD's there is a +/- 10% from the total cost. This means the total is approximately around $6.45 million and $7.89 million.

Turner Construction Company has provided a pay application form for the concrete work performed on site that gives a more accurate cost value for the work. This pay application form was submitted on May 15, 2012, so it doesn't account for all the work to be completed nor does it account for all change orders associated with the **Table 11** breaks down the pay application into the cost values that are important for the cost analysis.

Table 11: Turner Pay App. Cost Values (information provided by Turner Construction Co.)

Turner Pay Application Cost Values	
Description of Work	**Scheduled Values**
CATWALK/MEZZANINE	
Framed Slab	$50,600
FIRST FLOOR	
Framed Slab	$599,300
Columns up to Second	$165,899
Topping Slabs	$12,999
Grade Beams on North Side	$13,600
SECOND FLOOR	
Framed Slab	$624,801
Columns up to Third	$130,100
THIRD FLOOR	
Framed Slab	$585,699
Columns up to Fourth	$134,701
FOURTH FLOOR	
Framed Slab	$567,201
Columns up to Fifth	$131,100
FIFTH FLOOR	
Framed Slab	$606,899

Columns up to PH01	$139,000
PENTHOUSE LEVEL 01	
Framed Slab	$605,279
Columns up to PH02	$187,900
Intermediate Beams at 8’-8” on north side	$25,999
PENTHOUSE LEVEL 02	
Framed Slab	$291,400
Columns up to Roof	$69,020
2 Rows of intermediate beams between PH01 and the Roof	$85,601
Piers	$13,400
Curbs	$16,600
ROOF	
Framed Slab	$248,700
Beams on west and south sides	$23,200
Curbs	$6,500
SUPERSTRUCTURE TOTAL	$5,335,498
CHANGE ORDERS	
Change Order #1 Concrete	$1,500,000

After calculating the budgeted cost for concrete work that applies to the analysis a total of $5,335,498 was attributed to the cast in place construction. This is a more accurate cost value than the estimated value as this is the Turner’s actual budgeted amount for the concrete construction. **Appendix O** provides Turner’s pay application form with all the concrete construction cost values.

The calculated cost to implement a precast concrete structural system is $5.4 million by vendor values and $7.8 million estimated by RSMeans values. Because the vendor pricing didn’t account for column dimensions, weight of miscellaneous steel for each member, grouting amounts for different sized members, etc. as it was a lump sum price and the cost values from RSMeans Cost Assemblies data were restricted to certain sized members and didn’t fully apply to the member designed for this structure a 25% cost of the difference between the two values was added to the lower number. The average of the two numbers wasn’t used because Nitterhouses vendor price would be more accurate price as they build columns, beams, and planks that would meet the specifications of the building. RSMeans is a general tool to calculate an approximate cost for the system. Information provided within the Assemblies Cost Data manual didn’t specify different types of precast concrete units and the construction involved. The total cost for the precast structural system would be $6 million. An additional $0.3 million is also added to this value, as the additional costs associated with the crane increase must be factored. The grand total of the precast structural system is $6.3 million.

A precast structural system would be greatly beneficial to the project as it reduces the total project schedule by 17 works days or 3.4 weeks. Also the cost to implement this system would be $6.3 million, which is significantly lower than Jacob's detailed estimated cost of $7.2 million. Turner's pay application provides information indicating that the cost budgeted for the superstructure analyzed was $5.3 million, which is significantly lower than the precast system. There was a change order for concrete work made on the project for $1.5 million. This has ultimately affected the cost budgeted for concrete on the job.

Because there isn't a breakdown of the concrete change order submitted by Turner the construction costs associated with the analysis was divided by the total structure work, which included structural steel, foundations, shear walls, etc. The cost of slab, beam, and column construction accounted for 65% of the structural construction. This is the percentage taken from the change order and added to the structural work budgeted by Turner. This creates a total superstructure cost of $6.3 million.

The cost to implement a precast concrete structural system is roughly the same cost that Turner budgeted for the cast in place system. The precast system is also cheaper than what has originally been estimated by Jacobs. Because a precast structural system doesn't create additional costs to the project and reduces the schedule by approximately 3.4 weeks it is ultimately a feasibly procedure for the project. The Maryland Public Health Laboratories would benefit from using this proposed system if only the cost and schedule between the two systems were analyzed.

Unfortunately, a precast structural system can't be implemented based off the design of a cast in place structure. There are requirements and design standards that precast units must meet to be sufficient in a project design. Members are design to withstand certain loads and a structural analysis must be performed to establish whether these members could actually perform under the given circumstances within the new precast design. This will be provided in the structural breadth within this analysis.

Structural Breadth Analysis: Precast Concrete Structural Design on a Typical Floor

Problem Identification

In the previous analysis the feasibility of implementing a precast concrete structural system in place of a cast in place structural system was performed using original the original structural design. A break-down of the superstructure was conducted and divided into precast members. This can't be simply done in a structural sense as there are things to consider when designing a precast structural system. A major structural issue that was introduced when implementing a precast structural system was the elimination of drop panels at each of the major structural columns. Another area that needs to be considered is the applied load hollow core planks can resist at given spans without experiencing rupture. To do so an structural analysis must be conducted on a typical building floor (Floor 3), that will analysis the loading at columns with drop panels and of hollow core planks.

Punching Shear & Moment at Columns

The Maryland Public Health Laboratories elevated floor slab system was design as a 10" two-way flat slab with 8" deep drop panels at each column. The dimensions of these drop panels are 6'6" x 7' at exterior columns and 9'6" x 7'3" at interior columns. **Figure 18** provides an image of a flat slab with drop panels below the slab at each column head. The purpose of these panels is to reduce punching shear or shearing stress at the column. This is the load applied by the column onto the slab above, which if to great can actually puncture through the given slab. The drop panel creates a surface area that the load from the column can distributed across alleviating a great amount of load applied to a small amount of area.

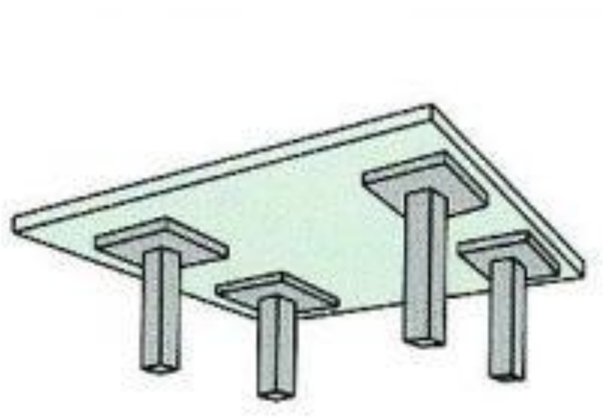


Figure 18: Flat Slab with Drop Panels (image provided by concrete.org.uk)

Also, if the dimensions of the drop panel are large enough, they increase moment resistance. The drop panels designed on the Maryland Public Health Laboratories are designed as such to provide moment resistance to the two way-flat slab designed at each elevated floor.

After discussions with industry professionals at Nitterhouse Concrete Products it was mentioned that these drop panels would be eliminated from the design if precast concrete units were to be used for the structural system of the building. This significantly increases the punching shear at the column to slab connections and increases the moment within the slab. To better understand the punching shear experienced at these connections calculations have been done to achieve the shear stress.

Punching Shear Analysis

To effectively calculate the punching shear experienced at an interior column, the ultimate compressive load (P_u) must be calculated at each. This value is equivalent to the ultimate shear load (V_u) at theses given locations. The concrete column that will be evaluated is columns C7 on the third floor of the building. **Figure 19** is a plan view of the two columns being evaluated for shear stress.

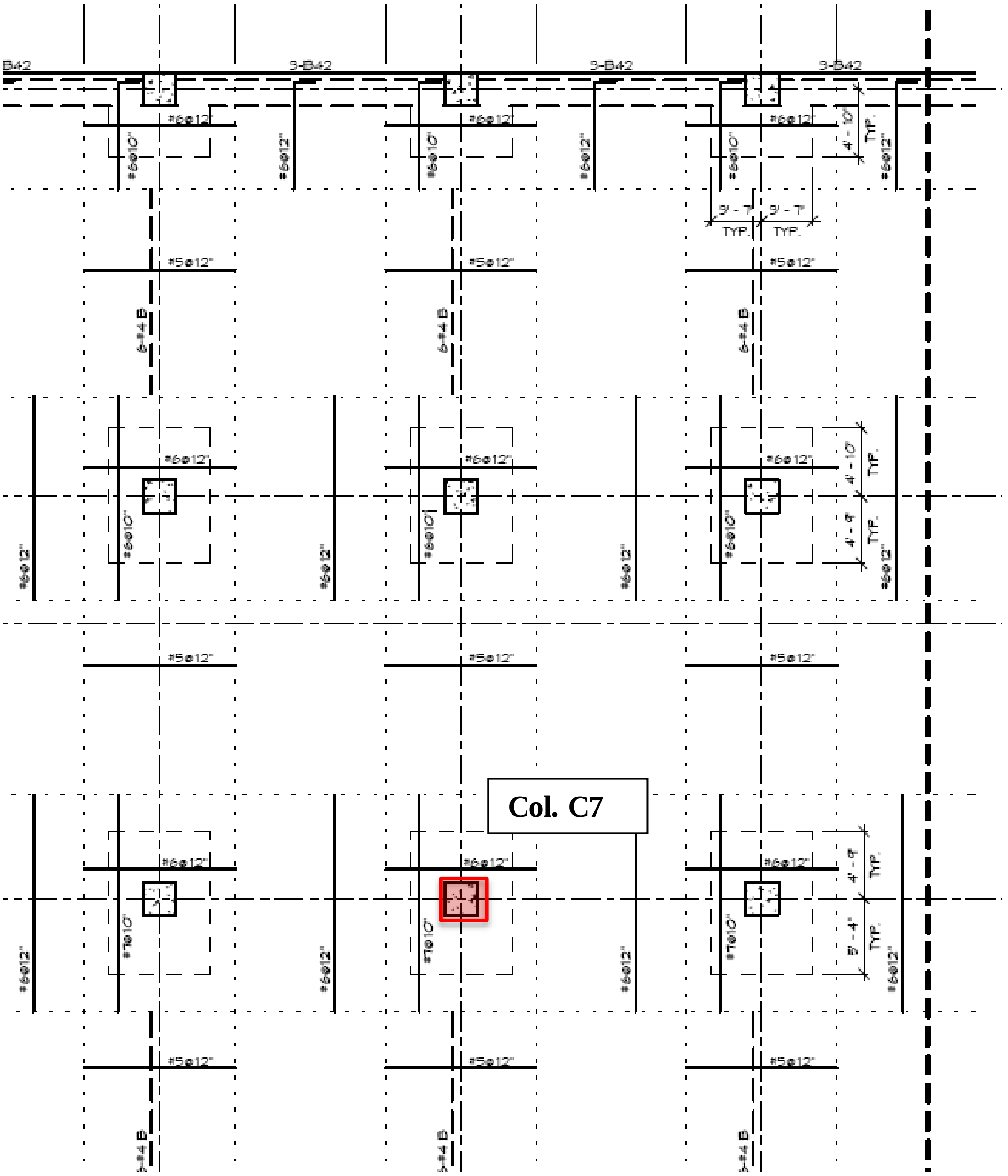


Figure 19: Plan View of Columns for Punching Shear Calculations

To calculate the ultimate compressive load of the interior column (C7) the equations (1.1) and (1.2) is used.

Roof Compressive Load: $P_u = 1.2L_D + 0.5(S\ orL_R)$ (1.1)

Floor Compressive Load: $P_u = 1.2L_D + 1.6(L_L)$ (1.2)

L_D is the dead load applied to the column, L_L is the reduced live load of the typical floor, S is the applied snow load, and L_R is the roof load. The greater applied load between the snow load and roof live load will be used in the equation.

A reduction of live load must be done using the maximum value produced between equations (1.3) and (1.4)

$$L_L = L_0\ x\ 0.4 \qquad (1.3)$$

$$L_L = L_0\ x \left[0.25 + \sqrt{\frac{15}{\#Floors\ Above\ x\ K_{LL}A_T}}\right] \qquad (1.4)$$

L_0 is the unreduced live load of the typical floor, which was 125 psf. K_{LL} is the live load element factor. A_T is the tributary area of the column. For the interior column the tributary are would be 641.78 ft^2. Figure 1 shows the tributary area of column C7.

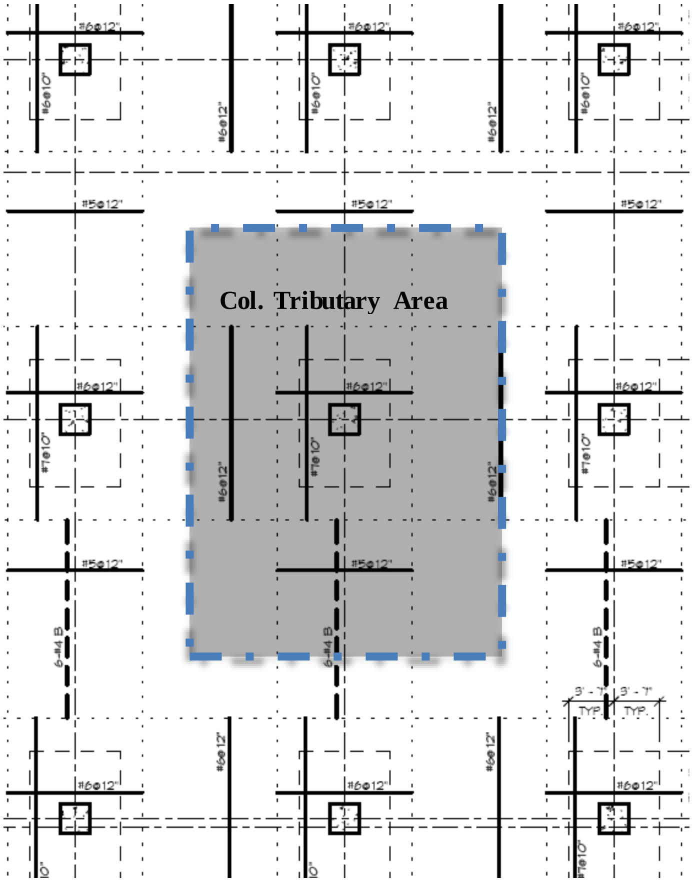


Figure 20: Tributary Area of Col. C7

This area was calculated by taking the average of the lengths of the adjacent bays in the vertical directions of plan and multiplying that value by the average of the widths of the adjacent bays in the horizontal directions. Column C7 is located 21'-4" from column both column lines 6 and 8. C7 is also located 28'-6" from column line D and 31' – 8" from column line B. This produces a tributary area dimensions of 21'-4" x 30'.

The column being evaluated exists on the third floor so there are four floors above. The K_{LL} of an interior column is 4. This value is obtained from Table 4-2 in the "Reduction in Live Loads" section of *ASCE 7-05*. Using all given values the calculated reduced live loads using equations (1.3) and (1.4) is 50 psf. and 36 psf. 50 psf. will be used because it's the greater value between the two.

The floor dead load is calculated using the desired precast hollow core planks designed for the building. A 8" deep hollow core plank with 2" topping has a precast weight of 61.25 psf. and a concrete topping weight of 25 psf., which produces a combined weight of 86.25 psf. These weights were provided by the Nitterhouse's specifications of this unit. HDR have indicated in their design data that the designed dead load for a floor is 8 psf. in addition to its self-weight. This produces a total floor dead load of 94.25 psf.

The roof is dead load is comprised of both a concrete structural slab and the roofing system that resides on top of the structure. Because the roof is designed using hollow core planks the calculated 86.25 psf. for the slab system can be used. The roofing system is comprised of a roof paver system, pedestals, filter fabric, 6" rigid roof insulation, drainage board, protection board, a rubberized asphalt membrane, and primer. **Figure 21** shows a detail of the roof that will apply load to column C7. **Figure 22** shows a perspective drawing of the components of the roof assembly.

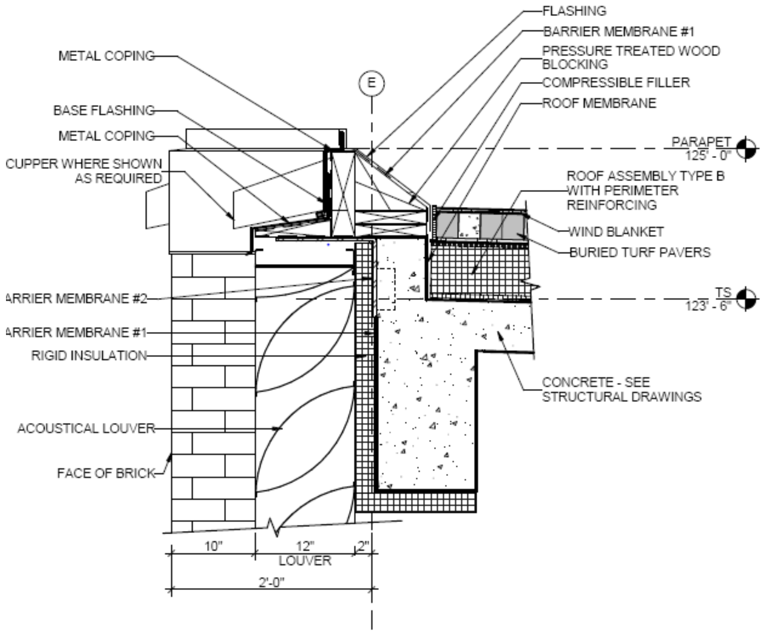


Figure 21: Detail of Roof Above Column C7 (image provided by HDR, Inc.)

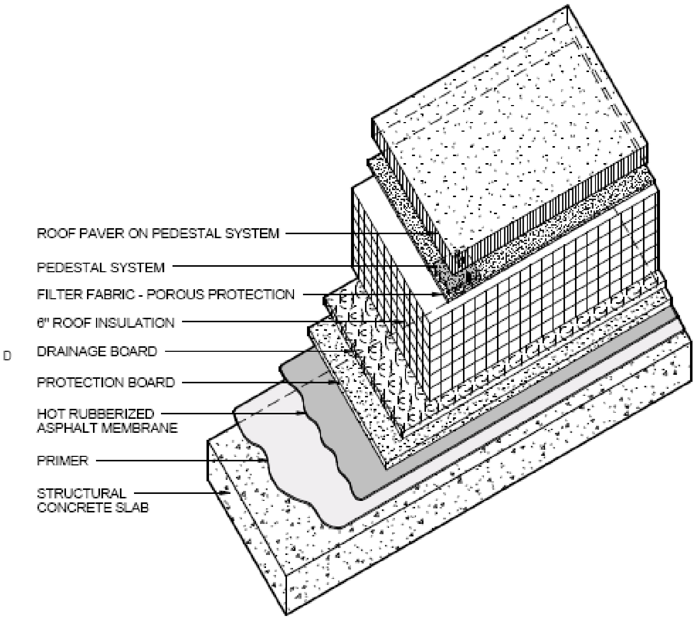


Figure 22: Roof Assembly Breakdown (image provided by HDR, Inc.)

The dead load of the roof assembly is the summation of weights per square foot of all components of the assembly. The roof paver is approximately 2 psf. as provided by the vendor Grassy Pavers. Rigid insulation for roofs and walls is calculated by the depth. According to the Florida Building Code rigid insulation is 0.75 psf. per inch depth. Because there is 6" rigid insulation board, the total weight of the insulation is 4.5 psf. The filter fabric is 0.5 psf. and both the drainage board and protection board are 1 psf. The hot rubberized asphalt membrane is approximated to be 1 psf. This was established using specification of HRM 714 – Hot-Applied Rubberized Asphalt Membrane provided by the vendor, W.R. Meadows. Lastly, the pedestal system's weight is negligible because they are only placed in certain locations and not across the entire roof area. The total dead load of the roof assembly totals to 10 psf. This is added to the structural weight of 86.25 psf. to produce a roof total dead load of 96.25 psf. HDR indicates in their design data that green roof systems, as demonstrated above, have dead loads of 40 psf. in addition to the self-weight. This brings the total roof dead load to 136.25 psf.

The last values need for equation (1.1) is the snow load and roof live load. The roof live load has been calculated and is indicated in HDR's design data as 30 psf. minimum. The snow load can be calculated with equation (1.5)

Flat-Roof Snow Load:

$$S = 0.7C_eIP_g \tag{1.5}$$

C_e is the snow exposure factor, which is 0.9 in the Baltimore area. I is the snow load importance factor, which is 1.0 in the Baltimore area. Lastly, P_g is the ground snow load, which is 25 psf. All these values are provided in "Snow Loads" section in ASCE *7-05*. The approximate snow load value is 16 psf. which is less than the roof live load of 30 psf. Therefore the roof live load will be used in equation (1.1).

Using the load values above in equations (1.1) and (1.2), calculated roof and floor ultimate compressive load of 211.5 psf. and 193.1 psf. are achieved. Multiply the roof load of 211.5 psf. by the column tributary area, 641.78 ft^2, and dividing that number by 1000 will provide calculated lbs. of force in kips. This value is approximately 136 kips. This must be done to the floor load of 193.1 psf. as well, but will be multiplied by 4 because that is the quantity of floors above the column. This provides a value of approximately 496 kips. The summation of compressive loads totals to a total ultimate compressive load of 632 kips. This value is equivalent to the ultimate shear strength load (V_u).

The next step is to calculate the shear strength of the slab. This is calculated using equation (1.6), which is provided by the American Concrete Institution (ACI) in the *ACI 318-05*[6] manual.

$$V_c = \varphi 4 b_0 d \sqrt{f'_c} \tag{1.6}$$

This equation is used to analyze slabs without shear reinforcement and is in contact with square column members. The variable φ represents the strength reduction factor for Plain concrete, which is 0.55. This is necessary because we must account for imperfections in the concrete. Nominal punching shear wouldn't need the reduction factor. The variable d is flexural depth, which is the depth of the bottom reinforcement. Using the Nitterhouse specifications for the 8" deep precast slab with 2" topping, it is determined that the reinforcement strand height is 1.75". The depth of the strands is 10" minus the 1.75", which is 8.25". It is important to note that the depth d cannot be less than 0.8 the actual depth D. In this case 8.25" is greater than 8" therefore this is adequate. The variable b_0 is the perimeter of the critical section of the column. This is calculated by dividing the flexural depth d by half. This produces a value of 4.125". The critical perimeter exists at the calculated value of 4.125" from each of the columns faces. Because the column being analyzed is 28"x 28" the critical area has dimensions of 36'-3"x 36'-3". This produces a critical perimeter b_0 of 145". Lastly, f'_c is the ultimate compressive strength of the concrete used. The hollow core planks are made from 6000 psi concrete.

The given values above are used to calculate shear strength of 1416 psf. The calculated punching shear load was 984 psf. The shear strength of the slab is greater than the applied load from the column ($V_c \geq V_u$), therefor the precast design can be implemented in the building for any given typical building floor (floors 2-5). Because of time constraints a total analysis on all given floor types and for alternate columns couldn't be conducted.

Comparison to Original Design (No Drop Panels)

The original cast in place concrete systems was created using 10" deep slabs with 8" concrete panels at the main structural columns. These components serve to significantly reduce punching shear. If a punching shear analysis was performed of the original design at the column analyzed above, but without the drop panel, the shear load would be greater than the shear strength. Thus, the columns would cause the concrete slab to rupture in the critical area.

Normal concrete, which was used on the given project, has a weight of 150 pcf. The slabs are 10" deep, which makes the weight of the concrete 180 psf. This is the dead load for the floor systems and structural portion of the roof. The roof's assembly system will remain the same.

Therefor the roof dead load is 190 psf. Due to HDR's design data an additional 8 psf. and 40 psf. are to be applied to the self-weights of the floor and roof systems. The total dead load for both the floor and roof are 188 psf. and 230 psf.

The live loads for the floor and roof will remain the same as there will be no change in occupancy. The snow load will remain the same because the building is within the same location. Using equations (1.1) and (1.2) the ultimate compressive load applied onto a slab at a given structural is 1513 psf. This value is also the shear load.

The cast in place slab design requires tensile reinforcing to be placed 1" above the bottom of the slab or at 9" deep. This will create a critical area with the dimensions 37"x 37". The critical perimeter would be 148". The concrete used for these slabs has a compressive strength of 4000 psi. Using the given values in equation 1.6 will produce a total shear strength of 1287 psf., which is less than the applied shear load ($V_u \geq V_c$). This is not adequate for structural design, as the column would punch through the concrete floor slab. The drop panels designed at each column provide an increase in shear capacity that makes the structural design acceptable.

There are reasons why the precast system is strong enough to withstand the shear load, unlike the cast in place system. The concrete used to design the precast units is stronger than the cast in place concrete used for the system. Nitterhouse uses concrete that is 6000 psi, while 4000 psi concrete was used on site. These affect the shear strength of each system. Another reason is that the planks are lighter than cast in place concrete. The total precast weight of a hollow core plank is 61.25 psf., which includes grouting. The additional 25 psf. topping creates a total member weight of 86.25 psf. The concrete floor slab designed for the project was approximately 180 psf. This creates a significant difference in dead load values associated with each system.

Structural Evaluation

As previously stated, the original cast is place concrete system was designed with 8" drop panels at each of the main structural columns. After discussions with precast vendors, Nitterhouse Concrete, implementation of a precast structural system would eliminate these components from the design. A punching shear analysis on the interior column C7 showed that with the new hollow core plank slabs the new slab's shear strength was greater than the applied shear load at the slab and column connection. This allows for the implementation of the precast systems without additional structure necessities.

If the shear strength was less than the shear load at the column there would be a need to increase the shear capacity. This can be done in several ways. The first method would be increasing depth of the slab. This will increase the shear strength of the slab, but if all slab depths were increase this would create a greater applied load. The dead load associated of each floor would increase as more concrete would be to create the slabs.
This would an added cost to the project as the amount of concrete purchased for the floor slabs would increase.

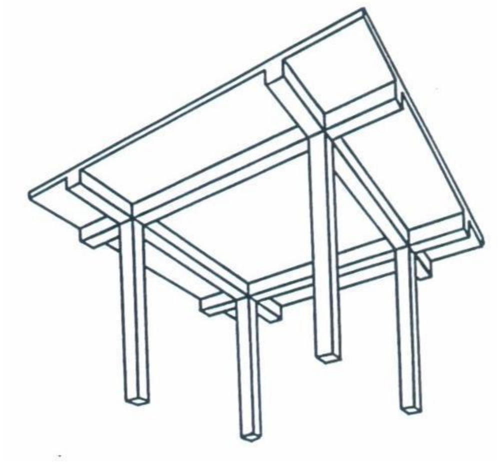


Figure 23: Two-way Beam Support System

A two-way beam support system can be implemented into the design. **Figure 23** provides an image of a two-way beam support system. Structural beams would be grouted to the top of columns level to columns and the hollow core planks be connect to the top face of each beam. This allows the applied shear load to be transferred across the beam and not directly at the critical area of the slab at the column. Unfortunately this would create significant costs to incorporate. This system would be implemented at the basement level through the 5th floor, as these slabs extend throughout the entire building. There would be an additional 164 beams needed per floor and 984 for the building system. The total length of the summations of these beams would be approximately 3563 ft. Using the provided pricing of $155/ linear foot, this would cost the project an additional $152,520.

Not only is there a cost associated with producing and erecting the additional precast structural beams there is a need to rearrange the mechanical plenum space. These beams would need sufficient plenum space, which would ultimately change the entire design of the MEP lines. Because of the nature of this building the MEP system is very complex and the plenum space is extremely valuable. To increase the needed plenum space floor to floor heights would need to increase, which in turns would add costs the building envelope. As the building envelope's surface area increases, the need for additional materials and construction increase and therefore the cost.

Also, the schedule duration would be increase as there would be more members to be erected into place. The time it takes to build the façade systems would grow as there will be a larger surface area for the building to cover. This method of increasing shear would be the most infeasible.

The last two methods would be to increase the dimensions of the column or add shear rails and studs within the given slab. It is extremely uncommon to see precast planks produced with shear reinforcement such as rails and studs, so the most viable solution would be increased column dimensional size. This wouldn't add additional dead load to the structure as deepening the slabs would, but there would still be an increase in the amount of concrete need to create these members. This increased amount of concrete would create additional costs to the total project budget.

Hollow Core Slab Design

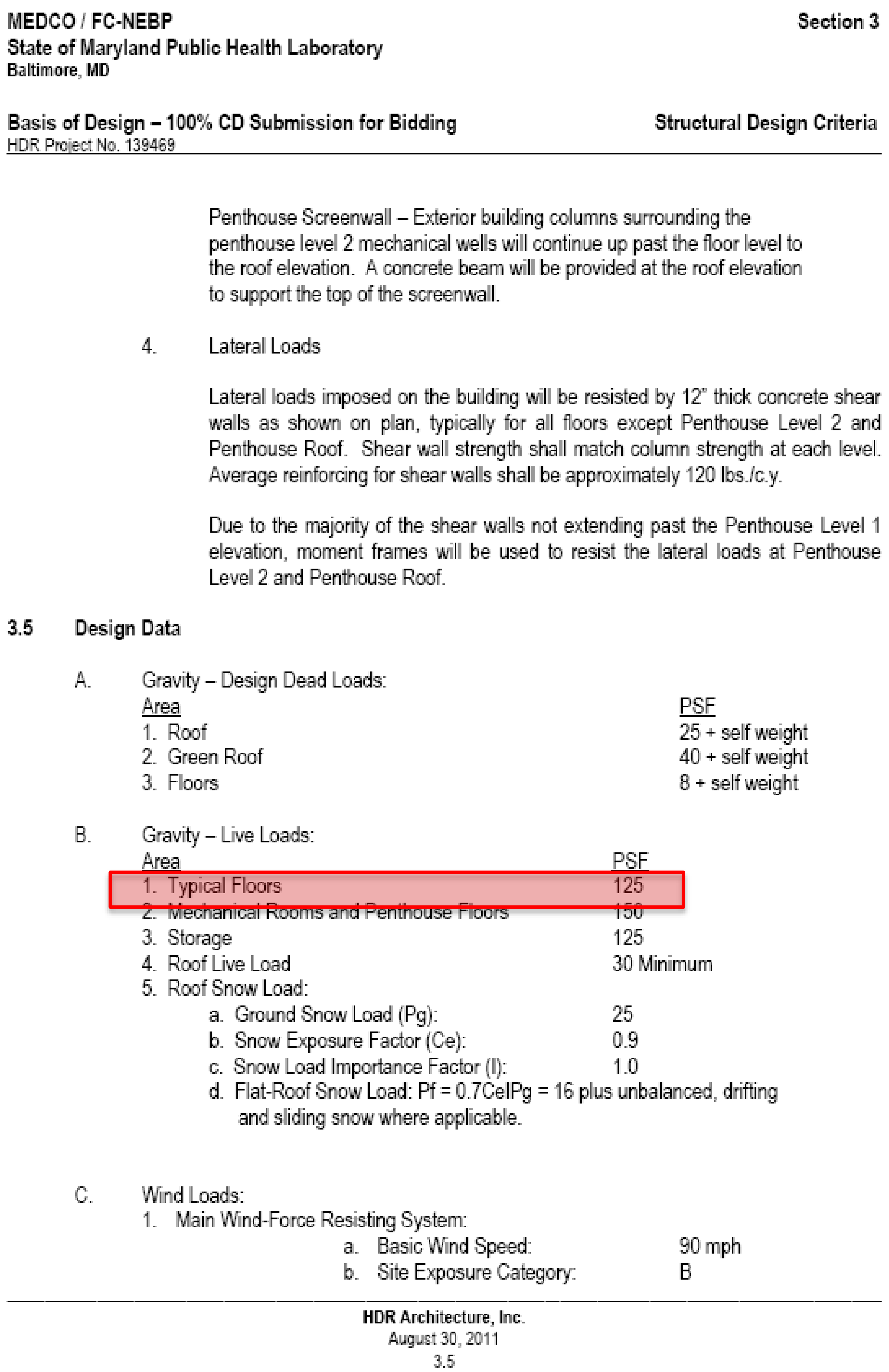
Originally the precast hollow core slabs were designed as 8" hollow core planks with 2" topping. It was mentioned by industry professionals at Nitterhouse Concrete products that the typical dimensions of these planks were 4'x 32'. Planks typically don't exceed 4' in width, but can span from 16'-60' in length. To allow for 32' spans mentioned by this individual there must 6-7 strand members at ½" diameter placed 1.75 in. above the bottom of the plank. These strand members have a maximum tensile stress of the concrete $10\sqrt{f'_c} = 755$ psi., where f'_c of precast concrete compressive strength is equal to 6000 psi. Using 6 reinforcement strands within the design will produce an allowable superimposed service load of 67 psf. Using 7 strands provides a greater allowable superimposed service load of 90 psf. Unfortunately, these two allowable superimposed loads don't meet the designed loads of the original structure.

The superimposed load is the load imposed on a structure other than dead load. Because this structural analysis is being performed on the structure of the third floor this would be the live load associated with a typical building floor. HDR provided design data and calculations and was able to come up with a typical floor live load of approximately 25 psf. **Figure 24** shows this calculated load in their Basis of Design – 100% CD Submission for Bidding. Using the American Society of Civil Engineers (ASCE) "Table 4-1 Minimum Uniformly Distributed Live Loads, L_0, and Minimum Concentrated Live Load" provided in the 2010 Edition of ASCE 7 the live load for this typical building would be either 50-80 psf. In the "Occupancy or Use" column assumptions were made regarding the use of the Maryland Public Health Laboratories as there wasn't an exact match with the given types. These were the assumptions that could possible fit this facility:

1. Office use – 50 psf.
2. Hospitals: Operating rooms, laboratories – 60 psf.
3. Hospitals: Corridors above first floor – 80 psf.

As HDR's calculated live load is the greatest live load, this will be the load used for the allowable superimposed load for the hollow core plank design.

To meet the required allowable superimposed load the hollow core planks used for the Maryland Public Health Laboratories must be either 29' spans using 7 reinforcement strands or 27' spans using 6 reinforcement spans. A span of 29' using 7 reinforcement bars at ½" diameter has an allowable load of 128 psf. A span of 27' using 6 reinforcement bars at ½" diameter has an allowable load of 129 psf. Each is greater than the calculated superimposed load of 125 psf. for a typical building floor. Because 29' is greater than 27' and has an equivalent allowable superimposed load this will be the length of the hollow core planks used for the slab construction on the project. Note that if we were to design the slab for the penthouse mechanical spaces we would need to adjust the span length of a hollow core plank to 27' using 7 reinforcement strands, as the



MEDCO / FC-NEBP **Section 3**
State of Maryland Public Health Laboratory
Baltimore, MD

Basis of Design – 100% CD Submission for Bidding **Structural Design Criteria**
HDR Project No. 139469

Penthouse Screenwall – Exterior building columns surrounding the penthouse level 2 mechanical wells will continue up past the floor level to the roof elevation. A concrete beam will be provided at the roof elevation to support the top of the screenwall.

4. Lateral Loads

Lateral loads imposed on the building will be resisted by 12" thick concrete shear walls as shown on plan, typically for all floors except Penthouse Level 2 and Penthouse Roof. Shear wall strength shall match column strength at each level. Average reinforcing for shear walls shall be approximately 120 lbs./c.y.

Due to the majority of the shear walls not extending past the Penthouse Level 1 elevation, moment frames will be used to resist the lateral loads at Penthouse Level 2 and Penthouse Roof.

3.5 Design Data

A. Gravity – Design Dead Loads:

Area	PSF
1. Roof	25 + self weight
2. Green Roof	40 + self weight
3. Floors	8 + self weight

B. Gravity – Live Loads:

Area	PSF
1. Typical Floors	125
2. Mechanical Rooms and Penthouse Floors	150
3. Storage	125
4. Roof Live Load	30 Minimum
5. Roof Snow Load:	
a. Ground Snow Load (Pg):	25
b. Snow Exposure Factor (Ce):	0.9
c. Snow Load Importance Factor (I):	1.0

d. Flat-Roof Snow Load: Pf = 0.7CeIPg = 16 plus unbalanced, drifting and sliding snow where applicable.

C. Wind Loads:

1. Main Wind-Force Resisting System:

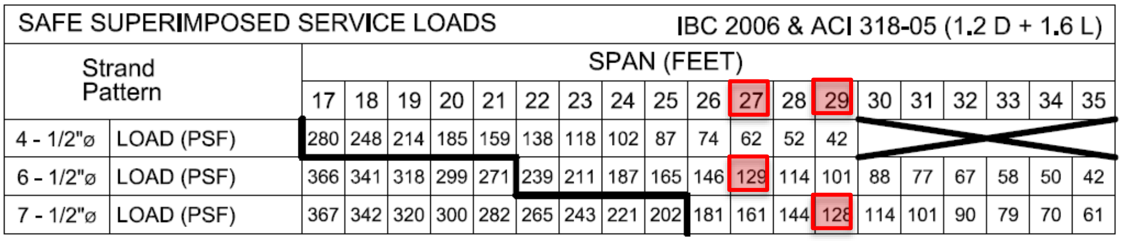
a. Basic Wind Speed: 90 mph

b. Site Exposure Category: B

HDR Architecture, Inc.
August 30, 2011
3.5

Figure 24: Design Data for MPHL Typical Floor (provided by HDR Inc.)

mechanical space has a live load of 150 psf. Because we are only evaluating a typical building floor (Floor 3) we will neglect the mechanical spaces. **Figure 25** is the allowable safe superimposed service load table for an 8" hollow core plank with 2" topping (2hr. fire rating)



SAFE SUPERIMPOSED SERVICE LOADS IBC 2006 & ACI 318-05 (1.2 D + 1.6 L)

Strand Pattern		SPAN (FEET)																		
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
4 - 1/2"ø	LOAD (PSF)	280	248	214	185	159	138	118	102	87	74	62	52	42						
6 - 1/2"ø	LOAD (PSF)	366	341	318	299	271	239	211	187	165	146	129	114	101	88	77	67	58	50	42
7 - 1/2"ø	LOAD (PSF)	367	342	320	300	282	265	243	221	202	181	161	144	128	114	101	90	79	70	61

Figure 25: Allowable Superimposed Load Table (image provided by Nitterhouse Concrete Products)

Using the 29' span hollow core planks to create the floor slab system there would be an increase in member produced for the building. The original precast concrete design needed 1617 planks to fulfill the design. This number would have to increase to 1794 planks.

The increase in the number planks would have no effect to the overall cost of the slab system. Because the vendor price for the system was given as $8.00 per square foot and the overall square footage of the buildings slab design had not changed the overall cost for using more slabs at shortened spans would remain the same.

Increasing the number of planks used will however effect the duration of the scheduled task. Each lift of a plank is 10 minutes. If 1794 planks are to be lifted this would increase the amount of time needed to place each plank to 37.4 days or 7.5 weeks, based on a 5 day 8 hour schedule. This adds an additional 3.8 days to the originally calculated lift time using 32' x 4' planks. With the additional planks there will still be a reduced schedule of approximately 18 days or 3.6 weeks.

Precast Superstructure Analysis Conclusion

In conclusion to Analysis #1 it has been determined that implementing a precast structural system to this building would be beneficial to the Maryland Public Health Laboratories project. Without additional cost associated with the change in structures, this system is able to be erected quicker than the originally designed cast in place structure. The total schedule savings on the project is approximately 3.4 weeks, which is a significant duration of time. Also, a 6 day work week wouldn't need to be implemented to construct the building's superstructure in the originally scheduled timeframe. This would cut cost spending on overtime rates.

After a structural analysis on both the hollow core plank system and columns it has been determined that there is no need to implement additional structure for the increase in punching shear due to the elimination of drop panels. Precast panels are able to withstand shear load applied by the column face without rupture or allowing the column to "punch" through the slab. Because the system met these structural requirements, the precast system could be implemented into the building's structural design. It is important to note that for a true feasibility study, structural design for a precast structure would be performed for every member.

As this system doesn't create additional costs, reduces schedule, and meets structural requirements it would be an adequate system design. The Maryland Public Health Laboratories should use this type of superstructure to mitigate lost time from unforeseen conditions experienced on site.

Technical Analysis #2: Virtual Mock-ups for Façade Systems

Problem Identification

Throughout the durations of the Maryland Public Health Laboratories project there have been a significant amount of change orders and schedule set-backs due lack of quality and error in construction. This is predominately due to the subcontractor confusion with the design documents. There are certain details that are vague or difficult to read within the drawings that have caused subcontractors to perform work incorrectly.

Incorrect work predominantly occurred during the foundation construction of the building. There were several areas where waterproofing along foundation walls were absent or installed incorrectly. This created issues amongst general contractor, Turner, and management team, Jacobs, as they discussed the implications and consequences for not having waterproofing in originally designed for spaces.

Along with waterproofing, small contracting groups who are unfamiliar to the magnitude and complexity of the building design have installed materials incorrectly. These companies, typically WBE and MBE, have been awarded the plumbing contracts and have installed P-traps and waste lines at incorrect depths within the foundation. This has caused for change orders and cutting these pieces from the concrete. Re-installation has occurred creating additional time and money to the project.

As the one of the most complex phases of the project is the building envelope construction, it would be beneficial if there were visual aid in the design. This phase is complex due to the use of four different façade systems used within the design. These include curtain wall, storefront glass, metal paneling, and a brick veneer. Virtual Mock-ups of connections of these specific façade systems to the structural design and to one another will help clarity of the design. Confusion in the design documents will be reduced as subcontractors can view these connections with a third dimensional perception.

Research Plan & Objectives

In order to properly research this topic and establish an all-around feasibility analysis there are many aspects to consider. A general understanding of virtual mock-ups must be researched and how they are beneficial to projects will be established. Costs associated with the creation of virtual mock ups will be compared to the produced benefits. Also, the research regarding the increase in quality, safety, and other indirect aspects will demonstrate the

This information will be provided mostly by industry professionals. Industry professionals will be able to provide their experiences with virtual models and what benefits they've noticed on their respective projects. They can also give their opinion whether virtual mock-ups would be beneficial on the Maryland Public Laboratories project, given the circumstances and design details.

The benefits and savings associated with virtual mock-ups tend to be qualitative so case studies will help provide a general idea for what to expect using this type of technology on the project. These case studies will provide virtual mock-ups that were implemented on projects of similar sizes and for systems of equal degree of complexity. These case studies are provided through company websites such as Mortenson Construction, and will provide reasoning why companies chose to use this models and direct benefits experienced during the project.

Application Methodology

To effectively research the analysis topic of the implementation of a precast concrete structural system, the following steps must be taken:

1. Research case studies that have implement similar technology to understand associated costs and benefits.
2. Conduct three interviews with industry professionals who have been a part of project that have used virtual mock-ups are have witnessed virtual mock-ups amongst their respective companies.
3. Establish pros and cons list to preliminarily investigate feasibility of the use of virtual mock-ups.
4. Calculate a typical overhead charge for the additional time spent to create virtual mock-ups for the curtain wall system of the building envelope
5. Compare established overhead to researched cost savings associated with other projects. Use current change order costs added to the Maryland Public Laboratories project to create an overall cost analysis.
6. Create a general schedule impact analysis by using research date from industry professional's experience and cases studies that have used virtual mock-ups.
7. Schedule impact analysis will indicate the dates when the beginning of the construction of precast concrete member will occur and when installation will occur in the overall schedule.
8. Lastly, an overall feasibility analysis will be conducted, considering all aspects that are involved with virtual mock-ups of the building envelope used on this project.

Technology Overview

Virtual mock-ups are visual aids that are becoming more prevalent in the construction industry. These three dimensional images of building systems depict details that are difficult to conceptualize in a two dimensional state. Most commonly virtual mock ups are used on building envelope systems, complex room designs, connection details, and other intricately designed systems.

Figure 26: Virtual Mock-Up Example SketchUp (image provided by Mortenson Construction)

Because these 3-D images provide significant detail, they help contractors to understand how certain systems are built effectively. This assures quality and potentially reduces error in construction. These images are typically produced using software such as Revit or Google Sketchup and will be implemented into a Building Information Modeling plan. Virtual mock-ups can be manipulated to account for any changes in design, which makes them flexible and easily implemented.

Industry Professional Opinions

In conclusion to many interviews with design & construction visualization coordinators at Jacobs and BIM managers at Mortenson Construction, regarding the topic of virtual mock ups, all members were in favor of the technology. All have been a part of projects that have implemented such technology and expressed their satisfaction with produced outcome. The clarification of the drawings was one of the biggest assets mentioned during the interviews as they allowed for improved quality of construction and reduction in change orders. Also, each participant indicated that the main reason for virtual mock-ups was to assure quality products. Because of such a strongly favored industry opinion on the topic, virtual mock-ups were further investigated.

Implementation of Technology

It is vital that the idea of virtual mock-ups is establish early in the request for proposal phase or suggested to the owner. This is so because most owners do not understand virtual mock-ups and the benefits they can produce on a project. It is a fairly new procedure in the industry and most owners are oblivious to its existence. Owners tend to ignore this technology when creating a request for proposal and the technology is absent from the design plans.

In order to implement such an analysis topic, it is important that HDR, the design firm of the Maryland Public Health Laboratories project, suggest virtual mock-ups for the design. HDR has created a virtual model for the building as a visual aid for the owner. This same model can be used as the basis for virtual mock-ups. Many preliminary steps have been completed in the design of the 3D building model, which reduces the time and cost designing the mock-ups. Significant detail must be added to portray the information need to create a viable virtual mock-up, but with a 3D model already established this will be much easier than scratch from scratch.

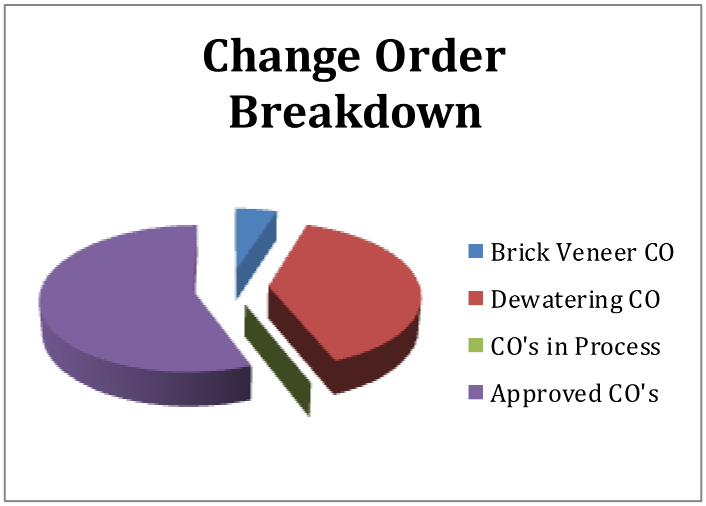
Direct/Indirect Benefits

Virtual mock-ups provide many benefits to a project in several areas such as cost, schedule, quality and safety. The 3-D representative of a building system allows contractors to understand the necessary detail to complete their work to the utmost quality and efficiency. For many projects the cost to implement such technology doesn’t compare to the invaluable benefits.

The Maryland Public Health Laboratories will benefit from virtual mock-ups in numerous ways. With the reduction of subcontractor confusion with the drawings, the building envelope will be able to be constructed with less error. This will positively affect the overall quality of the product as construction will easily be able to follow the original designs. Façade system connections to the buildings superstructure and other façade systems will be efficiently performed as detailed 3-D models will represent how to make these connections. Also, if there was conflict in the original design indicated within the 3-D mock-up, the ability to analyze alternative solutions to design and constructability issues can be quickly achieved.

The increase in construction quality will lead to reduction in cost. The reduction of cost occurs as there will be less change orders due to incorrect installation of the building envelope. Clashing and inadequate design can be recognized prior to construction of the building envelop system. Noticing these issues allow for quickened solutions and the elimination of potential change orders. Currently there is $2.5 million in approved and pending change orders on the project, $75,000 associated with the building's envelope. The implementation of these virtual-mock ups would reduce this number to potentially $37,500.

Table 12: Project Change Order Break Down



Along with quality and cost aspects of construction, virtual mock-ups would help save significant time on a project. The process of constructing the building envelope will become easier as the detail of the 3-D model would help articulate how to efficiently build each of the façade systems to contractors. The learning curve associated with the construction of these facades systems would reduce and subcontractors can more efficiently build without strongly focusing on installing material incorrectly. Industry professionals have seen a couple days to a couples days saved using these virtual mock-ups to articulate how systems must be built. Based off industry professional opinion and similar project comparison, a reduction of 1-2.5 weeks is the most likely amount of time attributed to the use of virtual mock-ups.

The last benefit that would be experienced by the Maryland Public Health Laboratories project would be safety. Safety is the main goal of Jacobs management team and virtual mock-ups are a great way to ensure this safety. As subcontractors study these models they sufficiently understand what is necessary to effectively install the building envelope and those façade systems that comprise the envelope. This ultimately reduces potential hazards from performing unfamiliar tasks. There haven't been prominent safety concerns on site, but additional effort to ensure safety is always beneficial to any construction project.

Associated Overhead Costs

With the implementation of any new technology or process there will be a cost associated. The production of virtual mock-ups occurs during the design phases of a building project. HDR has already established a model for MEP coordination and visualization purposed for the owner, therefore there isn't a great amount of work that needs to be added to model to create these mock-ups.

The main cost and virtually the only cost in creating these virtual mock-ups is connected to the time spent on the task. Speaking with industry professionals from both Mortenson Construction (uses 3-D Mock-ups on all projects) and Jacobs Engineering, it takes approximately 1-2 weeks for one person to create all necessary mock-ups for a building project. Design teams will not hire additional manpower for this task, but designate someone on their taskforce to work on these mock-ups. A given approximate cost overhead cost associated was around $3,000- 4,000 (given by Mortenson).

Within a case study presented by Mortenson the labor cost to construct a mock-up is approximately $82/hr., assuming that the designer would work an 8-10 hour work day this would produce a cost range of $3,280-9,840. Based on HDR's design fee, $6,242,000, this is a very small sum of money. This would make HDR's design fee $6,245,000- 6,251,840, which makes a relatively small impact on the total project budget.

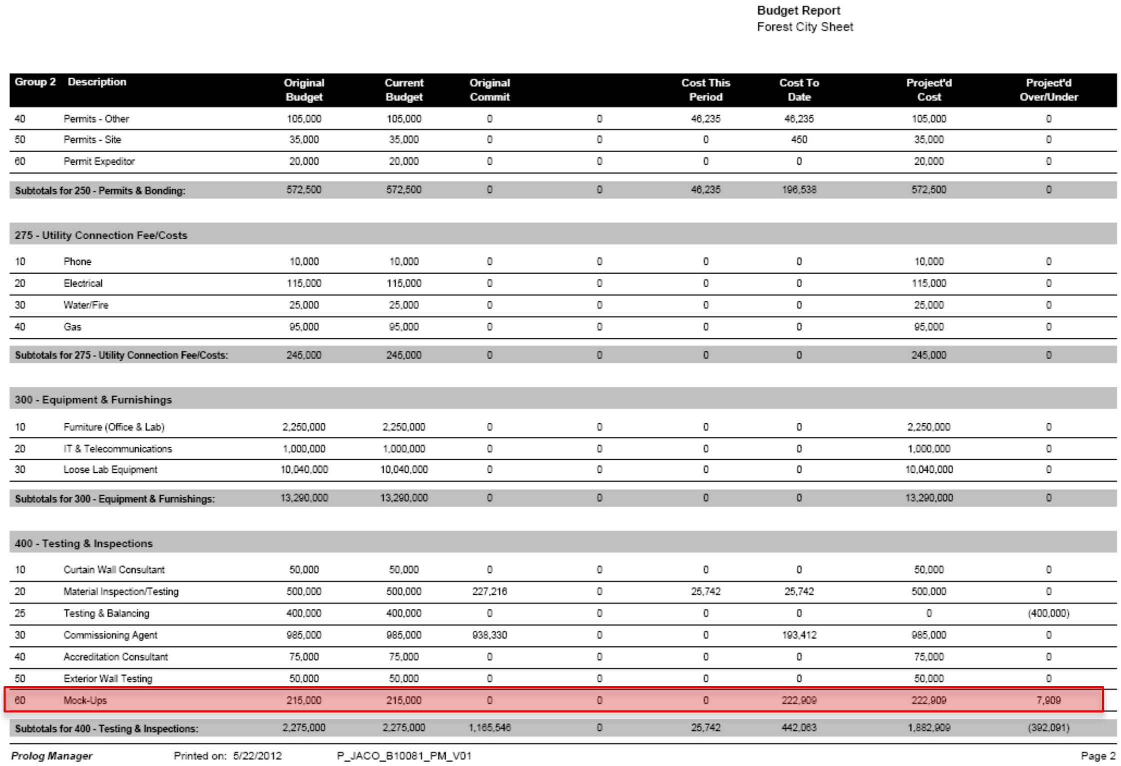
Associated Cost Savings

Cost savings associated with virtual mock-ups tend to come in the form of task efficiency and decrease in the number of construction errors. The reduction in material installation errors ultimately reduces change orders added to the project. Both Mortenson Construction and Jacobs Engineering have attributed a cost savings percentage of around 0.1-0.6% when virtual mock-ups were created for building systems. Depending on the level of detail of the mock-up and the difficulty of construction of the building system, this percentage ranges. After further discussion with industry professionals, it was established that such a complex façade system would greatly benefit from the use of virtual mock-ups. Even though the complexity in the design and the magnitude of the system are significant, this system only comprises 17% of the total project. Because the building's envelope is that small compared to a Mortenson case study project where 47 mock-ups were to detail 75% of interior construction, only a saving percentage of 0.3% is used. The building in the case study that achieved a 0.7% cost savings to the total was the Greenfield Hospital constructed in Wisconsin.

Using virtual mock-ups to detail the façade connections to each other and the skeleton of the building could produce 0.3% savings in the system. This completely ignores the change orders associated with the system. The envelope of the building is estimated to cost $19,069,953 or $81.50/s.f., approximately 17% of total building cost. With these virtual mock-ups implemented on the project, $57,210 can be saved through efficient work and schedule savings.

Along with money saved through work performed efficiently, costs associated through change orders are reduced from the project. Mortenson explained how they have noticed approximately a reduction in half of their change order costs when implementing virtual mock-ups. If this were the case, The Maryland Public Health Laboratories would save $375,000 based off the current brick veneer change order. Because construction of the building's envelope remains in the process to date, overall costs data can't be obtained. These change order cost savings for the project are based off current progress of the project.

In addition to increased productivity, efficient work, and reduction in project change orders, in certain circumstances physical models can be eliminated from the project. For this project the owner has require physical mock-ups for commissioning purpose, but occasionally virtual mock-ups can be used as substitutions. Mock-ups required on the Maryland Public Health Laboratories project include, sample glass, metal panel, roofing and gutter mock-ups used for architecture review. A full-sized curtain wall physical mock-up is provided off-site for wind load, water spray, moisture intrusion/seepage, and deflection testing. If those weren't required by the owner for commissioning purposes and were to be substituted by virtual mock-ups, the project could save $222,909. This value is indicated in Jacob's budget report show in **Figure?** The potential savings is significant with the implementation of virtual mock-up on the project.



Budget Report
Forest City Sheet

Group 2	Description	Original Budget	Current Budget	Original Commit		Cost This Period	Cost To Date	Project'd Cost	Project'd Over/Under
40	Permits - Other	105,000	105,000	0	0	46,235	46,235	105,000	0
50	Permits - Site	35,000	35,000	0	0	0	460	35,000	0
60	Permit Expeditor	20,000	20,000	0	0	0	0	20,000	0
Subtotals for 250 - Permits & Bonding:		572,500	572,500	0	0	46,235	196,538	572,500	0
275 - Utility Connection Fee/Costs									
10	Phone	10,000	10,000	0	0	0	0	10,000	0
20	Electrical	115,000	115,000	0	0	0	0	115,000	0
30	Water/Fire	25,000	25,000	0	0	0	0	25,000	0
40	Gas	95,000	95,000	0	0	0	0	95,000	0
Subtotals for 275 - Utility Connection Fee/Costs:		245,000	245,000	0	0	0	0	245,000	0
300 - Equipment & Furnishings									
10	Furniture (Office & Lab)	2,250,000	2,250,000	0	0	0	0	2,250,000	0
20	IT & Telecommunications	1,000,000	1,000,000	0	0	0	0	1,000,000	0
30	Loose Lab Equipment	10,040,000	10,040,000	0	0	0	0	10,040,000	0
Subtotals for 300 - Equipment & Furnishings:		13,290,000	13,290,000	0	0	0	0	13,290,000	0
400 - Testing & Inspections									
10	Curtain Wall Consultant	50,000	50,000	0	0	0	0	50,000	0
20	Material Inspection/Testing	500,000	500,000	227,216	0	25,742	25,742	500,000	0
25	Testing & Balancing	400,000	400,000	0	0	0	0	0	(400,000)
30	Commissioning Agent	985,000	985,000	938,330	0	0	193,412	985,000	0
40	Accreditation Consultant	75,000	75,000	0	0	0	0	75,000	0
50	Exterior Wall Testing	50,000	50,000	0	0	0	0	50,000	0
60	Mock-Ups	215,000	215,000	0	0	0	222,909	222,909	7,909
Subtotals for 400 - Testing & Inspections:		2,275,000	2,275,000	1,165,546	0	25,742	442,063	1,882,909	(392,091)

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Figure 27: Budget for Physical Mock-Ups (image provided by Jacobs Engineering)

Schedule Impact

To create virtual mock-ups for the Maryland Public Laboratories project there will need to be additional time provided in the design phases. The additional time need would be approximately 1-2 weeks to create all necessary building envelope mock-ups for the building's façade system. This 1-2 week is an average amount of time spent, provided by both industry professionals at Jacobs Engineering and Mortenson Construction.

Even though this is additional work and time it will not ultimately affect the overall project schedule as these mock-up aren't essential to the progress of the building. These mock-ups can be created any time prior to the construction of the building façade. Preferably these mock-ups should be created well in advanced to this building phase, as it will allow contractors and managers to sufficiently study the detail and understand the what procedures must be taken to complete the work efficiently.

HDR began the Maryland Public Laboratories design in early 2010, completing the design for submission in late 2011, roughly 2 years. The documents were issued for construction on December 8, 2011. It would be logical that around December 8, 2011, an HDR designer on the project would produce the necessary façade mock-ups for the project. With the given amount to create these models, this designer should be completed with his or her work on approximately December 23, 2011.

This is the only time expenditure involved with creating virtual mock-ups. Even though this is time expenditure, it doesn't affect the overall schedule of the project, as these models can be created during the project. These mock-ups can be refigured or changed during the process of construction, but the time spent doing so is negligible to the amount of time consumed from the project schedule. These mock-ups take up minimal amount of time compared to the time savings that certain projects have experienced.

Projects such as the Greenfield Hospital in Wisconsin have seen significant project schedule reductions due to the use of virtual mock-ups. Project teams have spent +/- 1,056 hours on mock-ups, which is approximately 12.5 weeks and project superintendents have estimated that there was 2.5 weeks of work or 17.5 days saved in time from these models. These mock-ups included laboratory interiors, which differ from building facades systems, but the complexity of each, are similar. Using the projected amount of time (1-2 weeks; average 1.5 weeks) to implement virtual mock-ups on Maryland Public Laboratories project with the time savings rate of the Greenfield Hospital project a total time savings can be obtained for the project.

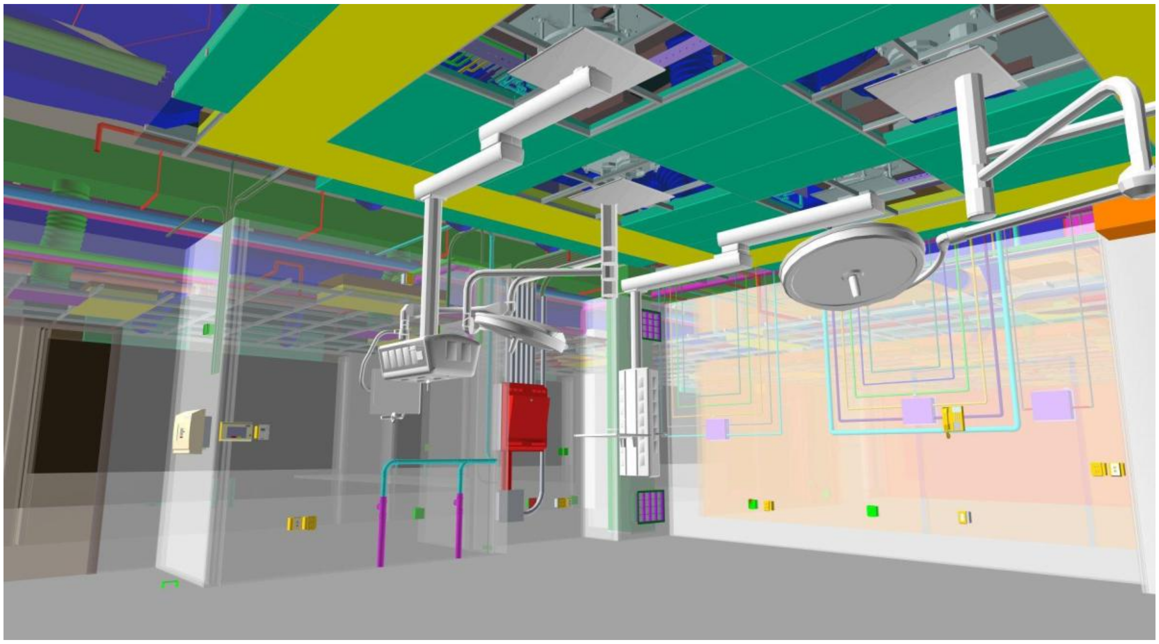


Figure 7: Virtual Mock-Up of Laboratory Interior in Greenfield Hospital Project (image provided by Mortenson Construction)

The industry professional opinion, 1.5 weeks or 18 days (144hrs.) can produce a potential savings of 2-4 days from the building envelope phase. Unlike, the Greenfield Hospital project, the virtual mock-ups would be created to support systems that make up only 35% of the building schedule. The Greenfield Hospital project used interior virtual mock-ups that were used during approximately more than 50% of the buildings construction. Because there are very little studies done on time savings due to virtual mock-ups, qualitative data is provided by comparison. Construction of the building envelope begins on July 27, 2012 and goes through March 28, 2013, which is a total of 245 days or 49 weeks. Implementing virtual mock-ups on the project will reduce building envelop construction to approximate March 25 -27.

This isn't a significant reduction in time, but it is a reduction in schedule none the less. Because the design process for the virtual mock-ups occur prior to the building envelope phase and can be produced during construction they don't affect the critical path. Therefor there isn't any negative impact on the schedule. However, these mock-ups do produce little schedule savings so overall there is a positive schedule impact when implementing these virtual mock-ups to the project.

Pros/Cons

To fully understand the impact of implementing virtual mock-ups for the building façade systems a pros/cons table is provided below.

Table 13: Virtual Mock-up Pros/Cons List

PROS	CONS
Increase in quality of building envelope	Additional time spent in design phase creating models
Installation is quicker and more efficient	Additional overhead cost for design team
Safer installation due to contractor comfortability and knowledge	
Significant schedule savings due to efficient installation	
Cost savings associated with reduction of change orders	

Feasibility Analysis

In conclusions to all data acquired, professional opinions, research conducted, and evaluations performed the implementation of virtual mock-ups on the Maryland Public Laboratories project would be greatly beneficial. The use of virtual mock-ups would effectively portray the construction and connection details of a complex building system, such as the building façade, allowing contractors and managers to easily visualize the process. The ability to easily visualize how to perform a task and what is required to effectively produce the product will ensure quality and reduce errors during construction.

The increased efficiency performing a task directly relates to the speed at which the task is completed. With virtual mock-ups implemented on the project the learning curve to perform a task is reduced. Contractors understand what needs to be done to complete a building system. In examples, such as the Greenfield Hospital Project, approximately 1056 hours were put into creating virtual mock-ups and roughly 2.5 weeks were saved from the total project schedule. Industry professionals have indicated that if virtual mock-ups were to be created for the building façade systems of similar rate of savings would be associated due to the complexity of the project. If this were to be applied to the Maryland Public Laboratories project, approximately 2-4 days can be potentially saved from the building envelope schedule. This was based off industry professional opinions and comparison between other projects that implemented virtual mock-ups.

Another important aspect that virtual mock-ups enhance is safety. When models can be properly analyzed and construction precautions can be established beforehand, many potential hazards can be eliminated prior to performing a task. Contractors can understand the requirements and materials need to construct a product and how to go about it safely.

In addition to quality, work efficiency, reduced schedule, and safety, virtual mock-ups have proven to be a cost saver. They are able to help reduce project costs in two ways. Increased work performance and reduction of change orders attributed to a given project. Virtual mock-ups would potentially be able to save 0.3% in building envelope construction and reduce change orders to about 50%. This can potentially accumulate to $94,710 in project savings to date. The expenditures associated with creating these mock-ups would be the increased overhead cost of $3,000-$9,840, which is relatively small compared to the potential savings.

Virtual Mock-Up Analysis Conclusion

In conclusion to all the research and analysis perform on the analysis of virtual mock-ups it has been determined that virtual mock-ups would be an asset to the Maryland Public Health Laboratories. Industry professionals who are directly involved with Building Information Modeling (BIM) and virtual mock-ups have express only high opinions regarding the topic. They've shared that only good can come from these visual tools, but it is imperative that it's brought to all parties' attention early in the building's preconstruction phase.

From a feasibility standpoint the time and costs to create virtual mock-ups for the given project do not compare to the potential cost savings produced by such models. The Maryland Public Health Laboratories can potentially experience a cost savings of roughly $95,000 if virtual mock-ups detailing the façade system were created. The most noticeable benefit from these models is the project quality. There has been several quality issue experienced on site that have led to change orders. These change orders can be significantly reduced as subcontractors can accurately understand their scope of work, prepare, and execute their task efficiently and effectively. The Maryland Public Health Laboratories would overall benefit from virtual mock-ups; therefor this technological tool should be implemented on the current project and other with great magnitudes of complexity and size.

Technical Analysis #3: Implementation of Dewatering System

Problem Identification

One of the most significant issues that have been experienced on the Maryland Public Health Laboratories project to date was the high water table. During the excavation of the building's footprint project teams noticed that there was unexpected flooding within the excavated area. As excavation continued to proceed, flooding continued to pose as a problem as the amount of water entering the excavated area increased.

In the general region the water table in East Baltimore is at 36.5' above sea level or 30.5' deep from grade level. This number was established from research done by Jacobs Engineering. Because the building's design only reaches depths of 20' below grade the water table didn't pose as a problem for excavation.

Also, geotechnical reports were conducted for the given site based off fifteen soil test borings. These tests were conducted in random locations within the buildings footprint. After the testing was conducting, the report stated that the ground water table existed approximately at 44'-47' above sea level. This indicates that the ground water table is approximately 20'-27' below grade. The tested water table depth provided by in the geotechnical report assures that no portion of the building's design will constructed beneath the water table. This continued to provide confidence in project teams that there was no need for dewatering equipment for the project.
The actual level of the water table experienced on the project site was 45' above sea level or 18' below grade. This unforeseen high water table created significant problem for the site. The significant amount of water entering the excavation site was removed by means of dewatering pumps and lines. This equipment however was procured after the problem had occurred, causing the project to lose time and money.

Figure 28: Flooding in Excavated Site (image provide by Jacobs Engineering)

There was a wellpoint plan implemented on the projects prior to excavation, as these wellpoints were to be installed around the excavation stite along the sheeting. Unfortunately, the system was suitable for removing the amount of water that existed within the excavation perimeter.

To mitigate the problem and continue with excavation, Jacobs had to obtain an approved change order of $585,000. These were individual change orders for deep wells, a french drain system, test pile program, a sump manifold, a lower wick manifold, wick drains, wick testing, additional dewatering costs and damages do to groundwater settlement were added to the total project budget. It also accounted for the cost to rent the dewatering equipment, deliver and install the equipment, and the additional manpower and shifts added to the project to make up for the lost

time. The flooding that occurred delayed the project approximately 2 months, as many of the tasks were delayed. The construction of the foundation and spread footings had to be pushed back until a sufficient amount of water was removed from designated areas.
To absolve the severity of the problem that occurred on the Maryland Public Laboratories project, a dewatering system could have been implemented prior to the excavation phase. Dewatering systems eject the water within the ground of the building footprint and assure that no such problem mentioned above will occur during excavation. The use of a dewatering system on the project would relieve the excess water that would have affected the excavation.

Research Plan & Objectives

To effectively implement a dewatering system on the Maryland Public Health Laboratories project preliminary research must be conducted. The essential document needed to begin the analysis is the geotechnical report. The project's geotechnical report, created by Schnabel Engineering, provides crucial information regarding soil types, ground water table depths, pressure test readings and allowable soil bearing capacities. A specific dewatering system, appropriate for the site conditions, can be chosen using the provided data. This is based mostly off soil conditions and excavation dimensions.

Once a desired system has been designated, the size of the system must be determined. Sizing of the system will allow for many plans and sub-analyses to begin. Sizing of the system will provide information regarding the type of equipment and materials needed to dewater the water beneath the building footprint. To effectively size a dewatering system, resources such as, *Construction Dewatering and Groundwater Control: New Methods and Applications, Third Editions,* will be used. Discharge flow and influence length equations will allow for an accurate design and mapping of the select system.

Once the system has been selected and sized pricing of the equipment, installation, materials, and labor will be obtained from industry professionals from both Griffin Dewatering and Mersino Dewatering. These prices will be used to establish a total dewatering system's cost for the proposed system, which in turn will be used in a cost analysis. The cost analysis will compare the costs associated with the designed system to the original system and the associated change orders.

A schedule impact analysis will also be conducted after the task duration to install, operate, and remove the designed dewatering system has been implemented into the project schedule. This will provide an understanding whether this system will impact the critical path of the project.

Lastly, a feasibility analysis will determine whether the designed system is beneficial to the Maryland Public Health Laboratories project. The goal is to eliminate all change orders and indirect costs created from the flooding issue experienced on the project by implementing a system that will effectively dewater the excavation site.

Application Methodology

To effectively research the analysis topic of dewatering systems, the following steps must be taken:

1. Conduct interviews with Griffin Dewatering Company about the process of choosing, sizing, place, and estimating a dewatering system.
2. Chose a specific dewatering system that will be best suited for the site's conditions.
3. Size the equipment and potential wells need to effectively dewater the site.
4. Create a mapping of the dewatering system on the site plan.
5. Establish a cost analysis of the dewatering system. The cost associated with implementing the system and the money saved by the system.
6. Evaluate the impact of the schedule to determine if the system will effectively mitigate lost project time.
7. Conduct a feasibility study to determine if implementing a dewatering system would be beneficial to the project.

System Overview

Dewatering systems are typically used in locations with a relatively high ground water table or when excavation of a structure will exceed the depth of the water table. These systems remove water from wet soils, ejecting water to the surface at grade level. The removal of the excess water allows for excavation to reach deeper without being negatively affected by the ground water.

Ground water can create flooding in the excavated site, as experienced on the Maryland Public Health Laboratories project; damage installed building materials, and compromises the structural integrity of the soil the building resides upon. It is important to reduce the amount of water by the use of these systems, as it will greatly prevent the mentioned issues from occurring.

Every dewatering system is specifically designed to meet condition for the intended site. Preliminary testing performed by geotechnical engineers provides critical data in the form of geotechnical reports that will define information regarding the soil type of the site and the water table. In addition to the ground water table and soil types different stratums or aquifers provide all necessary values and information to perform calculation to accurately select, size, and map a dewatering system appropriate to a project site. This will be conducted in a mechanical analysis provided within this section.

Mechanical Breadth: Dewatering System Selection, Sizing and Placement

System Selection

The type of system used on a site is determined through several factors regarding the soil type present beneath the building's footprint and the size and conditions of the site excavation. The Maryland Public Health Laboratories project is located in an already established area that is confined by existing structure and roadways. There is insufficient room to install large amounts of equipment around the perimeter of the building footprint.

The buildings excavation two reach a maximum of 32' for the installation of 2 spread footers, but predominately stays at a depth of 20'. This maximum depth of excavation allows for only the soils in Stratum A and Stratum B to affect the dewatering system chosen. The topsoil doesn't affect the dewatering system as it is removed during the demolition of the existing parking lot prior to bulk excavation.

Stratum A is defined in the geotechnical report as existing fill and probable fill. This stratum reaches the depths between 5'-15'. The soils types that exist within this region are those consisting of sand, silt and clay containing asphalt, concrete, roots, organics, wood, brick fragments, geosynthetic fiber, metal, plastic, slag, glass, quartz fragments and gravel. This is all based on borings performed on-site.

The stratum directly below A, Stratum B, is defined in the geotechnical report as Patuxent Formation (Fine-Grained). This stratum reaches a depth of 55'. Borings performed on-site encountered soils such as fine-grained, Cretaceous Age soils. These soils contained lean clay (CL) and sandy elastic silt (MH), with varying amounts of gravel and trace mica.

The given information provided by the geotechnical report created by Schnabel Engineering and the excavation conditions allow the ability to select a system using Table 16.3 "Checklist for Selection of Predrainage Methods" in the *Construction Dewatering and Groundwater Control: New Methods and Applications, Third Editions* manual. This text is heavily referred to by dewatering subcontractors in the industry.

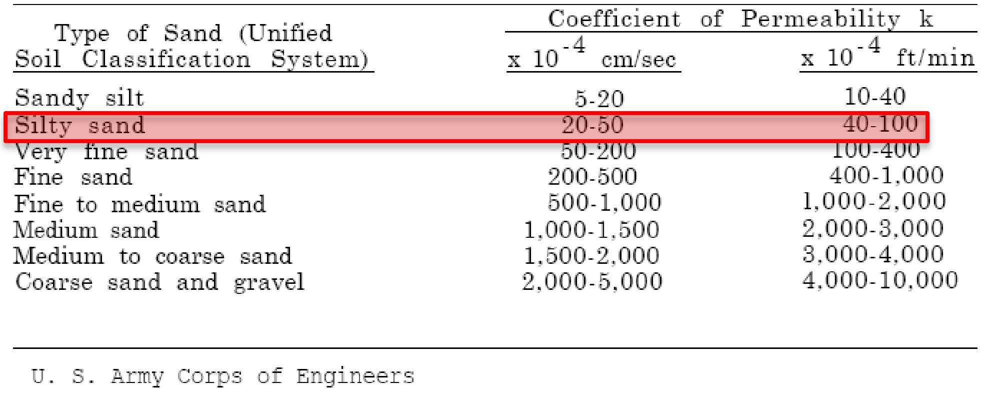
The dewatering system that best fits the data provided by the geotechnical report and given site conditions is deep wells. **Figure 29** provides an image of a deep well system on a construction site. Deep wells are an ideal system for confined site conditions, similar to the Maryland Public Health Laboratories project. These systems are able to be spaced further apart than others as they are able to eject water from a greater area. The excavation being performed on this project is to be at a maximum of 32' deep. Systems such as wellpoint systems and suction wells would need to be staged at multiple depths and can't perform in cramped conditions, as create interferences. The soils aren't ideal for a well point system, but the deep well system is more efficient than an ejector system (second option). **Appendix Q** provides the table used to select a dewatering system.

Figure 29: Deep Well Dewatering System (image provided by Griffin Dewatering Co.)

Deep Well System Sizing

To accurately design deep wells specific data is required. The permeability of the layer of soil being dewatered is very important. Stratum B is the desired layer of soil that is to be dewatered. As stated above, this layer is comprised of very fine-grained sands. The flow chart provided by Figure 1 "Flow Chart for Classifying Fine-Grained Soil (50% or More Passes No. 200 Sieve)" provided by *ASTM D2487 - 11* indicates that soils with the classification CL and MH would be designated as silty sands. Table 3-4 "Approximate Coefficient of Permeability for Various

Sands" provided in *Dewatering and Ground Control TM 5-818-5* by the U.S. Army Corp. of Engineers, indicates soils with the classification of "Silty Sand" has a coefficient of 20-50 x 10^{-4} cm/sec or 10-40 x 10^{-4} ft. /min. **Figure 30** is an image of the soil classifications and their respective coefficient of permeability *k*.



Type of Sand (Unified Soil Classification System)	Coefficient of Permeability k	
	x 10^{-4} cm/sec	x 10^{-4} ft/min
Sandy silt	5-20	10-40
Silty sand	20-50	40-100
Very fine sand	50-200	100-400
Fine sand	200-500	400-1,000
Fine to medium sand	500-1,000	1,000-2,000
Medium sand	1,000-1,500	2,000-3,000
Medium to coarse sand	1,500-2,000	3,000-4,000
Coarse sand and gravel	2,000-5,000	4,000-10,000

U. S. Army Corps of Engineers

Figure 30: Coefficient of Permeability for Soil Types (provided by the U.S. Army Corps. of Engineers)

The depth to reach the impermeable layer is necessary. An impermeable layer is the layer of soil that will not allow any moisture content to pass through the layer. It is typically formed by rock. This information is provided within the geotechnical report. Test borings performed by Schnabel Engineering Consultants indicated that a very compact disintegrate rock layer or the impervious at a depth of 70'. This is the depth of the impermeable layer that will be used to design the size of the deep well dewatering system. **Figure 31** is an image of a typical well and the measurement necessary to perform system design calculations. It is important to note all calculations are based on a static ground water table level.

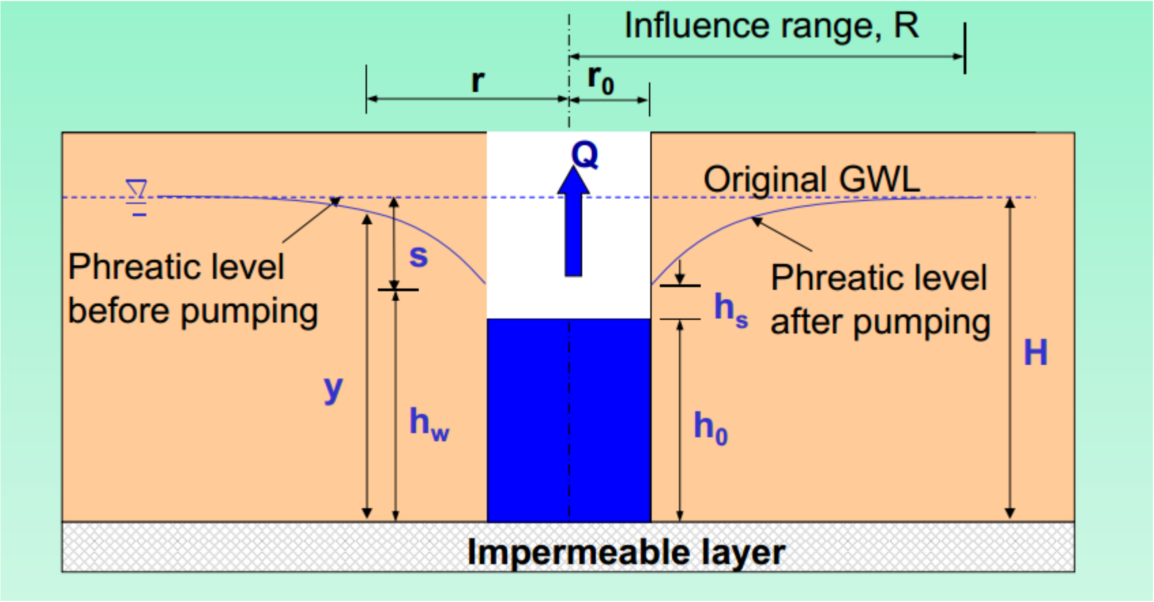


Figure 31: Deep Well Design Measurements (image provided by nptel.iitm.ac.in)

The height of the ground water table was indicated in the geotechnical report 18'. Sichardt's influence range equation (3.1) is used to obtain the radius of the area soil that a single deep well is able to draw water from.

$$R_0 = C'(H - h_w)\sqrt{k} \tag{3.1}$$

The variable R_0 is the radius length of the influence area. Researchers, Mansur and Kaufmann, establish *C'*, which is a constant that is 3,000 for deep wells and 15,000-2,000 for single wells. Because the desired system is a deep well system, the value for this constant will be 3,000. Variable H is the total water head, which is 52' (15.85 m.). h_w is lowered water level in the equivalent well, which is approximately 30' (9.144 m.). This value is the distance between the desired ground water table level and the impermeable level. Because the lowest depth of excavation is approximately 32' a desired ground water table depth of 40' (30' from impermeable layer) was chosen. It's typical that the water table level is reduced 5-10' below the deepest level of the excavation. Lastly, k is the coefficient of permeability. For this soil it was determined to be between 20-50 x 10^{-4} cm/sec (20-50 x 10^{-6} m/s). The median value of the range is 35 x 10^{-4} cm/sec, so this will be used for variable k. The equation is in terms of meter and seconds. The calculated radial length of the influence area is 118.99 m. or 390.40 ft.

The second calculation that needs to be performed is an equivalent radius that the well system services. This can be calculated using equation (3.2) or (3.3). The maximum value between the two is used for the

$$r_e = \sqrt{\frac{XY}{\pi}} \tag{3.2}$$

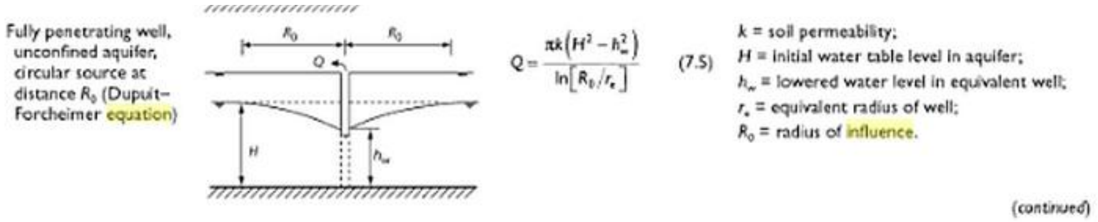
$$r_e = \frac{X+Y}{\pi} \tag{3.3}$$

The variables X and Y are the site excavation dimensions. The excavation is approximately 308' x 96' or 93.88 m. x 29.26 m. These dimensions were determined by measuring the building's footprint plotted on the site within HDR's Plot Plan drawing C1.101. A dewatering site plan is provided in **Appendix R** shows the excavated area on the plot plan and the dimensions of this are. The calculated r_e is 39.20 m. or 128.61 ft.

This radial length can be used to calculate the total discharge rate for the entire deep well system. Calculations are done using the Dupuit-Forchheimer equation (3.4) for total discharge of deep well systems for a rectangular site.

$$Q = \frac{\pi k (H^2 - h_w{}^2)}{\ln\left[\frac{R_0}{r_e}\right]} \tag{3.4}$$

The variable Q is the total discharge rate for a deep well system. The given data produces a total discharge rate for the deep well system is 0.01659 m^3/s. **Figure 32** shows the provides a schematic diagram with the necessary formula for the aquifer (layer) type, well penetration, and formula associated. The image is taken from Table 7.1 " Simple Formulae for Estimation of Steady-state Flow Rate" in *Groundwater Lowering in Construction: A Practical Guide to Dewatering* by Pat Michael Cashman and M. Preene.



Fully penetrating well, unconfined aquifer, circular source at distance R_0 (Dupuit–Forcheimer equation)

$$Q = \frac{\pi k\left(H^2 - h_w^2\right)}{\ln\left[R_0/r_e\right]} \qquad (7.5)$$

k = soil permeability;
H = initial water table level in aquifer;
h_w = lowered water level in equivalent well;
r_e = equivalent radius of well;
R_0 = radius of influence.

(continued)

Figure 32: Schematic Diagram Full Penetration Well (image from Groundwater Lowering in Construction: A Practical Guide to Dewatering)

To potentially save time and costs to install the system wells have been designed to only reach a depth of 50'. This partial penetration within the aquifer factors the total flow rate produced by equation (3.4). The equation (3.5) is used to calculate the factored flow rate.

$$Q_{pp} = \beta Q_{fp} \tag{3.5}$$

Q_{pp} is the flow rate of a partially penetrated well. Q_{fp} is the flow rate of a fully penetrated well, which was calculated using equation (3.4). The variable β is the partial penetration factor for radial flow. This factor can be determined using the graph provided below.

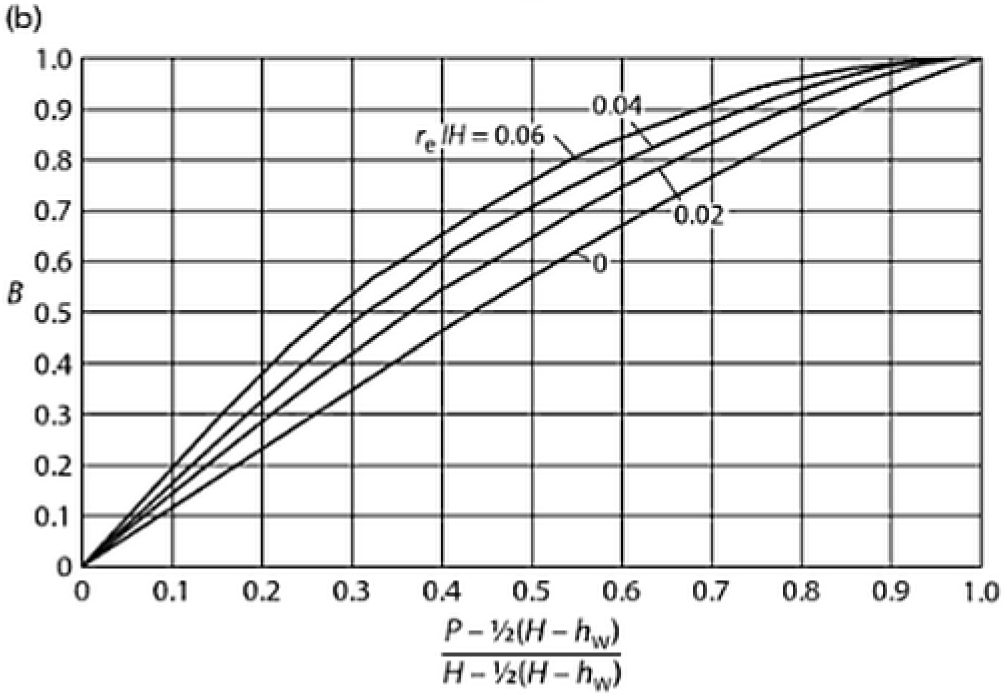


Figure 33: Partial Penetration Factor Graph (image from Groundwater Lowering in Construction: A Practical Guide to Dewatering)

The value *P* is the distance from the ground water table to the maximum depth of the penetration. **Figure 34** provides a schematic design of a partially penetrated well. This value is 32' or 10.91 m. if 50' wells are to be implemented. The equation used for the x-axis produces a value of 0.6. To determine the graph line associated with the partial the penetration the value of r_e is divided by the total water head *H*. This produces a ratio of 2.47, which isn't indicated on the graph. Because the water head is relatively shallow and the excavation area is large, the partial penetration factor is 1.0. If water head were to be extremely deep and the site were to be smaller there would be a factor for drilling a well only partially through an aquifer. Because the value is 1.0 the flow rate of the deep well system will remain the same.

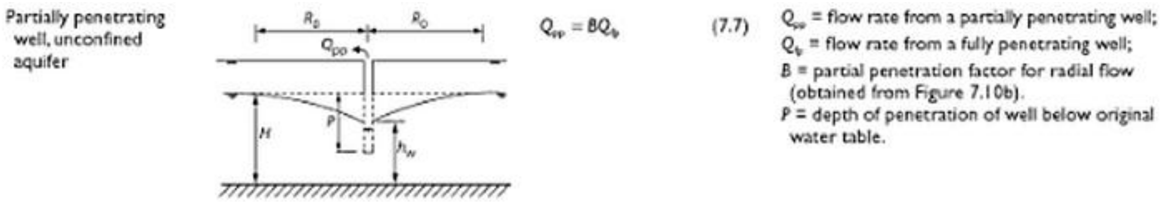


Figure 34: Schematic Diagram of Partially Pentrating Well (image from Groundwater Lowering in Construction: A Practical Guide to Dewatering)

In order to calculate the number of well need to sufficient dewater the site, the diameter of the drill used to create the wells must be measured. To determine the radius of the deep well it is important to know what type of drilling will be performed to create the wells. After discussions with industry professionals at Griffin Dewatering, it was mentioned that the typical drilling process used for soils that are sand would be a rotary drill. Permits for drilling the state of Maryland are very difficult to obtain, but the subcontractors that Griffin Dewatering uses to drill the wells for their dewatering systems are all permitted to drill in the state of Maryland. The process of obtaining the permits for drilling in Maryland is negligible in this analysis.

A medium sized rotary rig is best suited for sands and clays, which are present within the stratum layers of the excavated site. These drills are able to cut into the earth by circulating fluid as it is pumped down the drill pipe. The drill pipe begins to rotate due to the circulation of fluid. The drilling bit at the end of the drill pipe is able to cut into the ground surface because of this rotation. The upward pressure created by the loose soil and return circulation of the drill pipe allows excess soil rise to grade. The soil drilled from the well is then stored in a mud tube. This process is depicted in **Figure 35**.

The typical size drill used to create wells using a medium sized rotary rig is 12 in.

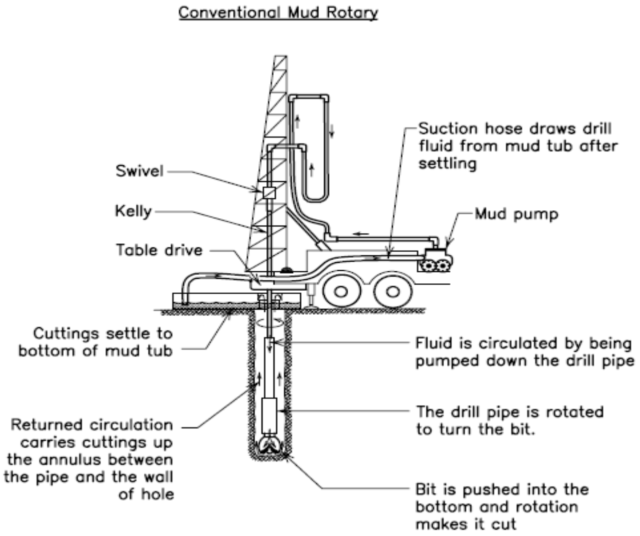


Figure 35: Conventional Rotary Drilling Process (image from *Construction Dewatering and Ground Controls: New Methods and Applications, Third Editions*)

or 0.3048 m. in diameter. This will be the diameter attributed to the wells drilled on the Maryland Public Health Laboratories project.

The maximum yield of discharge from a single well is calculated using the equation (3.6).

$$Q_{max} = 2\pi r_0 h_0 \frac{\sqrt{k}}{15} \qquad (3.6)$$

The variable r_0 in this equations is the radius of the well beign drilled. The variable h_0 is the depth of the drawdown. The drawdown is the difference between the desired ground water table depth and the excavatin depth. This is typically the difference between the total water head and the head that is to be achieved (H-h_w). h_0 is 22 ft. or 6.71 m. The maximum yield of discharge from a single well is calculated to be 0.002532 m^3/s

To obtain the number of deep wells to successfully dewater the site the total yield discharge of the deep well system (0.01659 m^3/s) must be divided by that of a single deep well (0.002532 m^3/s). This produces a value of 6.5 wells, which is rounded up to the nearest well. Thus, a total of 7 wells spread radially would be enough to sufficient dewatering the Maryland public Laboratories.

Spacing & Mapping of Deep Wells

It was calculated that 7 wells spread radially could dewater the project site, but this would place several wells within the excavation perimeter. If deep wells exist within the perimeter of the excavation site, excavation couldn't occur during the dewatering process. It is logical to spread the deep wells along the perimeter of the excavated site.

A logical method of locating deep wells is to equally space them along each face of the excavation site. As this site is rectangular and the long sides are roughly 70% greater in length than the short sides all wells can be placed along both of the longer sides. This will allow for 4 wells to be placed on the north side of the perimeter and 3 on the south side. Because the previous calculations for total yield discharge flow Q were performed using equations used for deep wells aligned in a circle, a new equation must be used to calculate deep wells in specific locations from the center of the influence area. Forchheimer's equation (3.7) is used when more than one deep well is used for a dewatering system and are placed in a non-circular layout.

$$Q = \frac{\pi k(H^2 - {h_w}^2)}{\ln R_0 - \left(\frac{1}{N-1}\right)\ln(x_1 x_2 x_3 \ldots . x_n)} \qquad (3.7)$$

The variable N is the number of deep wells calculated for the system and x_n is the distance from a given deep well to the center of the influence area (center of the excavation site. This equation is needed to compare flow discharge rates.

The deep wells are designated by a number 1-7 and there given locations are as follows:

- Well #1 – coordinates [46', 50'] x_1 = 118 ft. (35.98 m.)

- Well #2 – coordinates [108', 50'] $x_2 = 67$ ft. (20.31 m.)
- Well #3 – coordinates [200', 50'] $x_3 = 67$ ft. (20.31 m.)
- Well #4 – coordinates [262', 50'] $x_4 = 118$ ft. (35.98 m.)
- Well #5 – coordinates [77', 0'] $x_5 = 48$ ft. (14.63 m.)
- Well #6 – coordinates [154', 0'] $x_6 = 91$ ft. (27.66 m.)
- Well #7 – coordinates [231', 0'] $x_7 = 91$ ft. (27.66 m.)

The x values were each obtained by determining the location (coordinates) of the deep well and then using the Pythagorean Theorem to obtain the distance from the center of the influence area. Deep wells were spaced relatively equal to one another. On the north end of the excavation perimeter the spacing between wells #3 and #4 is larger as well #6 on the south perimeter end is directly south of the influence area center.

Using all the provided values, the maximum discharge flow rate can be obtained using equation (3.7). The indicated layout produces a discharge flow rate of approximately 0.01793 m^3/s. This value is greater than the discharge flow rate calculated for a circular deep well layout, which indicates that this is an adequate layout for the Maryland Public Health Laboratories site. The difference between the two values relates to the margin of safety. This layout provides an adequate margin of safety.

It is also important to coordinate the wells with respects to the existing conditions of the site. Because the Maryland Public Health Laboratories exists in a previous developed urban area there are existing utilities within the ground that must be accounted for before drilling. The only existing line that pass through the building foot print area are two electrical conduits that service the parking lot lighting the building is to constructed upon and two sewer lines. In preparation to the demolition of the site necessary to begin construction the two sewer lines have been shut down and the power to the street lamps have been depowered. Because these utility lines are to be removed from the site during excavation, the potential of damaging the lines isn't of main concern.

To effectively dewater the site the coordinates of the deep wells have been specifically chosen to not interfere with existing utility lines that would prevent the drill from accessing the desired depth of 50 ft. If the drill were to clash with these lines another drill in a different location would have to be created, which creates additional time associated with the task. Because the deep wells have been both placed to achieve efficient system discharge flow and not interfere with existing conditions the layout established will the appropriate dewatering used for the project.

Pump Sizing

In order to accurately size a pump the total discharge flow rate must be calculated for a given dewatering system. Also, the total head must be tested for and established. The calculated discharge flow rate for the deep well dewatering system used for the Maryland Public Health Laboratories site was 0.01793 m^3/s. There is 1 m^3/s for every 15, 850.3231 US gal. /min. This flow rate is equivalent to 284 gal. /min. The total head was determined to be 52'. A pump size can be selected using charts provided by the US Army Corp. of Engineers. **Figure 36** provides the pump sizing charts. Using these charts it is determined that a 3" pump is the most suitable pump for each of the deep wells. Because of the inconsistency between the two charts as a 3" pump doesn't exceed 300 gpm in the top chart and does in the bottom chart, a 4" pump will also be used in the schedule and cost analysis topics. After speaking with industry professionals from Griffin Dewatering Co. most submersible pumps used in deep wells range from 5-8" in diameter.

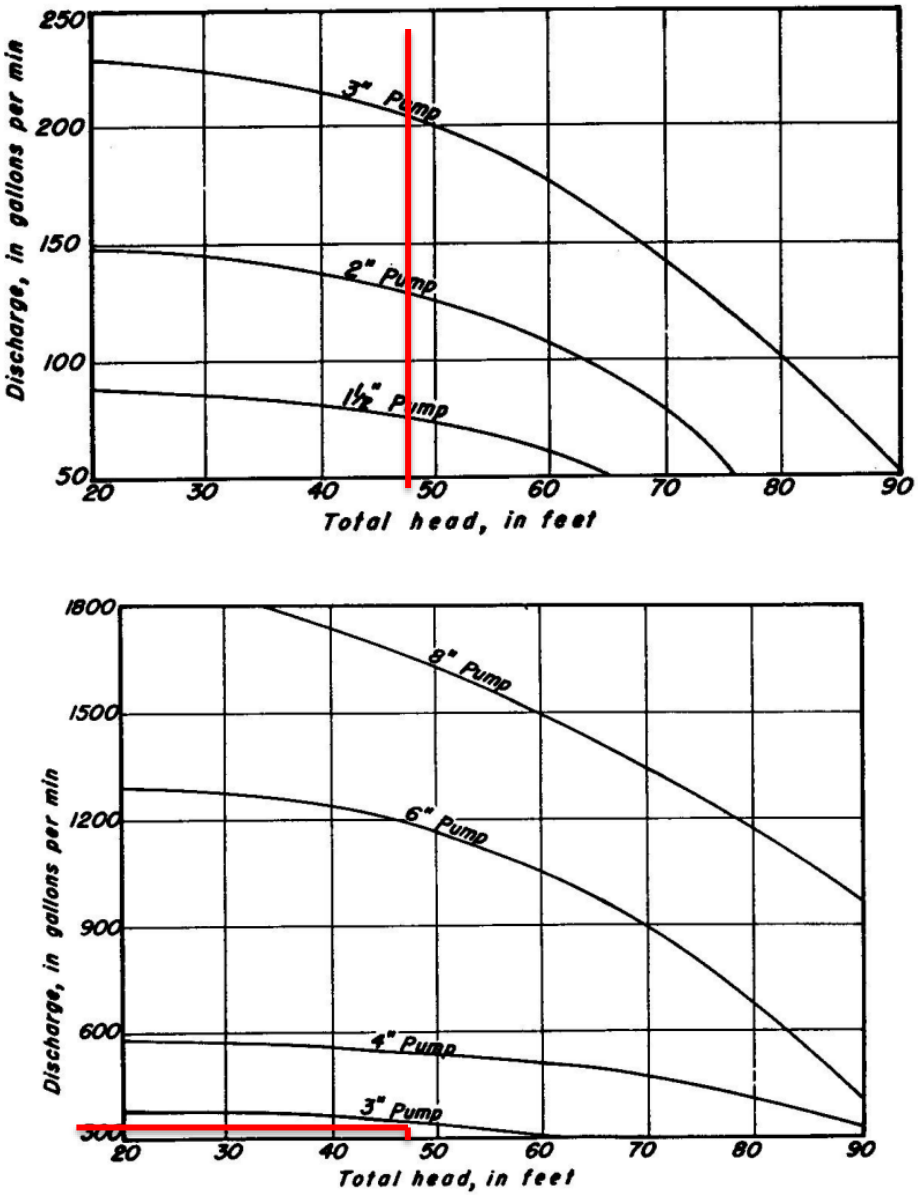


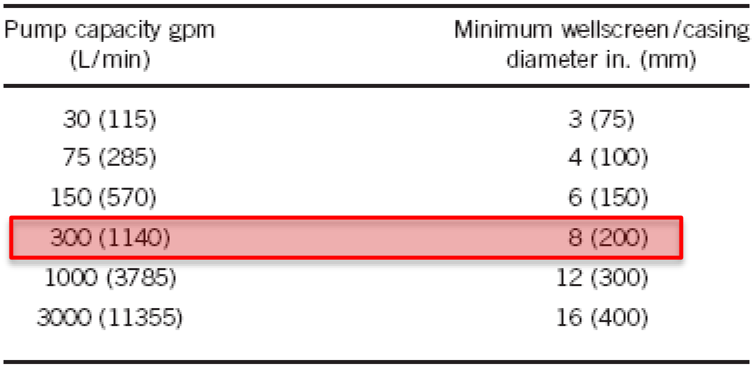
Figure 36: Pump Sizing Chart (provided by the US Army Corp. of Engineers)

Casing/Wellscreen Sizing

The casing is the component that is placed within the well and protects the pumping equipment. Wellscreens are typically made from stainless steel and are perforated to allow water to seep through the casing. This water is then pumped up to the surface and discharged from the soil. **Figure 37** provides an image of a stainless steel wire wellscreen.

Figure 37: Continuous Slot Stainless Steel wire Wellscreen. Courtesy of Johnson Screens (image from *Construction Dewatering and Ground Controls: New Methods and Applications, Third Edition)*

In order to accurately size the casing and wellscreen for a deep well, Table 18.1 in the *Construction Dewatering and Ground Controls: New Methods and Applications, Third Edition* must be used. The calculated capacity of flow required by the pump is 284 gal. /min. Table 18.1 indicates that in order to size the wellscreen and casing the pump capacity must be rounded upwards to the nearest capacity. This would be 300 gal./min., which indicates that there must be a minimum well screen and casing diameter of 8 in. **Figure 38** provides Table 18.1. for sizing wellscreen and casing for a deep well system.



Pump capacity gpm (L/min)	Minimum wellscreen/casing diameter in. (mm)
30 (115)	3 (75)
75 (285)	4 (100)
150 (570)	6 (150)
300 (1140)	8 (200)
1000 (3785)	12 (300)
3000 (11355)	16 (400)

Figure 38: Minimum Wellscreen/Casing Sizing Chart (image from *Construction Dewatering and Ground Controls: New Methods and Applications, Third Edition*

Scheduling and Sequencing

The dewatering system's schedule typically begins during the design phases of a building project. The planning and pricing is required prior to the bid submittal date. This is mostly common when the need for a dewatering system for a proposed site is apparent. On occasions, similar to the current Maryland Public Health Laboratories project, dewatering contractors are called by general contractors during the construction process. The typical duration of dewatering systems selection and planning depends on the complexity of the project and the degree of experience of the dewatering project manager. It has been mentioned that a lot of systems selections are based on industry professional's opinion and experience. A typical dewatering system of the caliber designed for the project roughly takes on average 2-3 weeks, given that geotechnical information is provided prior to the planning stages. The bid design was submitted

by HDR for construction on December 8, 2011, therefore any time prior to that and the beginning of early 2010 when the building design began would be the time designated for dewatering systems design and planning.
The installation durations are categorized by tasks as provided in **Table 14**. It is important to note that the installation of the discharge ground water storage tank will not affect the overall duration of the installation process, as it is to be installed during the placement of the discharge piping. The total duration to install seven deep wells is approximately 5.25

Table 14: Deep Well Installation Duration Breakdown (info. provided by Mersino Dewatering)

DEEP WELL INSTALLATION DURATION BY TASK (50' Deep Wells)			
Task Description	**Quantity of Work**	**Work Rate**	**Total Duration of Task**
Drilling of Deep Well	7 wells	2 wells/day	3.5 days
Pump equipment Installation and Backfill	7 wells	15 min./well	105 min. (1 hr. 45 min.)
Discharge Pipe Installation	612 ft.	400 ft./day	1.53 days
		Total Dewatering Installation Duration:	**5.25 days**

Once the dewatering system has been adequately installed, it will immediately begin operation, reducing the depth of the groundwater table. The dewatering system should be installed and ready to operate several days before excavation has reached the depth of the static water table. Industry professionals have mentioned that deep wells are typically installed once excavation begins.

Excavation for the Maryland Public Health Laboratories project began on February 1, 2012. The task of driving H-piles begins on February 27, 2012, marking the beginning of building construction after the site has been demolished. This date will be the date that subcontractors will begin dewatering installation. This will allow drilling and installation of the equipment to be 95% complete prior to the start of excavation, granted there is no installation errors made in the process. The dewatering system will be fully installed on the date excavation will occur.
To effectively dewatering the given site and assure that the groundwater table won't pose as an issue once the dewatering system is removed, the system will remain in place until all foundation construction below the original groundwater table is completed. This general rule of the removal of dewatering equipment was provided by a project manager at Mersino Dewatering.

The last task that performed underneath the original static water table depth is the slab on grade pour for the east half of the building. The whole process of pouring, finishing, and curing the slab will begin on June 11, 2012 and last to June 22, 2012. The dewatering system will remain installed until the date of June 22, 2012. This is a total of 143 days or 4.7 months.
After the eastern portion of the slab on grade is complete the dewatering will be removed from the site. Dewatering system removal duration is very relative. An industry professional has approximated the removal of the designed 7 system to take 2-3 days. This will need a crew of 4 workers and a crane to perform.

The summation of the entire dewatering system installation, operation, and removal process will take approximately 150 days. This duration allows for the Maryland Public Health Laboratories excavation site to be effectively dewatered, lowering the groundwater table to a depth of 40 ft. below grade. This duration will be used in the feasibility analysis section for comparison.

Cost Analysis of Dewatering System

There are several costs associated with a dewatering system, as there is the process of planning the system, drilling the well, renting the pumping equipment, and removing the equipment. With cost information provided by both Mersino Dewatering Services and Griffin Dewatering a total cost for the system can be achieved.

The first cost to calculate that is needs to be calculated is the cost for preliminary planning. Most companies, such as those stated in the previous paragraph, don't generally charge for a site investigation, but may need to conduct testing in the form of test bores. This testing determines information such as water table depths, number of aquifers and depths, soil classification types at specific aquifers and the permeability of these soils. Because these conditions have been previously tested for and the date has been collect and provided within the geotechnical report submitted by Schnabel Engineering, there will be cost for testing as this won't be performed by the dewatering contractor. The overhead cost associated for site supervision, system documentation, system plans, and other expenditures have been estimated to cost in the range of $1,200 - $6,000, depending on the complexity of the design. As the system design for the Maryland Public Health Laboratories project consists of several deep wells and doesn't implement any specialized equipment, or an additional perimeter well point system a medium of $2,400. This number was determined based on the size of the project and the equipment need to service the specific area. An additional 5% mark-up is added for other overhead costs associated with the system.

A crew of 2-4 people is used to install the dewatering systems on construction sites. The laborers of these crews are budgeted at $335 a day and a site supervisor is budgeted at $940. There is to be three laborers and a site supervisor on the crew assembly and operating the dewatering system for the site. The crew is only present on site during installation, system operation and demobilization of the system. The total duration that the crew will operate is 127.5 days, which produces a combined labor cost of $247,987.50.

Drilling costs is typically budgeted by the day. The equipment used to create the deep wells isn't typically rented. A rig that is able to drill a boring to the industry standard diameter of 36" to service a 12" diameter well after backfill is placed has a daily operations rate of $4,800. This rate is based off the Mid-Atlantic region. Because the cost is based off a daily rate the 3.5 day need to drill these holes will be round to the required full day, which would be 4 days. This creates a total equipment cost of $19,200.

The equipment used to pump the ground water to the system is broken down into these components:

- Submersible Pumps
- PVC Discharge Columns
- Well Casing and Screens
- Discharge Pipe and Discharge Tank

The submersible pump required to service each well has been sized to have a pump capacity of 280-300 GPM. The charts provided have indicated a 3"-4" submersible pump would be the typical diameter size of a pump of this capacity, but after discussions with industry cost estimators from Mersino a standard diameter size for a deep well is 6”. A 6” submersible pump that can provide such pump capacity would be a 5 HP electrical pump that would be priced at $3,500 each. As there are 7 deep wells positioned around the site and one submersible pump services each well the total cost for a pump would be $24,500.

The well casing and screen is inserted within the bored well. The designed well casing and screen of 8” diameter would be priced at $12 per linear foot. An industry standard sized 12” diameter well casing and screen is $20 per linear foot. This equipment reaches the entire depth of the well of 50 ft. Therefor the cost of a well casing and screen for a deep well would be priced at $600 for designed 18” diameter and $1,000 for industry standard 12” diameter. This creates a total cost for the well casing and screens of $4,200 or $7,000.

The discharge column that is placed within the well casing and screen is used to direct the water upwards to the ground surface. This piece of material is typically “PVC” piping that is 3” in diameter. The riser pipe is priced at $2 per linear foot. As this column is connect to the submersible pipe, which is roughly 2’-6” in length and extends to a height that is 1’-6” above the ground surface, the amount of “PVC” piping used for each well will be 49 ft. This creates a cost of $98 per column and $686 for the entire system.

Lastly the discharge pipe is the final major piece of equipment that must be priced. This is the pipe line that directs the discharged ground water from the deep wells to a point of regulated discharge. The project has been permitted to discharge water dewatered from the site at a certain rate into the maniple system. The line and tank sizing are typically directed and size by local regulations. Because the Maryland Public Health Laboratories project had a dewatering pumping system and line designed, which met regulations, this similar pipe line path and storage tank size will be used. The discharge pipe is an 8” high-density polyethylene (HDPE) discharge pipe that is priced at $25 per linear foot. This price includes all necessary valves and fittings. The amount of line needed to service the project is approximately 613 linear ft. This produces a total cost of $15,325.

In addition to the equipment cost a 10% markup is included. This markup charge accounts for miscellaneous system components such as riser pipe accessories (valves, fittings, etc.), control panels, pump cables, pressure gauges, flowmeters, pump accessories, etc. This markup percentage creates an additional cost of $5,849 or approximately $6,000.

The daily rental rate for deep well equipment for the entire system is provided by Griffin Dewatering cost information. There will be a $240.000 rental rate per day for the first 120 days and any additional time exceeding 120 days the rental rate reduces to $190.00. The total duration of the dewatering system operation is approximately 150 days. These accounts for the time spend procuring, installing, removing, and returning the equipment. The operational time of the equipment is 143 day. To install the system will take roughly a single day and removing the equipment will take 3 days. Lastly, an additional 3 days were added to procure and return all the equipment. This will produce a rental cost for the equipment of $34,500.

Backfill is necessary to fill in the borings to stabilize the well. The materials used as backfill are filter sand and miscellaneous backfill. As the standard well boring diameter is 36” and the well diameter is 12” at both 50 ft. vertical length the volume necessary to backfill is 353.43 C.F. or 13.09 C.Y. per deep well. As there are 7 deep well on-site, this creates a total need for 91.63 C.Y. of backfill. The cost per cubic yard of backfill is $40 per C.Y., which is a lump sum price of both the filter sand and miscellaneous backfill. The total cost of backfill associate with the design deep well system is $3665.19.

The next cost estimated is the electrical demand to run the dewatering system. The 5 HP pumps are to be continuously operating throughout the entirety of the work day. The operational hours are based on an 8 hour work day. Using the electrical cost equation (3.8) for motors an electrical cost rate per day can be achieved

$$\boldsymbol{Electrical\ Cost} = HP\ x\ 0.746\ x\ {}^{Kw\ cost}/_{motor\ efficiency} \qquad (3.8)$$

The date provided the Bureau of Labor Statistics provides an average electrical cost rate in the Washington D.C. – Baltimore area of 0.123 between the years 2012 and 2013. The dewatering system will be installed and operated during the dates in each year. The data was collected form the chart provided in the **Figure 39** below. The calculated total electrical cost is $3.57 per hour. This is based on a motor efficiency of 90%, as motors don’t operate on an ideal 100% efficiency.

The system will operate all hours of construction, 8 hr. days, for the implemented 6 day schedule. The system will be operating for approximately 955 hours. This produces an electrical cost of $3,581.25.

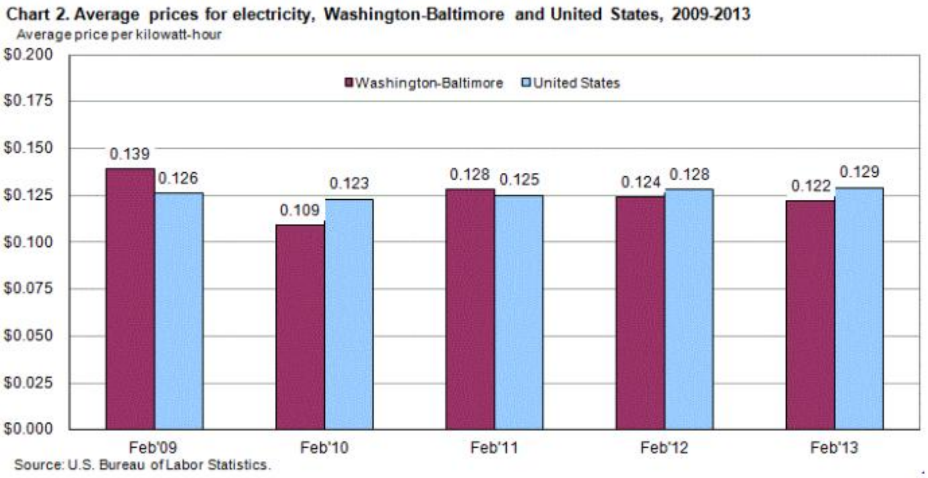


Figure 39: Average Electrical Cost Rates for the Washington D.C. - Baltimore Area (image provided by the Bureau of Labor Statistics)

Lastly, the removal of the system must be priced as the intention is to not have the system remain once the foundation construction has been completed above static groundwater level height (18 ft.). The cost associated with disassembling the system is $1,200 per deep well or a total of $8,400. There is no cost to seal the wells, as they will be backfilled and compacted. As mentioned above a crane is needed to remove the deep well equipment from the well. This crane cost is negligible because it is already rented during the months of dewatering for foundation and structural construction.

The summation of all the calculated costs for the designed deep well dewatering system provides a total systems cost of $390,596. A cost break down of the design system for the Maryland Public Health Laboratories is provided in **Appendix S.**

Feasibility Analysis

It is imperative that the costs and time durations calculated and broken down above are used in comparison to the groundwater issues the Maryland Public Health Laboratories suffered during the excavation. This will determine whether time and money can be saved implementing such a system, therefor defining the feasibility of the system.

Dewatering on the original site began on April 1, 2012 during the excavation of the project and lasted to June 3, 2012 before additional dewatering equipment was installed to remove the excess flooding with the excavating site. (Specified dates are based on schedule with delays) It was projected by Turner that is would take another 60 days before the dewatering system would be able to be removed from the site. The total duration of the installation, operation, and removal of the equipment is roughly 120 days when a 5 day removal period is implemented. This amount of time is due to the complexity of the system as there are several specialty systems, deep wells, and well points placed around the entire system.

The deep well system designed for the project and implemented prior to the building excavation phase will operate for approximately for 150 days as mentioned above. It will take an additional 30 days to operate such a system, which will in turn increase the cost for labor and supervision require. Both applied system durations are based off a 6 day work week, as this was the schedule implemented by Jacobs Engineering.

Even though the system designed to be installed prior to excavation requires an additional 30 days, it effectively dewaters the project site without schedule delays and additional change orders. After discussion with Jacobs project team members it was determine that there was a loss of 2 months in schedule due to implication of the unanticipated high groundwater table. This additional two months have significantly increased the total project budget.

The applications of the dewatering system with the additional changes to the current project and the designed system for this analysis aren't critical path construction paths. As the installation of these dewatering systems don't drive schedule the duration of the system only impacts project costs by the labor rates associated for each system. The flooding that occurred on the project that couldn't be prevented from the originally designed dewatering system due to misinformed planning, created additional equipment costs, damages costs, and costs associated to the prolonged project schedule.

The original dewatering contract for dewatering equipment consisted of the installation of seven deep sumps. This was originally estimated at $173,579.45, but was budgeted at $185,000 in Turner's pay application form. The change orders made to the project to mitigate the flooding issue were the addition of a french drain system, sump drains at mat shear walls, test pile program, dewatering operations, street striping, wick drains, deep wells, sump manifold, lower wick manifold, wick tests and sand filter which produced a total change order of $526,521.44.

An additional $59,444.68 has been attributed to damages created to building materials due to water exposure by the flooding. **Table 15** is a break-down of the original dewatering budgeted cost on the Maryland Public Health Laboratories and the additional change orders associated. This break down was created using Turner Pay Application form during the given time period and Turner's dewatering system break down and schedule cost impact, both provided in **Appendix T**. The total direct cost for dewatering on the Maryland Public Health Laboratories is approximately $770,381.

Table 15: Project Dewatering System's Cost Break Down (information provided by Turner Company)

MPHL Dewatering System's Cost Break-Down	
Description	**Cost**
7 Deep Sump Drains	$185,000
Change Orders	
French Drain System	$10,922.21
Sump Drains at Mat Shear Wall	$22,152.91
Test Pile Program	$55,119.36
Dewatering Services	$10,791.00
Street Stripping	$6,214.00
Wick Drain Installation	$27,090.94
Wash Station	$84,000.00
Field Notices	$30,452.00
Deep Wells	$137089.69
Sump Manifold	$26,832.18
Lower Wick Manifold	$34,997.15
Wick Tests	$8,820.00
Sand Filter	$59,900.00
Flood Water Damages	$59,444.68
Total Dewatering System's Cost with CO's	**$770,381.12**

Manpower costs such as additional manpower costs are associated with the additional work and dewatering operation that has occurred. A projection of 60 additional days has been established by Turner to remedy the flooded site. With estimated manpower costs of $1,000 per day, Griffin supervisor costs of $940 per day, and additional rental costs of $190 per day an additional $109,940 has been added to the cost of dewatering.

Additional indirect costs can be attributed to the project time lost due to the flooding. Concrete work ceased as the flooding affected the loading capacity of the soil. The ground would have settled if concrete was placed on top of the flooded soil potentially damaging the casted concrete as it cured. This creates schedule impact costs that are difficult to evaluate until the entirety of the project is complete. The crane rental was prolonged 3 months. The tower crane used on the project had a rental rate of $50,000 per month, which created an additional $150,000 to the total project cost. A projected $200,000 loss was estimated by Turner in addition to an added $600,000 in general conditions. Other indirect costs haven't been evaluated, but with 2 month delay to the project schedule there are bound to be other indirect costs that accumulate.

The total cost for the designed system that is intended to be implemented prior to excavation and is designed based of the known groundwater table depth is $390,595.84. This system cost roughly 50% more than the original system prior to the change orders. Even though this system costs a great amount more, it is able to assure that the Maryland Public Health Laboratories site is adequately dewatered for excavation and foundation construction. This system will eliminate the need for change orders on site. This reduces the project cost by $770,381. Also, the projected manpower and supervision costs totaling $109,940 are also eliminated from the projects total costs. Lastly, indirect costs such as prolonged crane rental costs and increased general conditions are not experienced on the project. The total of all costs associated with the unanticipated high groundwater table is $1,830,321, which is remains increasing.

Dewatering System Conclusion

Selecting, sizing, and mapping a dewatering system a crucial process when it is necessary that a project site reduce the groundwater table depth for construction. As this water table can negatively affect the structural properties, damage building materials, and reduce schedule, it is important that accurate test are performed to ensure the depth of this ground water table and the soils beneath the building footprint. The project teams working on Maryland Public Health Laboratories project didn’t anticipate the water table to be as high as noted and lost valuable time of the project schedule. This in turn created a need for significant change orders, thus additional cost to the total project budget.

The system designed in this analysis has been designed to be able to reduce the groundwater table to a depth that would not affect the excavation process. This eliminates all change orders associated with dewatering or flooding damages and allows the project to remain on schedule. The total duration is approximately 30 days have been added to the dewatering process compared to the original design (with change orders), but all tasks associated with the system aren’t critical path task. The duration of the dewatering process doesn’t impact the schedule, but the flooding that occurred because of the lack of dewatering affect critical path task. Two months have been lost because of the flooding, which creates significant direct and indirect costs.

Direct cost in the form of change orders have totaled to approximately $585,000 in addition to the original installed system. Projected indirect costs have cost the project upwards of $1.8 million and rising. The $390,595 spent on the analysis design will eliminate all change order costs and projected direct costs. A total of greater than $1.4 million can be saved if an adequate dewatering system were designed to reduce the unanticipated high groundwater table. In conclusion the Maryland Public Health Laboratories should pay for a more intensive system that would have been implemented prior to excavation as a schedule safety precaution.

Technical Analysis #4: Stormwater Harvesting System

Problem Identification

A building of the magnitude of the Maryland Public Laboratories will have a great cost associated with the design and construction. The total projected cost at the beginning of the project was estimated to be $110 million, but with the addition of change orders the total has increased to $112.5 million. This is a large sum of money provided by the owner for the construction of the new facility. Once the building has been turned over to the owner for operational use, it continues to generate costs. These costs include the energy required to power the building's operations, potable water for building occupants, and maintenance costs.
In order to make up for the cost to build the project and those associated with running the facility certain systems can be value engineered to reduce material cost, installation cost, or increase energy savings. A value engineering idea that has been mentioned on the project, but never implemented was the idea of a stormwater harvesting system used within the green roof design. The ability to use stormwater and domestic discharge water as grey water within the building, as well as reuse water consumed by the building and its occupants would create resource cost savings. This will reduce the cost of water bills and with time help to potential pay-off the cost of construction.

In addition to the cost savings associated with implementing the stormwater harvesting system, it will potentially achieve unattained LEED requirement points. The Maryland Public Laboratories project had Sustainable Deign Consulting do a preliminary LEED evaluation to provide a synopsis of the areas the building would earn points. Within the report it was indicated that four points were lost in the Water Efficiency category. The points missing points fell into the two sub-categories, Innovative Wastewater Technologies and Water Use Reduction. These two sub-categories directly relate to the value engineering topic regarding grey water systems. If the system were able to achieve these four points, the total points acquired by the Maryland Public Laboratories project would be 61 points. This would give the project a LEED Gold certification. Both the state of Maryland and city of Baltimore have mandated this project reach a sustainable rating of LEED Silver. This requirement has been established to project a sense of innovation and progression by the building to the community. A revival program has been enacted within the East Baltimore area as the community strives to rebuild the once impoverished area. Achieving LEED Gold will not only benefit owner's through reduction in operations cost, but will exceed the community, city, and states expectations for the building. A LEED Gold facility will be a great addition to the area and serve as an icon for the public.

Research Plan & Objectives

To accurately assess the feasibility of implementing a stormwater harvesting system a number of calculations, planning, costs, and schedule analyses must be conducted. Stormwater harvesting systems are designed to capture all water that can be potentially reused within the building and to reduce stormwater runoff. To begin a stormwater harvesting supply will be calculated in gallons. This will allow for accurate sizing of a cistern that is used to store the water. This can be calculated using a rainwater harvesting calculator provided by Contech.

The tank size will allow the ability to size the components, such as pumps, filters, and discharge piping involved with the system. Using the given sizes for each component, pricing for the system can calculated.

Also, the tank size will determine where in approximation to the building footprint the tank will be installed. A tank that serves structures over 100,000 S.F. will require a large area to be excavated. An evaluation of the parking lot north of the project footprint and west of the project trailer complex will be performed to determine whether this is a sufficient space to install the stormwater harvesting system.

If the desired location proves sufficient to install the system a demolition and excavation analysis will be performed. Demolition costs will be created based off HDR's proposed demolition for the Maryland Public Laboratories Project. This is due to the fact that this parking lot area was originally a part of the planned demolished portion. Excavation for the system will be researched and mapped on the site plan to demonstrate the location and depth the system will be installed. Also the size will provide a cost associated with the excavation. Lastly discharge lines will be also mapped to and from the building and indicated in the excavation plan.

Once all costs associated with designing the structure have been comprised, the value will be compared to the cost associated with the facilities water consumption. The cost savings produced by the rainwater harvesting system will be used as the basis for comparison. In addition a life cycle cost analysis will be conducted analyzing the cost savings over time and the cost associated with maintaining the system. The goal is to hopefully save enough money in the future to pay off the building project.

The total reused water will be calculated supplied by this system will be used for LEED evaluations. The quantity of water runoff conserved and re-introduced back into the building will hopefully be sufficient enough to meet point requirements in the Water Efficiency category. Sustainability consulting has determined that based on the design point lost within this category are due to the lack of innovative wastewater technologies and water use reduction.

A schedule impact and sequencing analysis will be done investigating where during the construction project this will occur and for how long. Because this type of construction occurs adjacent from the building project there should be little affect to the critical schedule and confliction of sequencing.

Lastly a feasibility study will conclude whether such a system would be beneficial to the Maryland Public Health Laboratory facility. It is the goal that a significant costs saving will be attributed to the system over time, compared to the additional upfront costs to the building's construction.

Application Methodology

To effectively research the analysis topic of stormwater harvesting, the following steps must be taken:

1. Conduct preliminary interviews with Contech Engineered Solutions, Jacobs Engineering, and Turner Company to discuss system sizing and water supply/demand for the Maryland Public Health Laboratories facility.
2. Use Rainwater Harvesting Calculator to efficiently size a system appropriate for the building required loads.
3. Map demolition and excavation for the proposed system installation.
4. Price system and calculate costs associated with the installation for a cost analysis.
5. Compare costs of system and installation with potentially savings cost through current water/sewer rates for Baltimore City.
6. Analyze the impacts on the schedule and determine the total duration of the installation of the system.
7. Compare runoff water and grey water values to LEED credit requirements to determine if additional point will be achieved.
8. Conduct an overall feasibility study for the stormwater harvesting system.

System Overview

Stormwater harvesting systems are systems designed to capture rainwater from the rooftop and hardscapes. Hardscapes are impervious surfaces such as courtyards, sidewalks and parking lots. Also, these systems can store discharged domestic water that can be reused as grey water.

Water that is discharged from the indicated locations is directed by means of building gutter systems and downspouts to a filtration pretreatment system. This is the location where discharged water is treated as pollutants and toxins are removed from the water source. This is beneficial as this will protect the cistern or storage tank from being damaged by such pollutants. The water is then introduced to the cistern where it's stored and then ejected back into the facility for grey water uses. **Figure 40** depicts the main components and path of the stormwater within a stormwater harvesting system.

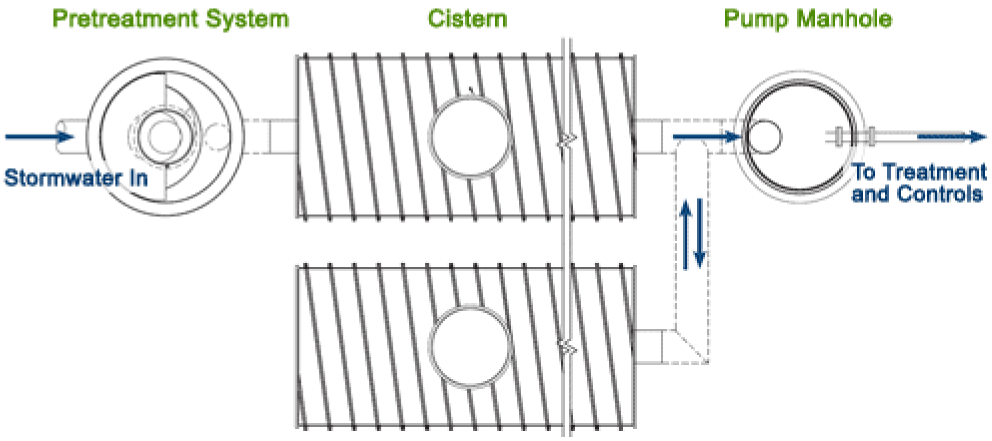


Figure 40: Stormwater Harvesting System Schematic (image provided by Contech Engineered Solutions)

A more descriptive schematic design is provided in **Figure 41**.

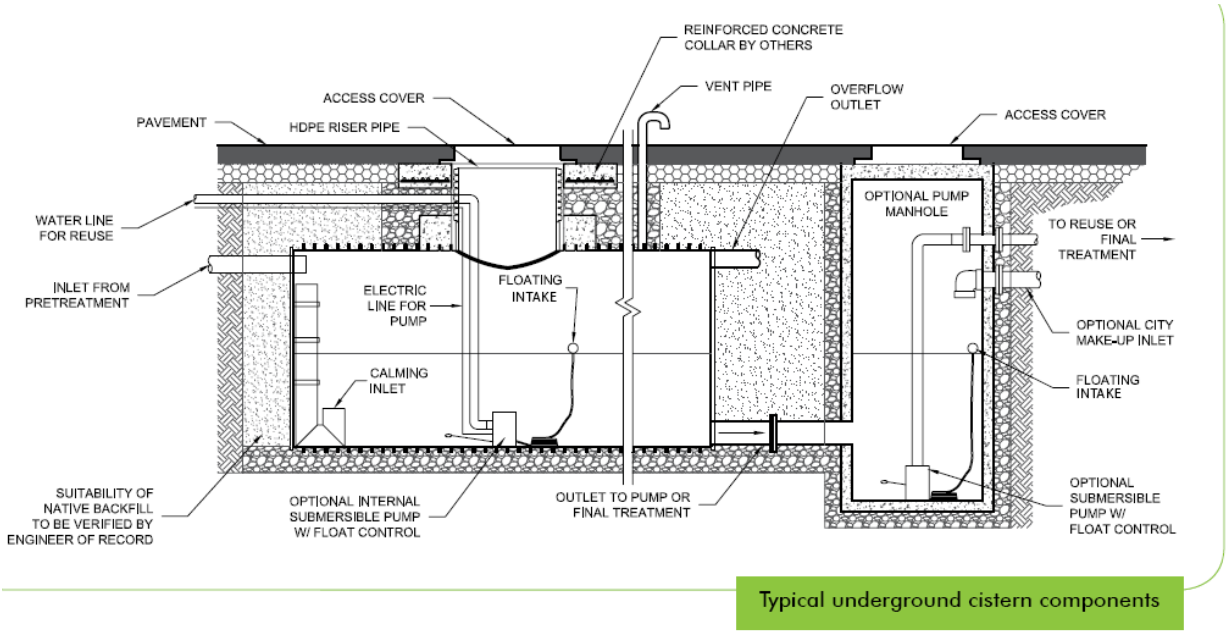


Figure 41: Schematic Design of an Underground Stormwater Harvesting System (image provided by Contech Engineered Solutions)

After discussion with industry professionals at Contech Engineered Solutions, the best suited system design for large scale facilities similar to the Maryland Public Health Laboratories would be an Underground Metal (UGM) Cistern. This system is used for large building project because they have the ability to store upwards to 100,000 gallons of water. If a greater quantity of water needs to be supplied to meet building load requirements additional cisterns can be link together in parallel to one another. **Figure 42** provides an image of the selected system.

Figure 8: Underground Metal Cistern System (image provided by Contech Engineered Solutions)

System Sizing

Using the Rainwater Harvesting Runoff Reduction Calculator provided by Contech, a tank size was able to be achieved. The catagories in the calculator are broken down into supply water and demand water. Supply water comes in the form of rooftop and hardscape runoff, greywater supply, and air conditioning. The average rain fall of Baltimore is 41.84 inches with a maxium value of 58 inches. These are used to calculate the amount of water per gallon will result in runoff from roofs and hardscapes.

Another potential water supply is grey water. There isn't an exact value for grey water for the building, but grey water was able to calculated by taking 65% of the domestic water discharge. The percent 65% accounts for water from sinks, shower and other similar sources. Toilets and urinals aren't included in the grey water calculation. Also, laboratory water discharge can’t be used for grey water as there are high amount of chemical and pollutants that could potentially be in the water source.

The water demand for the building is calculated by several sources. Irrigation, toilet use, laundry use, wash water use, and cooling loads necessary for the building. Using the designed occupancy by code of 1,600 occupants an estimate toilet demand be calculated. Half this occupancy will be present during the weekends. It is assumed occupants of the building use the bathrrom twice. Irrigation demand are based off peak loads. These occur during late spring through the summer. A total of 200 gpm are used during the peak loading period. The cooling loads is the factor that place a high demand on the building as the chillers operate by supplying a total of 250 gpm to the 5 air handling units, the fan coiling unit, and the process unit.

Theses loads are compared to one another one another to establish a demand size for cistrin. For the Maryland Public Health Laboratories there must be a dewatering system that can hold roughly 2.7 billion gallons of water a year. The facility can requires a supply of 1.3 billion gallons. Calculation have indicated that the smallest cistern size that will maximize run-off reduction and water consumption savings is one that would hold 250,000 gallons. A tank that could hold such a load would be approximately 665 ft. long with an 8 ft. diameter based on Urbangreen Underground Metal Cistern specifictions.

The 665 ft. cistern can be divided into five individul cisterns that are 133 ft. in length. Each of these tanks will be able to carry 48,545 gallons of water. This size will determine the size of excavation need to install these cisterns.

All calculator results are provided in **Appendix U.**

Site Selection, Demolition and Excavation

The area that is intended to house the stormwater harvesting system is the undemolished parking lot area north of the site. Assuming that building permits were obtained that allowed for the site to perform construction in that zone, this would allow a decent sized area to install this system. **Figure 43** provides an image of the intended area for installation.

The demolition process would be similar to the demolition that occurred on the Maryland Public Health Laboratories project. It would be a continuation of the task as roughly an additional 50% more area would need to be demolitioned. This will prolong the duration of the demolition task by 50% as well. Ashphalt and concrete curbs will be cut, demolitoned and salvaged during this process. Existing trees, concrete curbs, car stops, parking lot lamps, etc., will also be removed. Additional equipment will be need to support the demoliton. One bulldozer and excavator will be introduced to the project at this time. After the entire site has been adequately demolitioned, sitework contractors will begin excavating the building footprint. Sitework excavation for the installation of the stormwater harvesting system will continue to proceed once the excavation of the Maryland Public Health Labortories is completed.

The excavation has been set back to match the excavation of the building, as this is the requirement to meet zoning codes. The dimensions of the intended excavation area is 160’x 85’.

This allows approximately 5-7 ft. of spacing around the perimeter of cisterns. To minimize the cost of excavation a sloped excavation plan will be used.

Abidding by OSHA's maximum allowable slope the soil condition must be classified into one of the catagories A, B, and C. The soil that exists from grade to approximately 15' depth is silty clay or sandy silts. This type of soil would be classified as type A soil, which is provided in Appendix A to subpart P of part 1926 in the OSHA Regulation Standards.

With this slope we can define the maximum allowable slopes of excavation using Table B-1 provided in Appendix B of the same section. This table is provided in **Figure 44** and a excavation section is provided in **Figure 45**. Using the given maximum allowable slope, at a excavation depth of 15' the bottom of the excavtion site will have a dimensional area of 137'-6' x 62'-5".

The standard spacing between cisterns is half the pipe diameter based on Contech's Urbangreen Underground Metal Cistern specifications. This specification is provided in **Appendix V**. As the projected maximum discharge total is designed to reach 120 gpm. a steel pipe size of 8" is used based of the GPM per pipe size table. Therefore the spacing between cisterns is going to be 4". This excavation size also allows for 8 ft. diameter manifolds that connect the five parallel cisterns. The manifolds allow for discharge water to be easily distributed between the cisterns. Also, another 12 ft. allowance is made to house both the prefiltration system and pump manhole. These units are both 6 ft. in diameter and are placed in close proximity to the cisterns. The pump manhole will house a 10 gpm. pump that will service reusable water to the facility.

This system will only need one prefiltration unit as it has been designed as such to have one inlet into the cisterns. The discharge piping for both the hardscape and rooftops will connect prior to the prefiltration unit.

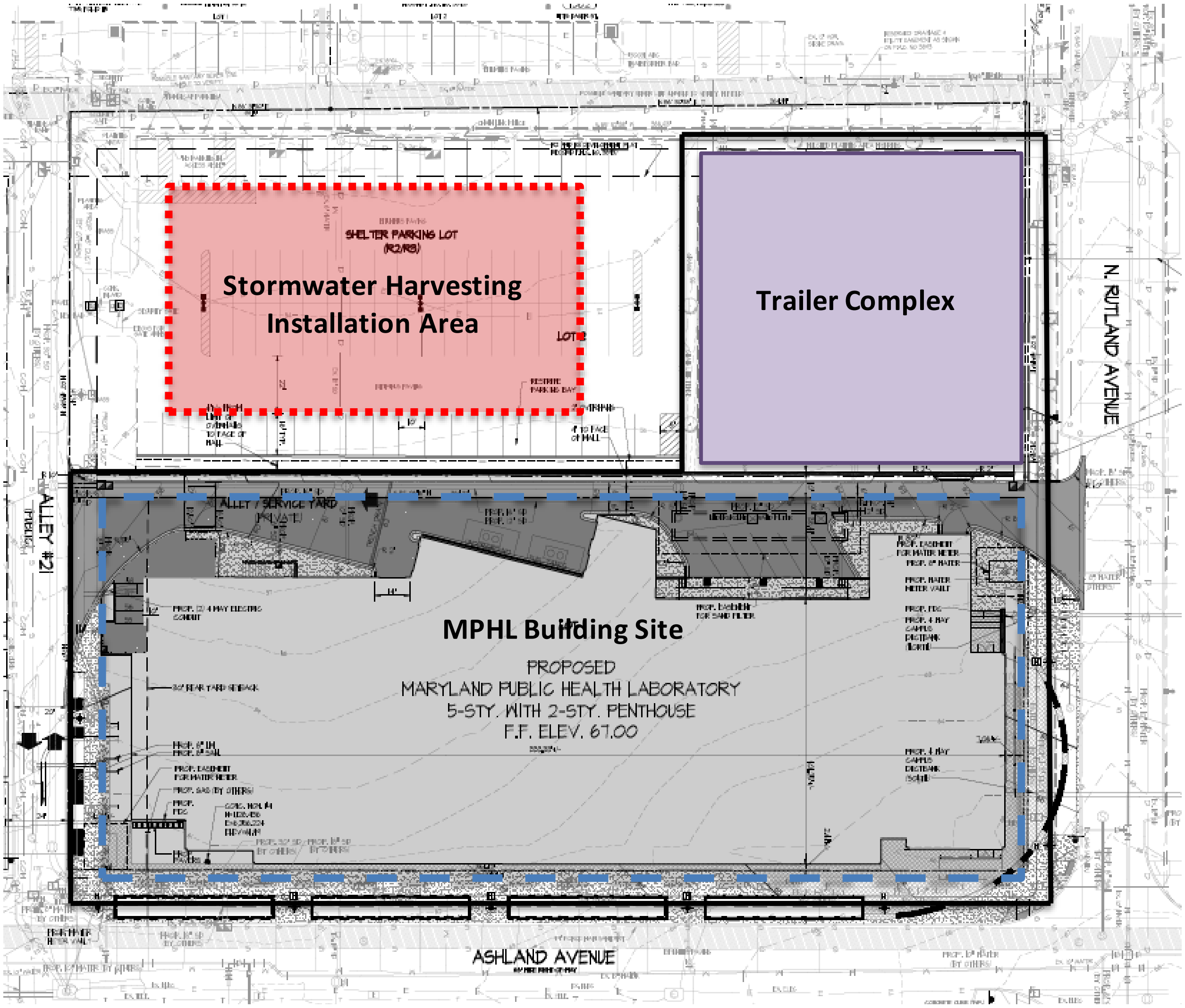


Figure 43: Stormwater Installation Map (plan provided by HDR, Inc.)

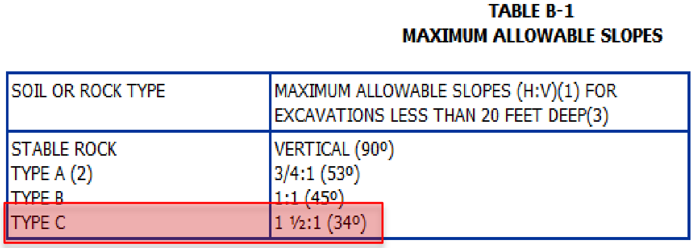


TABLE B-1
MAXIMUM ALLOWABLE SLOPES

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V)(1) FOR EXCAVATIONS LESS THAN 20 FEET DEEP(3)
STABLE ROCK	VERTICAL (90°)
TYPE A (2)	3/4:1 (53°)
TYPE B	1:1 (45°)
TYPE C	1 ½:1 (34°)

Figure 9: Table B-1 Maximum Allowable Excavation Slopes (image provided by OSHA)

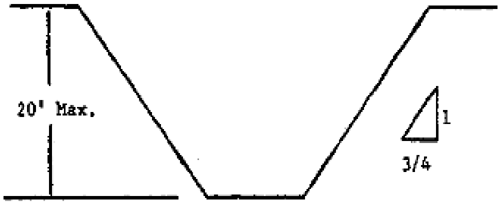


Figure 45: Section View of Excavation of Soil Class A (image provided by OSHA)

Installation Procedures

All the sitework tasks associated with the installation of the stormwater harvesting system will be done by sitework subcontractors Kayden Premier Enterprises. Demolition will be continuous with the demolition process of the Maryland Public Laboratories demolition. This will create an increase in duration spent on the project that will be later discussed in the scheduling impacts section. Demolition requires the asphalt be cut and removed, concrete curbs and sidewalk to be cut a removed, wheel stops removed, light poles removed, etc.

Once the excavation and site work for the building project has been complete and the foundation construction has begun, the two excavators and bulldozer will continue work by beginning the excavation for the stormwater harvesting installation. The west most site trailer will be placed into the back corner of the project trailer complex to allow easy access for the excavators and an access ramp into the excavation site. **Figure 46** provides an image indicating the trailer that must be brought north approximately 30 ft. to allow for this to occur.

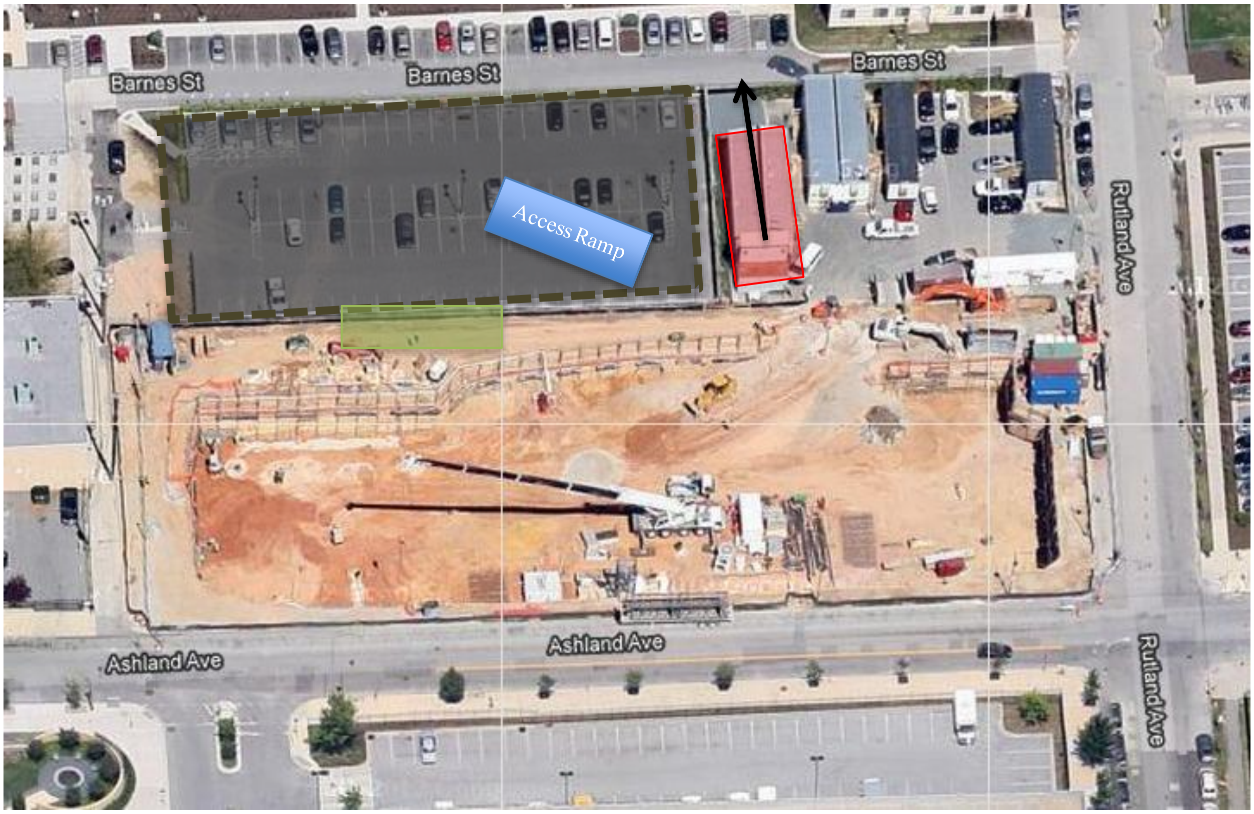


Figure 46: Site Adjustment Plan (image provided by Bing.com)

Once the excavation has occurred the crane used to install the H-piles and sheeting will be remobilized on site to place the cistern pieces. The cistern is divided into lengths of approximately 15 ft. Each cistern will be approximately 9 pieces. These pieces will be staged in the location marked by the green area in the picture above. Once all pieces have been assembled backfill will proceed. Because the system selected was an Underground Metal Cistern system it is durable enough to withstand the load applied when using native soil or the excavated soil as backfill. Thus, to the excavated soil from the installation area will be used to backfill. The nominal coverage of the cisterns must be a minimum of 8 in., which is far exceeding as the depth of the excavation was 15’.

Once the land has been compacted the re construction of the parking lot will occur. This is the final phase of the installation process for the stormwater harvesting system.

There are to be little to no coordination issues that occur during the installation of this system. The construction will occur simultaneous with the structural foundation and cast in place concrete superstructure construction of the Maryland Public Health Laboratory building. Crane picks and concrete deliveries will stage off Ashland Ave., which is in the opposite direction of the stormwater harvesting area. All work performed on the building will be done within the building footprint area so there will be little coordination confliction.

The only concerns with coordination will be the maneuvering of heavy equipment such as the bulldozer and excavator used for the excavation of the stormwater harvesting system. The narrow pass between the trailer complex and the Maryland Public Health Laboratories footprint will have to be properly supervised for safety reason.

System and Installation Costs

The cost associated with the stormwater harvesting system is a direct cost that will increase the total budget on the building project. These systems are designed and implemented to generate cost saving during a building's life span. The first cost to be analyzed is the equipment cost.

It was stated above that the design of the system consisted of 5 cisterns 133 ft. in length. Based on specification provided by Contech's Underground Metal Cisterns, the gallons per linear foot of an 8 ft. diameter cistern is approximately to carry 376 gal. per linear ft. Cisterns of this size can carry approximately 50,000 gallons of water each.

After discussion with an estimator at Contech it was mentioned that tanks between the ranges of 10,000-30,000 gal. will cost on average $2.25 per gallon. Large tanks ranging from sizing above 30,000 will cost on average $1.50 per gallon. This is the price that is associated with the cisterns used on the given project. Each of the 133 ft. cisterns will cost roughly $75,000 and. The total price of the cisterns to be installed for the project will be $375,000.

The other components associated with the system are the prefiltration system, control system, screening, filtration, disinfection and submersible pump. The estimator at Contech gave a lump sum price, which incorporated all these pieces. It was mentioned that the largest pump used within a rainwater harvesting system would be a 10 gmp. pump. This pump and the other components are priced at approximately $23,625.

The next component that needs to be priced is the piping. This includes the piping into and out of the stormwater harvesting system. The piping required will be approximately 243 feet of 8" metal piping and 128 feet of 6" diameter piping. The total cost for metal discharge and supply piping is $54,724.

The installation of the stormwater harvesting system is priced based off four main processes. These include the demolition, excavation, installation, and parking lot construction process. Demolition is priced by the area of asphalt cut and savaged, the concrete cut and savage, the removal of trees, curbs, lamps and other features. The total cost of this is a percentage of from the originally contracted demolition budget. The demolition totaled to approximate $22,237.

The excavation of the area intended to house the stormwater harvesting system is based of cubic yards. Also, stone backfill is to be placed beneath the cisterns for both drainage and to reduce settling. Using the given dimensions of the excavated site the total amount of soil that would need to be removed is 6,164.93 cubic yards. Excavation performed on the project has been budgeted at $29.22. Therefor the total price of excavation is $180,139.25.

It is necessary to lay a layer of gravel backfill before installing the cisterns. Once the cisterns are installed backfill is replaced into the excavated area. The backfill then becomes compacted in preparation for the reconstruction of the parking surface. This totals to a cost of $30,277.

Lastly, the installation of a new parking lot above the stormwater harvesting system will follow. This is the final stage of construction that must be calculated. Using RSMeans Site Work $ Landscape Cost Data a parking lot that had approximately 80 spaces, 4 handicap space, and was able to be lit by parking lot lamps would cost a total of $176,500 to build. This sized parking lot is almost exactly the same size that existed prior to demolition.

The total cost that would be associated with installing a stormwater harvesting system on the Maryland Public Health Laboratories project would be approximately $1.2 million. A cost data break down for the system is provided in **Appendix W**. Cost information has been provided by Contech Engineered Solutions, Turner, and RSMeans Cost Data.

Potential Cost Savings

The main two main reasons for implementing a stormwater harvesting system is two (1) reduce water consumption of the facility and (2) reduce water runoff. The city of Baltimore charges a minimum water rate of $0.0018 per gallon. This value has been provided by The Department of Public Works of Baltimore City. As the Maryland Public Health Laboratories facility requires a substantial amount of water to service their facility, any opportunity to save water would be beneficial.

Also, the rate to discharge water into the maniple sewer has a greater cost. The rate to discharge a gallon of water is approximately $0.0055. The building has an even greater water discharge. There have been systems, such as green roofs, that reduce the water run-off of the building, but other systems, such as stormwater harvesting systems can significantly reduce the buildings water run-off.

The “Rainwater Harvesting Runoff Calculator” provided by Contech gives a good estimate of how much potential savings a building can save with a stormwater harvesting system of certain size cisterns. Using all the design load values provided from HDR and project management teams, the potential cost savings produced from a stormwater system ranges from $455,360-459,335. Over a 21 year span the Maryland Public Health Laboratories could save $9,562,568.

It would take around 2.6 years for the system to pay off its installation cost and 241.8 years to pay for the entire building construction cost. Unfortunately a substantial amount of time must pass before a building payoff would be achieved. The system does save a large sum of money in water consumption and sewage bills and could potentially certify the facility with a LEED Gold certification.

Schedule Impact

The stormwater harvesting system can be view as a side project towards the main building project. There will be no schedule impact as the building schedule doesn't rely on any portion of the construction of the system to be complete by a certain date.

The duration of the system's installation will be approximately a month and a half to install based on industry. This doesn't account for the site demolition, as there is 4 month downtime period between demolition and the excavation of the designated stormwater harvesting area. This is because site work subcontractors will commence the task of excavating this area after the Maryland Public Health Laboratories excavation has been complete. This is scheduled to finish on June 12, 2012.

A breakdown of the duration of all the activities that comprise the stormwater harvesting system is provided blow. These durations were based of Jacobs Engineering baseline schedule. The equipment and manpower used for the demolition and excavation of the building project will also be implemented on the demolition, excavation, and sitework of the stormwater harvesting system. Because the tasks are extremely similar to the tasks of the building project, similar durations from the baseline schedule will be used. Also, the site because excavated and demolitions is roughly a half of the building site, therefor the durations will be halved.

Demolition of the proposed system area will take approximately 4 days, as it took 4 days to demolish the exact surface of the Maryland Public Health Laboratories site with double the equipment. Bulk excavation for the site took 16 days. Using the calculate cubic yards from above in comparison to the building site bulk excavation total of 24092.44 cubic yards, the excavation of the stormwater harvesting system is approximately 25% of the building excavation. Therefor it will take 8 days using half the equipment. Stone backfill can be completed in a single day.

The cisterns, prefiltration units, and ejector pump installation duration have been provided by Contech. Typically performed by the same sitework subcontractors that performed excavation and underground utility installation, these cistern pieces can be installed and fastened 10 per day. These pieces are typically 10-20 ft. in lengths. To meet the design each cistern is designed using 7 pieces, therefor it will take approximately 3.5 days to install all the cisterns. The manifolds used to connect the cisterns take approximately a day each to complete. Contech has stated that the manhole and pump installation typically takes 3-4 days and the prefiltration take a single day.

The installation of the underground stormwater and recirculation pipes are based off the baseline scheduled duration for the building utility lines. The excavation, installation and tie-ins of these pipelines will take approximately 10 days to complete. Backfill of the excavated areas are also is based of Jacobs baseline schedule, which they have scheduled to be 3 days. Because of the significantly smaller area this site can be backfilled in 1.5 days, half the duration of the buildings backfill.

The summations of the durations of each task totals 33 work days to complete the installation of the stormwater harvesting system. This is approximately 6.6 weeks or a little over a month and a half. A break down is provided in the table below of the scheduled durations.

Stormwater Schedul Analysis	
Description	**Duration (days)**
Site Demolitions	4
Excavation	8
Cistern Installation	3.5
Pump Manhole Construction	3-4
Prefilitration Installation	1
Manifold Installation	2
Backfill	1.5
Stormwater/Reusable Water Line Installation	10
Total Stormwater Harvesting Duration	33 days

The system should be installed and backfilled around late-July 2012 and will await tie-ins until mechanical work has begun. Also, the parking lot that is to be constructed on top of the system will wait until site improvement work is conducted. Both these tasks are performed later in the building project schedule, therefore remobilization of site crews will occur at this time. Again because the building isn't affected by the construction of this system, the installation of a stormwater harvesting system won't affect the critical path. The system can be implemented during construction at a variety of times, but seems most logical to begin after excavation and foundation construction of the building, as the sitework subcontractor won't need to remobilize. These workers would continue to proceed with excavation after the building excavation is

Sustainability Analysis

A major goal of project managers and the owner is to achieve the 2 LEED points to allow the Maryland Public Health Laboratories to become LEED Gold certified. Implementing a stormwater harvesting system was a way of possible achieving a portion of the lost 4 points in the Water Efficiency category. The subcategory the project lost 2 points in was Innovative Wastewater Technologies. LEED has expressed two options for achieving these points. (1) Reduce potable water use for sewage 50% and (2) treat 50% of wastewater onsite to tertiary standards and infiltration or reuse treated water. To achieve the point for the first option approximately 84% of the calculated supplied water from the building must be used to supply the toilet fixtures and urinals throughout the building. The problem that occurs is

Figure 47: LEED Logo (image provided by abelconstruction.com)

that the demand of these fixtures is so low in comparison to others systems in building. If water resides in the tank for too long (2-3 day) it must be sent to the sewage line. A lot of reusable water would be wasted because of this.

The second option is infeasible from the start. The laboratory produces significant amounts of waste water that can't be treated onsite or reused because of pollutants and chemicals in the source. This has been regulated by code, which makes this point virtually impossible to achieve given the facility type of the Maryland Public Health Laboratories.

The remaining two points that could be achieved are the in the Water Use Reduction subcategory. To achieve both points the facility must reduce the water consumed by 40%. With the current design of the building 31% water has been reduced, providing the project with 2 LEED Points. There will need to be a reduction of at least 19% to reach LEED Gold certification. Implementing the stormwater harvesting system only will allow a total of 2.23% of water consumed by the building to be reduced. The demand for water of a facility of this nature is so great in magnitude that simply taking sink, faucet, and shower water and combining it with both condensation from HVAC equipment and stormwater won't come close to being able to meet the requirements.

Unfortunately after the sustainability analysis it has been determined that if the Maryland Public Health Laboratories project is to earn a LEED Gold certification it must do so in other ways than designing systems to be more water efficient. The water demand load is too great in this type of facility to be able to greatly benefit from a water reduction system.

Feasibility Analysis

The practice of becoming more sustainable and energy efficient being strongly encouraged in today's building industry. A great way to do so is by reducing the amount of water that a building consumes. Certain systems, such as storm water harvesting systems, provide the opportunity to capture and retain supply water from rain, grey water, and HVAC condensation and reuse this water within the facility.

After several analyses it was determined if such a system was used with the Maryland Public Health Laboratories project about $455,360 would be saved in water bills. This is a fair amount of money saved by the owner, but is very small compared to the amount of money spend on the water needed to supply the building. Even so this is a cost savings. It would take $1.2 million to construct the system, which would mean the system would pay for itself after operating for 2.6 years. The time it would take to pay off for the entire building construction is irrelevant because these systems typically last for only 30 years.

There is no impact on the project schedule by the installation of the system as this system is separately installed from the building. There are no tasks that are fixated on the critical path. Hypothetically the system installation could take the entirety of the project without needing affecting the project schedule.

Unfortunately this system wasn't able to achieve any of the 4 lost LEED points in the Water Efficiency category. The facility is entirely too large and demand such a great load of water that implementing a stormwater harvesting system of the designed size would only reduce consumption by 2.23%, which is very minimal.

The idea of a stormwater harvesting system is great and it promotes the idea of sustainability. Unfortunately there aren't many substantial benefits to the building when the system is implemented.

Conclusion

In conclusion the research performed in this analysis it has been determined that this system is neither feasible nor unfeasible, especially regarding short term benefits. The idea of implementing a stormwater harvesting system is a great idea that expresses sustainability and innovation, a goal of building designers and the owner. Unfortunately the system doesn't have a great beneficial impact on water reduction and cost savings. There is a costs saving associated with the design. The owners of the Maryland Public Health Laboratories will be able to save approximately $455,360 annually if this system were to be implemented.

Overall, the application of this system should be decided by the owner. There aren't any major benefits or drawbacks to the system. The system does bring about additional sustainability feature to the building, but doesn't produce the necessary the water reduction savings and cost savings to earn the points to achieve LEED Gold Standard.

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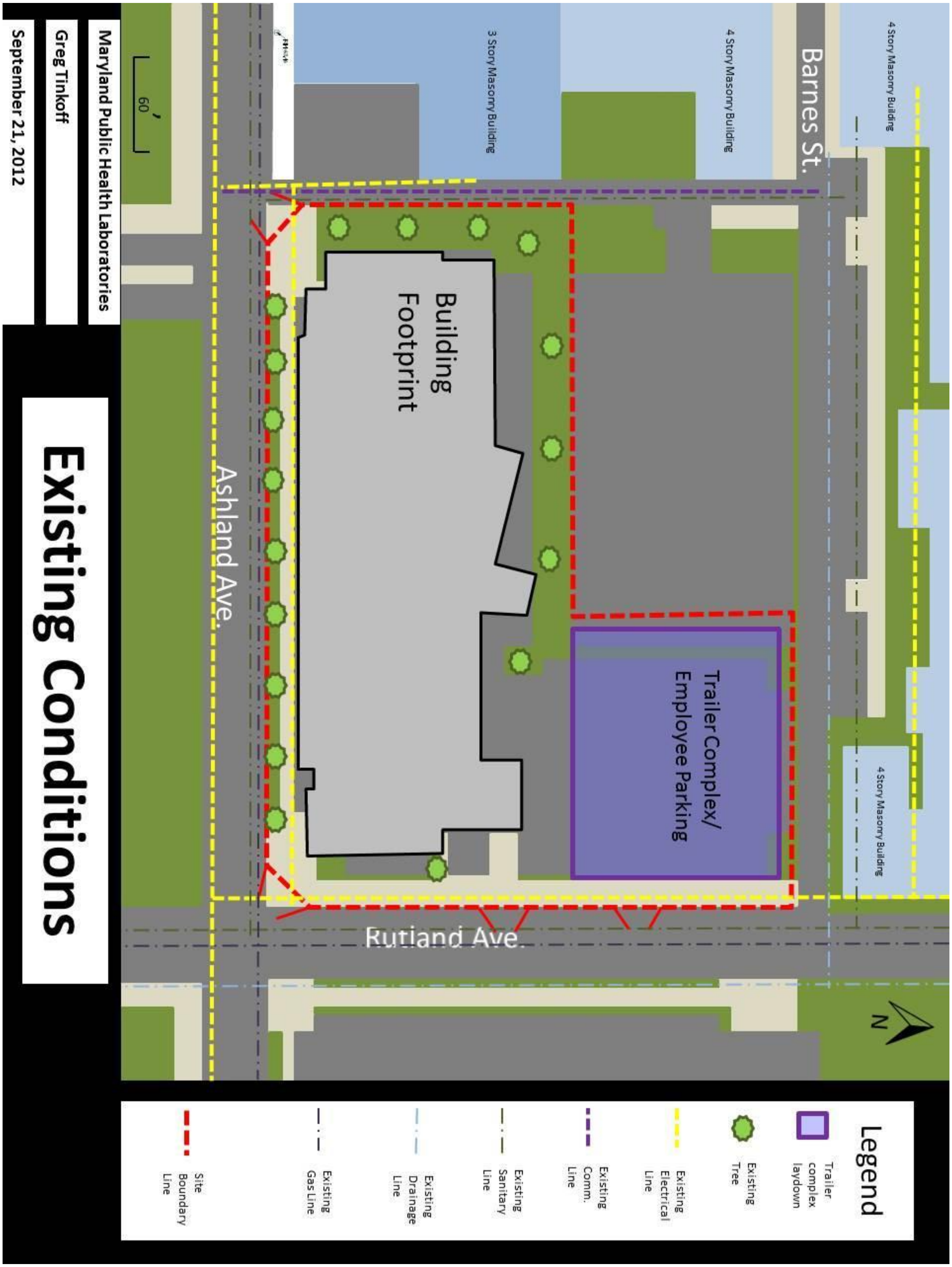
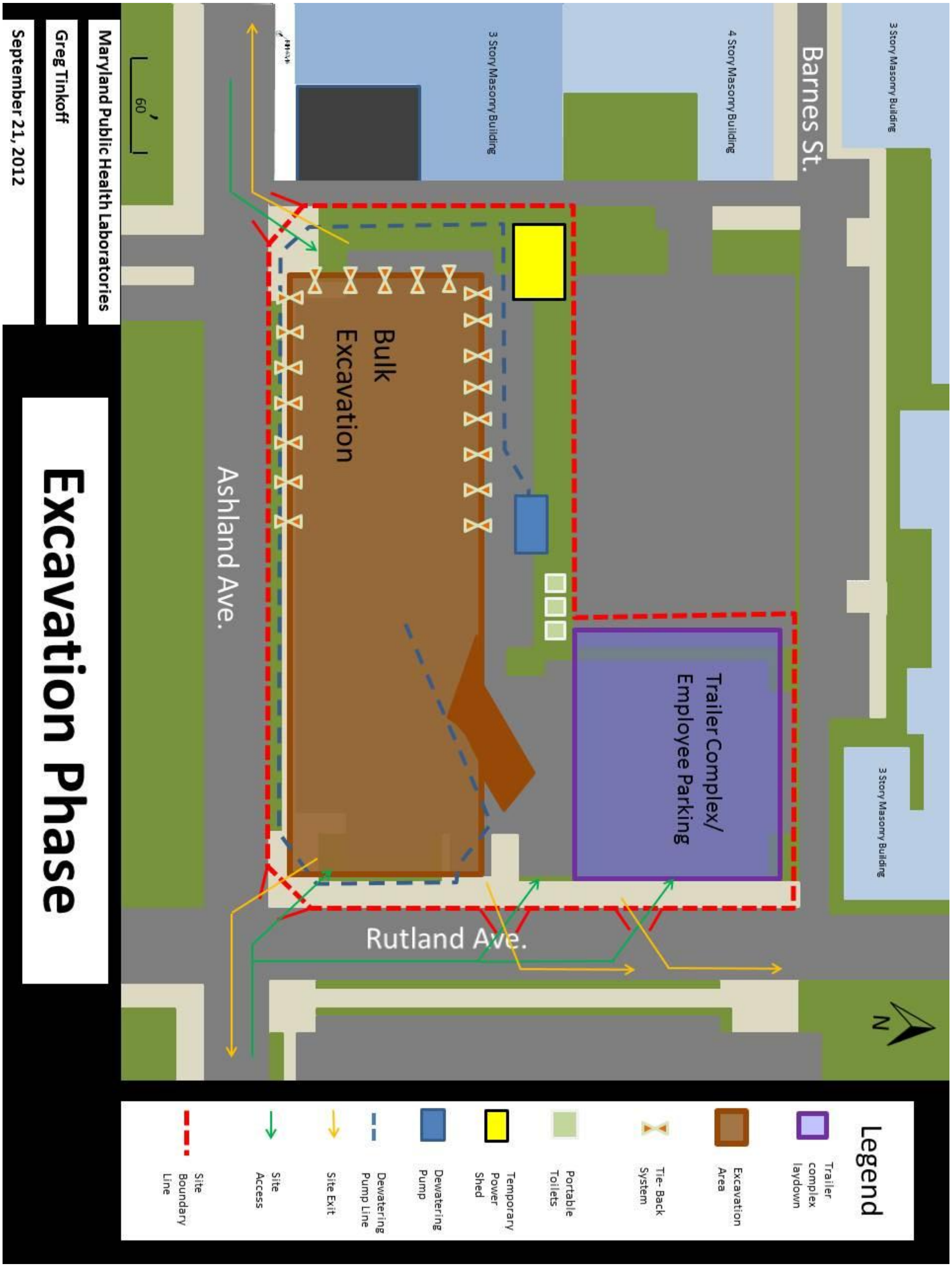
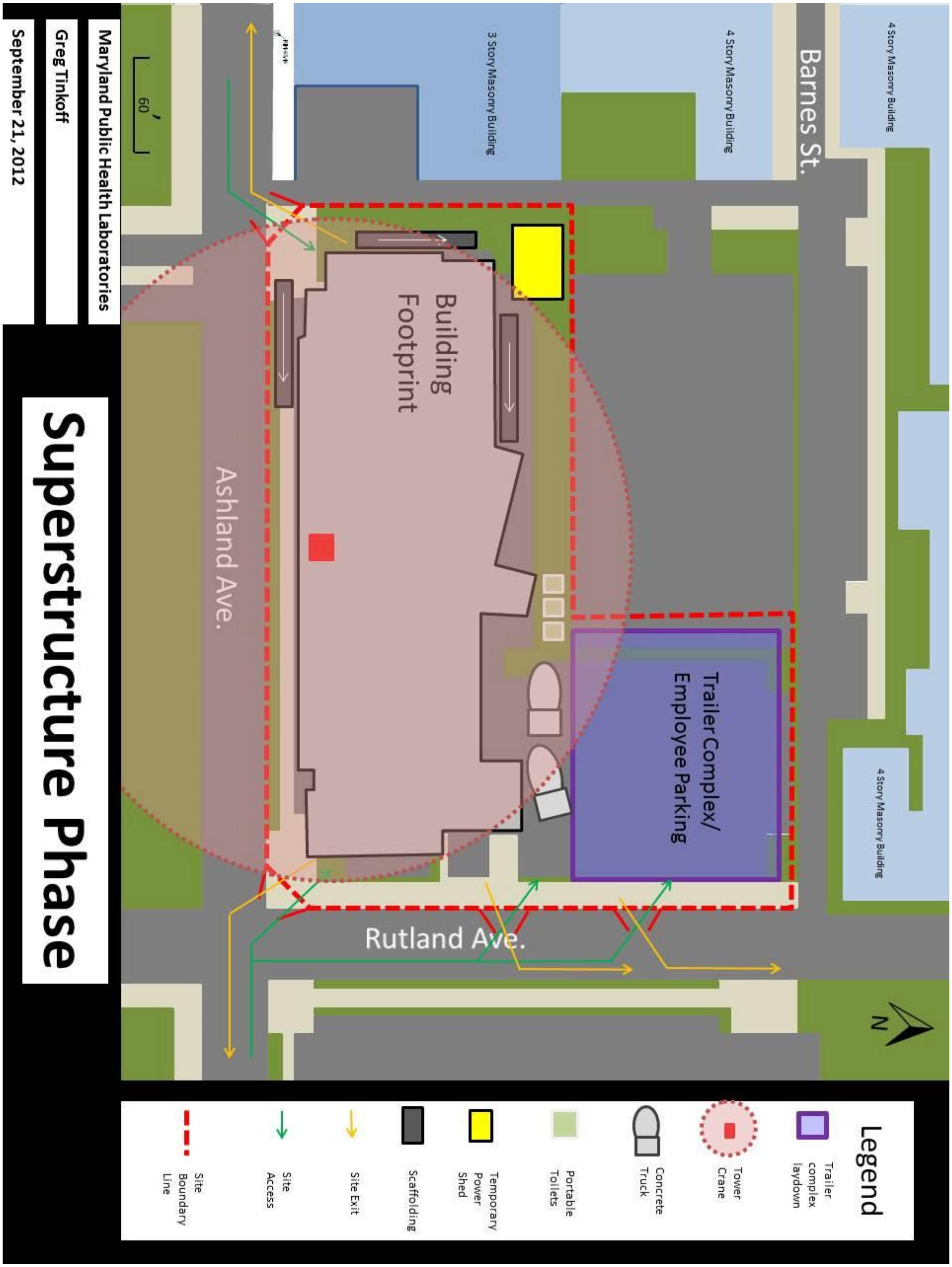
Appendix A: Existing Site Conditions


Existing Conditions
Maryland Public Health Laboratories
Greg Tinkoff
September 21, 2012
60'
Ashland Ave.
Rutland Ave.
Barnes St.
Building Footprint
Trailer Complex/ Employee Parking
3 Story Masonry Building
4 Story Masonry Building
4 Story Masonry Building
4 Story Masonry Building
N
Legend
Trailer complex laydown
Existing Tree
Existing Electrical Line
Existing Comm. Line
Existing Sanitary Line
Existing Drainage Line
Existing Gas Line
Site Boundary Line

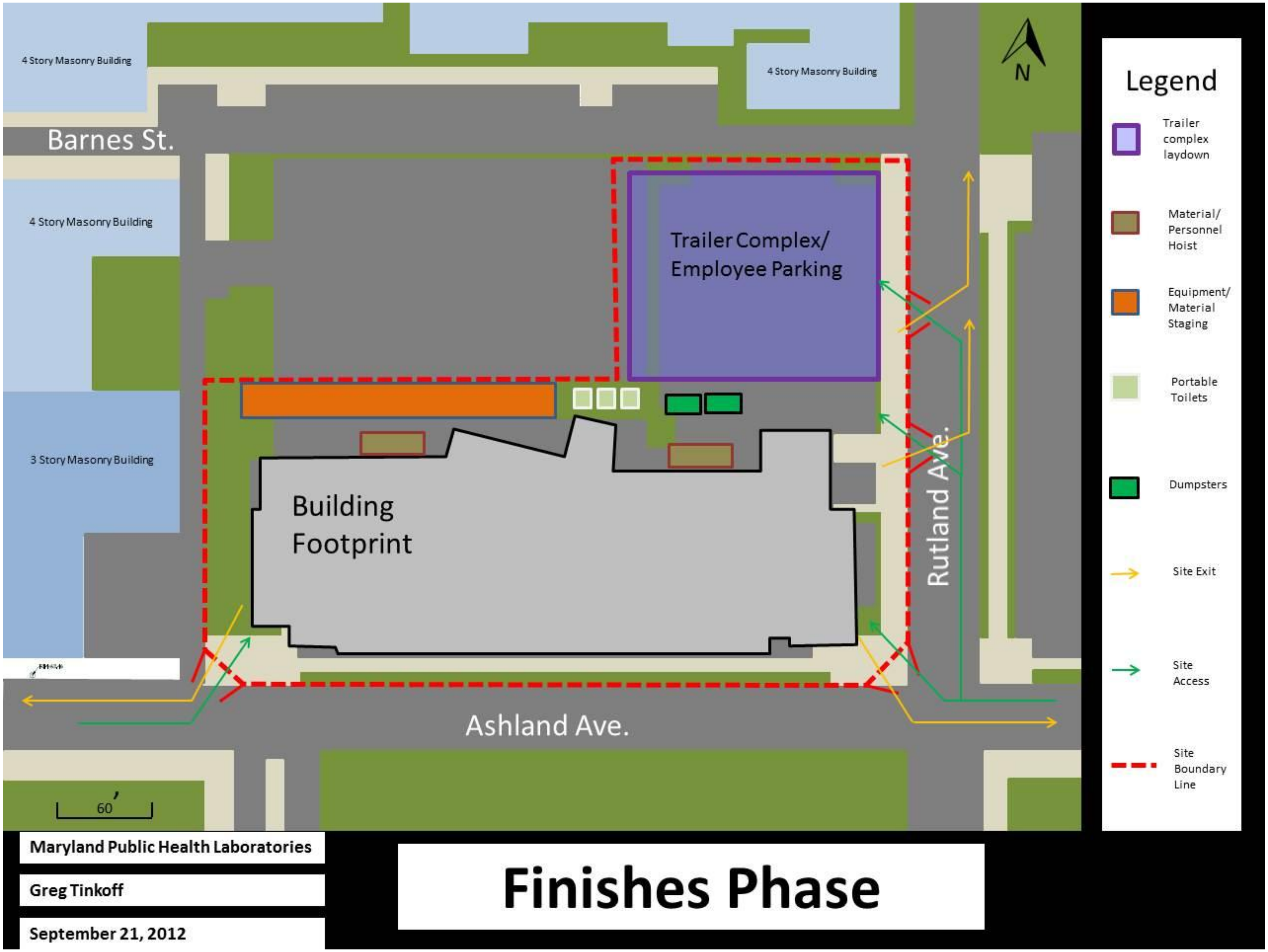
Appendix B: Excavation Phase Site Logistical Plan


Excavation Phase
Maryland Public Health Laboratories
Greg Tinkoff
September 21, 2012
60'
3 Story Masonry Building
4 Story Masonry Building
Barnes St.
3 Story Masonry Building
Bulk Excavation
Ashland Ave.
Trailer Complex/ Employee Parking
3 Story Masonry Building
Rutland Ave.
N
Legend
Trailer complex laydown
Excavation Area
Tie- Back System
Portable Toilets
Temporary Power Shed
Dewatering Pump
Dewatering Pump Line
Site Exit
Site Access
Site Boundary Line

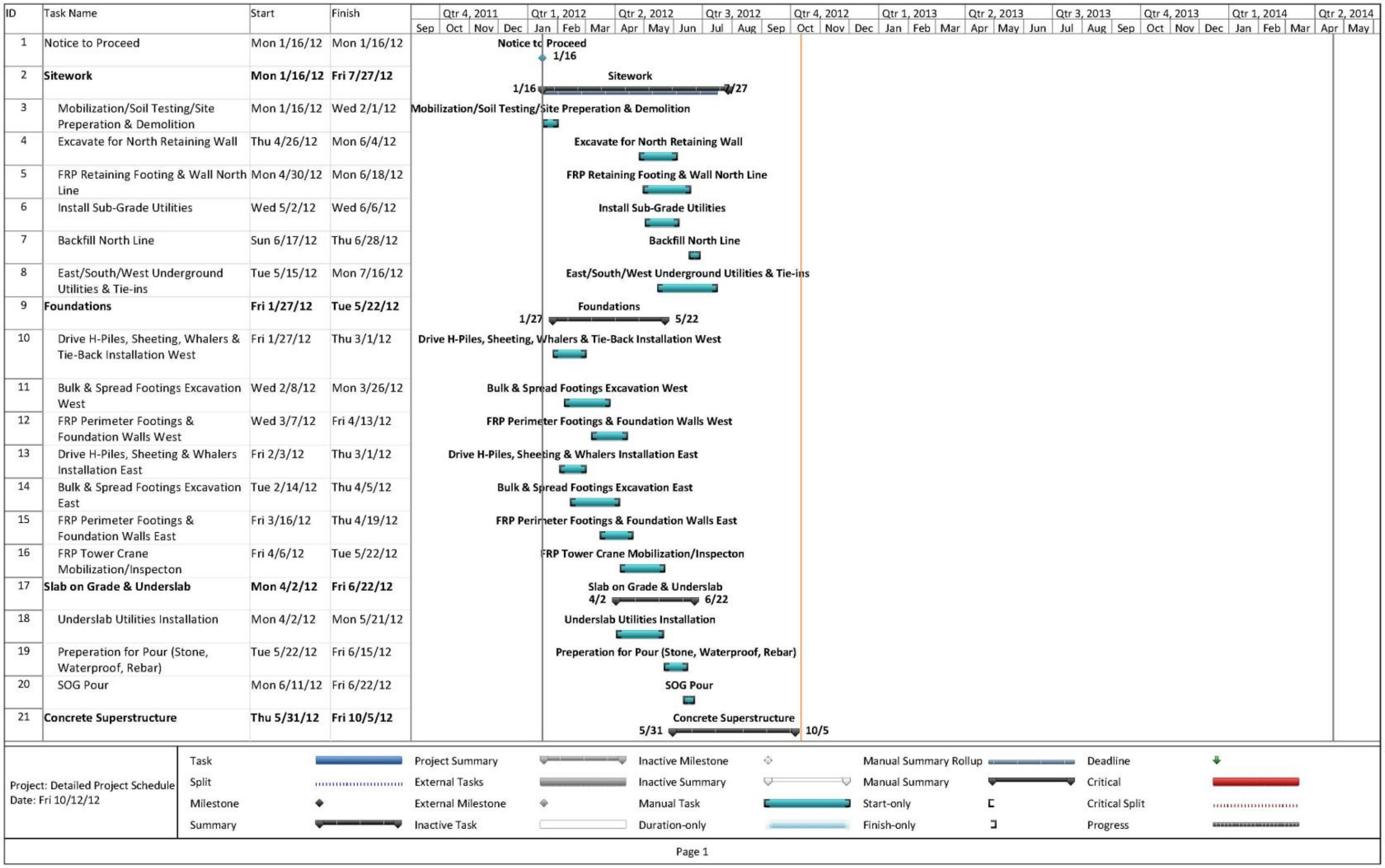
Appendix C: Superstructure Phase Site Logistical Plan


Superstructure Phase
Maryland Public Health Laboratories
Greg Tinkoff
September 21, 2012
60'
Building Footprint
Ashland Ave.
Rutland Ave.
Barnes St.
Trailer Complex/ Employee Parking
3 Story Masonry Building
4 Story Masonry Building
4 Story Masonry Building
4 Story Masonry Building
N
Legend
Trailer complex laydown
Tower Crane
Concrete Truck
Portable Toilets
Temporary Power Shed
Scaffolding
Site Exit
Site Access
Site Boundary Line

Appendix D: Finishes Phase Site Logistical Plan


4 Story Masonry Building
4 Story Masonry Building
Barnes St.
4 Story Masonry Building
3 Story Masonry Building
Trailer Complex/ Employee Parking
Building Footprint
Rutland Ave.
Ashland Ave.
N
60'
Legend
Trailer complex laydown
Material/ Personnel Hoist
Equipment/ Material Staging
Portable Toilets
Dumpsters
Site Exit
Site Access
Site Boundary Line
Maryland Public Health Laboratories
Greg Tinkoff
September 21, 2012
Finishes Phase

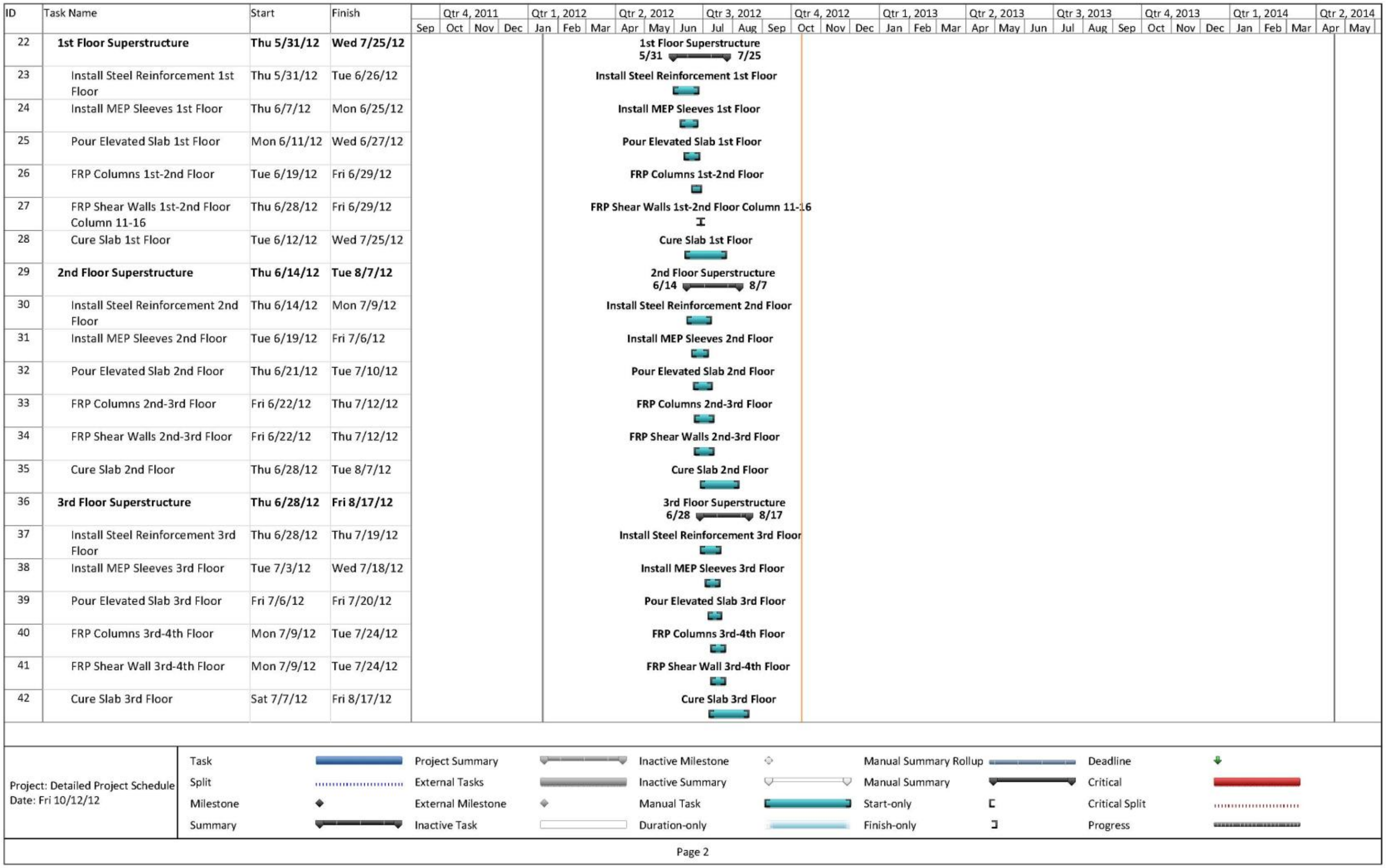
Appendix E: Detailed Schedule



ID	Task Name	Start	Finish
1	Notice to Proceed	Mon 1/16/12	Mon 1/16/12
2	**Sitework**	**Mon 1/16/12**	**Fri 7/27/12**
3	Mobilization/Soil Testing/Site Preperation & Demolition	Mon 1/16/12	Wed 2/1/12
4	Excavate for North Retaining Wall	Thu 4/26/12	Mon 6/4/12
5	FRP Retaining Footing & Wall North Line	Mon 4/30/12	Mon 6/18/12
6	Install Sub-Grade Utilities	Wed 5/2/12	Wed 6/6/12
7	Backfill North Line	Sun 6/17/12	Thu 6/28/12
8	East/South/West Underground Utilities & Tie-ins	Tue 5/15/12	Mon 7/16/12
9	**Foundations**	**Fri 1/27/12**	**Tue 5/22/12**
10	Drive H-Piles, Sheeting, Whalers & Tie-Back Installation West	Fri 1/27/12	Thu 3/1/12
11	Bulk & Spread Footings Excavation West	Wed 2/8/12	Mon 3/26/12
12	FRP Perimeter Footings & Foundation Walls West	Wed 3/7/12	Fri 4/13/12
13	Drive H-Piles, Sheeting & Whalers Installation East	Fri 2/3/12	Thu 3/1/12
14	Bulk & Spread Footings Excavation East	Tue 2/14/12	Thu 4/5/12
15	FRP Perimeter Footings & Foundation Walls East	Fri 3/16/12	Thu 4/19/12
16	FRP Tower Crane Mobilization/Inspecton	Fri 4/6/12	Tue 5/22/12
17	**Slab on Grade & Underslab**	**Mon 4/2/12**	**Fri 6/22/12**
18	Underslab Utilities Installation	Mon 4/2/12	Mon 5/21/12
19	Preperation for Pour (Stone, Waterproof, Rebar)	Tue 5/22/12	Fri 6/15/12
20	SOG Pour	Mon 6/11/12	Fri 6/22/12
21	**Concrete Superstructure**	**Thu 5/31/12**	**Fri 10/5/12**

Project: Detailed Project Schedule
Date: Fri 10/12/12

Page 1



ID	Task Name	Start	Finish
22	**1st Floor Superstructure**	**Thu 5/31/12**	**Wed 7/25/12**
23	Install Steel Reinforcement 1st Floor	Thu 5/31/12	Tue 6/26/12
24	Install MEP Sleeves 1st Floor	Thu 6/7/12	Mon 6/25/12
25	Pour Elevated Slab 1st Floor	Mon 6/11/12	Wed 6/27/12
26	FRP Columns 1st-2nd Floor	Tue 6/19/12	Fri 6/29/12
27	FRP Shear Walls 1st-2nd Floor Column 11-16	Thu 6/28/12	Fri 6/29/12
28	Cure Slab 1st Floor	Tue 6/12/12	Wed 7/25/12
29	**2nd Floor Superstructure**	**Thu 6/14/12**	**Tue 8/7/12**
30	Install Steel Reinforcement 2nd Floor	Thu 6/14/12	Mon 7/9/12
31	Install MEP Sleeves 2nd Floor	Tue 6/19/12	Fri 7/6/12
32	Pour Elevated Slab 2nd Floor	Thu 6/21/12	Tue 7/10/12
33	FRP Columns 2nd-3rd Floor	Fri 6/22/12	Thu 7/12/12
34	FRP Shear Walls 2nd-3rd Floor	Fri 6/22/12	Thu 7/12/12
35	Cure Slab 2nd Floor	Thu 6/28/12	Tue 8/7/12
36	**3rd Floor Superstructure**	**Thu 6/28/12**	**Fri 8/17/12**
37	Install Steel Reinforcement 3rd Floor	Thu 6/28/12	Thu 7/19/12
38	Install MEP Sleeves 3rd Floor	Tue 7/3/12	Wed 7/18/12
39	Pour Elevated Slab 3rd Floor	Fri 7/6/12	Fri 7/20/12
40	FRP Columns 3rd-4th Floor	Mon 7/9/12	Tue 7/24/12
41	FRP Shear Wall 3rd-4th Floor	Mon 7/9/12	Tue 7/24/12
42	Cure Slab 3rd Floor	Sat 7/7/12	Fri 8/17/12

Project: Detailed Project Schedule
Date: Fri 10/12/12

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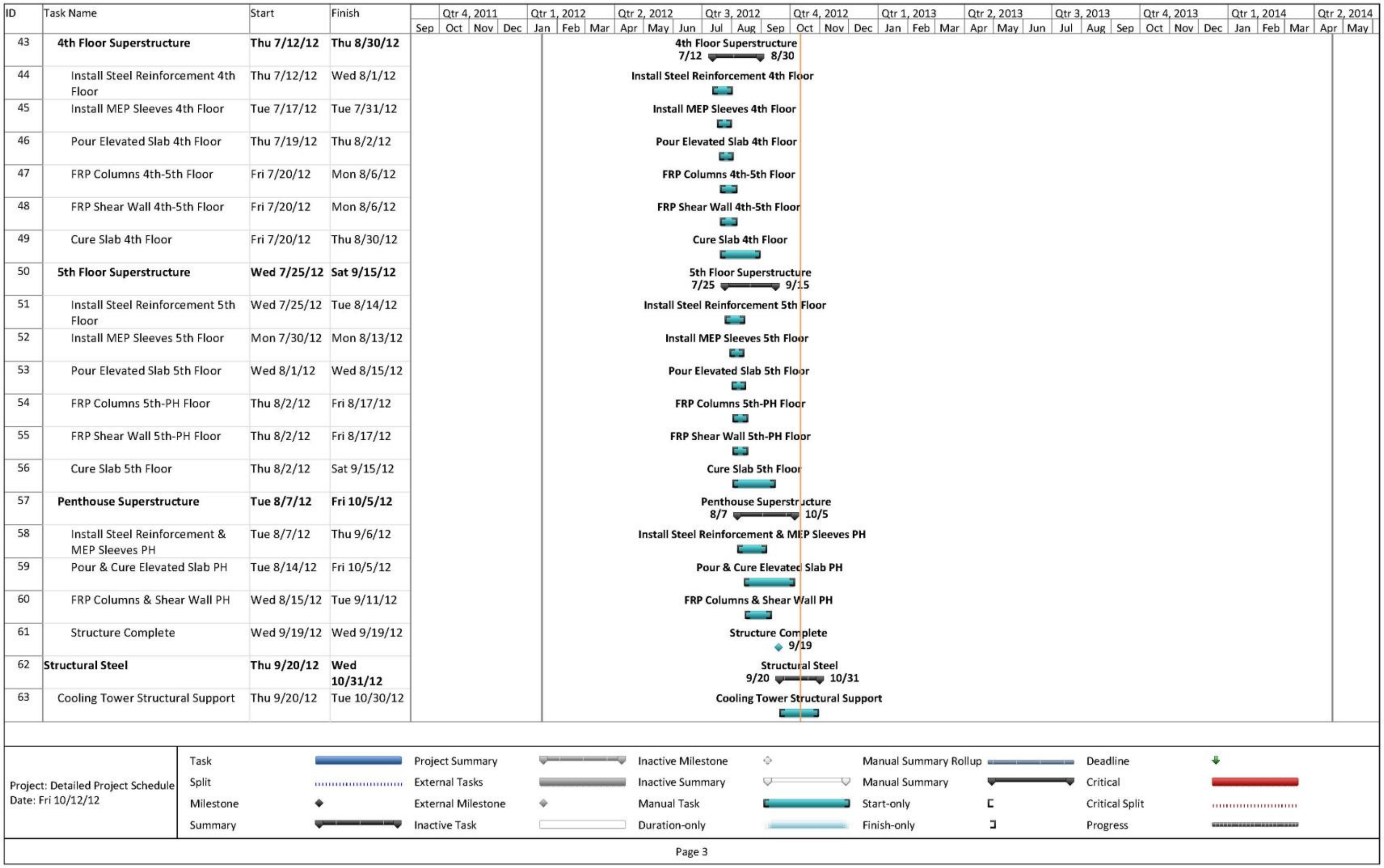

ID	Task Name	Start	Finish
43	**4th Floor Superstructure**	**Thu 7/12/12**	**Thu 8/30/12**
44	Install Steel Reinforcement 4th Floor	Thu 7/12/12	Wed 8/1/12
45	Install MEP Sleeves 4th Floor	Tue 7/17/12	Tue 7/31/12
46	Pour Elevated Slab 4th Floor	Thu 7/19/12	Thu 8/2/12
47	FRP Columns 4th-5th Floor	Fri 7/20/12	Mon 8/6/12
48	FRP Shear Wall 4th-5th Floor	Fri 7/20/12	Mon 8/6/12
49	Cure Slab 4th Floor	Fri 7/20/12	Thu 8/30/12
50	**5th Floor Superstructure**	**Wed 7/25/12**	**Sat 9/15/12**
51	Install Steel Reinforcement 5th Floor	Wed 7/25/12	Tue 8/14/12
52	Install MEP Sleeves 5th Floor	Mon 7/30/12	Mon 8/13/12
53	Pour Elevated Slab 5th Floor	Wed 8/1/12	Wed 8/15/12
54	FRP Columns 5th-PH Floor	Thu 8/2/12	Fri 8/17/12
55	FRP Shear Wall 5th-PH Floor	Thu 8/2/12	Fri 8/17/12
56	Cure Slab 5th Floor	Thu 8/2/12	Sat 9/15/12
57	**Penthouse Superstructure**	**Tue 8/7/12**	**Fri 10/5/12**
58	Install Steel Reinforcement & MEP Sleeves PH	Tue 8/7/12	Thu 9/6/12
59	Pour & Cure Elevated Slab PH	Tue 8/14/12	Fri 10/5/12
60	FRP Columns & Shear Wall PH	Wed 8/15/12	Tue 9/11/12
61	Structure Complete	Wed 9/19/12	Wed 9/19/12
62	**Structural Steel**	**Thu 9/20/12**	**Wed 10/31/12**
63	Cooling Tower Structural Support	Thu 9/20/12	Tue 10/30/12

Project: Detailed Project Schedule
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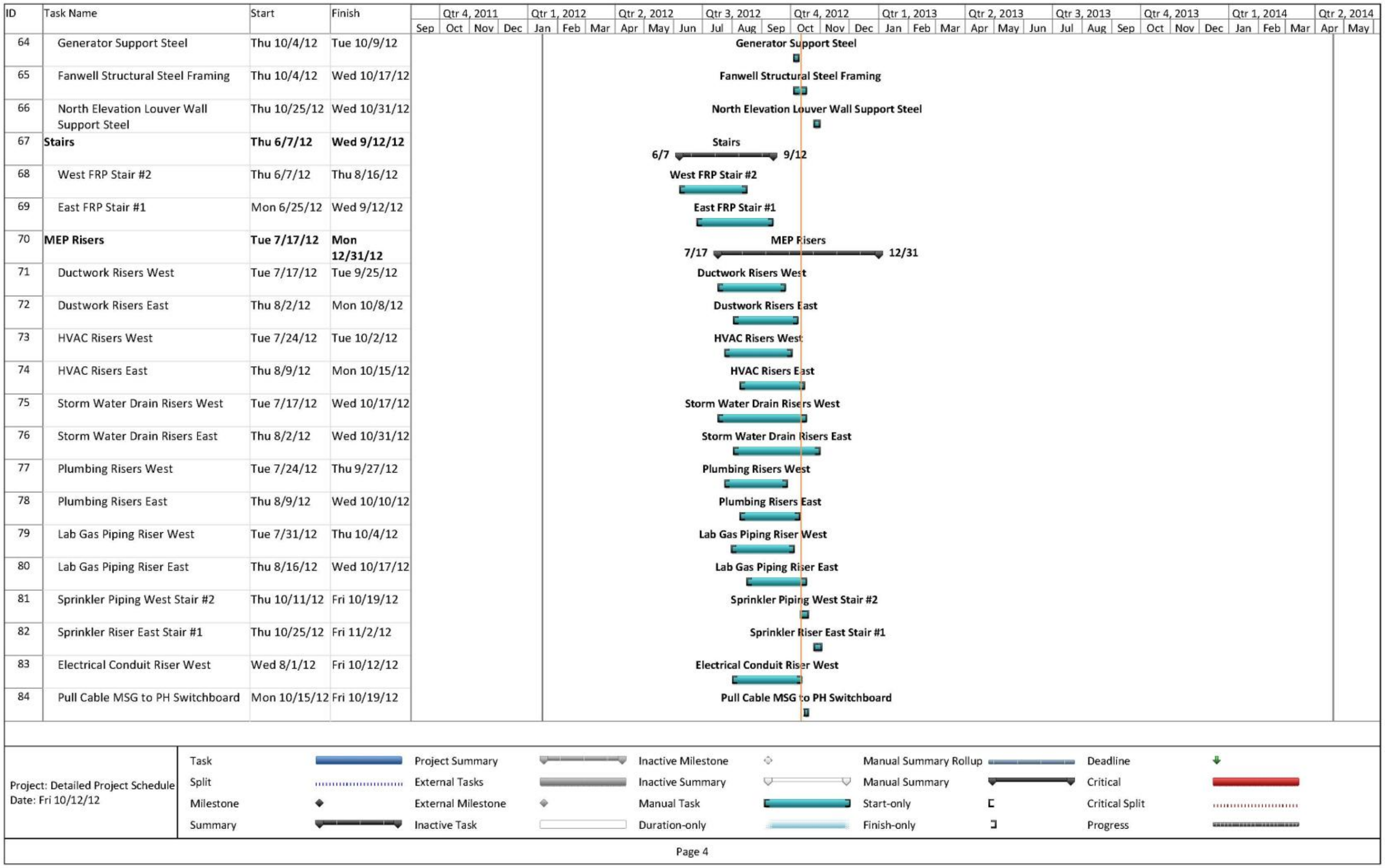

ID	Task Name	Start	Finish
64	Generator Support Steel	Thu 10/4/12	Tue 10/9/12
65	Fanwell Structural Steel Framing	Thu 10/4/12	Wed 10/17/12
66	North Elevation Louver Wall Support Steel	Thu 10/25/12	Wed 10/31/12
67	**Stairs**	**Thu 6/7/12**	**Wed 9/12/12**
68	West FRP Stair #2	Thu 6/7/12	Thu 8/16/12
69	East FRP Stair #1	Mon 6/25/12	Wed 9/12/12
70	**MEP Risers**	**Tue 7/17/12**	**Mon 12/31/12**
71	Ductwork Risers West	Tue 7/17/12	Tue 9/25/12
72	Dustwork Risers East	Thu 8/2/12	Mon 10/8/12
73	HVAC Risers West	Tue 7/24/12	Tue 10/2/12
74	HVAC Risers East	Thu 8/9/12	Mon 10/15/12
75	Storm Water Drain Risers West	Tue 7/17/12	Wed 10/17/12
76	Storm Water Drain Risers East	Thu 8/2/12	Wed 10/31/12
77	Plumbing Risers West	Tue 7/24/12	Thu 9/27/12
78	Plumbing Risers East	Thu 8/9/12	Wed 10/10/12
79	Lab Gas Piping Riser West	Tue 7/31/12	Thu 10/4/12
80	Lab Gas Piping Riser East	Thu 8/16/12	Wed 10/17/12
81	Sprinkler Piping West Stair #2	Thu 10/11/12	Fri 10/19/12
82	Sprinkler Riser East Stair #1	Thu 10/25/12	Fri 11/2/12
83	Electrical Conduit Riser West	Wed 8/1/12	Fri 10/12/12
84	Pull Cable MSG to PH Switchboard	Mon 10/15/12	Fri 10/19/12

Project: Detailed Project Schedule
Date: Fri 10/12/12

Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Critical, Critical Split, Progress

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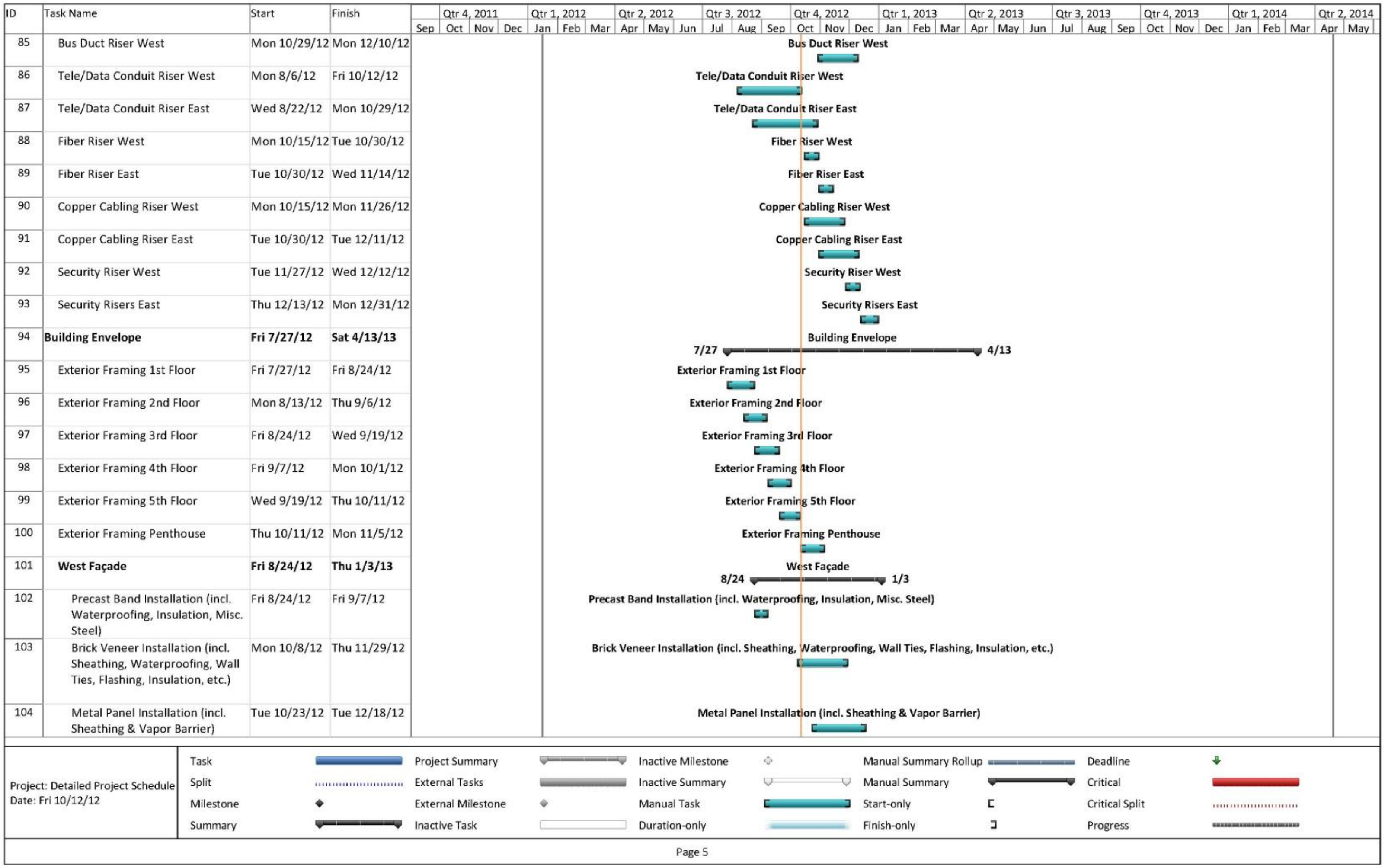

ID	Task Name	Start	Finish
85	Bus Duct Riser West	Mon 10/29/12	Mon 12/10/12
86	Tele/Data Conduit Riser West	Mon 8/6/12	Fri 10/12/12
87	Tele/Data Conduit Riser East	Wed 8/22/12	Mon 10/29/12
88	Fiber Riser West	Mon 10/15/12	Tue 10/30/12
89	Fiber Riser East	Tue 10/30/12	Wed 11/14/12
90	Copper Cabling Riser West	Mon 10/15/12	Mon 11/26/12
91	Copper Cabling Riser East	Tue 10/30/12	Tue 12/11/12
92	Security Riser West	Tue 11/27/12	Wed 12/12/12
93	Security Risers East	Thu 12/13/12	Mon 12/31/12
94	**Building Envelope**	**Fri 7/27/12**	**Sat 4/13/13**
95	Exterior Framing 1st Floor	Fri 7/27/12	Fri 8/24/12
96	Exterior Framing 2nd Floor	Mon 8/13/12	Thu 9/6/12
97	Exterior Framing 3rd Floor	Fri 8/24/12	Wed 9/19/12
98	Exterior Framing 4th Floor	Fri 9/7/12	Mon 10/1/12
99	Exterior Framing 5th Floor	Wed 9/19/12	Thu 10/11/12
100	Exterior Framing Penthouse	Thu 10/11/12	Mon 11/5/12
101	**West Façade**	**Fri 8/24/12**	**Thu 1/3/13**
102	Precast Band Installation (incl. Waterproofing, Insulation, Misc. Steel)	Fri 8/24/12	Fri 9/7/12
103	Brick Veneer Installation (incl. Sheathing, Waterproofing, Wall Ties, Flashing, Insulation, etc.)	Mon 10/8/12	Thu 11/29/12
104	Metal Panel Installation (incl. Sheathing & Vapor Barrier)	Tue 10/23/12	Tue 12/18/12

Project: Detailed Project Schedule
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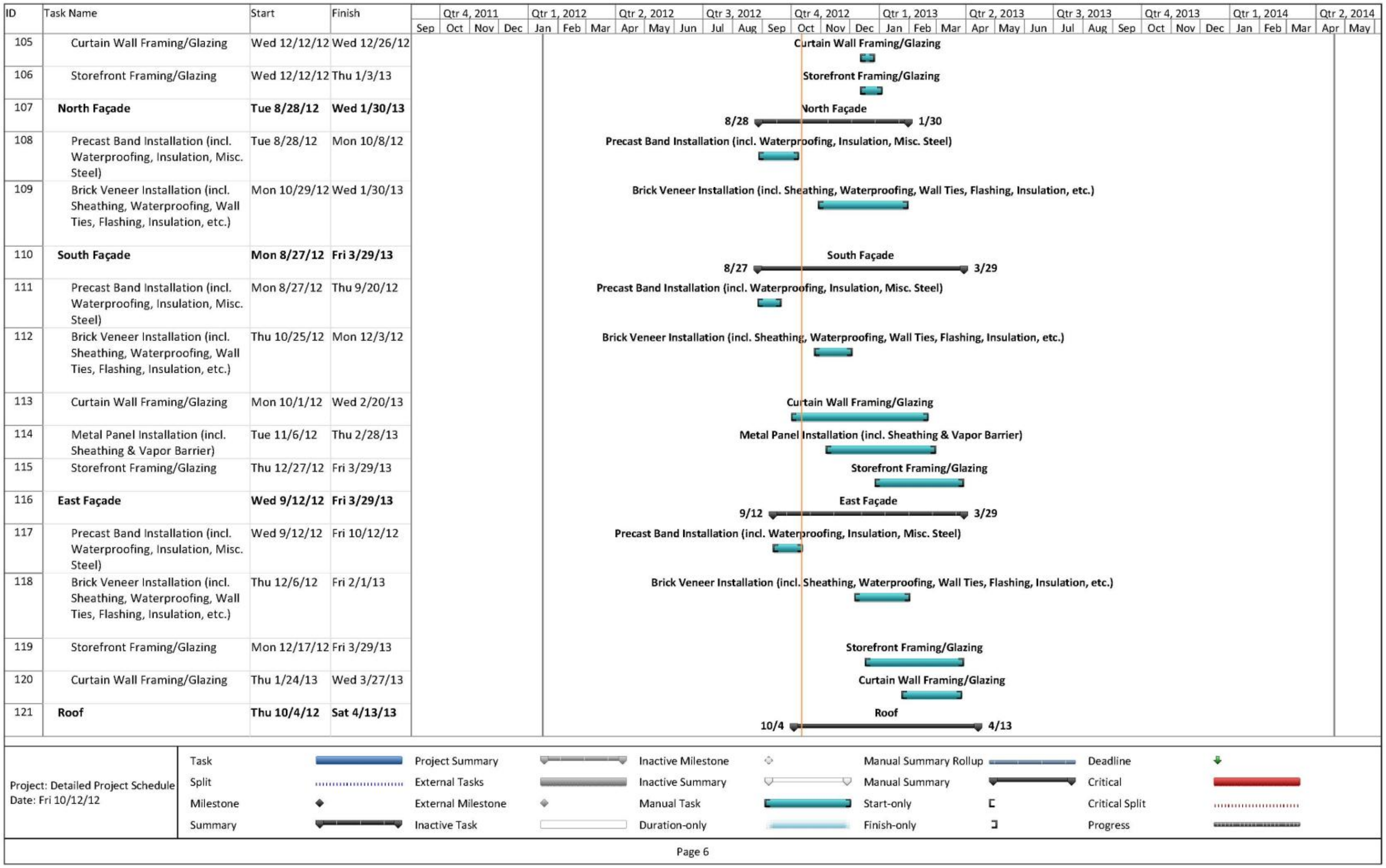

ID	Task Name	Start	Finish
105	Curtain Wall Framing/Glazing	Wed 12/12/12	Wed 12/26/12
106	Storefront Framing/Glazing	Wed 12/12/12	Thu 1/3/13
107	**North Façade**	**Tue 8/28/12**	**Wed 1/30/13**
108	Precast Band Installation (incl. Waterproofing, Insulation, Misc. Steel)	Tue 8/28/12	Mon 10/8/12
109	Brick Veneer Installation (incl. Sheathing, Waterproofing, Wall Ties, Flashing, Insulation, etc.)	Mon 10/29/12	Wed 1/30/13
110	**South Façade**	**Mon 8/27/12**	**Fri 3/29/13**
111	Precast Band Installation (incl. Waterproofing, Insulation, Misc. Steel)	Mon 8/27/12	Thu 9/20/12
112	Brick Veneer Installation (incl. Sheathing, Waterproofing, Wall Ties, Flashing, Insulation, etc.)	Thu 10/25/12	Mon 12/3/12
113	Curtain Wall Framing/Glazing	Mon 10/1/12	Wed 2/20/13
114	Metal Panel Installation (incl. Sheathing & Vapor Barrier)	Tue 11/6/12	Thu 2/28/13
115	Storefront Framing/Glazing	Thu 12/27/12	Fri 3/29/13
116	**East Façade**	**Wed 9/12/12**	**Fri 3/29/13**
117	Precast Band Installation (incl. Waterproofing, Insulation, Misc. Steel)	Wed 9/12/12	Fri 10/12/12
118	Brick Veneer Installation (incl. Sheathing, Waterproofing, Wall Ties, Flashing, Insulation, etc.)	Thu 12/6/12	Fri 2/1/13
119	Storefront Framing/Glazing	Mon 12/17/12	Fri 3/29/13
120	Curtain Wall Framing/Glazing	Thu 1/24/13	Wed 3/27/13
121	**Roof**	**Thu 10/4/12**	**Sat 4/13/13**

Project: Detailed Project Schedule
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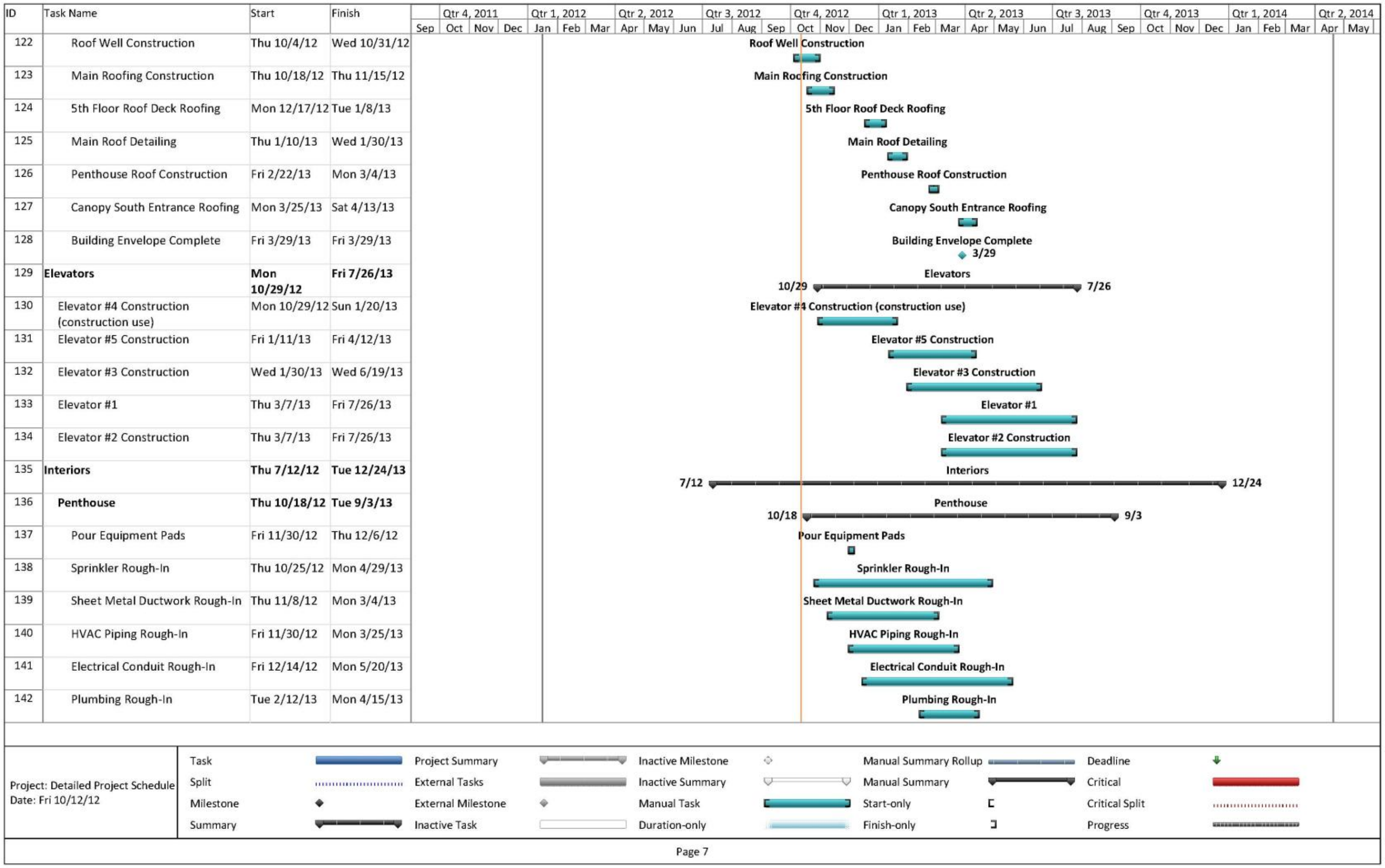

ID	Task Name	Start	Finish
122	Roof Well Construction	Thu 10/4/12	Wed 10/31/12
123	Main Roofing Construction	Thu 10/18/12	Thu 11/15/12
124	5th Floor Roof Deck Roofing	Mon 12/17/12	Tue 1/8/13
125	Main Roof Detailing	Thu 1/10/13	Wed 1/30/13
126	Penthouse Roof Construction	Fri 2/22/13	Mon 3/4/13
127	Canopy South Entrance Roofing	Mon 3/25/13	Sat 4/13/13
128	Building Envelope Complete	Fri 3/29/13	Fri 3/29/13
129	**Elevators**	**Mon 10/29/12**	**Fri 7/26/13**
130	Elevator #4 Construction (construction use)	Mon 10/29/12	Sun 1/20/13
131	Elevator #5 Construction	Fri 1/11/13	Fri 4/12/13
132	Elevator #3 Construction	Wed 1/30/13	Wed 6/19/13
133	Elevator #1	Thu 3/7/13	Fri 7/26/13
134	Elevator #2 Construction	Thu 3/7/13	Fri 7/26/13
135	**Interiors**	**Thu 7/12/12**	**Tue 12/24/13**
136	**Penthouse**	**Thu 10/18/12**	**Tue 9/3/13**
137	Pour Equipment Pads	Fri 11/30/12	Thu 12/6/12
138	Sprinkler Rough-In	Thu 10/25/12	Mon 4/29/13
139	Sheet Metal Ductwork Rough-In	Thu 11/8/12	Mon 3/4/13
140	HVAC Piping Rough-In	Fri 11/30/12	Mon 3/25/13
141	Electrical Conduit Rough-In	Fri 12/14/12	Mon 5/20/13
142	Plumbing Rough-In	Tue 2/12/13	Mon 4/15/13

ID	Task Name	Start	Finish
143	Natural Gas/Fuel Oil Piping Rough-In	Tue 2/12/13	Mon 3/25/13
144	MEP Trimout	Fri 5/10/13	Mon 8/5/13
145	Interior Construction and Finishes (Partition Walls, Flooring, Casework, Paint, etc.)	Thu 3/21/13	Tue 9/3/13
146	Cooling Tower Installation	Thu 10/18/12	Tue 4/23/13
147	Exhaust Fans Installation	Wed 11/7/12	Mon 3/18/13
148	Boilers B1-3 Installation	Fri 12/7/12	Mon 2/4/13
149	Hot Water Boilers HB1-4 Installation	Fri 12/14/12	Thu 1/31/13
150	Deaerator & Blow Down Tank Installation	Mon 12/17/12	Wed 2/13/13
151	AHU 1-5 Installation	Mon 12/31/12	Fri 3/8/13
152	Chiller 1-3 Installation	Tue 1/8/13	Mon 4/8/13
153	Chilled Water Pumps 1-4 Installation	Fri 1/11/13	Mon 3/25/13
154	Chilled Hot Water Exchanger Installation	Mon 1/14/13	Mon 4/1/13
155	Condenser Water Pump/Filter Installation	Mon 1/14/13	Wed 4/17/13
156	Switchboards/ATS DSHP, DMHP, SHP-1 Installation	Tue 3/5/13	Mon 4/15/13
157	Energize Normal Power	Mon 4/15/13	Mon 4/15/13
158	Switchgear Installation	Tue 3/5/13	Mon 5/20/13
159	ATS DEHP & DLHP Installation	Wed 3/6/13	Tue 5/28/13
160	Backboxes/VFD's/UPS Installation	Tue 3/12/13	Tue 6/18/13
161	Generator 1-2 Installation	Thu 11/1/12	Fri 6/28/13
162	Hot Water Pumps 1-8 Installation	Tue 12/18/12	Thu 2/14/13

Project: Detailed Project Schedule
Date: Fri 10/12/12

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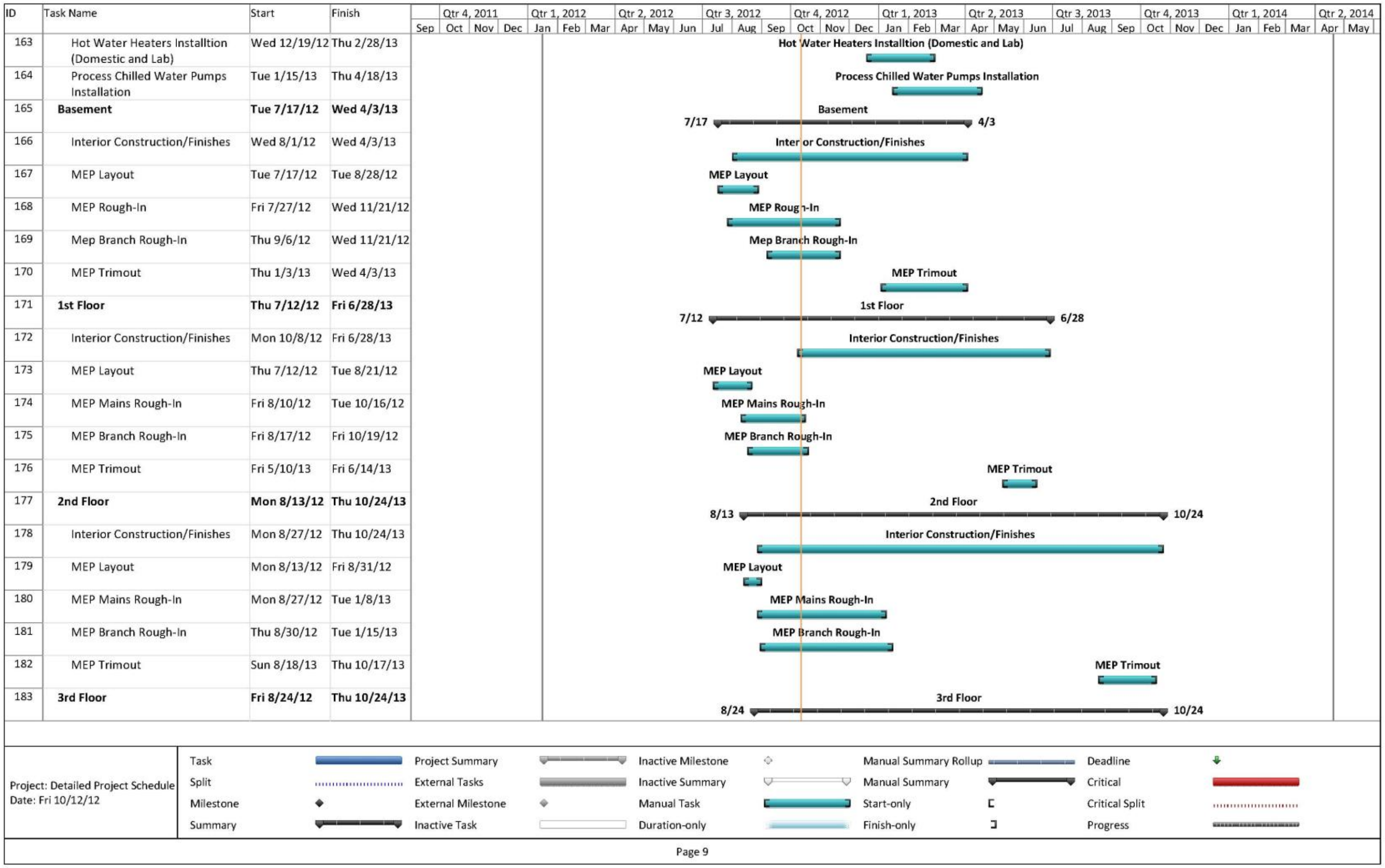

ID	Task Name	Start	Finish
163	Hot Water Heaters Installtion (Domestic and Lab)	Wed 12/19/12	Thu 2/28/13
164	Process Chilled Water Pumps Installation	Tue 1/15/13	Thu 4/18/13
165	**Basement**	**Tue 7/17/12**	**Wed 4/3/13**
166	Interior Construction/Finishes	Wed 8/1/12	Wed 4/3/13
167	MEP Layout	Tue 7/17/12	Tue 8/28/12
168	MEP Rough-In	Fri 7/27/12	Wed 11/21/12
169	Mep Branch Rough-In	Thu 9/6/12	Wed 11/21/12
170	MEP Trimout	Thu 1/3/13	Wed 4/3/13
171	**1st Floor**	**Thu 7/12/12**	**Fri 6/28/13**
172	Interior Construction/Finishes	Mon 10/8/12	Fri 6/28/13
173	MEP Layout	Thu 7/12/12	Tue 8/21/12
174	MEP Mains Rough-In	Fri 8/10/12	Tue 10/16/12
175	MEP Branch Rough-In	Fri 8/17/12	Fri 10/19/12
176	MEP Trimout	Fri 5/10/13	Fri 6/14/13
177	**2nd Floor**	**Mon 8/13/12**	**Thu 10/24/13**
178	Interior Construction/Finishes	Mon 8/27/12	Thu 10/24/13
179	MEP Layout	Mon 8/13/12	Fri 8/31/12
180	MEP Mains Rough-In	Mon 8/27/12	Tue 1/8/13
181	MEP Branch Rough-In	Thu 8/30/12	Tue 1/15/13
182	MEP Trimout	Sun 8/18/13	Thu 10/17/13
183	**3rd Floor**	**Fri 8/24/12**	**Thu 10/24/13**

Project: Detailed Project Schedule
Date: Fri 10/12/12

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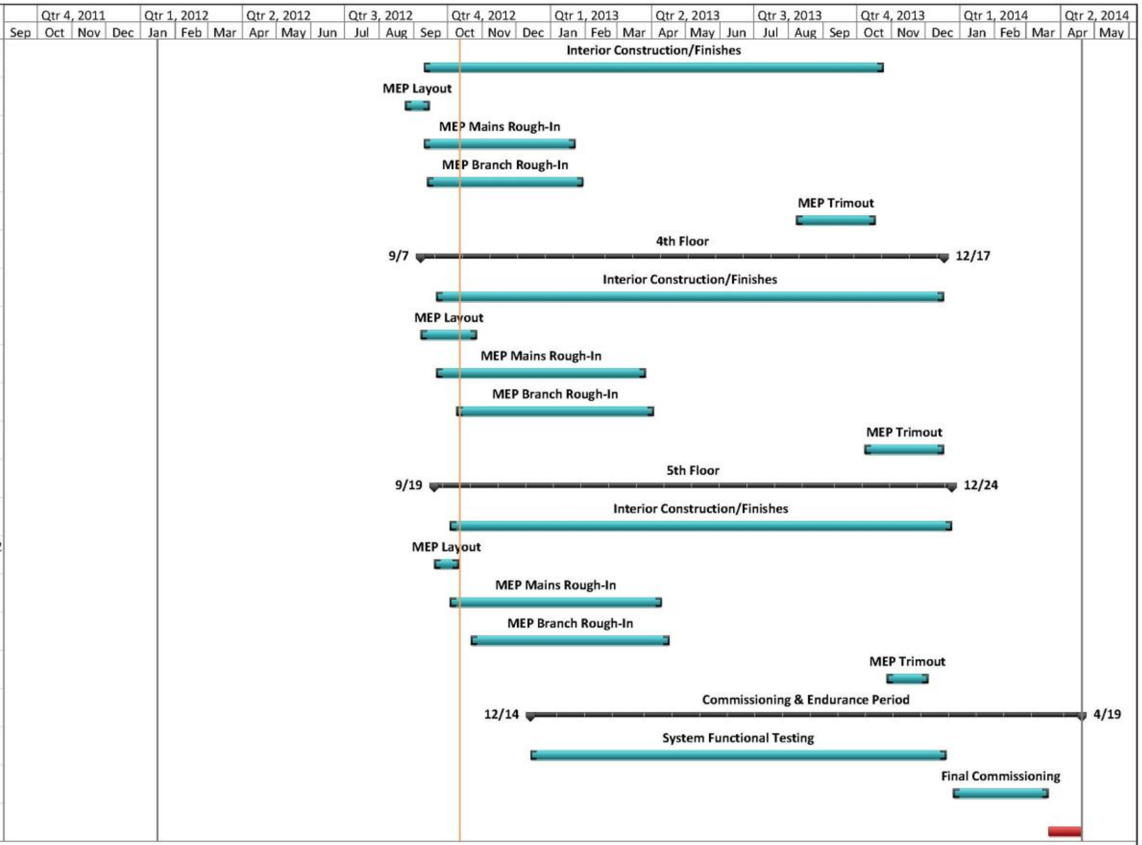
ID	Task Name	Start	Finish
184	Interior Construction/Finishes	Mon 9/10/12	Thu 10/24/13
185	MEP Layout	Fri 8/24/12	Fri 9/14/12
186	MEP Mains Rough-In	Mon 9/10/12	Tue 1/22/13
187	MEP Branch Rough-In	Thu 9/13/12	Tue 1/29/13
188	MEP Trimout	Thu 8/8/13	Thu 10/17/13
189	**4th Floor**	**Fri 9/7/12**	**Tue 12/17/13**
190	Interior Construction/Finishes	Fri 9/21/12	Tue 12/17/13
191	MEP Layout	Fri 9/7/12	Fri 10/26/12
192	MEP Mains Rough-In	Fri 9/21/12	Tue 3/26/13
193	MEP Branch Rough-In	Tue 10/9/12	Tue 4/2/13
194	MEP Trimout	Tue 10/8/13	Tue 12/17/13
195	**5th Floor**	**Wed 9/19/12**	**Tue 12/24/13**
196	Interior Construction/Finishes	Wed 10/3/12	Tue 12/24/13
197	MEP Layout	Wed 9/19/12	Wed 10/10/12
198	MEP Mains Rough-In	Wed 10/3/12	Tue 4/9/13
199	MEP Branch Rough-In	Mon 10/22/12	Tue 4/16/13
200	MEP Trimout	Mon 10/28/13	Tue 12/3/13
201	**Commissioning & Endurance Period**	**Fri 12/14/12**	**Sat 4/19/14**
202	System Functional Testing	Fri 12/14/12	Thu 12/19/13
203	Final Commissioning	Thu 12/26/13	Thu 3/20/14
204	Endurance Period	Fri 3/21/14	Sat 4/19/14

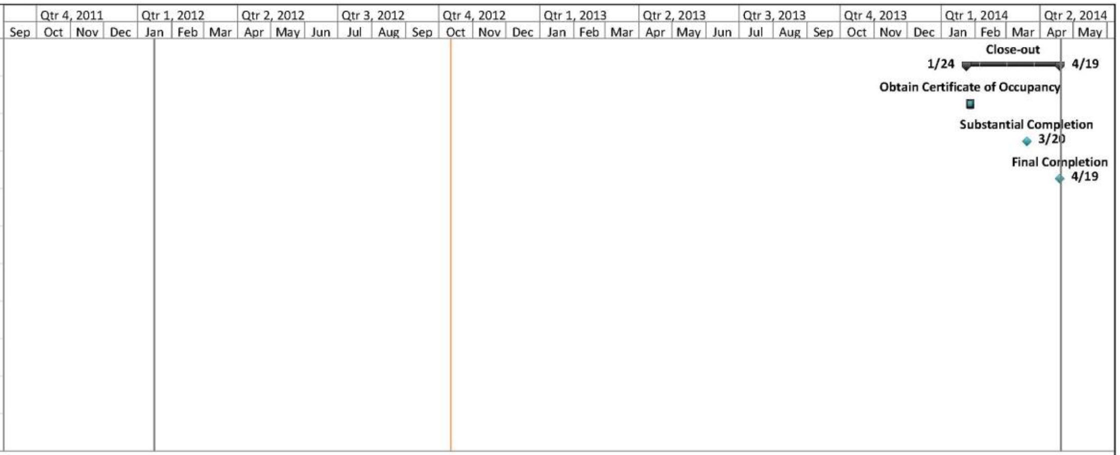


Project: Detailed Project Schedule
Date: Fri 10/12/12

Task
Split
Milestone ◆
Summary
Project Summary
External Tasks
External Milestone ◆
Inactive Task
Inactive Milestone ◇
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only [
Finish-only]
Deadline ↓
Critical
Critical Split
Progress

Page 10

ID	Task Name	Start	Finish
205	**Close-out**	**Fri 1/24/14**	**Sat 4/19/14**
206	Obtain Certificate of Occupancy	Fri 1/24/14	Thu 1/30/14
207	Substantial Completion	Thu 3/20/14	Thu 3/20/14
208	Final Completion	Sat 4/19/14	Sat 4/19/14
209			
210			
211			
212			
213			
214			
215			



Project: Detailed Project Schedule
Date: Fri 10/12/12

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⬇
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	⊏	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	⊐	Progress	▬

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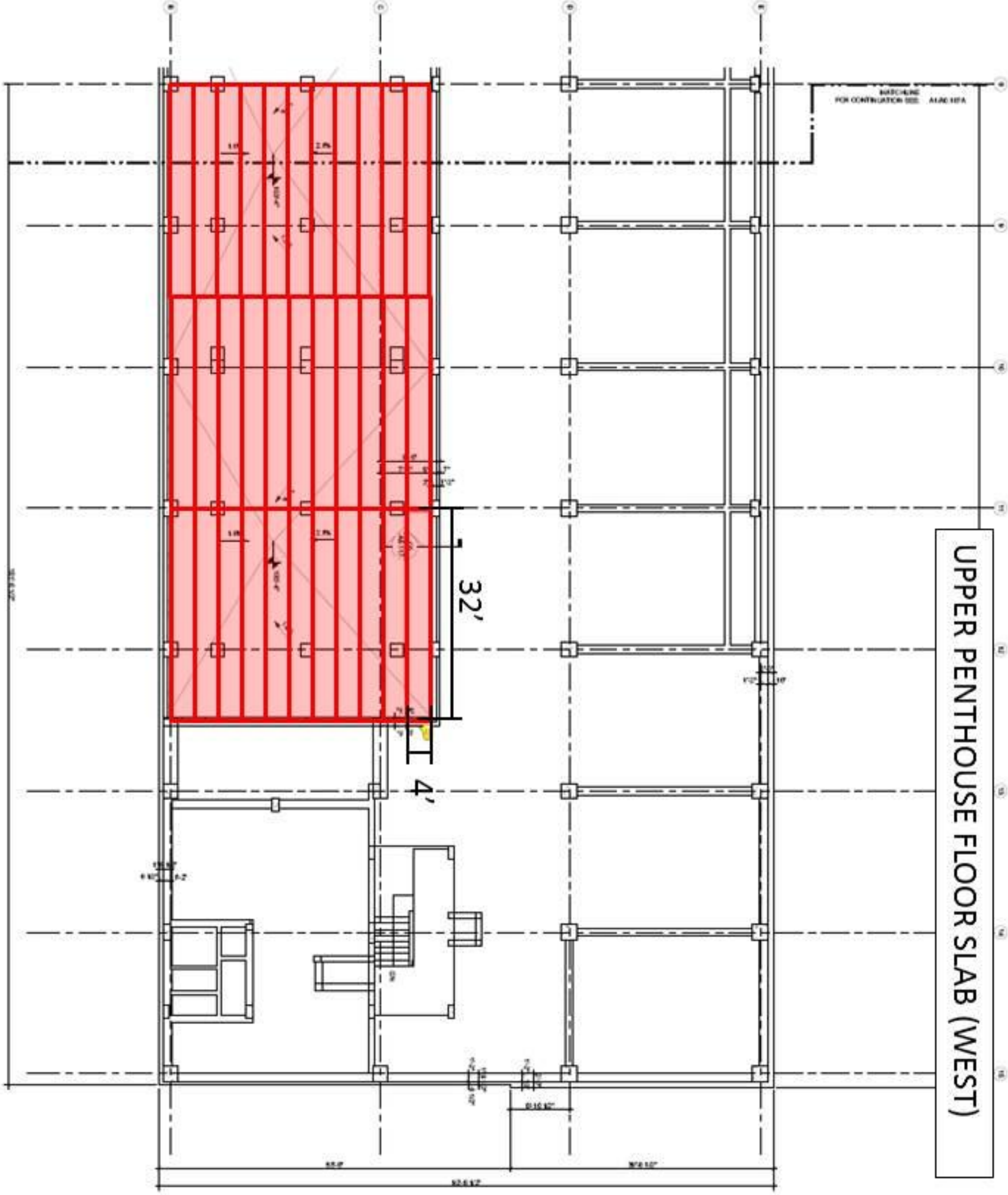
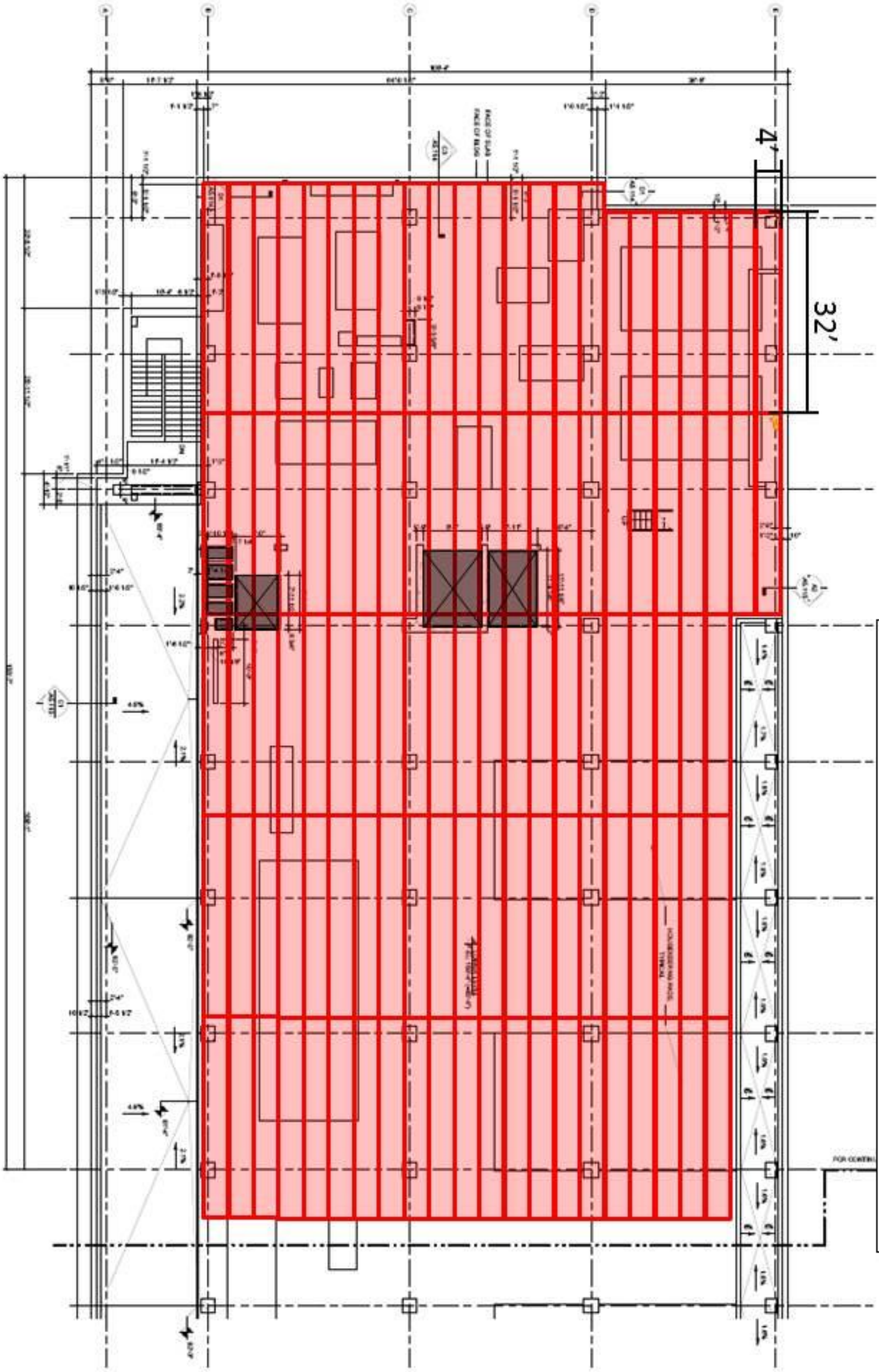
Appendix F: Hollow Core Plank Slab Layout Plan

UPPER PENTHOUSE FLOOR SLAB (EAST)

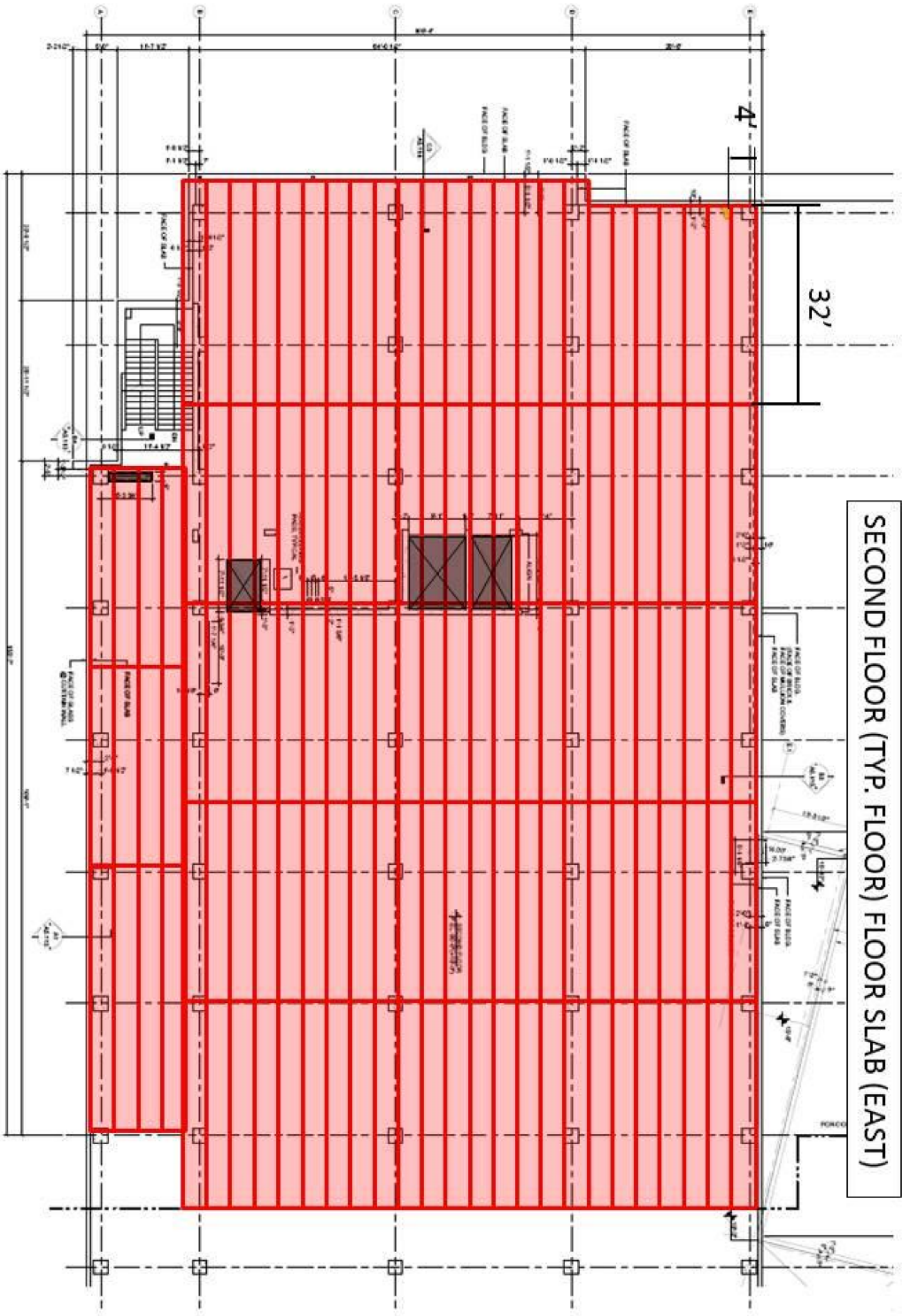


UPPER PENTHOUSE FLOOR SLAB (WEST)



LOWER PENTHOUSE FLOOR SLAB (EAST)


4'
32'
LOWER PENTHOUSE FLOOR SLAB (WEST)

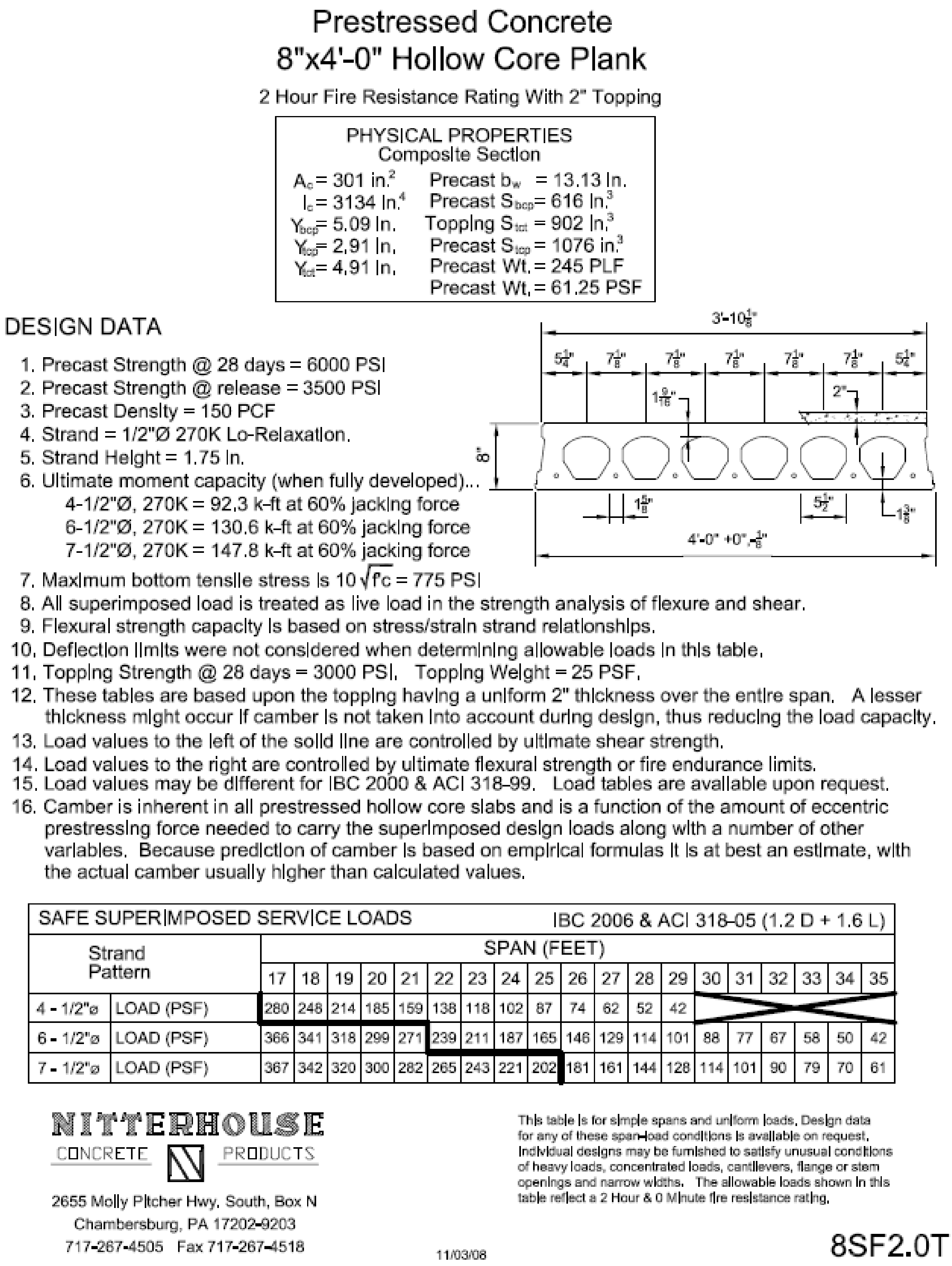

4'
32'
SECOND FLOOR (TYP. FLOOR) FLOOR SLAB (EAST)


SECOND FLOOR (TYP. FLOOR) FLOOR SLAB (WEST)
32'
4

SECOND FLOOR (TYP. FLOOR) FLOOR SLAB (EAST)

SECOND FLOOR (TYP. FLOOR) FLOOR SLAB (WEST)

Appendix G: Hollow Core Plank Specifications



Prestressed Concrete
8"x4'-0" Hollow Core Plank

2 Hour Fire Resistance Rating With 2" Topping

PHYSICAL PROPERTIES
Composite Section

A_c = 301 in.^{2} Precast b_w = 13.13 in.
I_c = 3134 in.^{4} Precast S_{bcp} = 616 in.^{3}
Y_{bcp} = 5.09 in. Topping S_{tct} = 902 in.^{3}
Y_{tcp} = 2.91 in. Precast S_{tcp} = 1076 in.^{3}
Y_{tct} = 4.91 in. Precast Wt. = 245 PLF
Precast Wt. = 61.25 PSF

DESIGN DATA

1. Precast Strength @ 28 days = 6000 PSI
2. Precast Strength @ release = 3500 PSI
3. Precast Density = 150 PCF
4. Strand = 1/2"Ø 270K Lo-Relaxation.
5. Strand Height = 1.75 in.
6. Ultimate moment capacity (when fully developed)...
   - 4-1/2"Ø, 270K = 92.3 k-ft at 60% jacking force
   - 6-1/2"Ø, 270K = 130.6 k-ft at 60% jacking force
   - 7-1/2"Ø, 270K = 147.8 k-ft at 60% jacking force
7. Maximum bottom tensile stress is $10\sqrt{f'c}$ = 775 PSI
8. All superimposed load is treated as live load in the strength analysis of flexure and shear.
9. Flexural strength capacity is based on stress/strain strand relationships.
10. Deflection limits were not considered when determining allowable loads in this table.
11. Topping Strength @ 28 days = 3000 PSI. Topping Weight = 25 PSF.
12. These tables are based upon the topping having a uniform 2" thickness over the entire span. A lesser thickness might occur if camber is not taken into account during design, thus reducing the load capacity.
13. Load values to the left of the solid line are controlled by ultimate shear strength.
14. Load values to the right are controlled by ultimate flexural strength or fire endurance limits.
15. Load values may be different for IBC 2000 & ACI 318-99. Load tables are available upon request.
16. Camber is inherent in all prestressed hollow core slabs and is a function of the amount of eccentric prestressing force needed to carry the superimposed design loads along with a number of other variables. Because prediction of camber is based on empirical formulas it is at best an estimate, with the actual camber usually higher than calculated values.

SAFE SUPERIMPOSED SERVICE LOADS IBC 2006 & ACI 318-05 (1.2 D + 1.6 L)

Strand Pattern		SPAN (FEET)																		
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
4 - 1/2"ø	LOAD (PSF)	280	248	214	185	159	138	118	102	87	74	62	52	42						
6 - 1/2"ø	LOAD (PSF)	366	341	318	299	271	239	211	187	165	146	129	114	101	88	77	67	58	50	42
7 - 1/2"ø	LOAD (PSF)	367	342	320	300	282	265	243	221	202	181	161	144	128	114	101	90	79	70	61

NITTERHOUSE
CONCRETE PRODUCTS

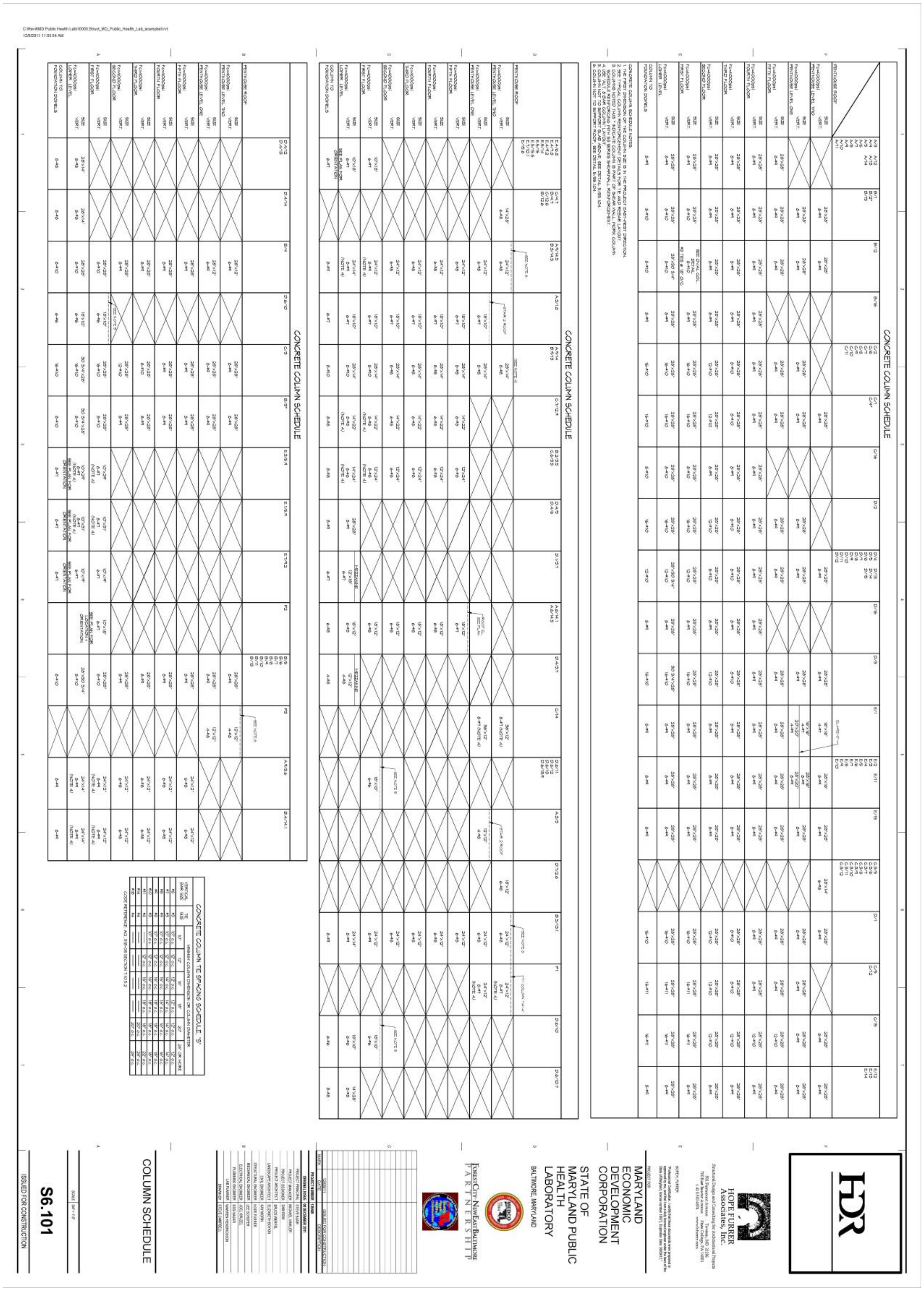
2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17202-9203
717-267-4505 Fax 717-267-4518

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths. The allowable loads shown in this table reflect a 2 Hour & 0 Minute fire resistance rating.

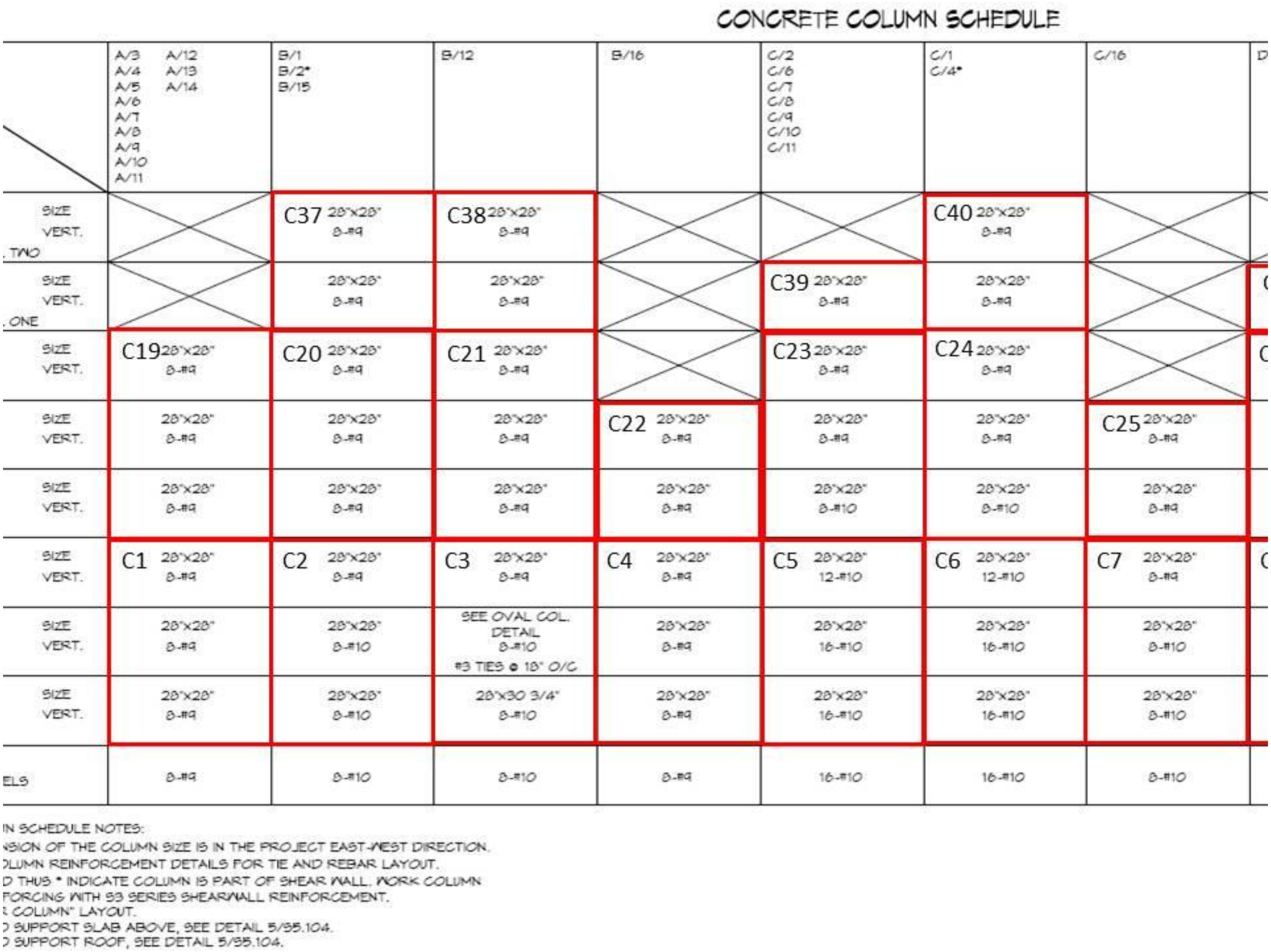
11/03/08

8SF2.0T

Appendix H: Precast Column Schedule


CONCRETE COLUMN SCHEDULE
CONCRETE COLUMN TIE SPACING SCHEDULE "S"
HDR
HOPE FURRER Associates, Inc.
MARYLAND ECONOMIC DEVELOPMENT CORPORATION
STATE OF MARYLAND PUBLIC HEALTH LABORATORY
BALTIMORE, MARYLAND
FOREST CITY NEW EAST BALTIMORE PARTNERSHIP
COLUMN SCHEDULE
S6.101
ISSUED FOR CONSTRUCTION

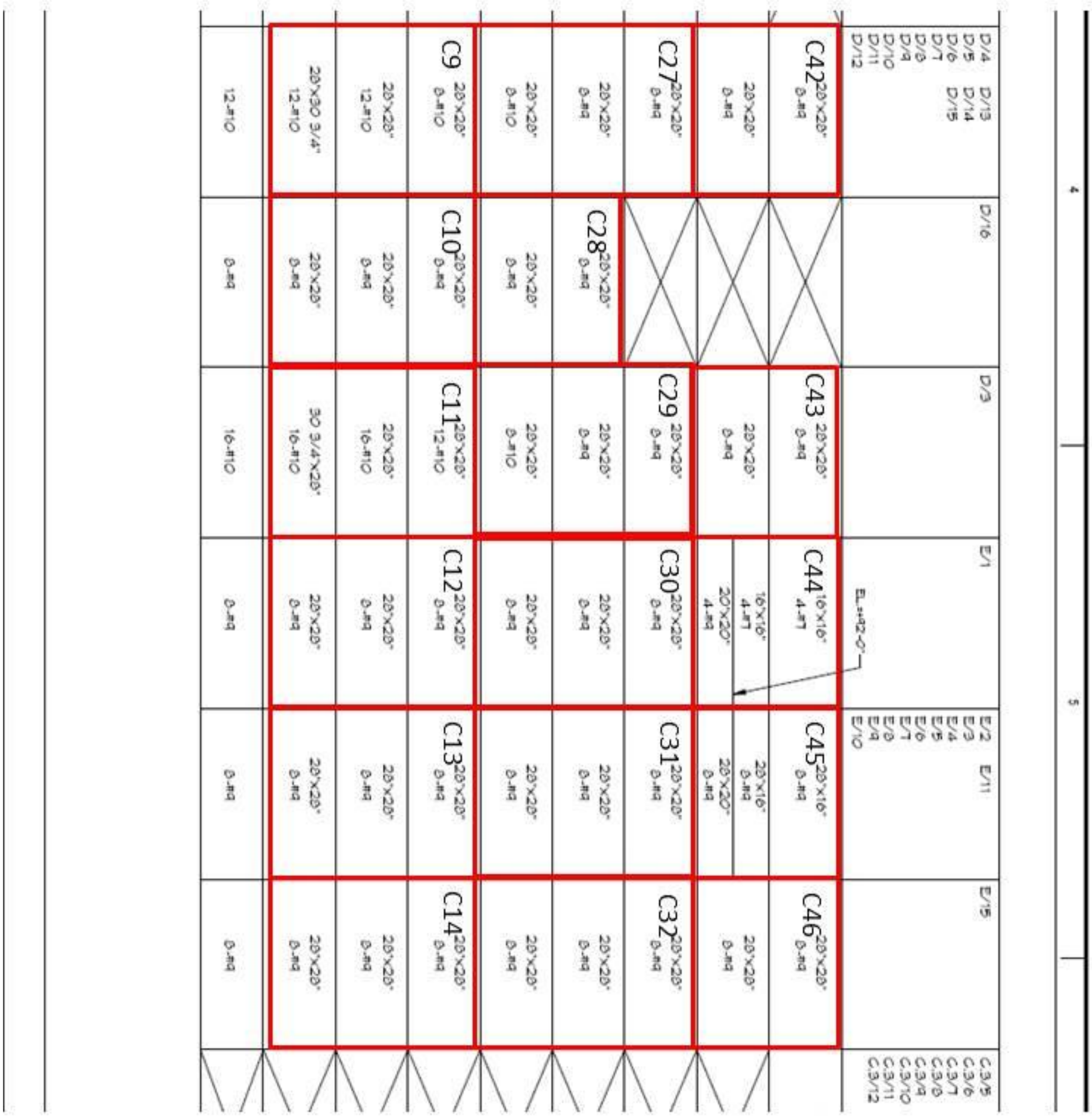
Appendix I: Precast Column Designation

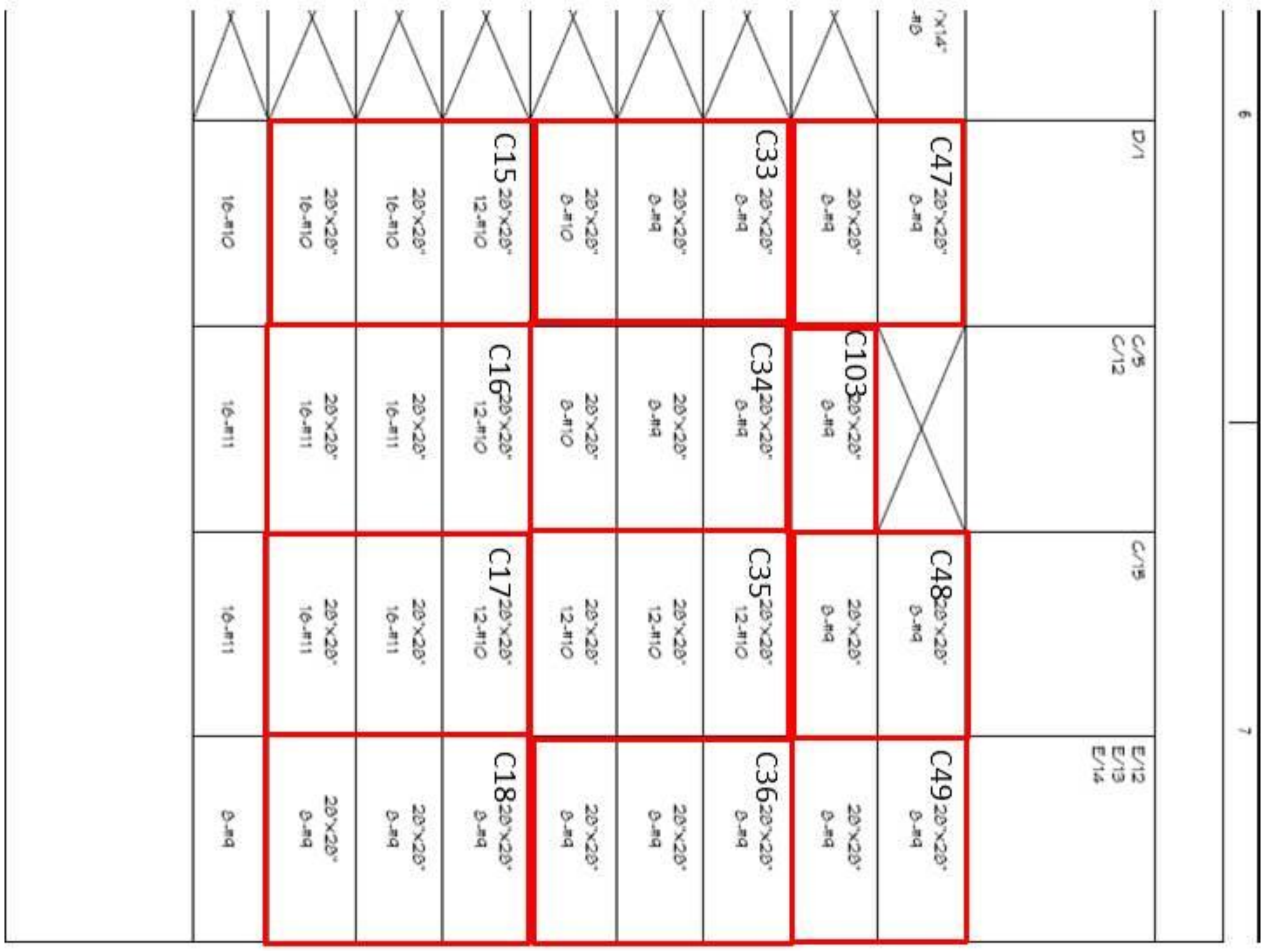


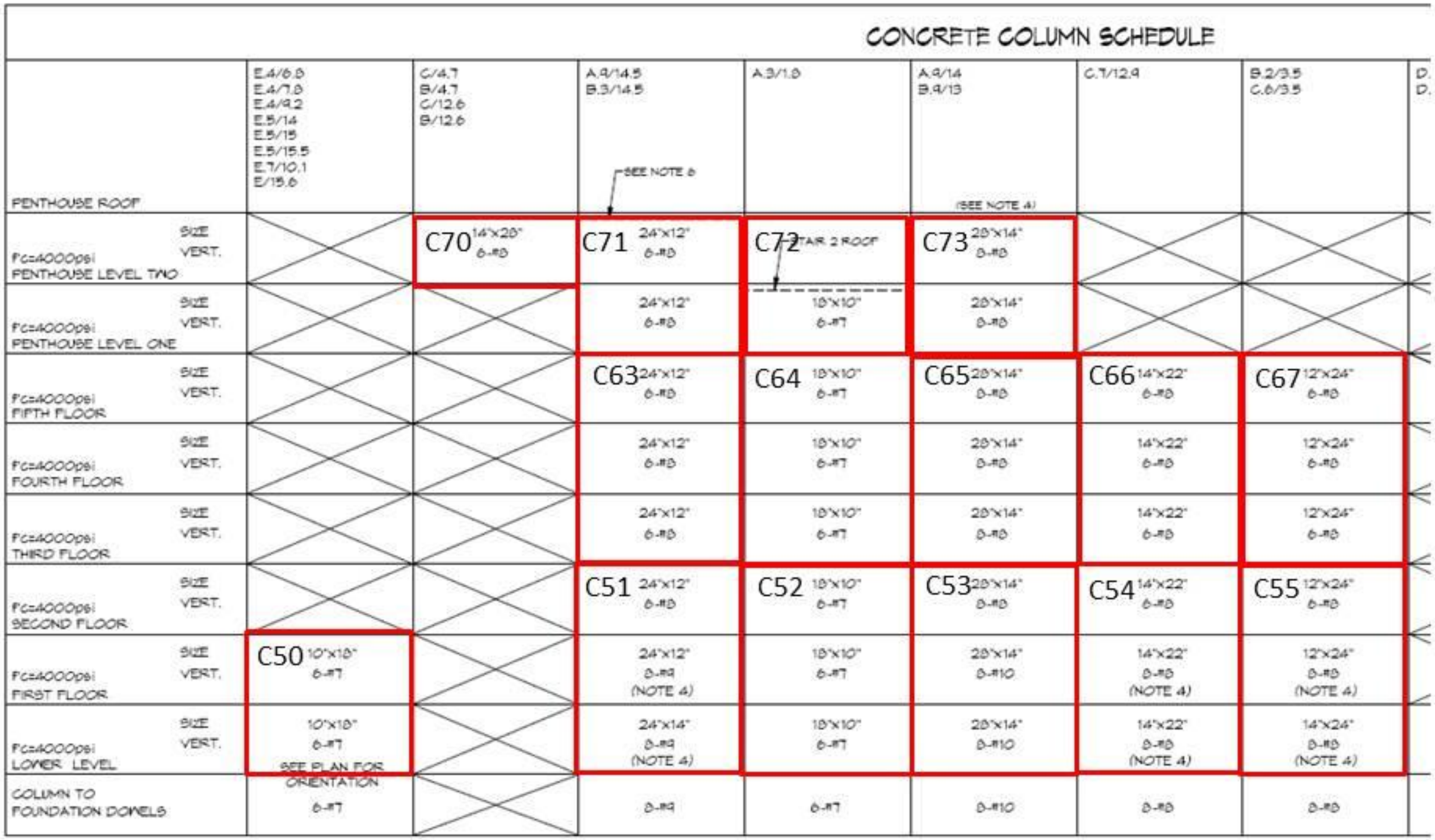
CONCRETE COLUMN SCHEDULE

	A/3 A/4 A/5 A/6 A/7 A/8 A/9 A/10 A/11 A/12 A/13 A/14	B/1 B/2* B/15	B/12	B/16	C/2 C/6 C/7 C/8 C/9 C/10 C/11	C/1 C/4*	C/16	D
SIZE VERT. . TWO		C37 28"x28" 8-#9	C38 28"x28" 8-#9			C40 28"x28" 8-#9		
SIZE VERT. . ONE		28"x28" 8-#9	28"x28" 8-#9		C39 28"x28" 8-#9	28"x28" 8-#9		C
SIZE VERT.	C19 28"x28" 8-#9	C20 28"x28" 8-#9	C21 28"x28" 8-#9		C23 28"x28" 8-#9	C24 28"x28" 8-#9		C
SIZE VERT.	28"x28" 8-#9	28"x28" 8-#9	28"x28" 8-#9	C22 28"x28" 8-#9	28"x28" 8-#9	28"x28" 8-#9	C25 28"x28" 8-#9	
SIZE VERT.	28"x28" 8-#9	28"x28" 8-#9	28"x28" 8-#9	28"x28" 8-#9	28"x28" 8-#10	28"x28" 8-#10	28"x28" 8-#9	
SIZE VERT.	C1 28"x28" 8-#9	C2 28"x28" 8-#9	C3 28"x28" 8-#9	C4 28"x28" 8-#9	C5 28"x28" 12-#10	C6 28"x28" 12-#10	C7 28"x28" 8-#9	C
SIZE VERT.	28"x28" 8-#9	28"x28" 8-#10	SEE OVAL COL. DETAIL 8-#10 #3 TIES @ 18" O/C	28"x28" 8-#9	28"x28" 16-#10	28"x28" 16-#10	28"x28" 8-#10	
SIZE VERT.	28"x28" 8-#9	28"x28" 8-#10	28"x30 3/4" 8-#10	28"x28" 8-#9	28"x28" 16-#10	28"x28" 16-#10	28"x28" 8-#10	
ELS	8-#9	8-#10	8-#10	8-#9	16-#10	16-#10	8-#10	

IN SCHEDULE NOTES:
NSION OF THE COLUMN SIZE IS IN THE PROJECT EAST-WEST DIRECTION.
OLUMN REINFORCEMENT DETAILS FOR TIE AND REBAR LAYOUT.
D THUS * INDICATE COLUMN IS PART OF SHEAR WALL. WORK COLUMN
FORCING WITH S3 SERIES SHEARWALL REINFORCEMENT.
E COLUMN" LAYOUT.
O SUPPORT SLAB ABOVE, SEE DETAIL 5/S5.104.
O SUPPORT ROOF, SEE DETAIL 5/S5.104.

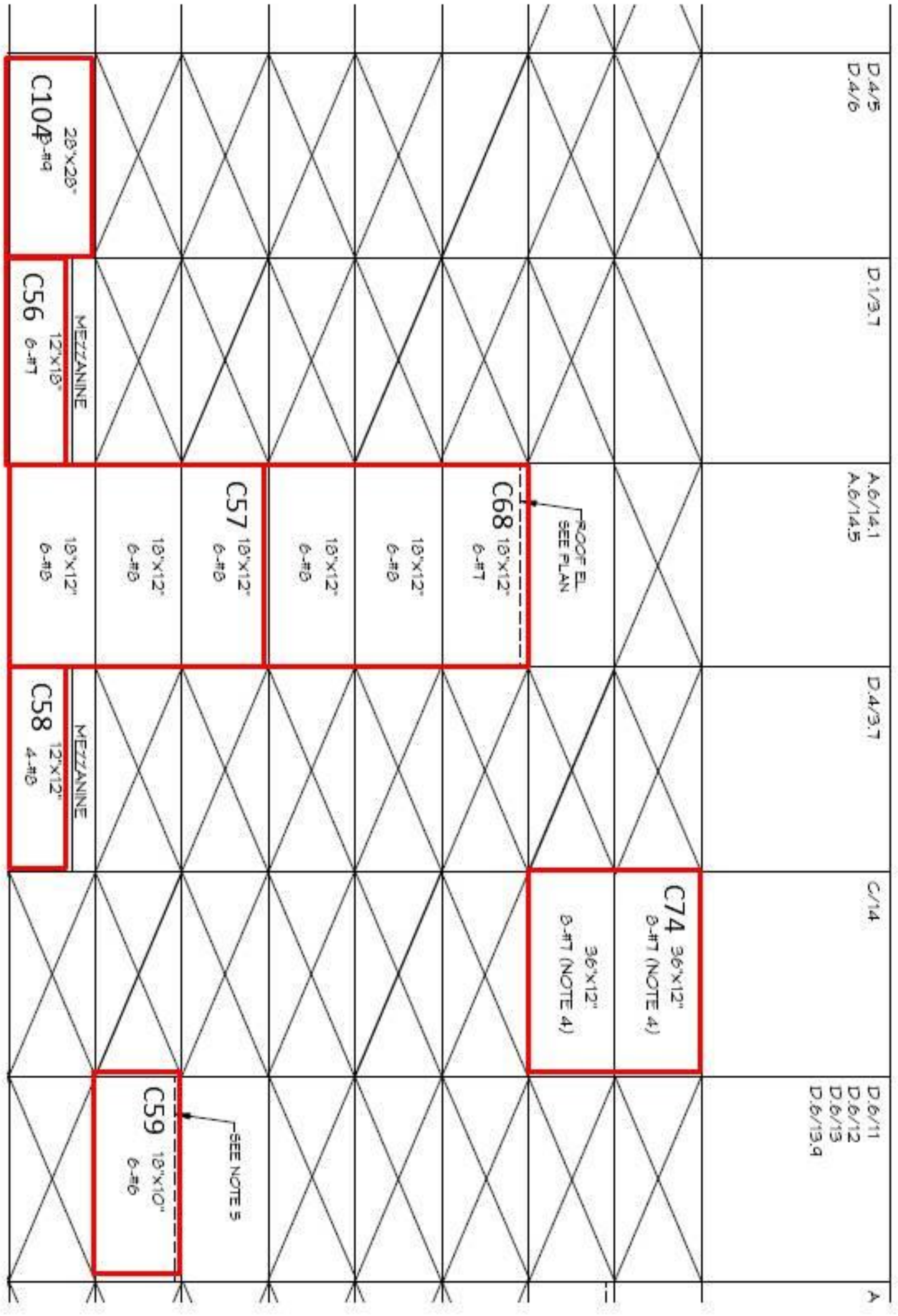

C42
C27
C9
C28
C10
C43
C29
C11
C44
C30
C12
C45
C31
C13
C46
C32
C14
EL.+42'-0"
4
5

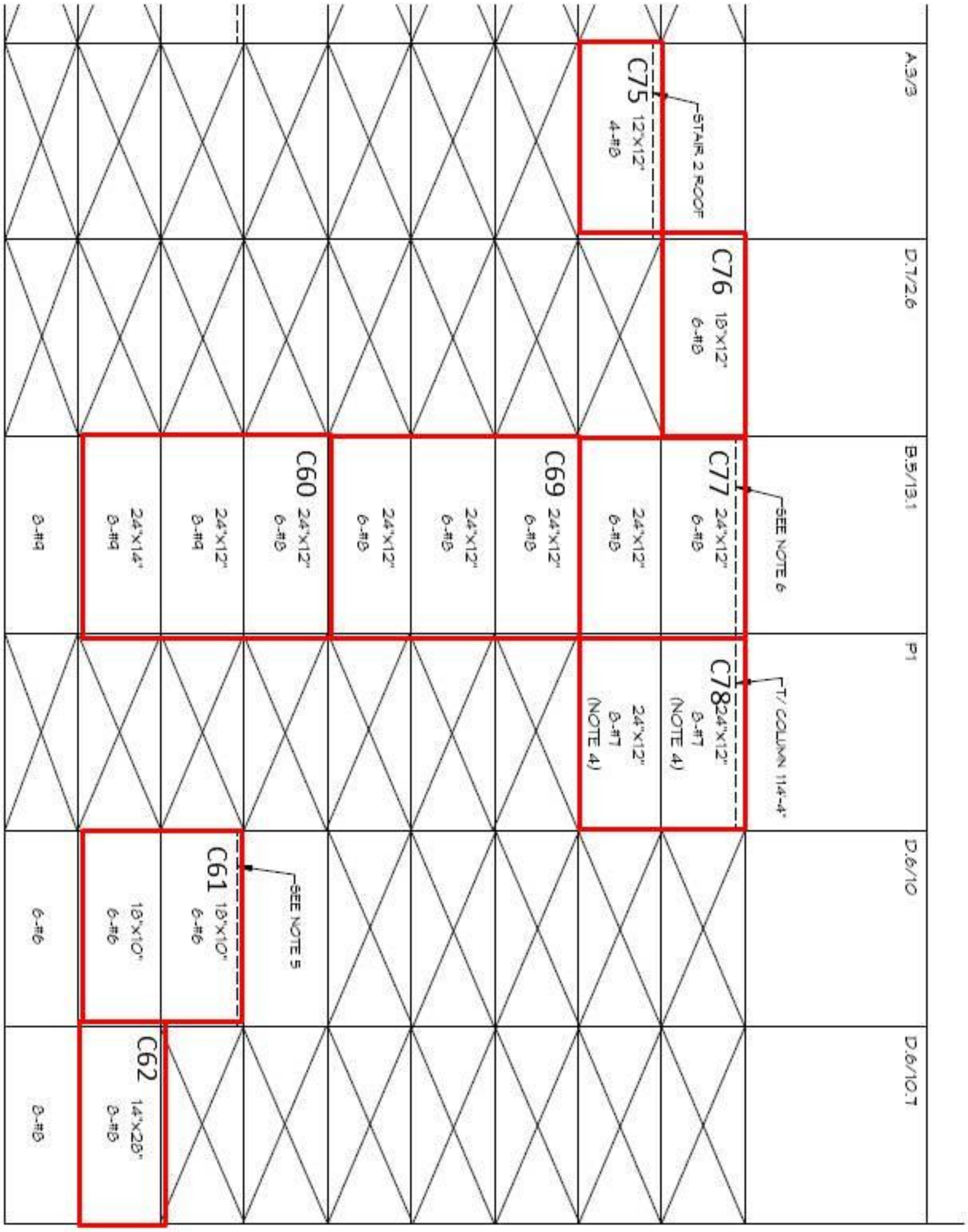

C15
C16
C17
C18
C33
C34
C35
C36
C47
C103
C48
C49
D/1
C/5
C/12
C/15
E/12
E/13
E/14
6
7

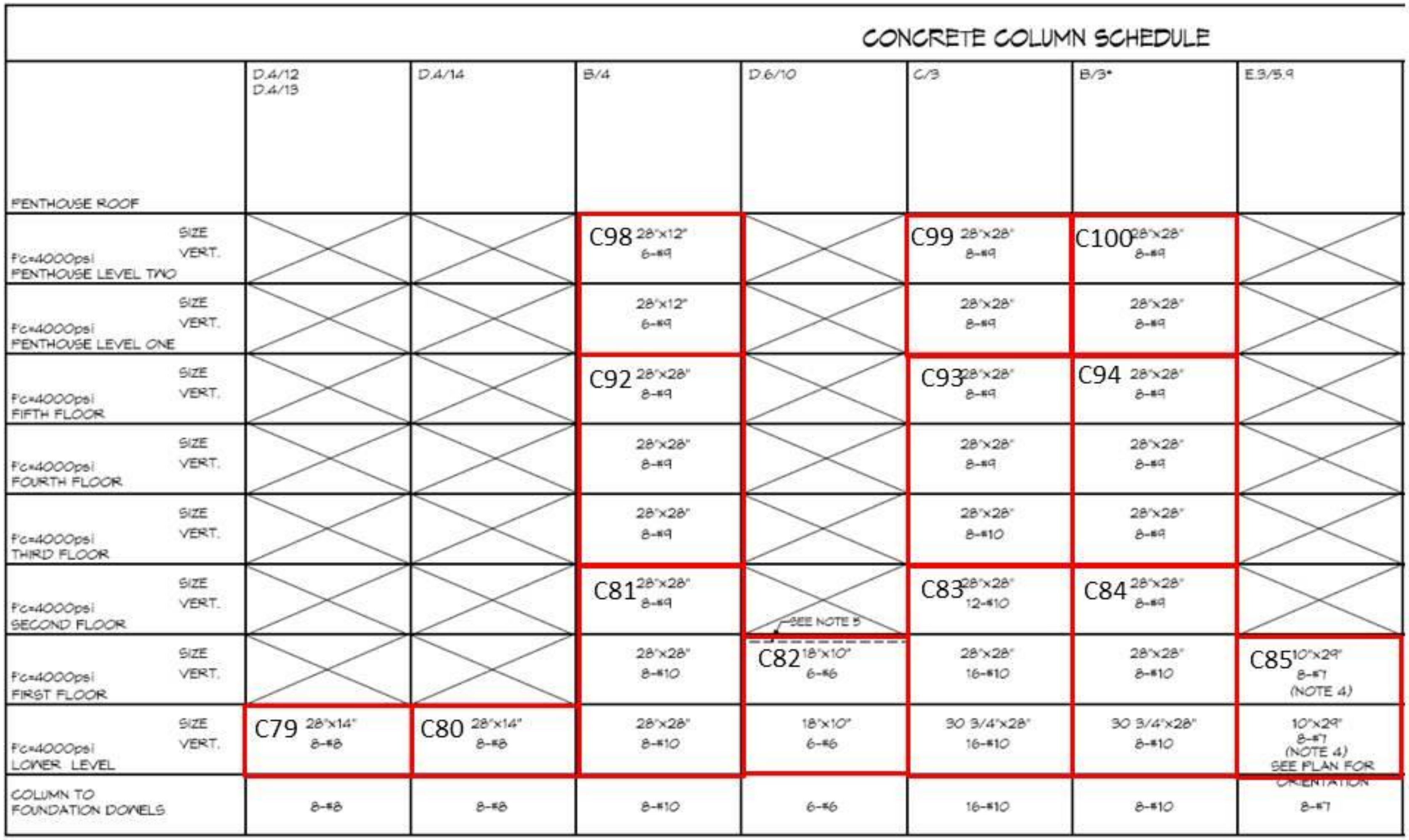


CONCRETE COLUMN SCHEDULE

PENTHOUSE ROOF		E.4/6.8 E.4/7.8 E.4/9.2 E.5/14 E.5/15 E.5/15.5 E.7/10.1 E/15.6	C/4.7 B/4.7 C/12.6 B/12.6	A.9/14.5 B.3/14.5 SEE NOTE 6	A.3/1.8	A.9/14 B.9/13 (SEE NOTE 4)	C.7/12.9	B.2/3.5 C.6/3.5	D. D.
Fc=4000psi PENTHOUSE LEVEL TWO	SIZE VERT.		C70 14"x20" 6-#8	C71 24"x12" 6-#8	C72 STAIR 2 ROOF	C73 28"x14" 8-#8			
Fc=4000psi PENTHOUSE LEVEL ONE	SIZE VERT.			24"x12" 6-#8	18"x10" 6-#7	28"x14" 8-#8			
Fc=4000psi FIFTH FLOOR	SIZE VERT.			C63 24"x12" 6-#8	C64 18"x10" 6-#7	C65 28"x14" 8-#8	C66 14"x22" 6-#8	C67 12"x24" 6-#8	
Fc=4000psi FOURTH FLOOR	SIZE VERT.			24"x12" 6-#8	18"x10" 6-#7	28"x14" 8-#8	14"x22" 6-#8	12"x24" 6-#8	
Fc=4000psi THIRD FLOOR	SIZE VERT.			24"x12" 6-#8	18"x10" 6-#7	28"x14" 8-#8	14"x22" 6-#8	12"x24" 6-#8	
Fc=4000psi SECOND FLOOR	SIZE VERT.			C51 24"x12" 6-#8	C52 18"x10" 6-#7	C53 28"x14" 8-#8	C54 14"x22" 6-#8	C55 12"x24" 6-#8	
Fc=4000psi FIRST FLOOR	SIZE VERT.	C50 10"x18" 6-#7		24"x12" 8-#9 (NOTE 4)	18"x10" 6-#7	28"x14" 8-#10	14"x22" 8-#8 (NOTE 4)	12"x24" 8-#8 (NOTE 4)	
Fc=4000psi LOWER LEVEL	SIZE VERT.	10"x18" 6-#7 SEE PLAN FOR ORIENTATION		24"x14" 8-#9 (NOTE 4)	18"x10" 6-#7	28"x14" 8-#10	14"x22" 8-#8 (NOTE 4)	14"x24" 8-#8 (NOTE 4)	
COLUMN TO FOUNDATION DOWELS		6-#7		8-#9	6-#7	8-#10	8-#8	8-#8	

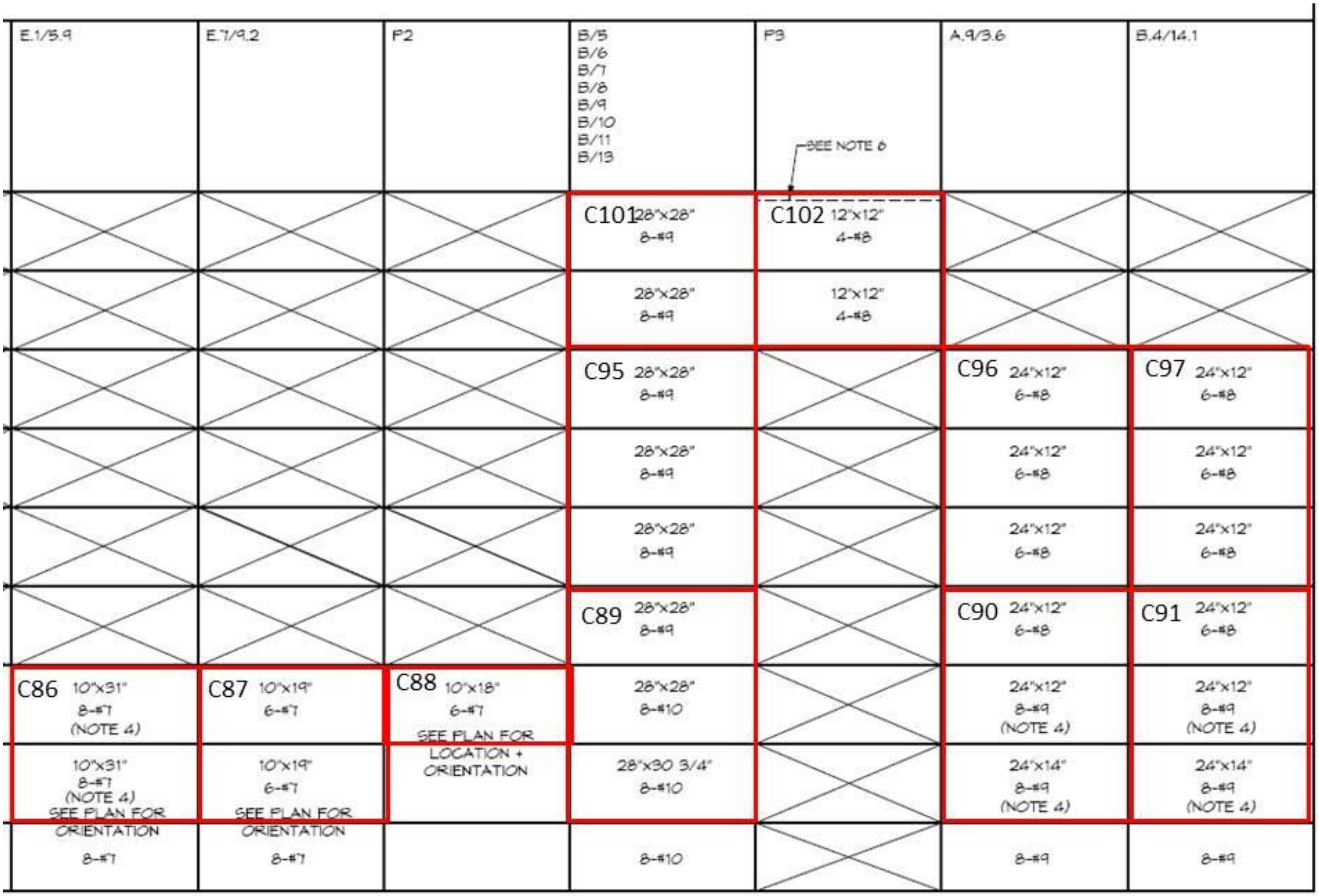

D.4/5
D.4/6
D.1/3.7
A.6/14.1
A.6/14.5
D.4/3.7
C/14
D.6/11
D.6/12
D.6/13
D.6/13.9
A
C104
28"x28"
8-#9
C56
12"x18"
6-#7
MEZZANINE
C57
18"x12"
6-#8
C68
18"x12"
6-#7
ROOF EL.
SEE PLAN
C58
12"x12"
4-#8
MEZZANINE
C74
36"x12"
8-#7 (NOTE 4)
C59
18"x10"
6-#6
SEE NOTE 5


A.3/3
D.7/2.6
B.5/13.1
P1
D.6/10
D.6/10.T
STAIR 2 ROOF
C75 12"x12" 4-#8
C76 18"x12" 6-#8
SEE NOTE 6
C77 24"x12" 6-#8
24"x12" 6-#8
C69 24"x12" 6-#8
24"x12" 6-#8
24"x12" 6-#8
C60 24"x12" 6-#8
24"x12" 8-#9
24"x14" 8-#9
8-#9
T/ COLUMN 114'-4"
C78 24"x12" 8-#7 (NOTE 4)
24"x12" 8-#7 (NOTE 4)
SEE NOTE 5
C61 18"x10" 6-#6
18"x10" 6-#6
6-#6
C62 14"x28" 8-#8
8-#8



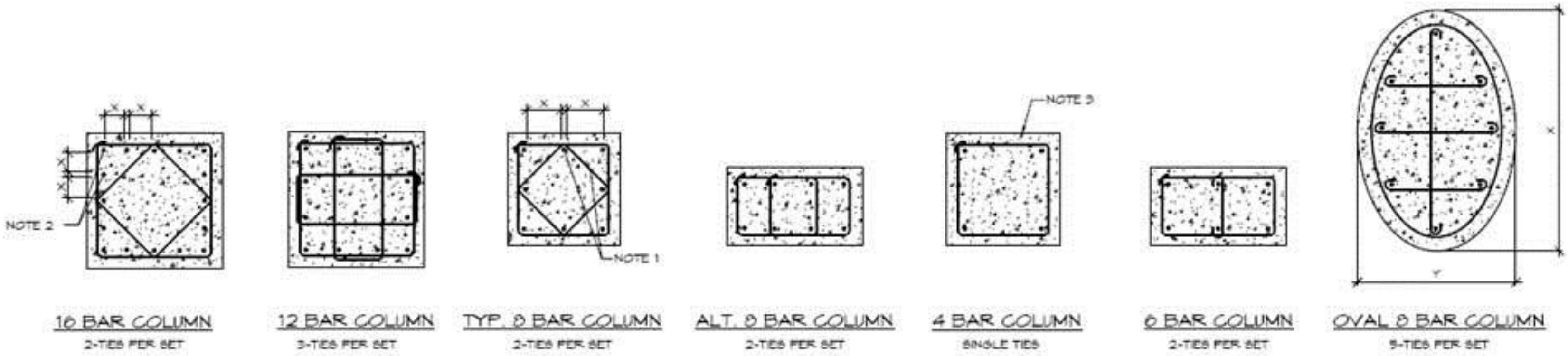
CONCRETE COLUMN SCHEDULE

	D.4/12 D.4/13	D.4/14	B/4	D.6/10	C/3	B/3*	E.3/5.9
PENTHOUSE ROOF							
F'c=4000psi PENTHOUSE LEVEL TWO SIZE VERT.			C98 28"x12" 6-#9		C99 28"x28" 8-#9	C100 28"x28" 8-#9	
F'c=4000psi PENTHOUSE LEVEL ONE SIZE VERT.			28"x12" 6-#9		28"x28" 8-#9	28"x28" 8-#9	
F'c=4000psi FIFTH FLOOR SIZE VERT.			C92 28"x28" 8-#9		C93 28"x28" 8-#9	C94 28"x28" 8-#9	
F'c=4000psi FOURTH FLOOR SIZE VERT.			28"x28" 8-#9		28"x28" 8-#9	28"x28" 8-#9	
F'c=4000psi THIRD FLOOR SIZE VERT.			28"x28" 8-#9		28"x28" 8-#10	28"x28" 8-#9	
F'c=4000psi SECOND FLOOR SIZE VERT.			C81 28"x28" 8-#9	SEE NOTE 5	C83 28"x28" 12-#10	C84 28"x28" 8-#9	
F'c=4000psi FIRST FLOOR SIZE VERT.			28"x28" 8-#10	C82 18"x10" 6-#6	28"x28" 16-#10	28"x28" 8-#10	C85 10"x29" 8-#7 (NOTE 4)
F'c=4000psi LOWER LEVEL SIZE VERT.	C79 28"x14" 8-#8	C80 28"x14" 8-#8	28"x28" 8-#10	18"x10" 6-#6	30 3/4"x28" 16-#10	30 3/4"x28" 8-#10	10"x29" 8-#7 (NOTE 4) SEE PLAN FOR ORIENTATION
COLUMN TO FOUNDATION DOWELS	8-#8	8-#8	8-#10	6-#6	16-#10	8-#10	8-#7



E.1/5.9	E.7/9.2	F2	B/5 B/6 B/7 B/8 B/9 B/10 B/11 B/13	F3 SEE NOTE 6	A.9/3.6	B.4/14.1
			C101 28"x28" 8-#9	C102 12"x12" 4-#8		
			28"x28" 8-#9	12"x12" 4-#8		
			C95 28"x28" 8-#9		C96 24"x12" 6-#8	C97 24"x12" 6-#8
			28"x28" 8-#9		24"x12" 6-#8	24"x12" 6-#8
			28"x28" 8-#9		24"x12" 6-#8	24"x12" 6-#8
			C89 28"x28" 8-#9		C90 24"x12" 6-#8	C91 24"x12" 6-#8
C86 10"x31" 8-#7 (NOTE 4)	C87 10"x19" 6-#7	C88 10"x18" 6-#7 SEE PLAN FOR LOCATION + ORIENTATION	28"x28" 8-#10		24"x12" 8-#9 (NOTE 4)	24"x12" 8-#9 (NOTE 4)
10"x31" 8-#7 (NOTE 4) SEE PLAN FOR ORIENTATION	10"x19" 6-#7 SEE PLAN FOR ORIENTATION		28"x30 3/4" 8-#10		24"x14" 8-#9 (NOTE 4)	24"x14" 8-#9 (NOTE 4)
8-#7	8-#7		8-#10		8-#9	8-#9

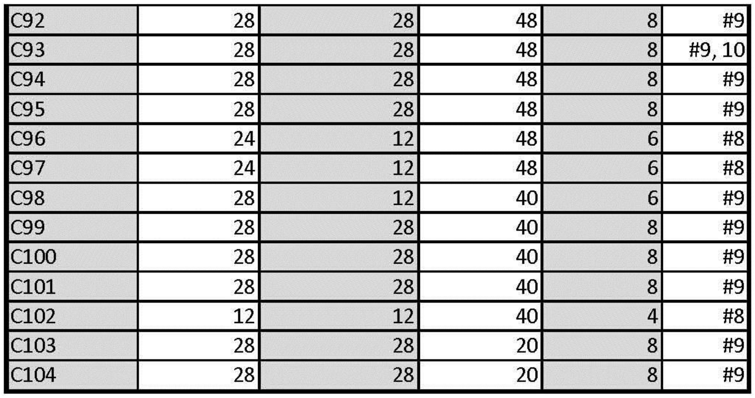
Column Reinforcement Types.



PRECAST BEAM SCHEDULE

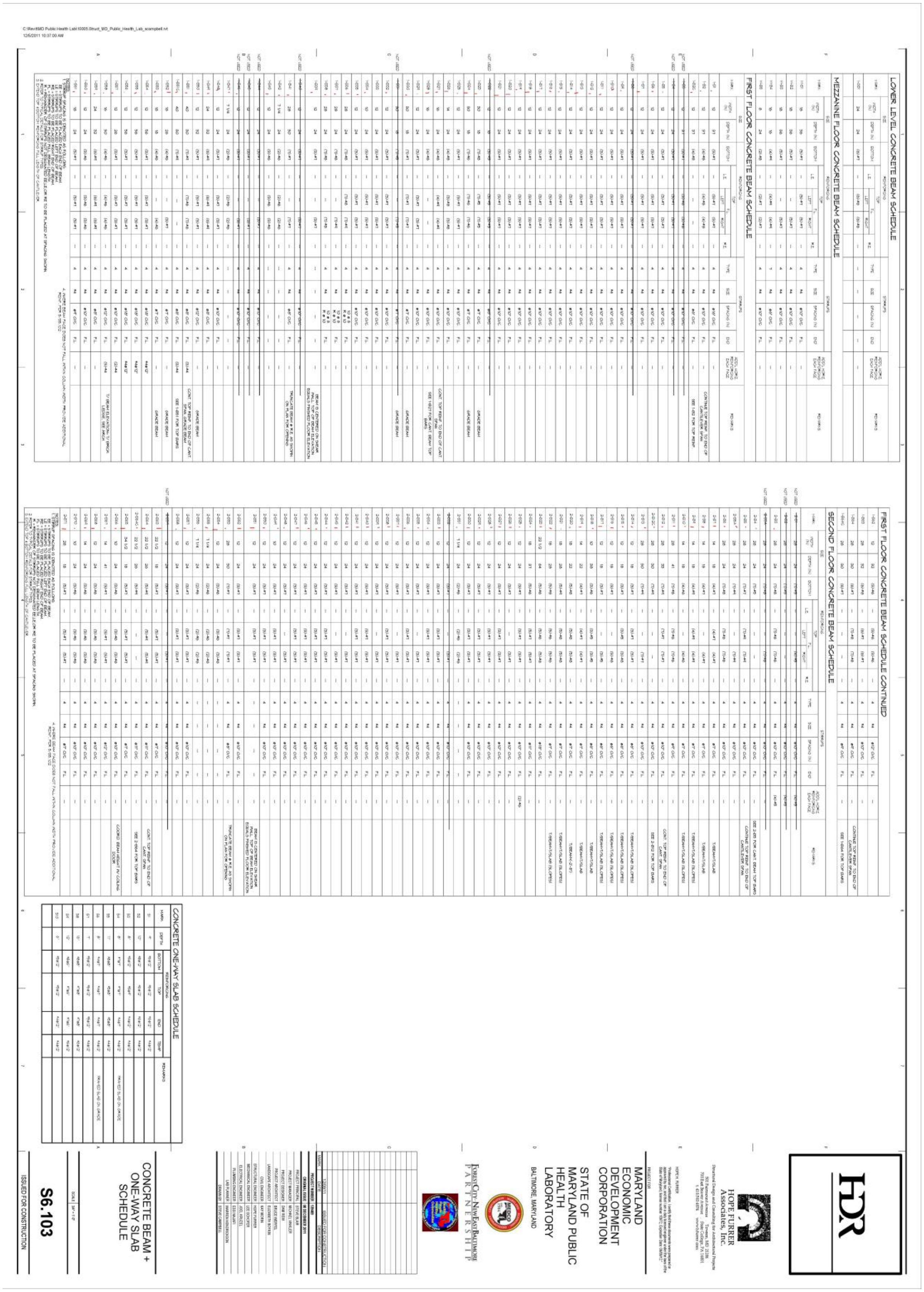
Column No.	Width (in.)	Thickness (in.)	Height (ft.)	Reinf. Typ.	Rebar #
C1	28	28	54	8	#9
C2	28	28	54	8	#9,10
C3	28	28	54	8	#9,10
C4	28	28	54	8	#9
C5	28	28	54	16 & 12	#10
C6	28	28	54	16 & 12	#10
C7	28	28	54	8	#9,10
C8	28	28	54	16 & 12	#10
C9	28	28- 30-3/4	54	12 & 8	#10
C10	28	28	54	8	#9
C11	28	28- 30-3/4	54	16 & 12	#10
C12	28	28	54	8	#9
C13	28	28	54	8	#9
C14	28	28	54	8	#9
C15	28	28	54	16 & 12	#10
C16	28	28	54	16 & 12	#10,11
C17	28	28	54	16 & 12	#10,11
C18	28	28	54	8	#9
C19	28	28	48	8	#9
C20	28	28	48	8	#9
C21	28	28	48	8	#9
C22	28	28	32	8	#9
C23	28	28	48	8	#9,10
C24	28	28	48	8	#9,10
C25	28	28	32	8	#9
C26	28	28	48	8	#9,10
C27	28	28	48	8	#9,10
C28	28	28	32	8	#9
C29	28	28	48	8	#9,10
C30	28	28	48	8	#9
C31	28	28	48	8	#9
C32	28	28	48	8	#9
C33	28	28	48	8	#9,10
C34	28	28	48	8	#9,10
C35	28	28	48	12	#10
C36	28	28	48	8	#9
C37	28	28	40	8	#9
C38	28	28	40	8	#9
C39	28	28	20	8	#9
C40	28	28	40	8	#9
C41	28	28	20	8	#9
C42	28	28	40	8	#9
C43	28	28	40	8	#9
C44	16-20	16-20	40	4	#7, #9

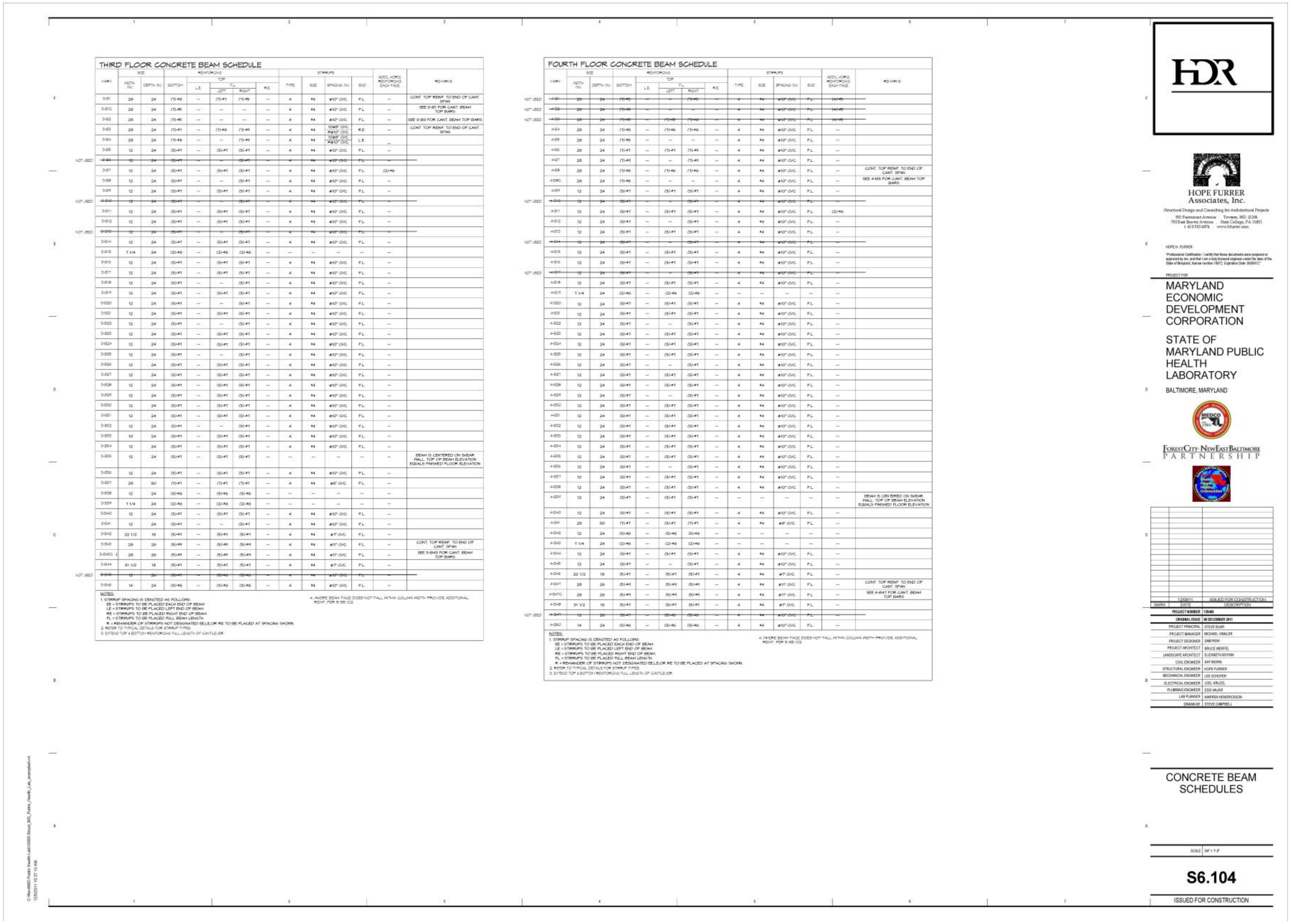
C45	28	16-20	40	8	#9
C46	28	28	40	8	#9
C47	28	28	40	8	#9
C48	28	28	40	8	#9
C49	28	28	40	8	#9
C50	10	18	48	6	#7
C51	24	12-14	54	6 & 8	#9
C52	18	10	54	6	#7
C53	28	14	54	8	#8, 10
C54	14	22	54	6 & 8	#8
C55	12-14	24	54	6 & 8	#8
C56	12	18	10	6	#7
C57	18	12	54	6	#8
C58	12	12	10	4	#8
C59	18	10	18	6	#6
C60	24	12-14	54	6 & 8	#8, 9
C61	18	10	38	6	#6
C62	14	28	20	8	#8
C63	24	12	48	6	#8
C64	18	10	48	6	#7
C65	28	14	48	8	#8
C66	14	22	48	6	#8
C67	12	24	48	6	#8
C68	18	12	48	6	#7, 8
C69	24	12	48	6	#8
C70	14	28	20	6	#8
C71	24	12	40	6	#8
C72	18	10	20	6	#7
C73	28	14	40	8	#8
C74	36	12	40	8	#7
C75	12	12	20	4	#8
C76	18	12	20	6	#8
C77	24	12	40	6	#8
C78	24	12	40	8	#7
C79	28	14	20	8	#8
C80	28	14	20	8	#8
C81	28	28	54	8	#9, 10
C82	18	10	38	6	#6
C83	28- 30-3/4	28	54	16 & 12	#10
C84	28	28	54	8	#9, 10
C85	10	29	38	8	#7
C86	10	31	38	8	#7
C87	10	19	38	6	#7
C88	10	18	18	6	#7
C89	28	28- 30-3/4	54	8	#9, 10
C90	24	12-14	54	8 & 6	#8, 9
C91	24	12-14	54	8 & 6	#8, 9



C92	28	28	48	8	#9
C93	28	28	48	8	#9, 10
C94	28	28	48	8	#9
C95	28	28	48	8	#9
C96	24	12	48	6	#8
C97	24	12	48	6	#8
C98	28	12	40	6	#9
C99	28	28	40	8	#9
C100	28	28	40	8	#9
C101	28	28	40	8	#9
C102	12	12	40	4	#8
C103	28	28	20	8	#9
C104	28	28	20	8	#9

Appendix J: Beam Schedule


LOWER LEVEL CONCRETE BEAM SCHEDULE
MEZZANINE FLOOR CONCRETE BEAM SCHEDULE
FIRST FLOOR CONCRETE BEAM SCHEDULE
FIRST FLOOR CONCRETE BEAM SCHEDULE CONTINUED
SECOND FLOOR CONCRETE BEAM SCHEDULE
CONCRETE ONE-WAY SLAB SCHEDULE
HDR
HOPE FURRER Associates, Inc.
MARYLAND ECONOMIC DEVELOPMENT CORPORATION
STATE OF MARYLAND PUBLIC HEALTH LABORATORY
BALTIMORE, MARYLAND
FOREST CITY NEW EAST BALTIMORE PARTNERSHIP
CONCRETE BEAM + ONE-WAY SLAB SCHEDULE
S6.103
ISSUED FOR CONSTRUCTION



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THIRD FLOOR CONCRETE BEAM SCHEDULE

	MARK	SIZE		REINFORCING					STIRRUPS				ADD'L HORIZ. REINFORCING EACH FACE	REMARKS
		WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP				TYPE	SIZE	SPACING (IN)	END		
					L.E.	F.L.		R.E.						
						LEFT	RIGHT							
	3-B1	28	24	(1)-#8	—	(1)-#7	(1)-#8	—	4	#4	@10" O/C	F.L.	—	CONT. TOP REINF. TO END OF CANT. SPAN
	3-B1C	28	24	(1)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 3-B1 FOR CANT. BEAM TOP BARS
	3-B2	28	24	(1)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 3-B3 FOR CANT. BEAM TOP BARS
	3-B3	28	24	(1)-#7	—	(1)-#8	(1)-#9	—	4	#4	10@8" O/C R@10" O/C	R.E.	—	CONT. TOP REINF. TO END OF CANT. SPAN
	3-B4	28	24	(1)-#8	—	—	(1)-#9	—	4	#4	10@8" O/C R@10" O/C	L.E.	—	
	3-B5	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~3-B6~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	3-B7	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	(2)-#6	
	3-B8	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B9	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~3-B10~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	3-B11	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B12	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~3-B13~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	3-B14	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B15	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
	3-B16	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B17	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B18	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B19	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B20	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B21	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B22	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B23	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B24	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B25	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B26	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B27	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B28	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B29	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B30	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B31	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B32	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B33	10	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B34	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B35	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	—	—	—	—	—	BEAM IS CENTERED ON SHEAR WALL. TOP OF BEAM ELEVATION EQUALS FINISHED FLOOR ELEVATION
	3-B36	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B37	28	30	(7)-#7	—	(7)-#7	(7)-#7	—	4	#4	@8" O/C	F.L.	—	
	3-B38	12	24	(3)-#6	—	(3)-#6	(3)-#6	—	—	—	—	—	—	
	3-B39	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
	3-B40	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B41	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	3-B42	22 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
	3-B43	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	CONT. TOP REINF. TO END OF CANT. SPAN
	3-B43C	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	SEE 3-B43 FOR CANT. BEAM TOP BARS
	3-B44	31 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
NOT USED	~~3-B45~~	~~12~~	~~20~~	~~(3)-#7~~	~~—~~	~~(3)-#6~~	~~(3)-#6~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	3-B46	14	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	—	

NOTES:
1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
   RE = STIRRUPS TO BE PLACED RIGHT END OF BEAM.
   FL = STIRRUPS TO BE PLACED FULL BEAM LENGTH.
   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER S-55.102

FOURTH FLOOR CONCRETE BEAM SCHEDULE

	MARK	SIZE		REINFORCING					STIRRUPS				ADD'L HORIZ. REINFORCING EACH FACE	REMARKS
		WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP				TYPE	SIZE	SPACING (IN)	END		
					L.E.	F.L.		R.E.						
						LEFT	RIGHT							
NOT USED	~~4-B1~~	~~28~~	~~24~~	~~(1)-#9~~	~~—~~	~~—~~	~~(1)-#9~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~(4)-#5~~	
NOT USED	~~4-B2~~	~~28~~	~~24~~	~~(1)-#9~~	~~—~~	~~—~~	~~—~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~(4)-#5~~	
NOT USED	~~4-B3~~	~~28~~	~~24~~	~~(1)-#9~~	~~—~~	~~(1)-#8~~	~~(1)-#8~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~(4)-#5~~	
	4-B4	28	24	(1)-#8	—	(1)-#6	(1)-#6	—	4	#4	@10" O/C	F.L.	—	
	4-B5	28	24	(1)-#9	—	—	—	—	4	#4	@10" O/C	F.L.	—	
	4-B6	28	24	(1)-#7	—	(1)-#7	(1)-#9	—	4	#4	@10" O/C	F.L.	—	
	4-B7	28	24	(1)-#9	—	—	(1)-#9	—	4	#4	@10" O/C	F.L.	—	
	4-B8	28	24	(1)-#8	—	(1)-#6	(1)-#6	—	4	#4	@10" O/C	F.L.	—	CONT. TOP REINF. TO END OF CANT. SPAN
	4-B8C	28	24	(1)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 4-B8 FOR CANT. BEAM TOP BARS
	4-B9	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~4-B10~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	4-B11	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	(2)-#6	
	4-B12	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B13	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~4-B14~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	4-B15	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B16	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED	~~4-B17~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	4-B18	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B19	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
	4-B20	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B21	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B22	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B23	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B24	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B25	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B26	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B27	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B28	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B29	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B30	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B31	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B32	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B33	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B34	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B35	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B36	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B37	10	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B38	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B39	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	—	—	—	—	—	BEAM IS CENTERED ON SHEAR WALL. TOP OF BEAM ELEVATION EQUALS FINISHED FLOOR ELEVATION
	4-B40	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B41	28	30	(7)-#7	—	(7)-#7	(7)-#7	—	4	#4	@8" O/C	F.L.	—	
	4-B42	12	24	(3)-#6	—	(3)-#6	(3)-#6	—	—	—	—	—	—	
	4-B43	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
	4-B44	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B45	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
	4-B46	22 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
	4-B47	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	CONT. TOP REINF. TO END OF CANT. SPAN
	4-B47C	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	SEE 4-B47 FOR CANT. BEAM TOP BARS
	4-B48	31 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
NOT USED	~~4-B49~~	~~12~~	~~20~~	~~(3)-#7~~	~~—~~	~~(3)-#6~~	~~(3)-#6~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
	4-B50	14	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	—	

NOTES:
1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
   RE = STIRRUPS TO BE PLACED RIGHT END OF BEAM.
   FL = STIRRUPS TO BE PLACED FULL BEAM LENGTH.
   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER S-55.102

HDR

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HEALTH
LABORATORY

BALTIMORE, MARYLAND

FORESTCITY-NEWEASTBALTIMORE
PARTNERSHIP

MARK	DATE	DESCRIPTION
	12/08/11	ISSUED FOR CONSTRUCTION

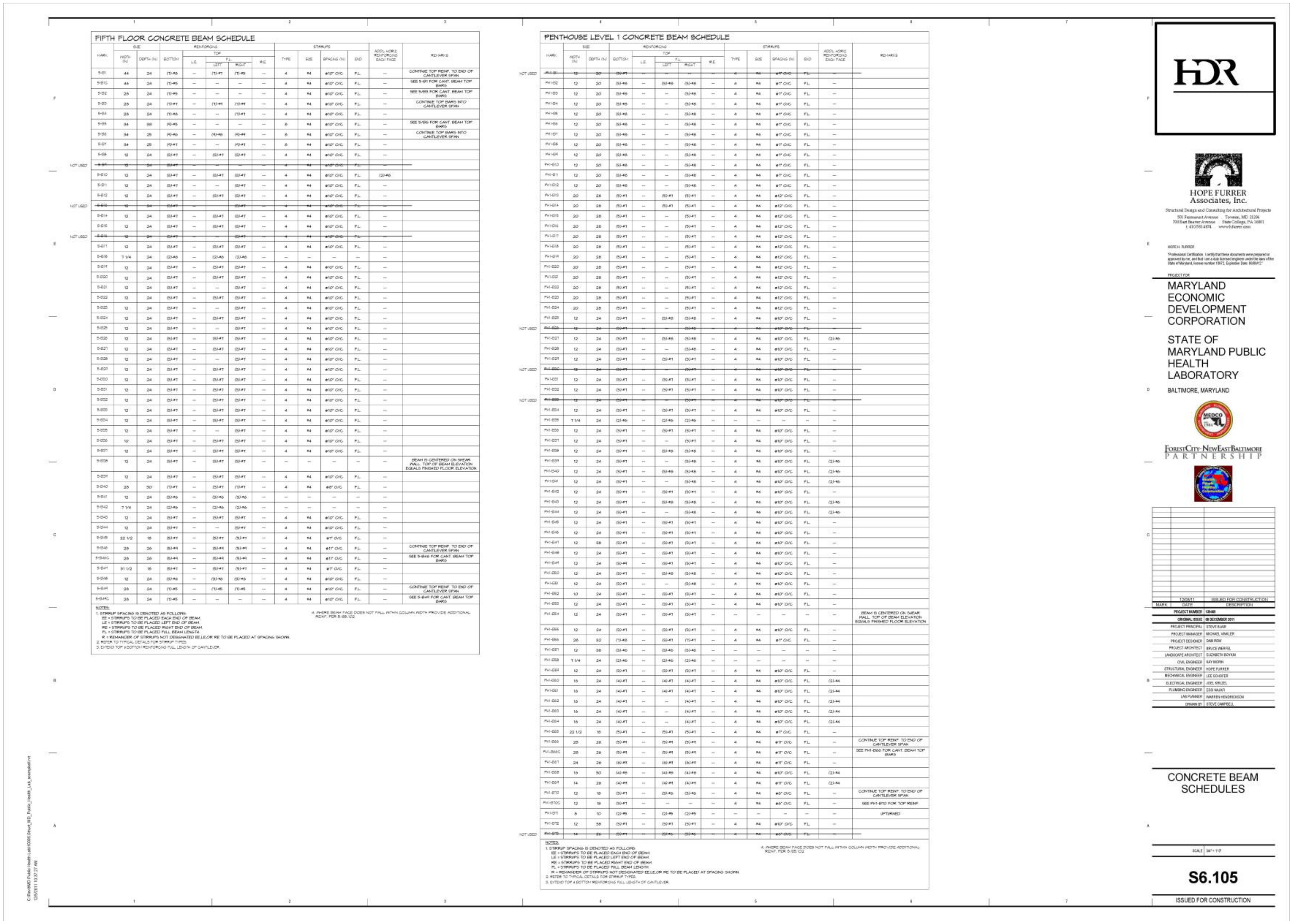
PROJECT NUMBER	135460
ORIGINAL ISSUE	08 DECEMBER 2011
PROJECT PRINCIPAL	STEVE BLAIR
PROJECT MANAGER	MICHAEL VINKLER
PROJECT DESIGNER	DAM REW
PROJECT ARCHITECT	BRUCE WERFEL
LANDSCAPE ARCHITECT	ELIZABETH BOYKIN
CIVIL ENGINEER	KAY MORIN
STRUCTURAL ENGINEER	HOPE FURRER
MECHANICAL ENGINEER	LEE SCHOFER
ELECTRICAL ENGINEER	JOEL KRUZEL
PLUMBING ENGINEER	ESSI NAJAR
LAB PLANNER	WARREN HENDRICKSON
DRAWN BY	STEVE CAMPBELL

CONCRETE BEAM
SCHEDULES

SCALE 3/4" = 1'-0"

S6.104

ISSUED FOR CONSTRUCTION



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FIFTH FLOOR CONCRETE BEAM SCHEDULE

MARK	SIZE		REINFORCING				STIRRUPS				ADD'L HORIZ REINFORCING EACH FACE	REMARKS
	WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP			TYPE	SIZE	SPACING (IN)	END		
				L.E.	F.L. LEFT	F.L. RIGHT	R.E.					
5-B1	44	24	(7)-#8	—	(7)-#7	(7)-#9	—	4	#4	@10" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN
5-B1C	44	24	(7)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 5-B1 FOR CANT. BEAM TOP BARS
5-B2	28	24	(7)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 5-B3 FOR CANT. BEAM TOP BARS
5-B3	28	24	(7)-#7	—	(7)-#9	(7)-#9	—	4	#4	@10" O/C	F.L.	—	CONTINUE TOP BARS INTO CANTILEVER SPAN
5-B4	28	24	(7)-#8	—	—	(7)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B5	34	38	(9)-#8	—	—	—	—	8	#4	@10" O/C	F.L.	—	SEE 5-B6 FOR CANT. BEAM TOP BARS
5-B6	34	28	(9)-#8	—	(9)-#9	(9)-#9	—	8	#4	@10" O/C	F.L.	—	CONTINUE TOP BARS INTO CANTILEVER SPAN
5-B7	34	28	(9)-#7	—	—	(9)-#7	—	8	#4	@10" O/C	F.L.	—	
5-B8	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~5-B9~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~—~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
5-B10	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	(2)-#6	
5-B11	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B12	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~5-B13~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~		~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
5-B14	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B15	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~5-B16~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
5-B17	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B18	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
5-B19	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B20	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B21	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B22	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B23	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B24	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B25	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B26	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B27	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B28	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B29	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B30	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B31	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B32	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B33	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B34	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B35	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B36	10	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B37	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B38	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	—	—	—	—	—	BEAM IS CENTERED ON SHEAR WALL. TOP OF BEAM ELEVATION EQUALS FINISHED FLOOR ELEVATION
5-B39	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B40	28	30	(7)-#7	—	(5)-#7	(7)-#7	—	4	#4	@8" O/C	F.L.	—	
5-B41	12	24	(3)-#6	—	(3)-#6	(3)-#6	—	—	—	—	—	—	
5-B42	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
5-B43	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B44	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
5-B45	22 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
5-B46	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN
5-B46C	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	SEE 5-B46 FOR CANT. BEAM TOP BARS
5-B47	91 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
5-B48	12	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	—	
5-B49	28	24	(7)-#8	—	(7)-#8	(7)-#8	—	4	#4	@10" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN
5-B49C	28	24	(7)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE 5-B49 FOR CANT. BEAM TOP BARS

NOTES:

1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
   RE = STIRRUPS TO BE PLACED RIGHT END OF BEAM.
   FL = STIRRUPS TO BE PLACED FULL BEAM LENGTH.
   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER 5/S5.102

PENTHOUSE LEVEL 1 CONCRETE BEAM SCHEDULE

MARK	SIZE		REINFORCING				STIRRUPS				ADD'L HORIZ REINFORCING EACH FACE	REMARKS
	WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP			TYPE	SIZE	SPACING (IN)	END		
				L.E.	F.L. LEFT	F.L. RIGHT	R.E.					
NOT USED ~~PH1-B1~~	~~12~~	~~20~~	~~(3)-#7~~	~~—~~	~~—~~	~~—~~	~~—~~	~~4~~	~~#4~~	~~@7" O/C~~	~~F.L.~~	~~—~~	
PH1-B2	12	20	(3)-#8	—	(3)-#8	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B3	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B4	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B5	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B6	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B7	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B8	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B9	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B10	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B11	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B12	12	20	(3)-#8	—	—	(3)-#8	—	4	#4	@7" O/C	F.L.	—	
PH1-B13	20	28	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B14	20	28	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B15	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B16	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B17	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B18	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B19	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B20	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B21	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B22	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B23	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B24	20	28	(5)-#7	—	—	(5)-#7	—	4	#4	@12" O/C	F.L.	—	
PH1-B25	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~PH1-B26~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#8~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
PH1-B27	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B28	12	24	(3)-#7	—	—	(3)-#8	—	4	#4	@10" O/C	F.L.	—	
PH1-B29	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~PH1-B30~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
PH1-B31	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B32	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~PH1-B33~~	~~12~~	~~24~~	~~(3)-#7~~	~~—~~	~~—~~	~~(3)-#7~~	~~—~~	~~4~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
PH1-B34	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B35	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
PH1-B36	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B37	12	24	(3)-#7	—	—	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B38	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	—	
PH1-B39	12	24	(3)-#7	—	—	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B40	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B41	12	24	(3)-#7	—	—	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B42	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B43	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B44	12	24	(3)-#7	—	—	(3)-#8	—	4	#4	@10" O/C	F.L.	(2)-#6	
PH1-B45	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B46	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B47	12	36	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B48	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B49	12	24	(3)-#9	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B50	12	24	(3)-#7	—	(3)-#8	(3)-#8	—	4	#4	@10" O/C	F.L.	—	
PH1-B51	12	24	(3)-#7	—	—	(3)-#8	—	4	#4	@10" O/C	F.L.	—	
PH1-B52	10	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B53	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B54	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	—	—	—	—	—	BEAM IS CENTERED ON SHEAR WALL. TOP OF BEAM ELEVATION EQUALS FINISHED FLOOR ELEVATION
PH1-B55	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B56	28	32	(7)-#8	—	(3)-#7	(7)-#7	—	4	#4	@7" O/C	F.L.	—	
PH1-B57	12	36	(3)-#6	—	(3)-#6	(3)-#6	—	—	—	—	—	—	
PH1-B58	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	
PH1-B59	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH1-B60	16	24	(4)-#7	—	(4)-#7	(4)-#7	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B61	16	24	(4)-#7	—	(4)-#7	(4)-#7	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B62	16	24	(4)-#7	—	—	(4)-#7	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B63	16	24	(4)-#7	—	—	(4)-#7	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B64	16	24	(4)-#7	—	—	(4)-#7	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B65	22 1/2	18	(5)-#7	—	(5)-#7	(5)-#7	—	4	#4	@7" O/C	F.L.	—	
PH1-B66	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN
PH1-B66C	28	26	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@11" O/C	F.L.	—	SEE PH1-B66 FOR CANT. BEAM TOP BARS
PH1-B67	24	26	(6)-#9	—	(6)-#9	(6)-#9	—	4	#4	@11" O/C	F.L.	—	
PH1-B68	16	30	(4)-#8	—	(4)-#8	(4)-#8	—	4	#4	@10" O/C	F.L.	(2)-#4	
PH1-B69	14	26	(4)-#9	—	(4)-#9	(4)-#9	—	4	#4	@11" O/C	F.L.	(2)-#4	
PH1-B70	12	18	(3)-#7	—	(3)-#6	(3)-#6	—	4	#4	@8" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN
PH1-B70C	12	18	(3)-#7	—	—	—	—	4	#4	@8" O/C	F.L.	—	SEE PH1-B70 FOR TOP REINF.
PH1-B71	8	10	(2)-#5	—	(2)-#5	(2)-#5	—	—	—	—	—	—	UPTURNED
PH1-B72	12	36	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
NOT USED ~~PH1-B73~~	~~14~~	~~26~~	~~(3)-#7~~	~~—~~	~~(3)-#6~~	~~(3)-#6~~	~~—~~	~~4~~	~~#4~~	~~@8" O/C~~	~~F.L.~~	~~—~~	

NOTES:

1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
   RE = STIRRUPS TO BE PLACED RIGHT END OF BEAM.
   FL = STIRRUPS TO BE PLACED FULL BEAM LENGTH.
   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER 5/S5.102

HDR

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HOPE H. FURRER
"Professional Certification. I certify that these documents were prepared or approved by me, and that I am a duly licensed engineer under the laws of the State of Maryland, license number 19972, Expiration Date: 06/09/12."

PROJECT FOR

MARYLAND
ECONOMIC
DEVELOPMENT
CORPORATION

STATE OF
MARYLAND PUBLIC
HEALTH
LABORATORY

BALTIMORE, MARYLAND

FORESTCITY-NEWEASTBALTIMORE
PARTNERSHIP

MARK	DATE	DESCRIPTION
	12/08/11	ISSUED FOR CONSTRUCTION

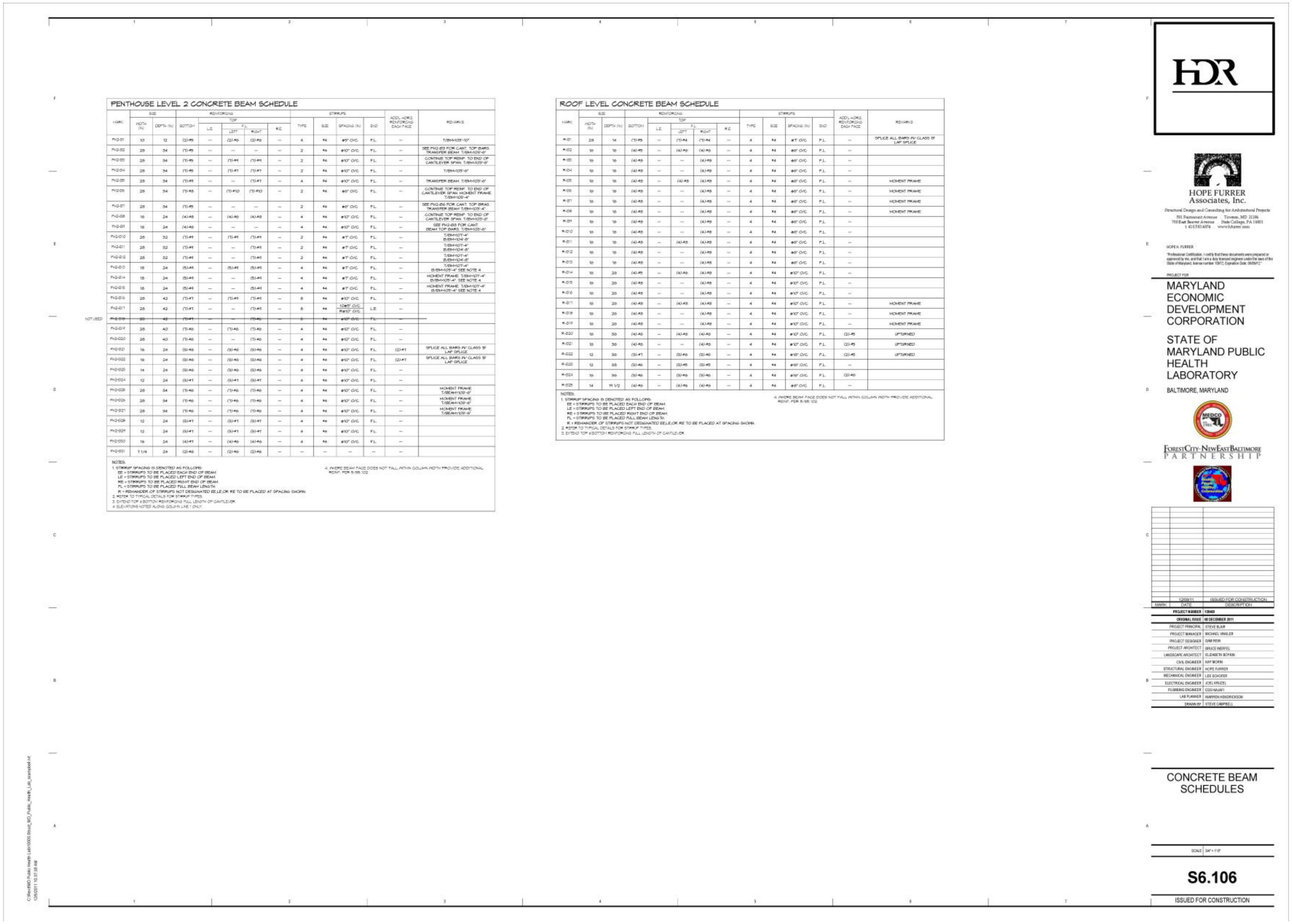
PROJECT NUMBER	139488
ORIGINAL ISSUE	08 DECEMBER 2011
PROJECT PRINCIPAL	STEVE BLAIR
PROJECT MANAGER	MICHAEL VINKLER
PROJECT DESIGNER	DAN ROW
PROJECT ARCHITECT	BRUCE WERFEL
LANDSCAPE ARCHITECT	ELIZABETH BOYKIN
CIVIL ENGINEER	KAY MORIN
STRUCTURAL ENGINEER	HOPE FURRER
MECHANICAL ENGINEER	LEE SCHOFER
ELECTRICAL ENGINEER	JOEL KRUZEL
PLUMBING ENGINEER	ESSI NAJAFI
LAB PLANNER	WARREN HENDRICKSON
DRAWN BY	STEVE CAMPBELL

CONCRETE BEAM
SCHEDULES

SCALE 3/4" = 1'-0"

S6.105

ISSUED FOR CONSTRUCTION



PENTHOUSE LEVEL 2 CONCRETE BEAM SCHEDULE

MARK	SIZE		REINFORCING					STIRRUPS				ADD'L HORIZ. REINFORCING EACH FACE	REMARKS
	WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP				TYPE	SIZE	SPACING (IN)	END		
				L.E.	F.L.		R.E.						
					LEFT	RIGHT							
PH2-B1	10	12	(2)-#5	—	(2)-#6	(2)-#6	—	4	#4	@5" O/C	F.L.	—	T/BM=105'-10"
PH2-B2	28	34	(7)-#9	—	—	—	—	2	#4	@10" O/C	F.L.	—	SEE PH2-B3 FOR CANT. TOP BARS. TRANSFER BEAM. T/BM=109'-6"
PH2-B3	28	34	(7)-#9	—	(7)-#9	(7)-#9	—	2	#4	@10" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN. T/BM=105'-6"
PH2-B4	28	34	(7)-#9	—	(7)-#7	(7)-#7	—	2	#4	@10" O/C	F.L.	—	T/BM=105'-6"
PH2-B5	28	34	(7)-#9	—	—	(7)-#7	—	4	#4	@10" O/C	F.L.	—	TRANSFER BEAM. T/BM=105'-6"
PH2-B6	28	34	(7)-#8	—	(7)-#10	(7)-#10	—	2	#4	@5" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN. MOMENT FRAME T/BM=109'-4"
PH2-B7	28	34	(7)-#9	—	—	—	—	2	#4	@5" O/C	F.L.	—	SEE PH2-B6 FOR CANT. TOP BRAG. TRANSFER BEAM T/BM=105'-4"
PH2-B8	16	24	(4)-#8	—	(4)-#8	(4)-#8	—	4	#4	@10" O/C	F.L.	—	CONTINUE TOP REINF. TO END OF CANTILEVER SPAN. T/BM=105'-6"
PH2-B9	16	24	(4)-#8	—	—	—	—	4	#4	@10" O/C	F.L.	—	SEE PH2-B8 FOR CANT. BEAM TOP BARS. T/BM=105'-6"
PH2-B10	28	32	(7)-#9	—	(7)-#9	(7)-#9	—	2	#4	@7" O/C	F.L.	—	T/BM=107'-4" B/BM=104'-8"
PH2-B11	28	32	(7)-#9	—	—	(7)-#9	—	2	#4	@7" O/C	F.L.	—	T/BM=107'-4" B/BM=104'-8"
PH2-B12	28	32	(7)-#9	—	—	(7)-#9	—	2	#4	@7" O/C	F.L.	—	T/BM=107'-4" B/BM=104'-8"
PH2-B13	18	24	(5)-#9	—	(5)-#9	(5)-#9	—	4	#4	@7" O/C	F.L.	—	T/BM=107'-4" B/BM=105'-4" SEE NOTE 4
PH2-B14	18	24	(5)-#9	—	—	(5)-#9	—	4	#4	@7" O/C	F.L.	—	MOMENT FRAME. T/BM=107'-4" B/BM=105'-4". SEE NOTE 4
PH2-B15	18	24	(5)-#9	—	—	(5)-#9	—	4	#4	@7" O/C	F.L.	—	MOMENT FRAME. T/BM=107'-4" B/BM=105'-4" SEE NOTE 4
PH2-B16	28	42	(7)-#7	—	(7)-#9	(7)-#9	—	6	#4	@10" O/C	F.L.	—	
PH2-B17	28	42	(7)-#7	—	—	(7)-#9	—	6	#4	10@5" O/C R@10" O/C	L.E.	—	
NOT USED ~~PH2-B18~~	~~28~~	~~42~~	~~(7)-#7~~	~~—~~	~~—~~	~~(7)-#8~~	~~—~~	~~6~~	~~#4~~	~~@10" O/C~~	~~F.L.~~	~~—~~	
PH2-B19	28	40	(7)-#8	—	(7)-#8	(7)-#8	—	4	#4	@10" O/C	F.L.	—	
PH2-B20	28	40	(7)-#8	—	—	(7)-#8	—	4	#4	@10" O/C	F.L.	—	
PH2-B21	16	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	(2)-#7	SPLICE ALL BARS W/ CLASS 'B' LAP SPLICE
PH2-B22	16	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	(2)-#7	SPLICE ALL BARS W/ CLASS 'B' LAP SPLICE
PH2-B23	14	24	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@10" O/C	F.L.	—	
PH2-B24	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH2-B25	28	34	(7)-#6	—	(7)-#6	(7)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME T/BEAM=109'-6"
PH2-B26	28	34	(7)-#6	—	(7)-#6	(7)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME T/BEAM=109'-6"
PH2-B27	28	34	(7)-#6	—	(7)-#6	(7)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME T/BEAM=109'-6"
PH2-B28	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH2-B29	12	24	(3)-#7	—	(3)-#7	(3)-#7	—	4	#4	@10" O/C	F.L.	—	
PH2-B30	16	24	(4)-#7	—	(4)-#6	(4)-#6	—	4	#4	@10" O/C	F.L.	—	
PH2-B31	7 1/4	24	(2)-#6	—	(2)-#6	(2)-#6	—	—	—	—	—	—	

NOTES:
1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
   RE = STIRRUPS TO BE PLACED RIGHT END OF BEAM.
   FL = STIRRUPS TO BE PLACED FULL BEAM LENGTH.
   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. ELEVATIONS NOTED ALONG COLUMN LINE 1 ONLY.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER S/S5.102

ROOF LEVEL CONCRETE BEAM SCHEDULE

MARK	SIZE		REINFORCING					STIRRUPS				ADD'L HORIZ. REINFORCING EACH FACE	REMARKS
	WIDTH (IN)	DEPTH (IN)	BOTTOM	TOP				TYPE	SIZE	SPACING (IN)	END		
				L.E.	F.L.		R.E.						
					LEFT	RIGHT							
R-B1	28	14	(7)-#5	—	(7)-#4	(7)-#4	—	4	#4	@7" O/C	F.L.	—	SPLICE ALL BARS W/ CLASS 'B' LAP SPLICE
R-B2	16	16	(4)-#5	—	(4)-#6	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B3	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B4	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B5	16	16	(4)-#5	—	(4)-#6	(4)-#6	—	4	#4	@8" O/C	F.L.	—	MOMENT FRAME
R-B6	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	MOMENT FRAME
R-B7	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	MOMENT FRAME
R-B8	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	MOMENT FRAME
R-B9	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B10	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B11	16	16	(4)-#5	—	(4)-#6	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B12	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B13	16	16	(4)-#5	—	—	(4)-#6	—	4	#4	@8" O/C	F.L.	—	
R-B14	16	26	(4)-#5	—	(4)-#6	(4)-#6	—	4	#4	@10" O/C	F.L.	—	
R-B15	16	26	(4)-#5	—	—	(4)-#6	—	4	#4	@10" O/C	F.L.	—	
R-B16	16	26	(4)-#5	—	—	(4)-#6	—	4	#4	@10" O/C	F.L.	—	
R-B17	16	26	(4)-#5	—	(4)-#6	(4)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME
R-B18	16	26	(4)-#5	—	—	(4)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME
R-B19	16	26	(4)-#5	—	—	(4)-#6	—	4	#4	@10" O/C	F.L.	—	MOMENT FRAME
R-B20	16	36	(4)-#6	—	(4)-#6	(4)-#6	—	4	#4	@10" O/C	F.L.	(2)-#5	UPTURNED
R-B21	16	36	(4)-#5	—	—	(4)-#5	—	4	#4	@10" O/C	F.L.	(2)-#5	UPTURNED
R-B22	12	36	(3)-#7	—	(3)-#6	(3)-#6	—	4	#4	@16" O/C	F.L.	(2)-#5	UPTURNED
R-B23	12	36	(3)-#6	—	(3)-#5	(3)-#5	—	4	#4	@16" O/C	F.L.	—	
R-B24	16	36	(3)-#6	—	(3)-#6	(3)-#6	—	4	#4	@16" O/C	F.L.	(2)-#6	
R-B25	14	19 1/2	(4)-#6	—	(4)-#6	(4)-#6	—	4	#4	@8" O/C	F.L.	—	

NOTES:
1. STIRRUP SPACING IS DENOTED AS FOLLOWS:
   EE = STIRRUPS TO BE PLACED EACH END OF BEAM.
   LE = STIRRUPS TO BE PLACED LEFT END OF BEAM.
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   R = REMAINDER OF STIRRUPS NOT DESIGNATED EE,LE,OR RE TO BE PLACED AT SPACING SHOWN.
2. REFER TO TYPICAL DETAILS FOR STIRRUP TYPES.
3. EXTEND TOP & BOTTOM REINFORCING FULL LENGTH OF CANTILEVER.
4. WHERE BEAM FACE DOES NOT FALL WITHIN COLUMN WIDTH PROVIDE ADDITIONAL REINF. PER S/S5.102

HDR

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HOPE H. FURRER
"Professional Certification. I certify that these documents were prepared or approved by me, and that I am a duly licensed engineer under the laws of the State of Maryland, license number 10972, Expiration Date: 06/09/12."

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LABORATORY

BALTIMORE, MARYLAND

ForestCity-NewEastBaltimore
PARTNERSHIP

MARK	DATE	DESCRIPTION
	12/08/11	ISSUED FOR CONSTRUCTION

PROJECT NUMBER	[illegible]
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LAB PLANNER	WARREN HENDRICKSON
DRAWN BY	STEVE CAMPBELL

CONCRETE BEAM
SCHEDULES

SCALE [illegible]

S6.106

ISSUED FOR CONSTRUCTION

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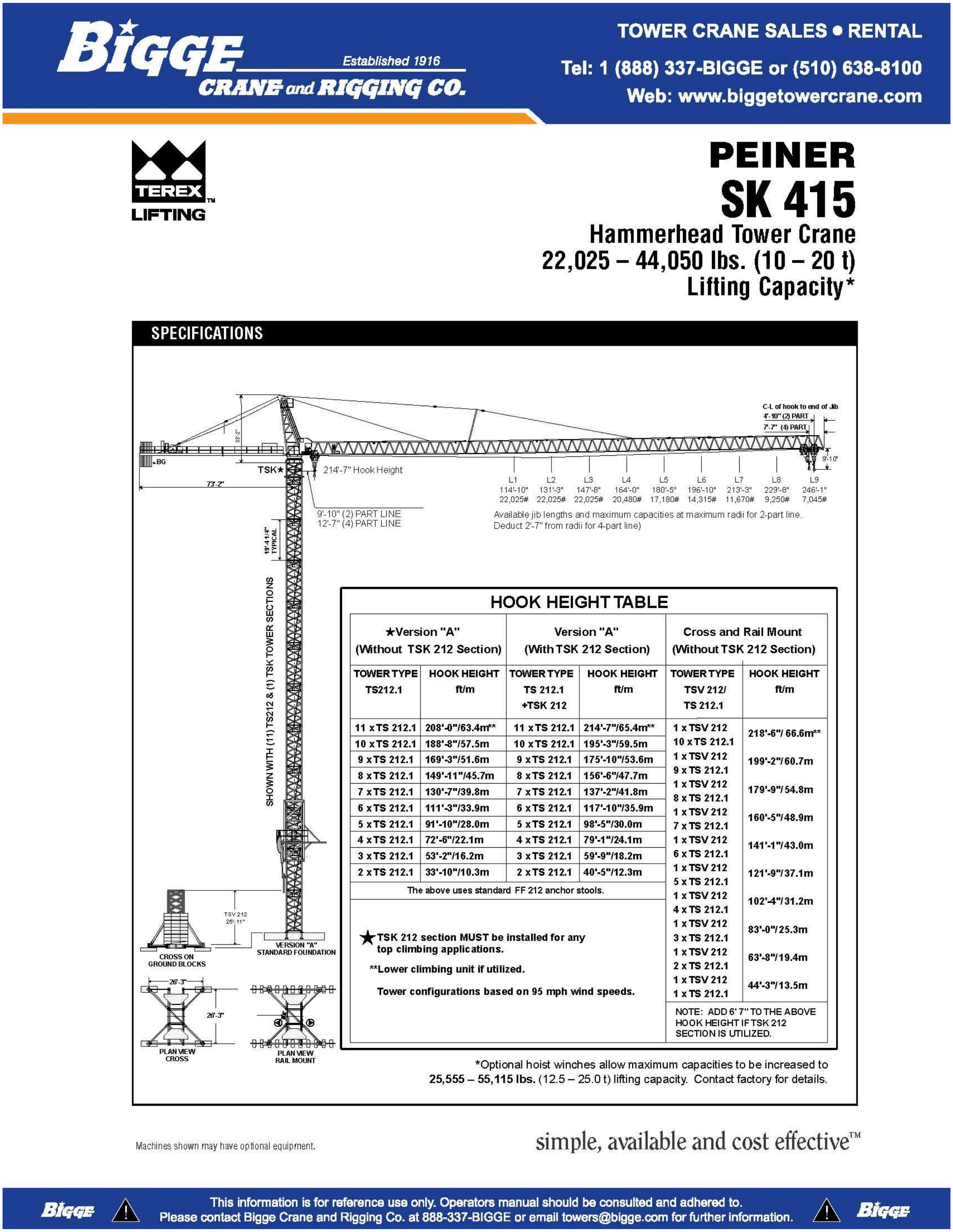
Appendix K: Tower Crane Specifications



BIGGE Established 1916
CRANE and RIGGING CO.

TOWER CRANE SALES • RENTAL
Tel: 1 (888) 337-BIGGE or (510) 638-8100
Web: www.biggetowercrane.com

TEREX LIFTING

PEINER
SK 415

Hammerhead Tower Crane
22,025 – 44,050 lbs. (10 – 20 t)
Lifting Capacity*

SPECIFICATIONS

L1	L2	L3	L4	L5	L6	L7	L8	L9
114'-10"	131'-3"	147'-8"	164'-0"	180'-5"	196'-10"	213'-3"	229'-8"	246'-1"
22,025#	22,025#	22,025#	20,480#	17,180#	14,315#	11,670#	9,250#	7,045#

Available jib lengths and maximum capacities at maximum radii for 2-part line. Deduct 2'-7" from radii for 4-part line)

HOOK HEIGHT TABLE

★Version "A" (Without TSK 212 Section)		Version "A" (With TSK 212 Section)		Cross and Rail Mount (Without TSK 212 Section)	
TOWER TYPE TS212.1	HOOK HEIGHT ft/m	TOWER TYPE TS 212.1 +TSK 212	HOOK HEIGHT ft/m	TOWER TYPE TSV 212/ TS 212.1	HOOK HEIGHT ft/m
11 x TS 212.1	208'-0"/63.4m**	11 x TS 212.1	214'-7"/65.4m**	1 x TSV 212 10 x TS 212.1	218'-6"/ 66.6m**
10 x TS 212.1	188'-8"/57.5m	10 x TS 212.1	195'-3"/59.5m	1 x TSV 212 9 x TS 212.1	199'-2"/60.7m
9 x TS 212.1	169'-3"/51.6m	9 x TS 212.1	175'-10"/53.6m	1 x TSV 212 8 x TS 212.1	179'-9"/54.8m
8 x TS 212.1	149'-11"/45.7m	8 x TS 212.1	156'-6"/47.7m	1 x TSV 212 7 x TS 212.1	160'-5"/48.9m
7 x TS 212.1	130'-7"/39.8m	7 x TS 212.1	137'-2"/41.8m	1 x TSV 212 6 x TS 212.1	141'-1"/43.0m
6 x TS 212.1	111'-3"/33.9m	6 x TS 212.1	117'-10"/35.9m	1 x TSV 212 5 x TS 212.1	121'-9"/37.1m
5 x TS 212.1	91'-10"/28.0m	5 x TS 212.1	98'-5"/30.0m	1 x TSV 212 4 x TS 212.1	102'-4"/31.2m
4 x TS 212.1	72'-6"/22.1m	4 x TS 212.1	79'-1"/24.1m	1 x TSV 212 3 x TS 212.1	83'-0"/25.3m
3 x TS 212.1	53'-2"/16.2m	3 x TS 212.1	59'-9"/18.2m	1 x TSV 212 2 x TS 212.1	63'-8"/19.4m
2 x TS 212.1	33'-10"/10.3m	2 x TS 212.1	40'-5"/12.3m	1 x TSV 212 1 x TS 212.1	44'-3"/13.5m

The above uses standard FF 212 anchor stools.

★TSK 212 section MUST be installed for any top climbing applications.

****Lower climbing unit if utilized.**

Tower configurations based on 95 mph wind speeds.

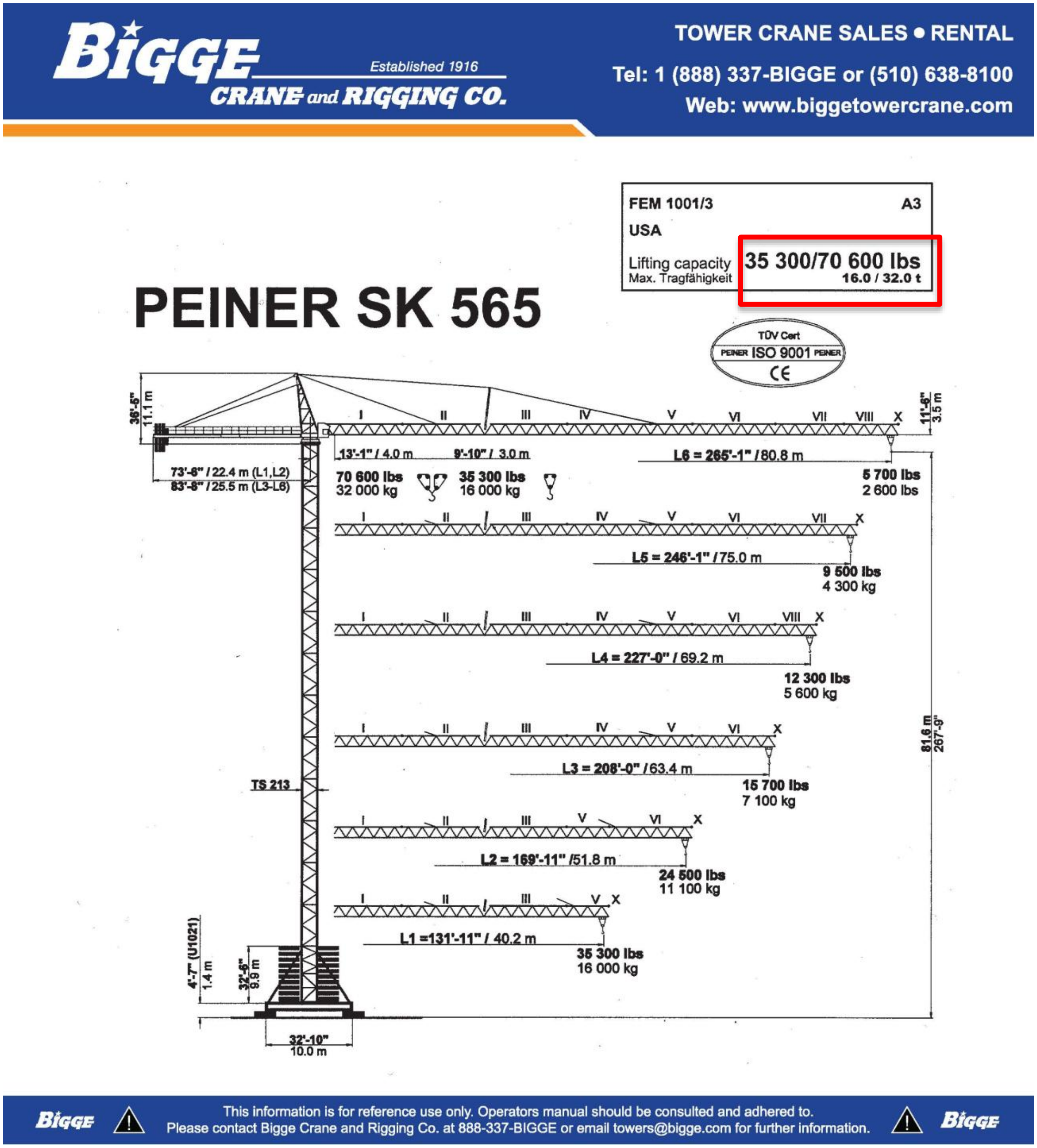
NOTE: ADD 6' 7" TO THE ABOVE HOOK HEIGHT IF TSK 212 SECTION IS UTILIZED.

*Optional hoist winches allow maximum capacities to be increased to **25,555 – 55,115 lbs.** (12.5 – 25.0 t) lifting capacity. Contact factory for details.

Machines shown may have optional equipment.

simple, available and cost effective™

Bigge ⚠ This information is for reference use only. Operators manual should be consulted and adhered to.
Please contact Bigge Crane and Rigging Co. at 888-337-BIGGE or email towers@bigge.com for further information. ⚠ Bigge



BIGGE CRANE and RIGGING CO. Established 1916

TOWER CRANE SALES ● RENTAL

Tel: 1 (888) 337-BIGGE or (510) 638-8100

Web: www.biggetowercrane.com

FEM 1001/3	A3
USA	
Lifting capacity Max. Tragfähigkeit	35 300/70 600 lbs 16.0 / 32.0 t

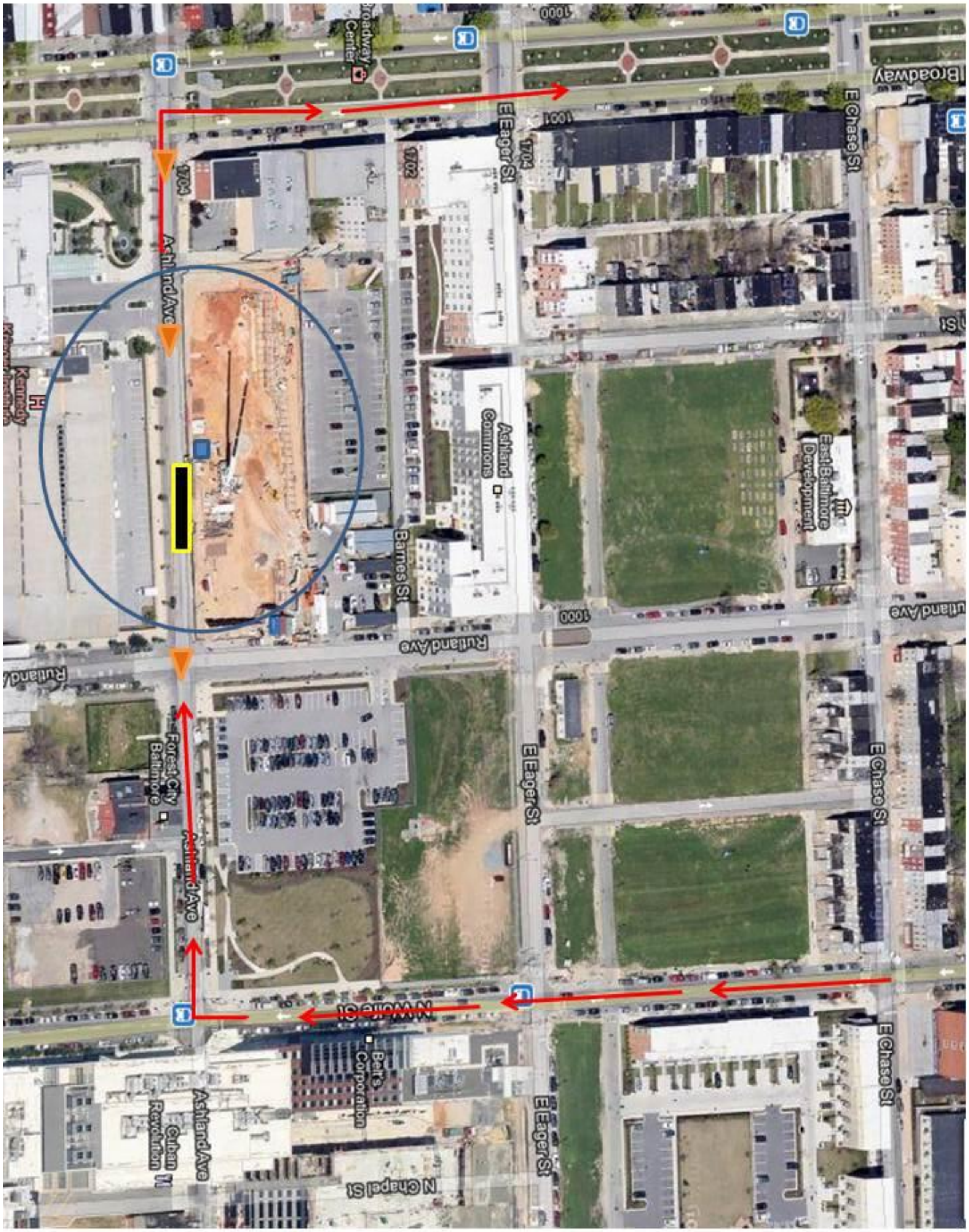
PEINER SK 565

TÜV Cert PEINER ISO 9001 PEINER CE

This information is for reference use only. Operators manual should be consulted and adhered to.
Please contact Bigge Crane and Rigging Co. at 888-337-BIGGE or email towers@bigge.com for further information.

Appendix L: Delivery Logistical Plan


N Broadway
Ashland Ave
1704
1702
1001
1000
Barnes St
E Eager St
Ashland Commons
Rutland Ave


Broadway
Broadway Center
1000
1001
1704
1702
E Eager St
E Chase St
Ashland Ave
Kennedy Krieger Institute
Ashland Commons
East Baltimore Development
Barnes St
Rutland Ave
Forest City Baltimore
N Wolfe St
Bell's Corporation
Cuban Revolution
N Chapel St

Appendix M: Precast Structural Cost Estimate (Vendor Pricing)

Precast Structural System Costs Analysis Sheet (Vendor Pricing)

SLAB PRODUCTION

Member Description	Dimensions (ft. x ft. x in.)	Quantity	Cost/Sq. Ft.	Total Cost
8" Hollow Core Slab with 2" Topping (2hr. FR)	32' x 4' x 8"	1739	$ 8.00	$ 1,780,736.00
	36' x 4' x 8"	94	$ 8.00	$ 108,288.00
	TOTAL	1833		$ 1,889,024.00

COLUMN PRODUCTION

Member Description	Col. #'s	Length (in.	Width (in.)	Height (ft.)	Quantity	Cost/Ft.	Total Cost
	E.4/6.8,7.8,9.2,14,15,15.5,10.1,15.6; E.7/9.2; P2	10	18	36	10	$ 140.00	$ 50,400.00
	E.3/5.9	10	29	36	1	$ 140.00	$ 5,040.00
	E.1/5.9	10	31	38	1	$ 140.00	$ 5,320.00
	D.4/3.7	12	12	8.5	1	$ 140.00	$ 1,190.00
	A.3/3	12	12	20	1	$ 140.00	$ 2,800.00
	P3	12	12	40	1	$ 140.00	$ 5,600.00
	D.1/3.7	12	18	8.5	1	$ 140.00	$ 1,190.00
	B.2/3.5; C.6/3.5	12	24	48	2	$ 140.00	$ 13,440.00
	B.2/3.5; C.6/3.5	14-12*	24	54	2	$ 140.00	$ 15,120.00
	C.7/12.9	14	22	48	1	$ 140.00	$ 6,720.00
	C.7/12.9	14	22	54	1	$ 140.00	$ 7,560.00
	C/4.7; B/4.7; C/12.6; B/12.6; D.6/10.7	14	28	20	5	$ 140.00	$ 14,000.00
	D.6/11-13, 13.9	18	10	18	4	$ 140.00	$ 10,080.00
	A.3/1.8; D.6/10	18	10	36	2	$ 140.00	$ 10,080.00
	A.3/1.8; D.6/10	18	10	54	2	$ 140.00	$ 15,120.00
	D.7/2.6	18	12	20	1	$ 140.00	$ 2,800.00
	A.6/14.1; A.6/14.5	18	12	48	2	$ 140.00	$ 13,440.00
	A.6/14.1; A.6/14.5	18	12	54	2	$ 140.00	$ 15,120.00
	E/1	20-16*	20-16*	40	1	$ 140.00	$ 5,600.00

Precast Concrete (Compressive Strength 5,000 psi)	A.9/14.5; B.3/14.5; B.5/13.1; P1	24	12	40	4	$ 140.00	$ 22,400.00
	A.9/14.5; B.3/14.5; B.5/13.1; A.9/3.6; B.4/14.1	24	12	48	5	$ 140.00	$ 33,600.00
	A.9/14.5; B.3/14.5; B.5/13.1; A.9/3.6; B.4/14.1	24	14-12*	54	5	$ 140.00	$ 37,800.00
	B/4	28	12	40	2	$ 140.00	$ 11,200.00
	C.3/5-12; D.4/12-14	28	14	20	11	$ 140.00	$ 30,800.00
	A.9/14; B.9/13	28	14	40	2	$ 140.00	$ 11,200.00
	A.9/14; B.9/13	28	14	48	2	$ 140.00	$ 13,440.00
	A.9/14; B.9/13	28	14	54	2	$ 140.00	$ 15,120.00
	E/2-11	28	20-16*	40	10	$ 140.00	$ 56,000.00
	C/2,6-11; D/2; D.4/5; D.4/6	28	28	20	10	$ 140.00	$ 28,000.00
	B/12; B/16; C/16; D/16	28	28	32	4	$ 140.00	$ 17,920.00
	B/1,2*,15 ; B/12; C/1,4*; D/4-15; D/3; E/15; D/1; C/15; E/12-14; C/3; B/3*; B/5-11,13	28	28	40	35	$ 140.00	$ 196,000.00

	A/3-14; B/1,2*,15; C/2,6-11; C/1,4*; D/2; D/4-15; D/3; E/1; E/2-11; E/15; D/1; C/15; E/12-14; B/4; C/3; B/3*; B/5-11,13	28	28	48	66	$ 140.00	$ 443,520.00
	A/3-14; B/1,2*,15; B/16; C/2,6-11; C/1,4*; C/16; D/2; D/16; E/1; E/2-11; E/15; D/1; C/5,12; C/15; E/12-14	28	28	54	47	$ 140.00	$ 355,320.00
	B/12	30-3/4	28	20	1	$ 140.00	$ 2,800.00
	D/4-15; D/3; C/3; B/3*; B/5-11,13	0-3/4- 28*	28	54	23	$ 140.00	$ 173,880.00
	C/14	36	12	40	1	$ 140.00	$ 5,600.00
			TOTAL		271		$ 1,655,220.00

BEAM PRODUCTION

Member Description	**Beam #'s**	**Width (in.)**	**Detph (in.)**	**Legth (ft.)**	**Quantity**	**Cost/Ft.**	**Total Cost**
Lower Level							
Precast Concrete	1-GB1	24	24	18	1	$ 155.00	$ 2,790.00
Mezzanine Level							
Precast Concrete	M-B1-B3	18	36	16	3	$ 155.00	$ 7,440.00
(Compressive Strength	M-B4	16	16	40.5	1	$ 155.00	$ 6,277.50

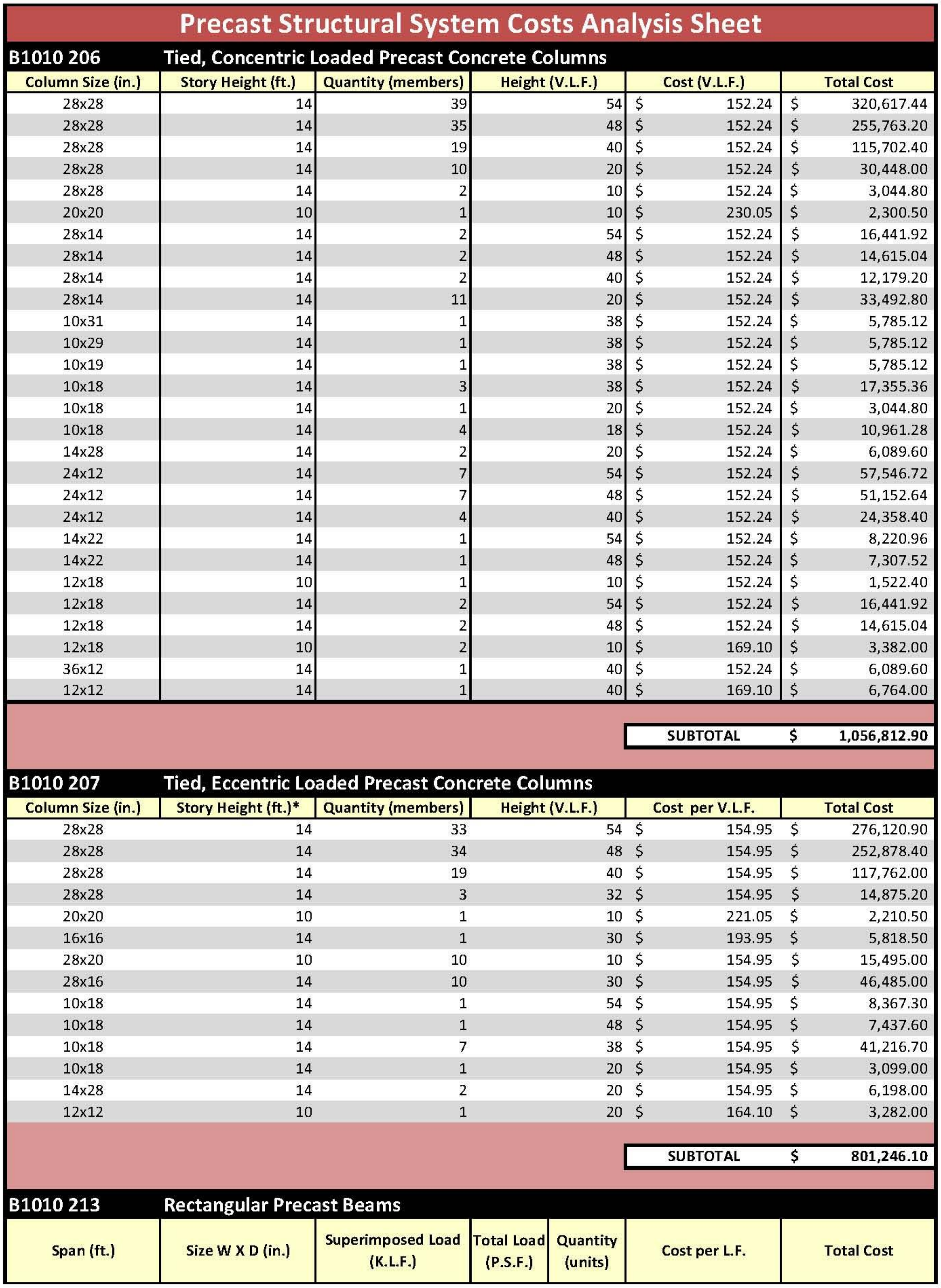
5,000 psi)	M-B5	8	24	54	1	$ 155.00	$ 8,370.00
First Level							
Precast Concrete (Compressive Strength 5,000 psi)	1-B1	12	37	23.35	3	$ 155.00	$ 10,857.75
	1-B5-21, 25, 29, 32-33, 35, 39, 43, 48, 60	12	24	36	25	$ 155.00	$ 139,500.00
	1-B23-24,	30	18	19.2	3	$ 155.00	$ 8,928.00
	1-B26	14	24	30.86	1	$ 155.00	$ 4,783.30
	1-B27-28	16	24	27	2	$ 155.00	$ 8,370.00
	1-B34	10	24	43.2	1	$ 155.00	$ 6,696.00
	1-B36-38	28	24	15.43	3	$ 155.00	$ 7,174.95
	1-B41	28	30	12.34	1	$ 155.00	$ 1,912.70
	1-B42, 47	7-1/4	24	59.59	2	$ 155.00	$ 18,472.90
	1-B49, 59	24	32	13.5	2	$ 155.00	$ 4,185.00
	1-B50, 62	12	32	27	2	$ 155.00	$ 8,370.00
	1-B51, 51C	40	30	8.64	2	$ 155.00	$ 2,678.40
	1-B52	18	26	22.15	1	$ 155.00	$ 3,433.25
	1-B53	18	18	32	1	$ 155.00	$ 4,960.00
	1-B54-56	12	56	15.43	3	$ 155.00	$ 7,174.95
	1-B57	12	26	33.23	1	$ 155.00	$ 5,150.65
	1-B58	16	30	21.6	1	$ 155.00	$ 3,348.00
	1-B59	24	32	13.5	1	$ 155.00	$ 2,092.50
	1-B61	18	24	24	1	$ 155.00	$ 3,720.00
	1-B63	28	32	11.57	1	$ 155.00	$ 1,793.35
	1-B64, 64C	28	30	12.34	2	$ 155.00	$ 3,825.40
Second Level							
Precast Concrete (Compressive Strength 5,000 psi)	2-B3-6	28	24	15.43	5	$ 155.00	$ 11,958.25
	2-B7-10	14	18	41.14	4	$ 155.00	$ 25,506.80
	2-B11	28	41	9.03	1	$ 155.00	$ 1,399.65
	2-B12	28	33	11.22	1	$ 155.00	$ 1,739.10
	2-B12C, 13	28	30	12.34	3	$ 155.00	$ 5,738.10
	2-B14-17	12	18	48	4	$ 155.00	$ 29,760.00
	2-B18	10	38	27.28	1	$ 155.00	$ 4,228.40
	2-B19	14	22	33.66	1	$ 155.00	$ 5,217.30
	2-B20	18	22	26.18	1	$ 155.00	$ 4,057.90
	2-B21-22	18	28	20.57	2	$ 155.00	$ 6,376.70
	2-B23	22-1/2	64	7.2	1	$ 155.00	$ 1,116.00
	2-B24	18	37	15.57	1	$ 155.00	$ 2,413.35
	2-B25-30, B33-52, B54, B57-58, B68	12	24	36	29	$ 155.00	$ 161,820.00
	2-B31, B55	7-1/4	24	59.59	3	$ 155.00	$ 27,709.35
	2-B63	22-1/2	18	25.6	1	$ 155.00	$ 3,968.00

	2-B64, 64	22-1/2	26	17.72	2	$ 155.00	$ 5,493.20
	2-B65	34-1/2	18	16.69	1	$ 155.00	$ 2,586.95
	2-B66, B7	10	24	43.2	3	$ 155.00	$ 20,088.00
	2-B67	14	41	18.06	1	$ 155.00	$ 2,799.30
	2-B69	14	24	30.86	1	$ 155.00	$ 4,783.30
	2-B71	28	18	20.57	1	$ 155.00	$ 3,188.35
Third Level							
Precast Concrete (Compressive Strength 5,000 psi)	3-B1-4	28	24	15.43	4	$ 155.00	$ 9,566.60
	3-B5, 7-9, 11-12, 14, 16-32, 34-36, 38, 40-41	12	24	36	30	$ 155.00	$ 167,400.00
	3-B15, B3	7-1/4	24	59.59	2	$ 155.00	$ 18,472.90
	3-B33	10	24	43.2	1	$ 155.00	$ 6,696.00
	3-B37	28	30	12.34	1	$ 155.00	$ 1,912.70
	3-B42	22-1/2	18	25.6	1	$ 155.00	$ 3,968.00
	3-B43, 43	28	26	14.24	2	$ 155.00	$ 4,414.40
	3-B44	31-1/2	18	18.29	1	$ 155.00	$ 2,834.95
	3-B46	14	24	30.86	1	$ 155.00	$ 4,783.30
Fourth Level							
Precast Concrete (Compressive Strength 5,000 psi)	4-B4-8, 8C	28	24	15.43	6	$ 155.00	$ 14,349.90
	4-B9, 11-13, 15-16, 18, 20-40, 42, 44-45	12	24	36	31	$ 155.00	$ 172,980.00
	4-B19, B4	7-1/4	24	59.59	2	$ 155.00	$ 18,472.90
	4-B41	28	30	12.34	1	$ 155.00	$ 1,912.70
	4-B46	22-1/2	18	25.6	1	$ 155.00	$ 3,968.00
	4-B47, 47	28	26	14.24	2	$ 155.00	$ 4,414.40
	4-B48	31-1/2	18	18.29	1	$ 155.00	$ 2,834.95
	4-B50	14	24	30.86	1	$ 155.00	$ 4,783.30
Fifth Level							
Precast Concrete (Compressive Strength 5,000 psi)	5-B1, 1C	44	24	9.82	2	$ 155.00	$ 3,044.20
	5-B2-4	28	24	15.43	3	$ 155.00	$ 7,174.95
	5-B5	34	38	8.02	1	$ 155.00	$ 1,243.10
	5-B6-7	34	25	12.2	2	$ 155.00	$ 3,782.00
	5-B8, 10-12, 14-15, 17, 19-35, 37-39, 41, 43-44, 48	12	24	36	31	$ 155.00	$ 172,980.00
	5-B18, 42	7-1/4	24	59.59	2	$ 155.00	$ 18,472.90
	5-B36	10	24	43.2	1	$ 155.00	$ 6,696.00
	5-B40	28	30	12.3	1	$ 155.00	$ 1,906.50

	5-B45	22-1/2	18	25.6	1	$ 155.00	$ 3,968.00
	5-B46, 46	28	26	14.24	2	$ 155.00	$ 4,414.40
	5-B47	31-1/2	18	18.29	1	$ 155.00	$ 2,834.95
	5-B49, 49	28	24	14.43	2	$ 155.00	$ 4,473.30
Lower Penthouse Level							
Precast Concrete (Compressive Strength 5,000 psi)	PH1-B2-12	12	20	43.2	11	$ 155.00	$ 73,656.00
	PH1-B13-2	20	28	18.51	12	$ 155.00	$ 34,428.60
	PH1-B25, 27-29, 31-32, 34, 36-46, 48-51, 53-55, 59	12	24	36	26	$ 155.00	$ 145,080.00
	PH1-B35,	7-1/4	24	59.59	2	$ 155.00	$ 18,472.90
	PH1-B47,	12	38	22.74	3	$ 155.00	$ 10,574.10
	PH1-B52	10	24	43.2	1	$ 155.00	$ 6,696.00
	PH1-B56	28	32	11.57	1	$ 155.00	$ 1,793.35
	PH1-B60-6	16	24	27	5	$ 155.00	$ 20,925.00
	PH1-B65	22-1/2	18	25.6	1	$ 155.00	$ 3,968.00
	PH1-B66,	28	26	14.24	2	$ 155.00	$ 4,414.40
	PH1-B67	24	26	16.62	1	$ 155.00	$ 2,576.10
	PH1-B68	16	30	21.6	1	$ 155.00	$ 3,348.00
	PH1-B69	14	26	28.48	1	$ 155.00	$ 4,414.40
	PH1-B70,	12	18	48	2	$ 155.00	$ 14,880.00
	PH1-B71	8	10	129.6	1	$ 155.00	$ 20,088.00
Upper Penthouse Level							
Precast Concrete (Compressive Strength 5,000 psi)	PH2-B1	10	12	86.4	1	$ 155.00	$ 13,392.00
	PH2-B2-7,	28	34	10.89	9	$ 155.00	$ 15,191.55
	PH2-B8-9,	16	24	27	5	$ 155.00	$ 20,925.00
	PH2-B10-1	28	32	11.57	3	$ 155.00	$ 5,380.05
	PH2-B13-1	18	24	24	3	$ 155.00	$ 11,160.00
	PH2-B16-1	28	42	8.82	2	$ 155.00	$ 2,734.20
	PH2-B19-2	28	40	9.26	2	$ 155.00	$ 2,870.60
	PH2-B23	14	24	30.86	1	$ 155.00	$ 4,783.30
	PH2-B24,	12	24	36	3	$ 155.00	$ 16,740.00
	PH2-B31	7-1/4	24	59.59	1	$ 155.00	$ 9,236.45
Roof Level							
Precast Concrete (Compressive Strength 5,000 psi)	R-B1	28	14	26.45	1	$ 155.00	$ 4,099.75
	R-B2-13	16	16	40.5	12	$ 155.00	$ 75,330.00
	R-B14-19	16	26	24.92	6	$ 155.00	$ 23,175.60
	R-B20-21,	16	36	18	3	$ 155.00	$ 8,370.00
	R-B22	12	36	24	1	$ 155.00	$ 3,720.00
	R-B23	12	38	22.74	1	$ 155.00	$ 3,524.70
	R-B25	14	19-1/2	37.98	1	$ 155.00	$ 5,886.90
			TOTAL	2948.29	394		$ 1,880,842.85

TOTAL COST OF SUPERSTRUCTURE	**$**	**5,425,086.85**

Appendix N: Precast Structural Cost Estimate (RSMeans Cost Data)



Precast Structural System Costs Analysis Sheet

B1010 206 Tied, Concentric Loaded Precast Concrete Columns

Column Size (in.)	Story Height (ft.)	Quantity (members)	Height (V.L.F.)	Cost (V.L.F.)	Total Cost
28x28	14	39	54	$ 152.24	$ 320,617.44
28x28	14	35	48	$ 152.24	$ 255,763.20
28x28	14	19	40	$ 152.24	$ 115,702.40
28x28	14	10	20	$ 152.24	$ 30,448.00
28x28	14	2	10	$ 152.24	$ 3,044.80
20x20	10	1	10	$ 230.05	$ 2,300.50
28x14	14	2	54	$ 152.24	$ 16,441.92
28x14	14	2	48	$ 152.24	$ 14,615.04
28x14	14	2	40	$ 152.24	$ 12,179.20
28x14	14	11	20	$ 152.24	$ 33,492.80
10x31	14	1	38	$ 152.24	$ 5,785.12
10x29	14	1	38	$ 152.24	$ 5,785.12
10x19	14	1	38	$ 152.24	$ 5,785.12
10x18	14	3	38	$ 152.24	$ 17,355.36
10x18	14	1	20	$ 152.24	$ 3,044.80
10x18	14	4	18	$ 152.24	$ 10,961.28
14x28	14	2	20	$ 152.24	$ 6,089.60
24x12	14	7	54	$ 152.24	$ 57,546.72
24x12	14	7	48	$ 152.24	$ 51,152.64
24x12	14	4	40	$ 152.24	$ 24,358.40
14x22	14	1	54	$ 152.24	$ 8,220.96
14x22	14	1	48	$ 152.24	$ 7,307.52
12x18	10	1	10	$ 152.24	$ 1,522.40
12x18	14	2	54	$ 152.24	$ 16,441.92
12x18	14	2	48	$ 152.24	$ 14,615.04
12x18	10	2	10	$ 169.10	$ 3,382.00
36x12	14	1	40	$ 152.24	$ 6,089.60
12x12	14	1	40	$ 169.10	$ 6,764.00
				SUBTOTAL	$ 1,056,812.90

B1010 207 Tied, Eccentric Loaded Precast Concrete Columns

Column Size (in.)	Story Height (ft.)*	Quantity (members)	Height (V.L.F.)	Cost per V.L.F.	Total Cost
28x28	14	33	54	$ 154.95	$ 276,120.90
28x28	14	34	48	$ 154.95	$ 252,878.40
28x28	14	19	40	$ 154.95	$ 117,762.00
28x28	14	3	32	$ 154.95	$ 14,875.20
20x20	10	1	10	$ 221.05	$ 2,210.50
16x16	14	1	30	$ 193.95	$ 5,818.50
28x20	10	10	10	$ 154.95	$ 15,495.00
28x16	14	10	30	$ 154.95	$ 46,485.00
10x18	14	1	54	$ 154.95	$ 8,367.30
10x18	14	1	48	$ 154.95	$ 7,437.60
10x18	14	7	38	$ 154.95	$ 41,216.70
10x18	14	1	20	$ 154.95	$ 3,099.00
14x28	14	2	20	$ 154.95	$ 6,198.00
12x12	10	1	20	$ 164.10	$ 3,282.00
				SUBTOTAL	$ 801,246.10

B1010 213 Rectangular Precast Beams

Span (ft.)	Size W X D (in.)	Superimposed Load (K.L.F.)	Total Load (P.S.F.)	Quantity (units)	Cost per L.F.	Total Cost

15	12x16	2.34	2.52	51	$ 173.45	$ 132,689.25
15	12X24	5.60	5.90	162	$ 185.00	$ 449,550.00
15	18x20	5.85	6.73	2	$ 191.00	$ 5,730.00
15	18x36	5.80	6.40	3	$ 226.00	$ 10,170.00
15	24X28	15.12	15.82	26	$ 209.35	$ 81,646.50
15	24X36	25.23	26.13	29	$ 243.00	$ 105,705.00
20	12x16	1.22	1.44	17	$ 168.60	$ 57,324.00
20	12x20	2.03	2.28	46	$ 175.15	$ 161,138.00
20	12X24	3.02	3.32	122	$ 180.15	$ 549,457.50
20	18x28	6.18	6.70	4	$ 203.35	$ 20,335.00
20	18x36	10.33	11.00	5	$ 215.00	$ 21,500.00
25	12X36	5.18	5.63	5	$ 191.10	$ 23,887.50
25	18X20	1.86	2.24	4	$ 184.10	$ 18,410.00
25	18X24	2.69	3.14	23	$ 189.10	$ 108,732.50
30	12X28	1.65	2.00	4	$ 182.35	$ 21,882.00
30	12X36	2.79	3.24	1	$ 189.34	$ 5,680.05
					SUBTOTAL	**$ 1,773,837.30**

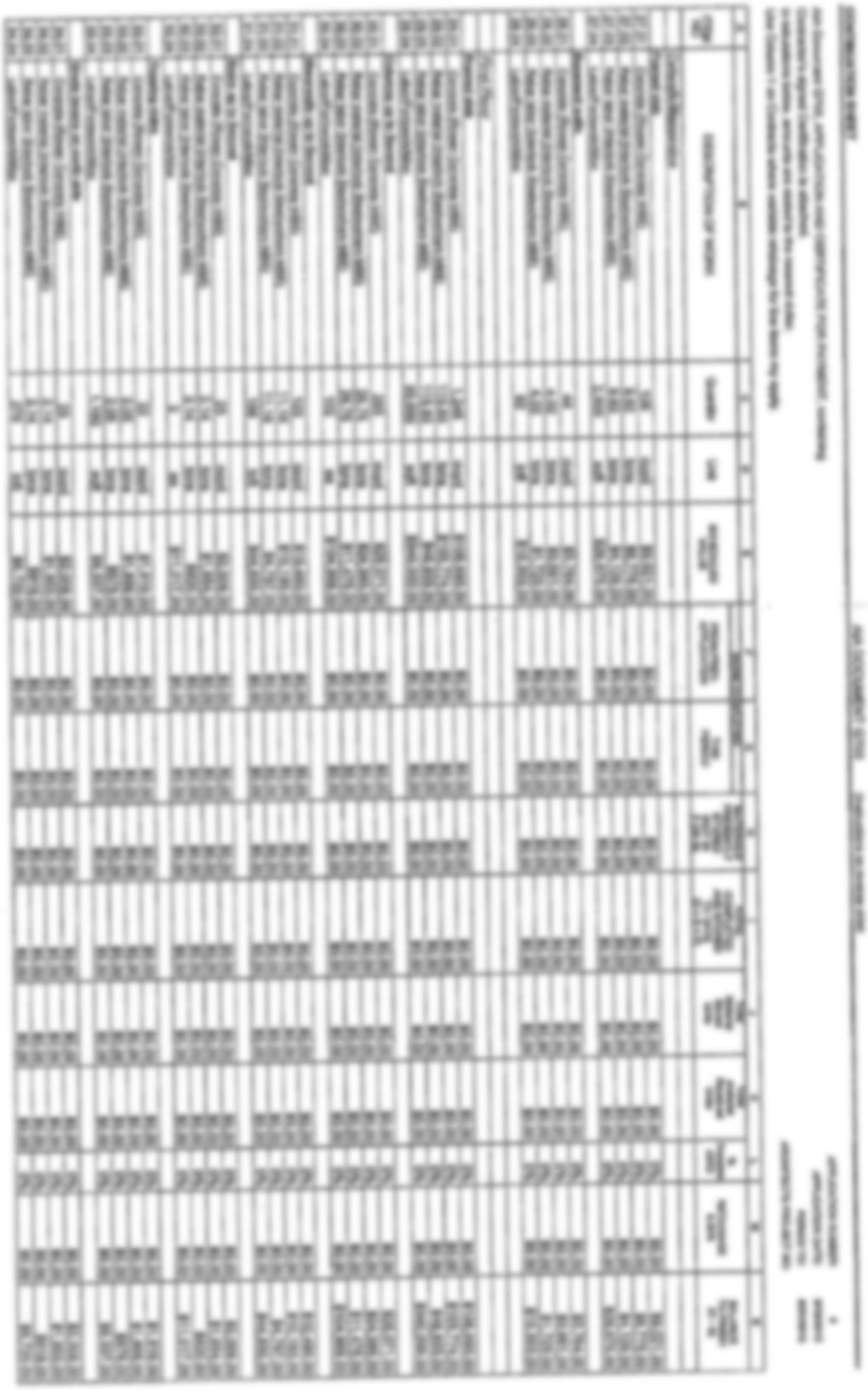
B1010 213 "L" Rectangular Precast Beams

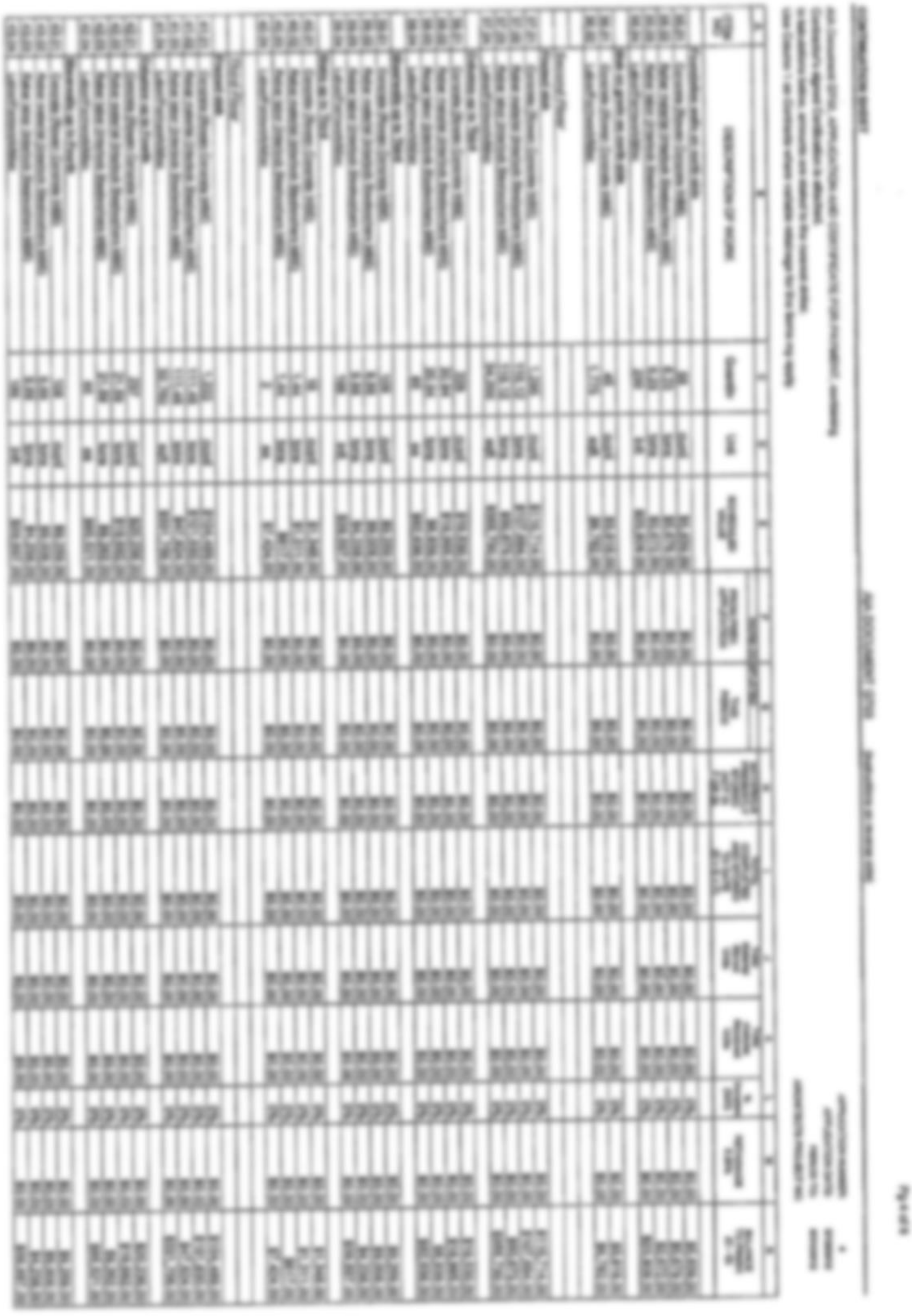
Span (ft.)	Size W X D (in.)	Superimposed Load (K.L.F.)	Total Load (P.S.F.)	Quantity (units)	Cost per L.F.	Total Cost
15	12X16	2.58	2.81	16	$ 185.00	$ 44,400.00
15	12X24	5.92	6.29	5	$ 202.00	$ 15,150.00
15	18x36	19.30	20.09	1	$ 248.00	$ 3,720.00
15	24x18	8.55	9.07	1	$ 220.00	$ 3,300.00
15	24x28	15.40	16.18	17	$ 243.00	$ 61,965.00
15	24X36	25.65	26.67	3	$ 271.50	$ 12,217.50
20	12x20	2.18	2.48	2	$ 180.15	$ 7,206.00
20	12x24	3.17	3.54	1	$ 197.75	$ 3,955.00
20	18x28	6.39	7.00	4	$ 225.35	$ 18,028.00
20	24x24	6.03	6.40	19	$ 293.00	$ 111,340.00
25	12x36	4.30	4.87	5	$ 217.60	$ 27,200.00
25	18x24	2.74	3.76	5	$ 211.60	$ 26,450.00
					SUBTOTAL	**$ 334,931.50**

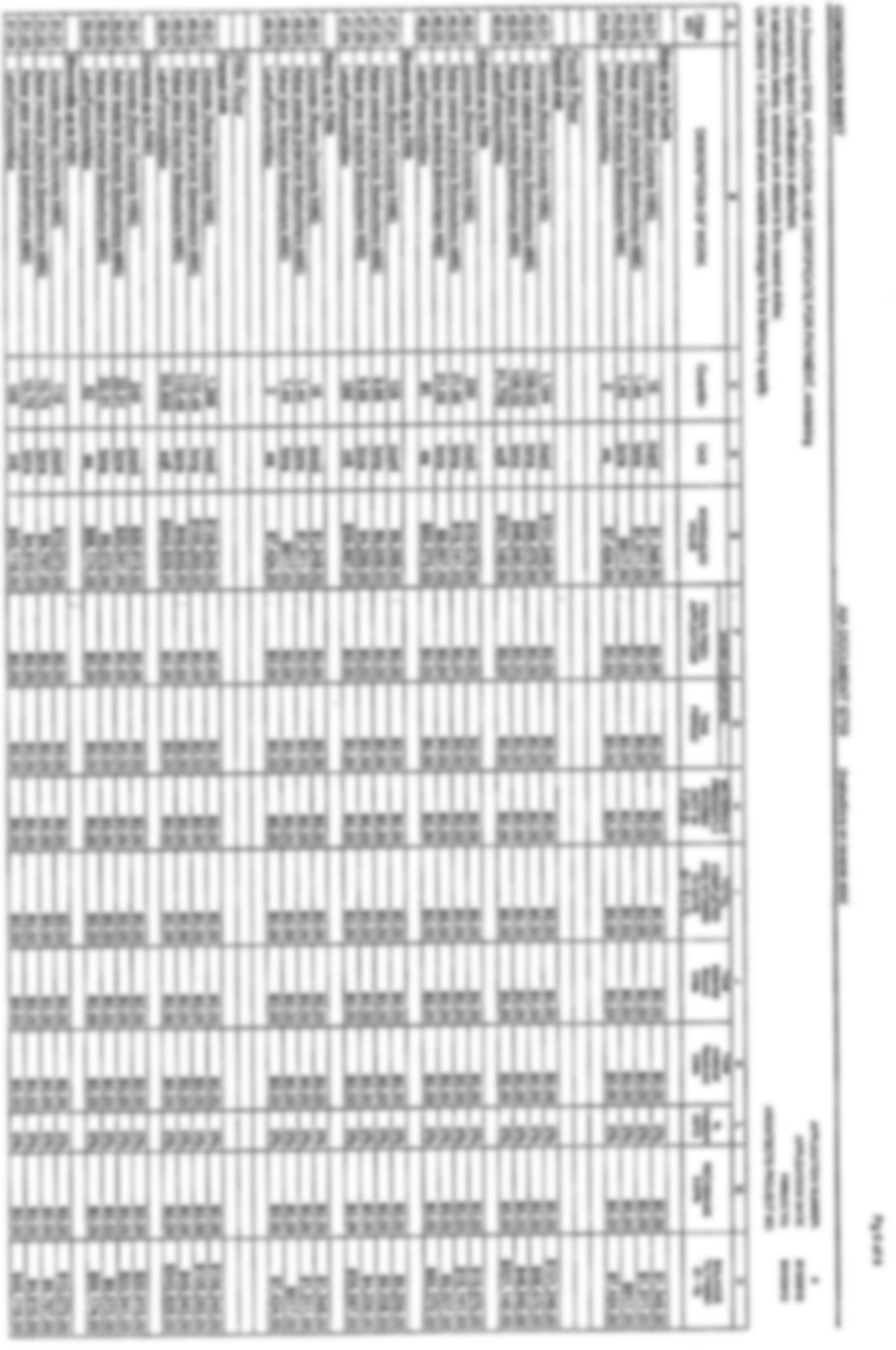
B1010 229

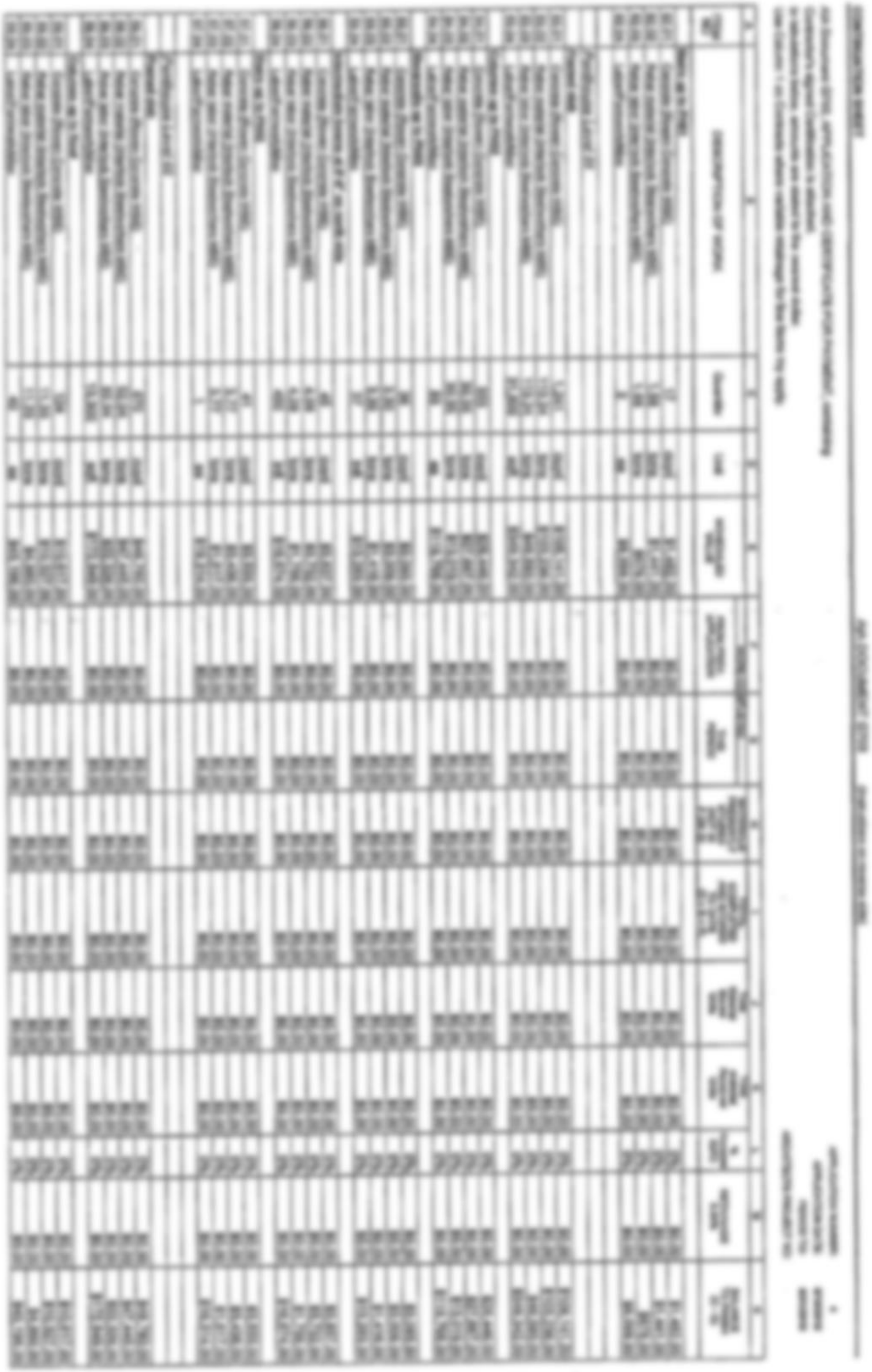
Span (ft.)	Superimposed Load (P.S.F.)	Total Depth (in.)	Dead Load (P.S.F.)	Total Load (P.S.F.)	Quantity (units)	Cost per S.F.	Total Cost
32	75	8	55	130	1833	$ 10.06	$ 2,360,317.44
			TOTAL COST OF SUPERSTRUCTURE				**$ 6,327,145.24**

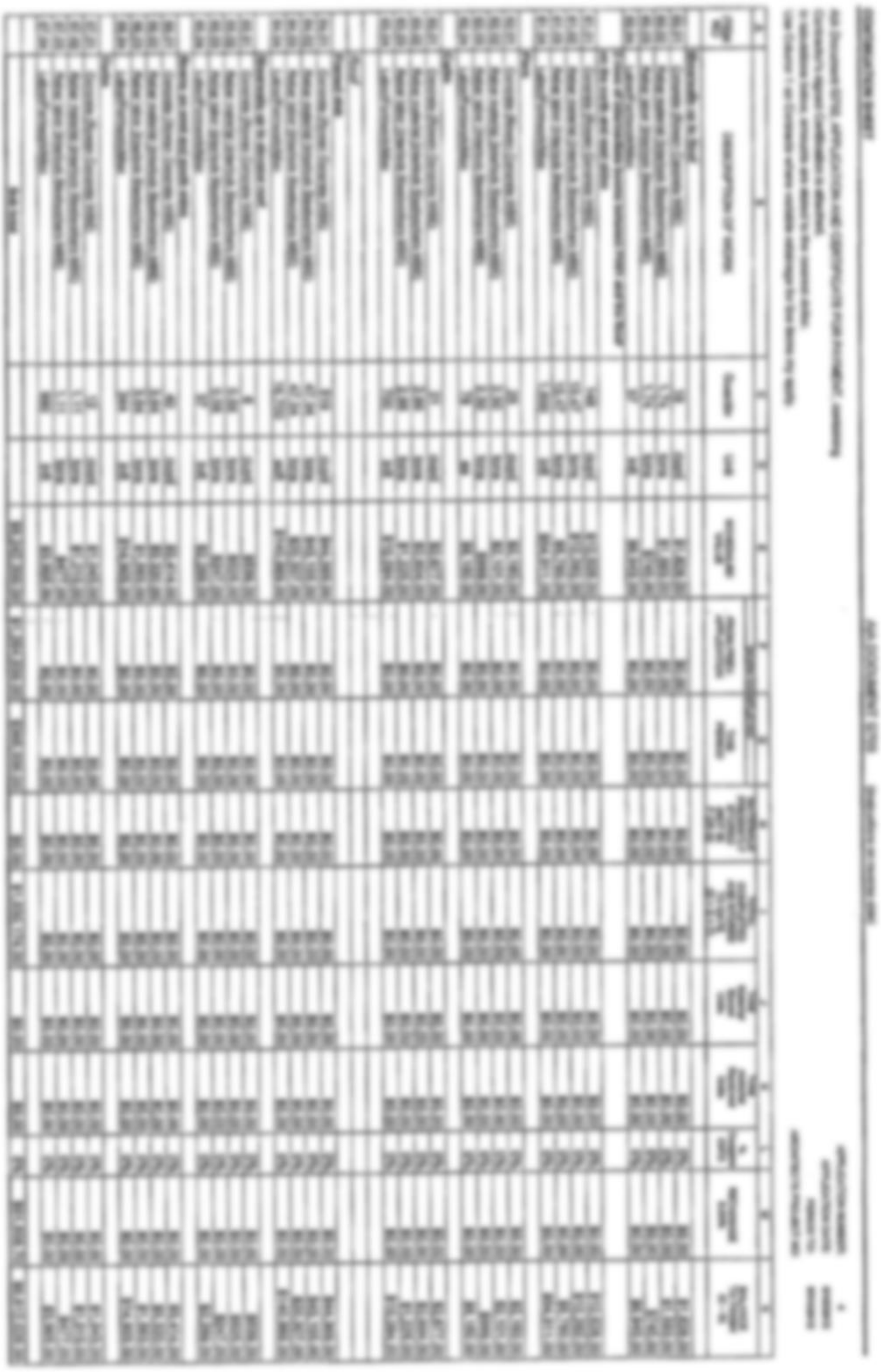
Appendix O: Turner Construction Pay Application Form

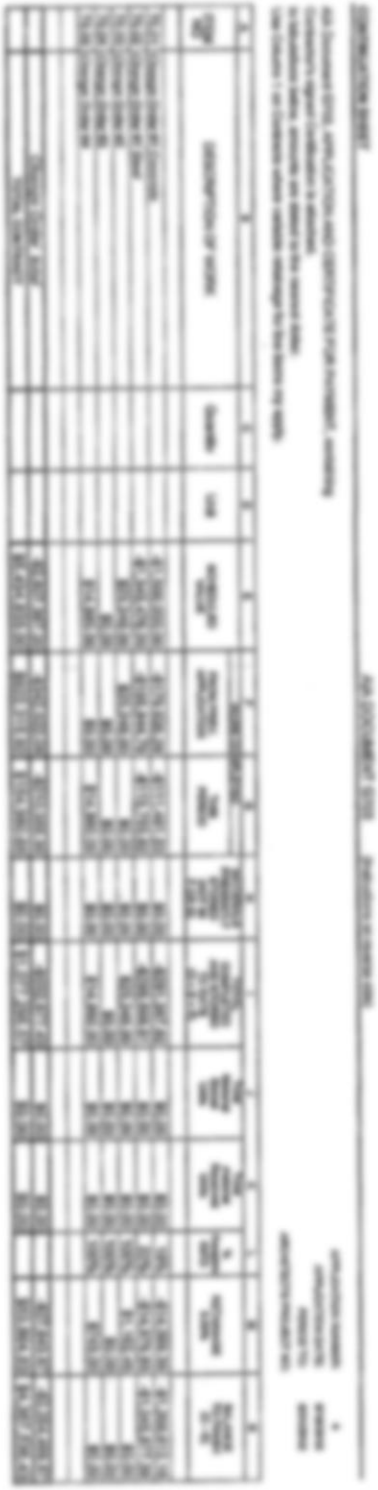












Appendix P: Selection Guide for Dewatering Systems

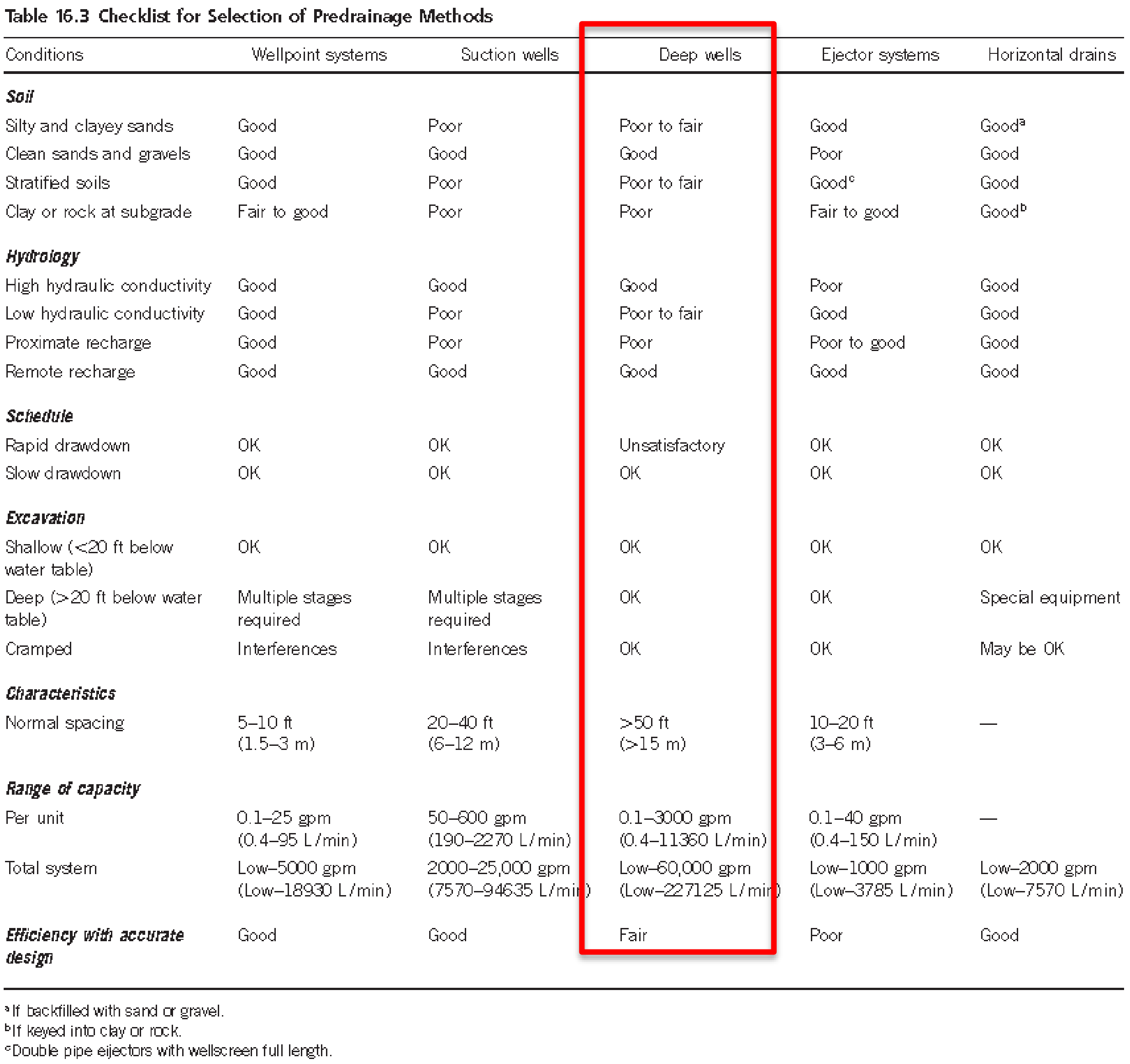


Table 16.3 Checklist for Selection of Predrainage Methods

Conditions	Wellpoint systems	Suction wells	Deep wells	Ejector systems	Horizontal drains
Soil					
Silty and clayey sands	Good	Poor	Poor to fair	Good	Good[a]
Clean sands and gravels	Good	Good	Good	Poor	Good
Stratified soils	Good	Poor	Poor to fair	Good[c]	Good
Clay or rock at subgrade	Fair to good	Poor	Poor	Fair to good	Good[b]
Hydrology					
High hydraulic conductivity	Good	Good	Good	Poor	Good
Low hydraulic conductivity	Good	Poor	Poor to fair	Good	Good
Proximate recharge	Good	Poor	Poor	Poor to good	Good
Remote recharge	Good	Good	Good	Good	Good
Schedule					
Rapid drawdown	OK	OK	Unsatisfactory	OK	OK
Slow drawdown	OK	OK	OK	OK	OK
Excavation					
Shallow (<20 ft below water table)	OK	OK	OK	OK	OK
Deep (>20 ft below water table)	Multiple stages required	Multiple stages required	OK	OK	Special equipment
Cramped	Interferences	Interferences	OK	OK	May be OK
Characteristics					
Normal spacing	5–10 ft (1.5–3 m)	20–40 ft (6–12 m)	>50 ft (>15 m)	10–20 ft (3–6 m)	—
Range of capacity					
Per unit	0.1–25 gpm (0.4–95 L/min)	50–600 gpm (190–2270 L/min)	0.1–3000 gpm (0.4–11360 L/min)	0.1–40 gpm (0.4–150 L/min)	—
Total system	Low–5000 gpm (Low–18930 L/min)	2000–25,000 gpm (7570–94635 L/mi)	Low–60,000 gpm (Low–227125 L/mi)	Low–1000 gpm (Low–3785 L/min)	Low–2000 gpm (Low–7570 L/min)
Efficiency with accurate design	Good	Good	Fair	Poor	Good

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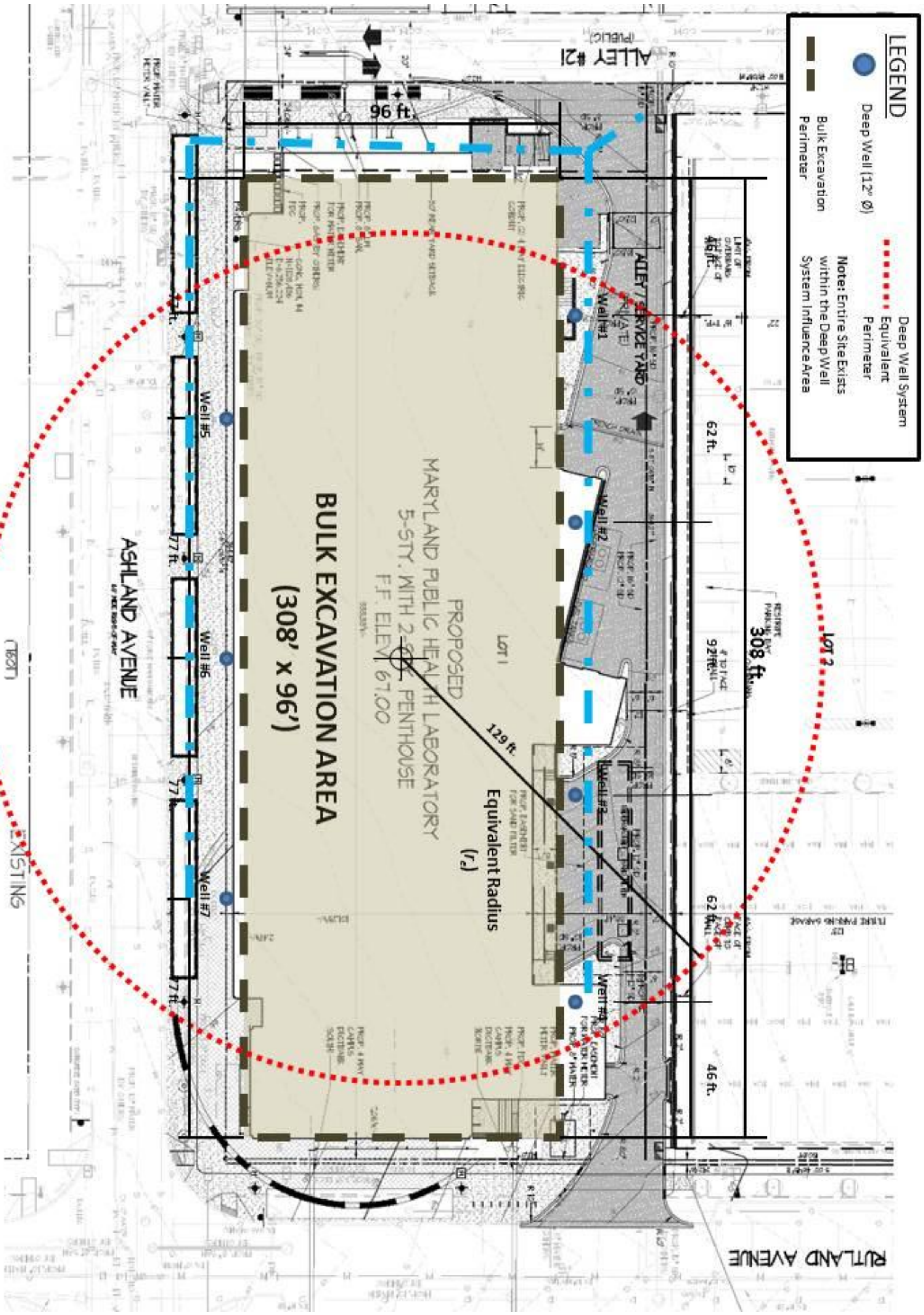
[a] If backfilled with sand or gravel.

[b] If keyed into clay or rock.

[c] Double pipe eijectors with wellscreen full length.

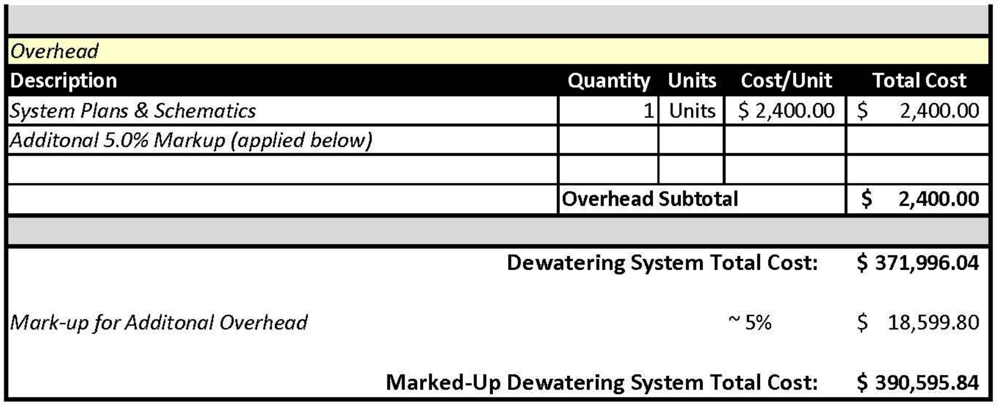
Appendix Q: Dewatering System Mapping Plan


LEGEND
● Deep Well (12" Ø)
Bulk Excavation Perimeter
Deep Well System Equivalent Perimeter
Note: Entire Site Exists within the Deep Well System Influence Area
ALLEY #2 (PUBLIC)
96 ft.
46 ft.
62 ft.
92 ft.
308 ft.
62 ft.
46 ft.
77 ft.
77 ft.
77 ft.
77 ft.
Well #1
Well #2
Well #3
Well #4
Well #5
Well #6
Well #7
ALLEY / SERVICE YARD (PRIVATE)
LOT 1
LOT 2
PROPOSED MARYLAND PUBLIC HEALTH LABORATORY 5-STY. WITH 2-STY. PENTHOUSE F.F. ELEV 67.00
BULK EXCAVATION AREA (308' x 96')
129 ft.
Equivalent Radius (r_e)
ASHLAND AVENUE
RUTLAND AVENUE
EXISTING

Appendix R: Dewatering System Cost Breakdown

Cost Break-Down of Designed Dewatering System

Equipment				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
Sumbersible Pump, 5 HP, 6" dia.	7	unit	$ 3,500.00	$ 24,500.00
Stainless Steel Wellscreen & Casing, 12" diam.	350	V.F.	$ 20.00	$ 7,000.00
PVC Discharge Column, 3" dia.	343	V.F.	$ 2.00	$ 686.00
High-Density Polyethlyne discharge piping, 8" diam.	613	L.F.	$ 25.00	$ 15,325.00
	Total Equipment Subtotal			**$ 47,511.00**
Mark-up for Misc. Dewatering Components			~ 10%	$ 4,751.10
	Marked-up Equip. Subtotal			**$ 52,262.10**
Materials				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
Filter Sand with misc. Backfill	91.63	C.Y.	$ 40.00	$ 3,665.19
	Materials Subtotal			**$ 3,665.19**
Equipment Rental Rates & Operation Rates				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
Deep Well Rental Rate (first 120 days)	120	day	$ 240.00	$ 28,800.00
Deep Well Rental Rate (after 120 days)	30	day	$ 190.00	$ 5,700.00
Drilling Rig, 36" bore dia.	4	day	$ 4,800.00	$ 19,200.00
	Rental & Opp. Subtotal			**$ 53,700.00**
Demobilization				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
Deep Well Removal	7	unit	$ 1,200.00	$ 8,400.00
	Demobilization Subtotal			**$ 8,400.00**
Power Requirements				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
Service 7 Submersible Pumps 5 HP	955	hr.	$ 3.75	$ 3,581.25
	Power Subtotal			**$ 3,581.25**
Crew Rates				
Description	**Quantity**	**Units**	**Cost/Unit**	**Total Cost**
3 Laborers	127.5	day	$ 355.00	$ 128,137.50
Site Supervisor	127.5	day	$ 940.00	$ 119,850.00
	Crew Rate Subtotal			**$ 247,987.50**



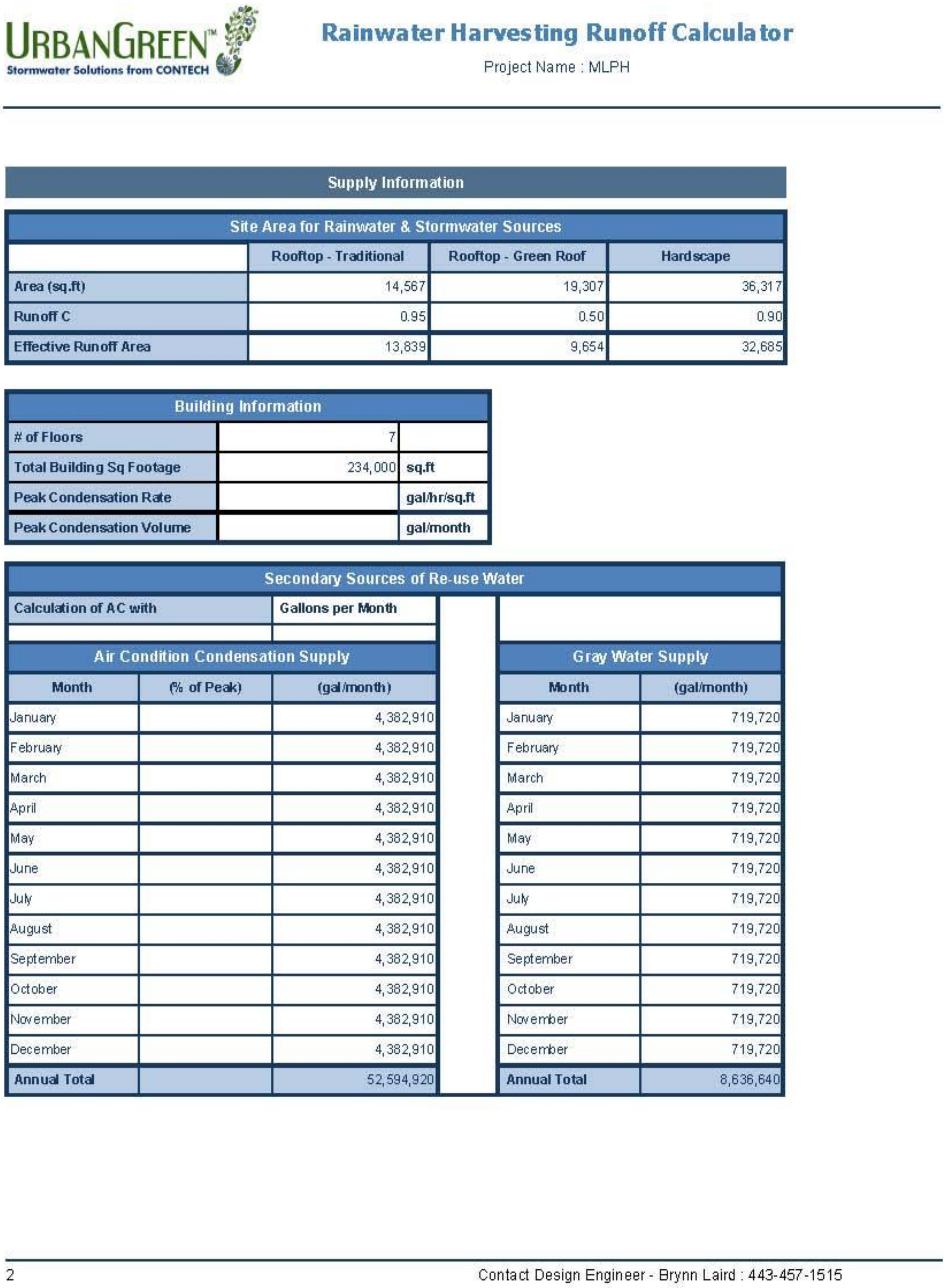
Overhead

Description	Quantity	Units	Cost/Unit	Total Cost
System Plans & Schematics	1	Units	$ 2,400.00	$ 2,400.00
Additonal 5.0% Markup (applied below)				
	Overhead Subtotal			**$ 2,400.00**

	Dewatering System Total Cost:	**$ 371,996.04**
Mark-up for Additonal Overhead	~ 5%	$ 18,599.80
	Marked-Up Dewatering System Total Cost:	**$ 390,595.84**

Appendix S: Turner Dewatering Pay Application Form

Appendix T: Rainwater Harvesting Runoff Calculator Values



UrbanGreen™ Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Supply Information

Site Area for Rainwater & Stormwater Sources

	Rooftop - Traditional	Rooftop - Green Roof	Hardscape
Area (sq.ft)	14,567	19,307	36,317
Runoff C	0.95	0.50	0.90
Effective Runoff Area	13,839	9,654	32,685

Building Information

# of Floors	7	
Total Building Sq Footage	234,000	sq.ft
Peak Condensation Rate		gal/hr/sq.ft
Peak Condensation Volume		gal/month

Secondary Sources of Re-use Water

Calculation of AC with	**Gallons per Month**

Air Condition Condensation Supply

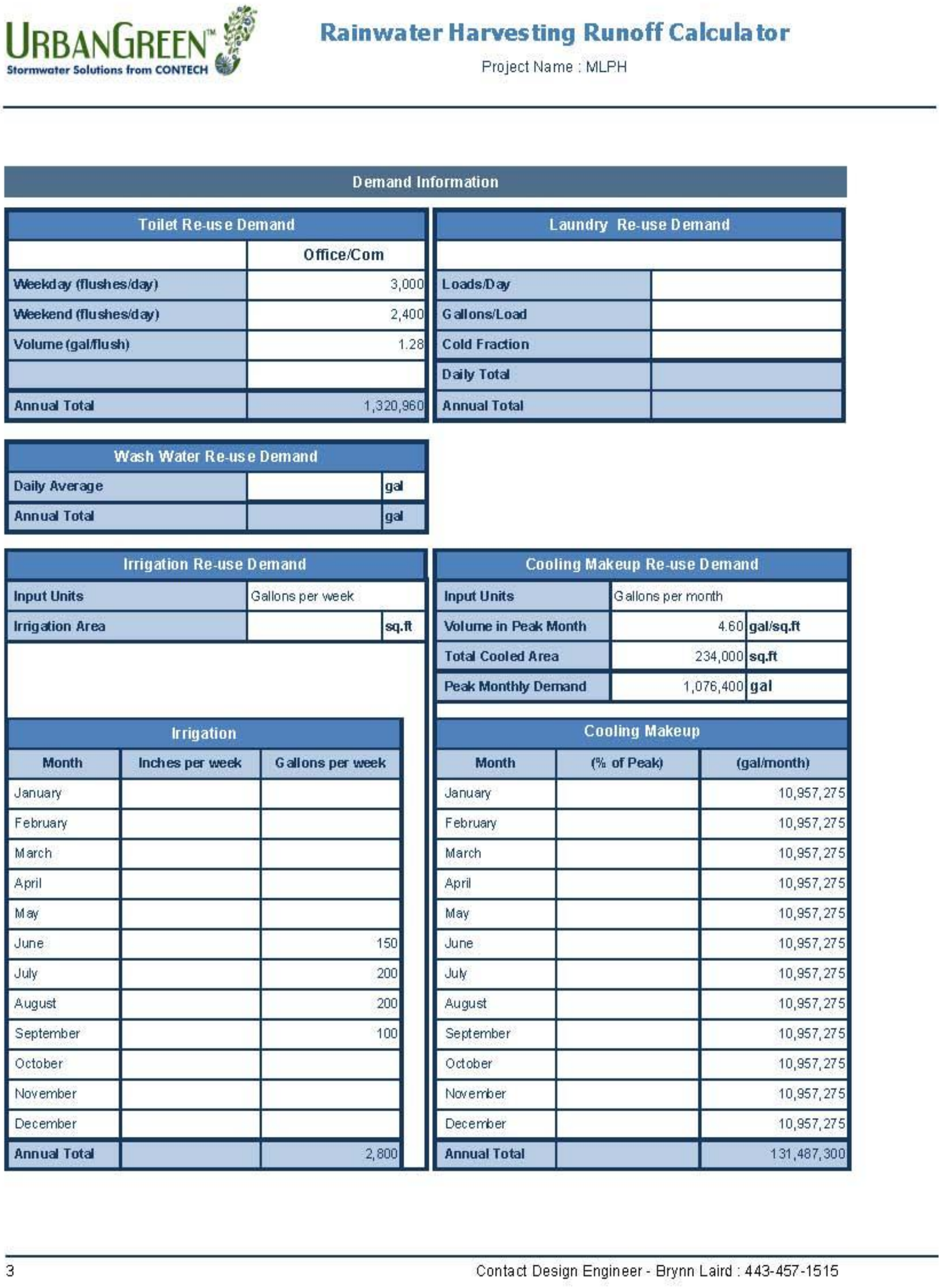
Month	(% of Peak)	(gal/month)
January		4,382,910
February		4,382,910
March		4,382,910
April		4,382,910
May		4,382,910
June		4,382,910
July		4,382,910
August		4,382,910
September		4,382,910
October		4,382,910
November		4,382,910
December		4,382,910
Annual Total		52,594,920

Gray Water Supply

Month	(gal/month)
January	719,720
February	719,720
March	719,720
April	719,720
May	719,720
June	719,720
July	719,720
August	719,720
September	719,720
October	719,720
November	719,720
December	719,720
Annual Total	8,636,640

2

Contact Design Engineer - Brynn Laird : 443-457-1515



URBANGREEN™ Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Demand Information

Toilet Re-use Demand	
	Office/Com
Weekday (flushes/day)	3,000
Weekend (flushes/day)	2,400
Volume (gal/flush)	1.28
Annual Total	1,320,960

Laundry Re-use Demand	
Loads/Day	
Gallons/Load	
Cold Fraction	
Daily Total	
Annual Total	

Wash Water Re-use Demand		
Daily Average		gal
Annual Total		gal

Irrigation Re-use Demand		
Input Units	Gallons per week	
Irrigation Area		sq.ft

Irrigation		
Month	Inches per week	Gallons per week
January		
February		
March		
April		
May		
June		150
July		200
August		200
September		100
October		
November		
December		
Annual Total		2,800

Cooling Makeup Re-use Demand		
Input Units	Gallons per month	
Volume in Peak Month	4.60	gal/sq.ft
Total Cooled Area	234,000	sq.ft
Peak Monthly Demand	1,076,400	gal

Cooling Makeup		
Month	(% of Peak)	(gal/month)
January		10,957,275
February		10,957,275
March		10,957,275
April		10,957,275
May		10,957,275
June		10,957,275
July		10,957,275
August		10,957,275
September		10,957,275
October		10,957,275
November		10,957,275
December		10,957,275
Annual Total		131,487,300

3

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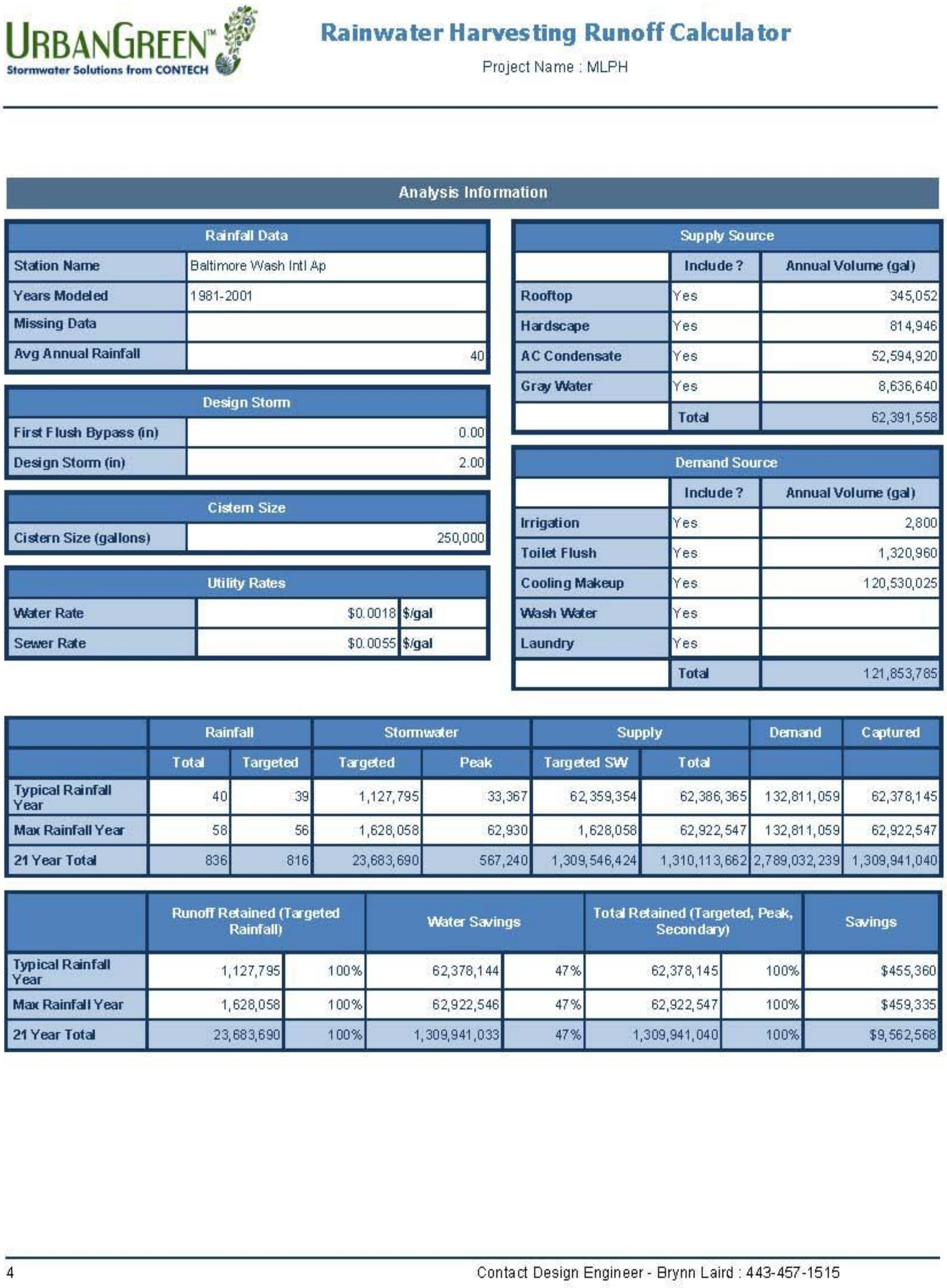

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Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Analysis Information

Rainfall Data	
Station Name	Baltimore Wash Intl Ap
Years Modeled	1981-2001
Missing Data	
Avg Annual Rainfall	40

Design Storm	
First Flush Bypass (in)	0.00
Design Storm (in)	2.00

Cistern Size	
Cistern Size (gallons)	250,000

Utility Rates		
Water Rate	$0.0018	$/gal
Sewer Rate	$0.0055	$/gal

Supply Source		
	Include ?	**Annual Volume (gal)**
Rooftop	Yes	345,052
Hardscape	Yes	814,946
AC Condensate	Yes	52,594,920
Gray Water	Yes	8,636,640
	Total	62,391,558

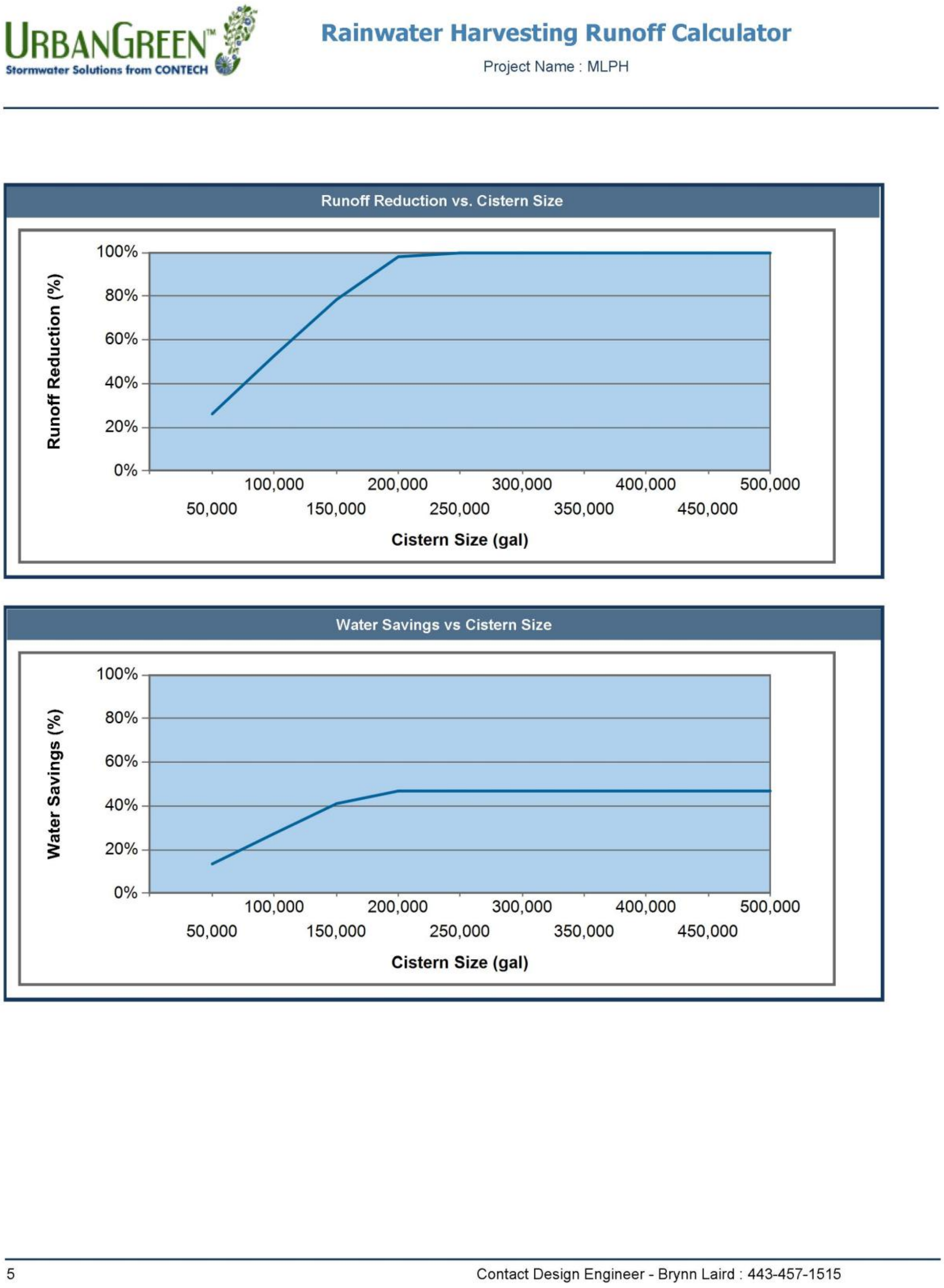
Demand Source		
	Include ?	**Annual Volume (gal)**
Irrigation	Yes	2,800
Toilet Flush	Yes	1,320,960
Cooling Makeup	Yes	120,530,025
Wash Water	Yes	
Laundry	Yes	
	Total	121,853,785

	Rainfall		Stormwater		Supply		Demand	Captured
	Total	Targeted	Targeted	Peak	Targeted SW	Total		
Typical Rainfall Year	40	39	1,127,795	33,367	62,359,354	62,386,365	132,811,059	62,378,145
Max Rainfall Year	58	56	1,628,058	62,930	1,628,058	62,922,547	132,811,059	62,922,547
21 Year Total	836	816	23,683,690	567,240	1,309,546,424	1,310,113,662	2,789,032,239	1,309,941,040

	Runoff Retained (Targeted Rainfall)		Water Savings		Total Retained (Targeted, Peak, Secondary)		Savings
Typical Rainfall Year	1,127,795	100%	62,378,144	47%	62,378,145	100%	$455,360
Max Rainfall Year	1,628,058	100%	62,922,546	47%	62,922,547	100%	$459,335
21 Year Total	23,683,690	100%	1,309,941,033	47%	1,309,941,040	100%	$9,562,568

4

Contact Design Engineer - Brynn Laird : 443-457-1515



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Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Runoff Reduction vs. Cistern Size

Water Savings vs Cistern Size

5

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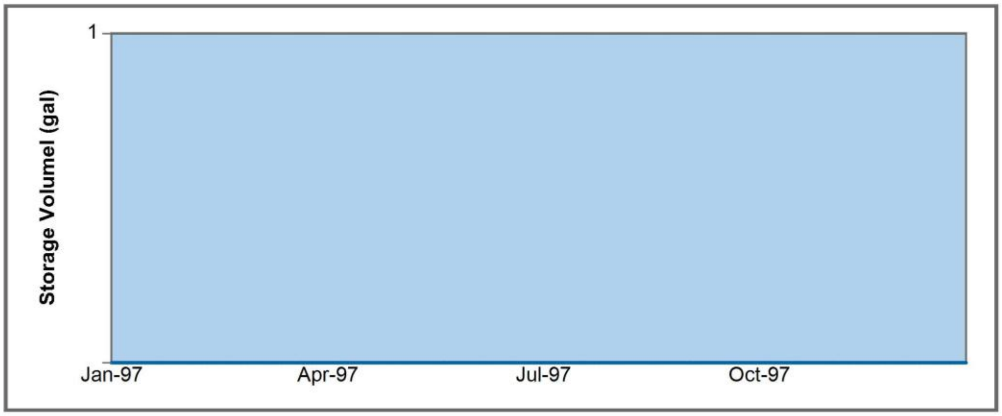
Rainwater Harvesting Runoff Calculator

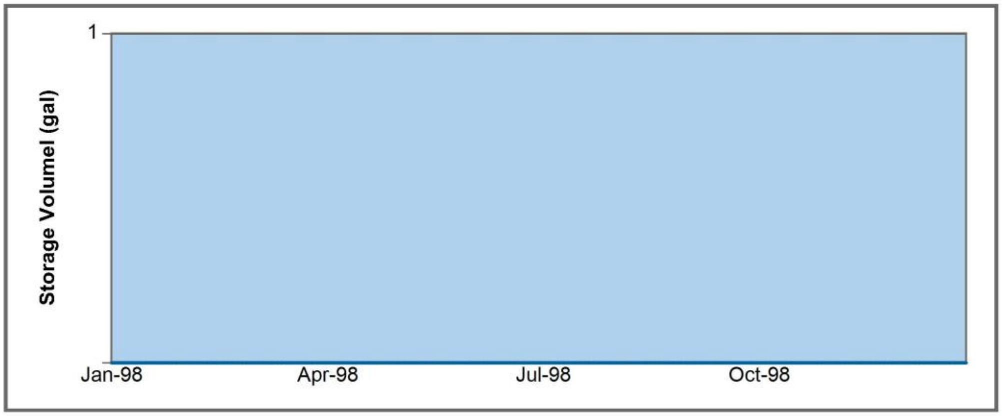
Project Name : MLPH

Daily Ending Cistern Volume Graph

Year 1997: Daily Ending Cistern Volume



Year 1998: Daily Ending Cistern Volume



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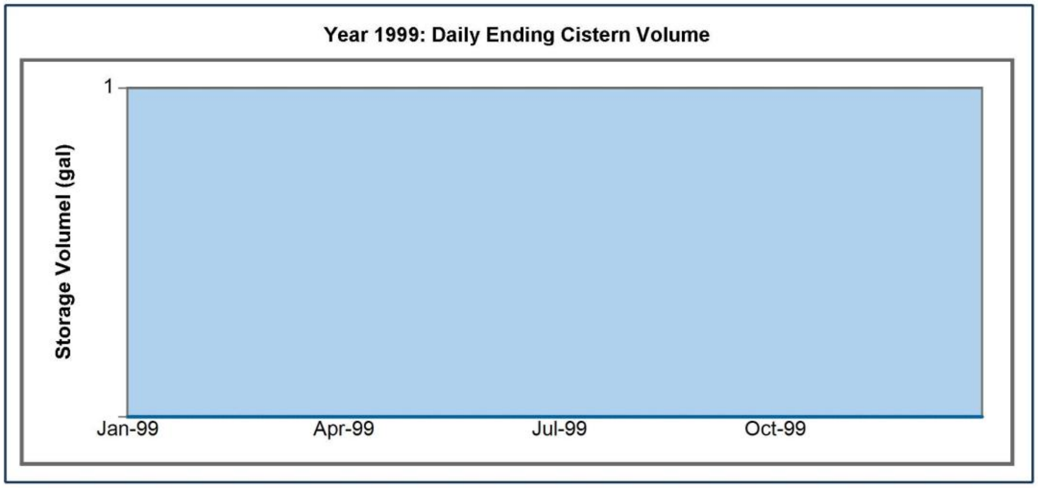
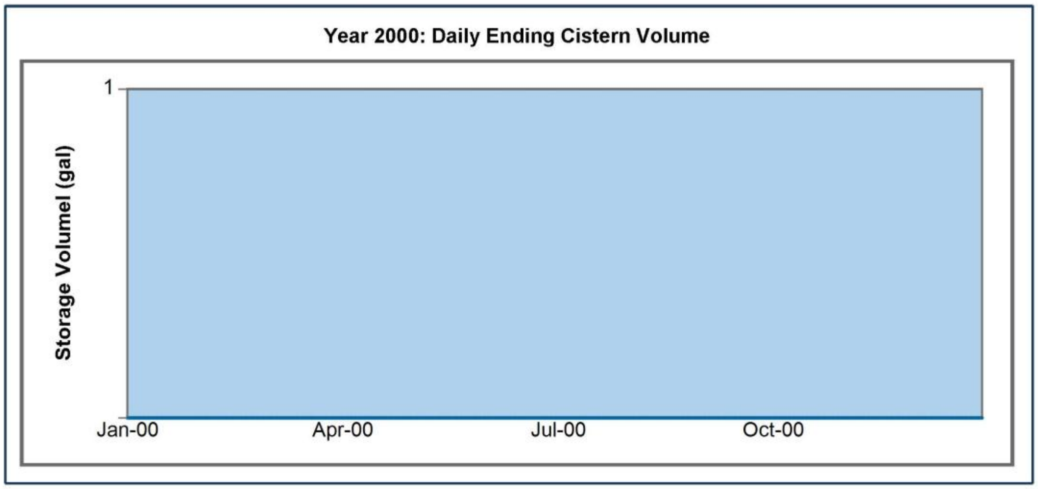
Rainwater Harvesting Runoff Calculator

Project Name : MLPH


Year 1999: Daily Ending Cistern Volume


Year 2000: Daily Ending Cistern Volume

7 Contact Design Engineer - Brynn Laird : 443-457-1515

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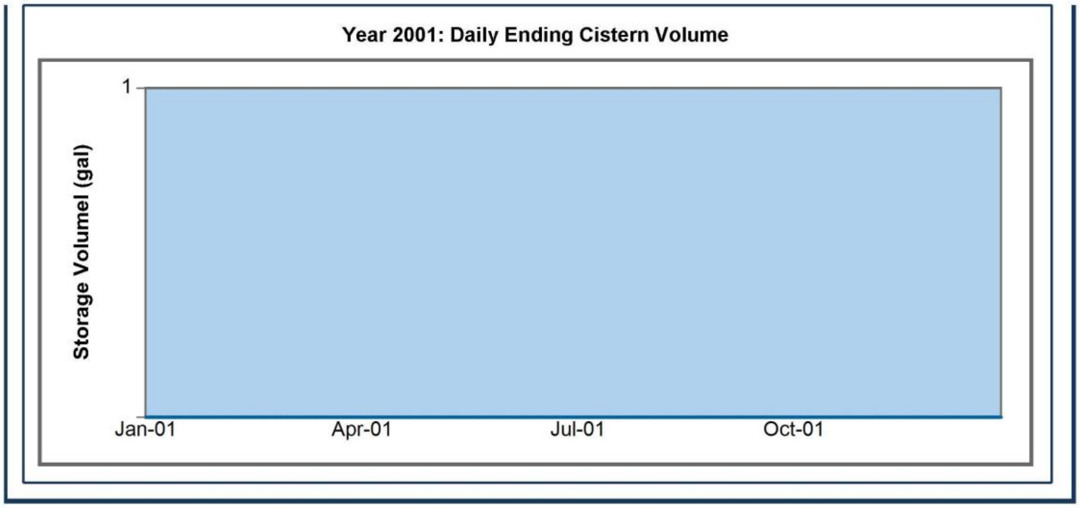
Rainwater Harvesting Runoff Calculator

Project Name : MLPH



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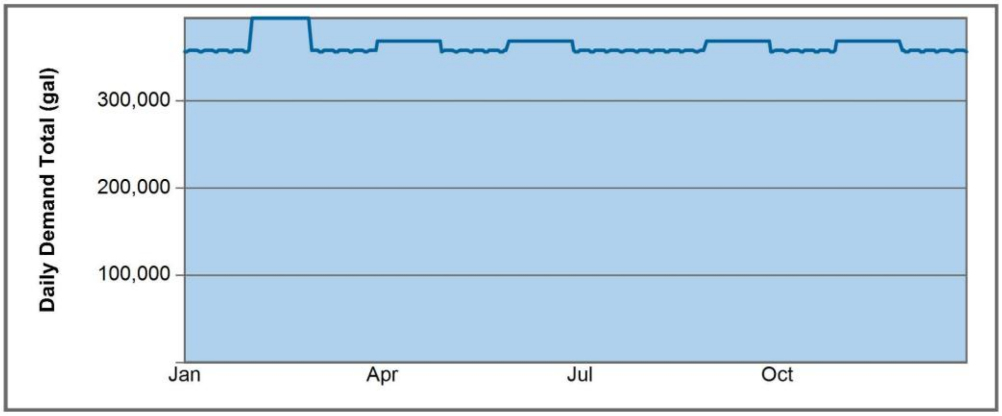
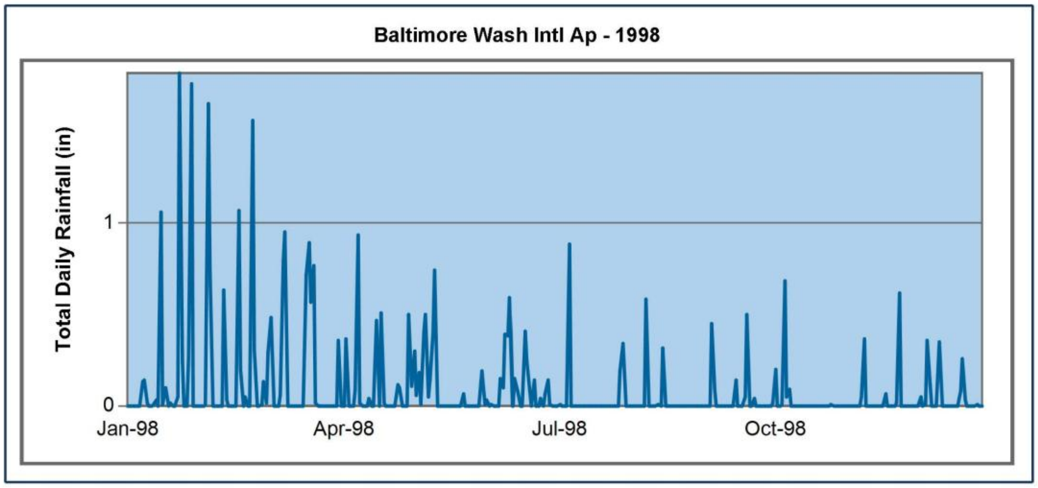
Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Total Daily Demand



Annual Rainfall History


Baltimore Wash Intl Ap - 1998

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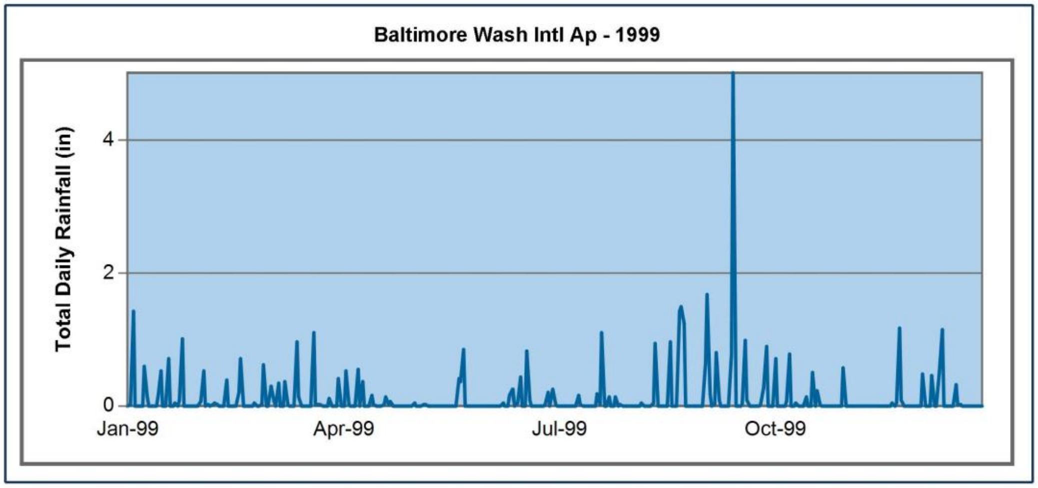
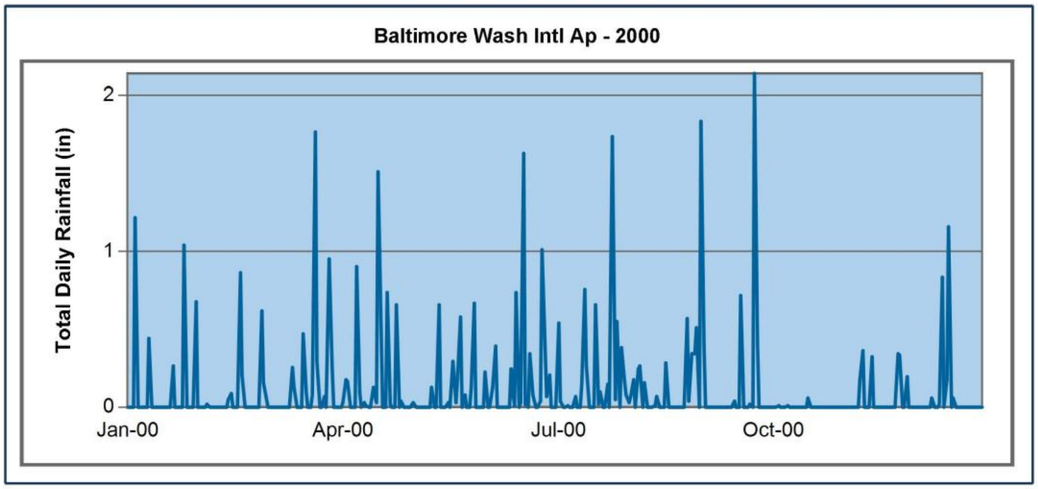
Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH





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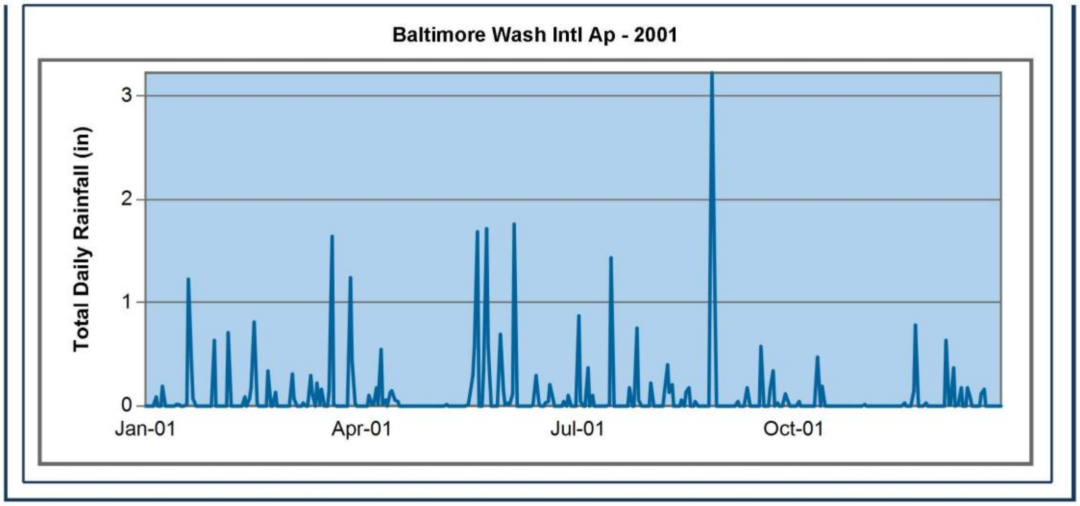
Rainwater Harvesting Runoff Calculator

Project Name : MLPH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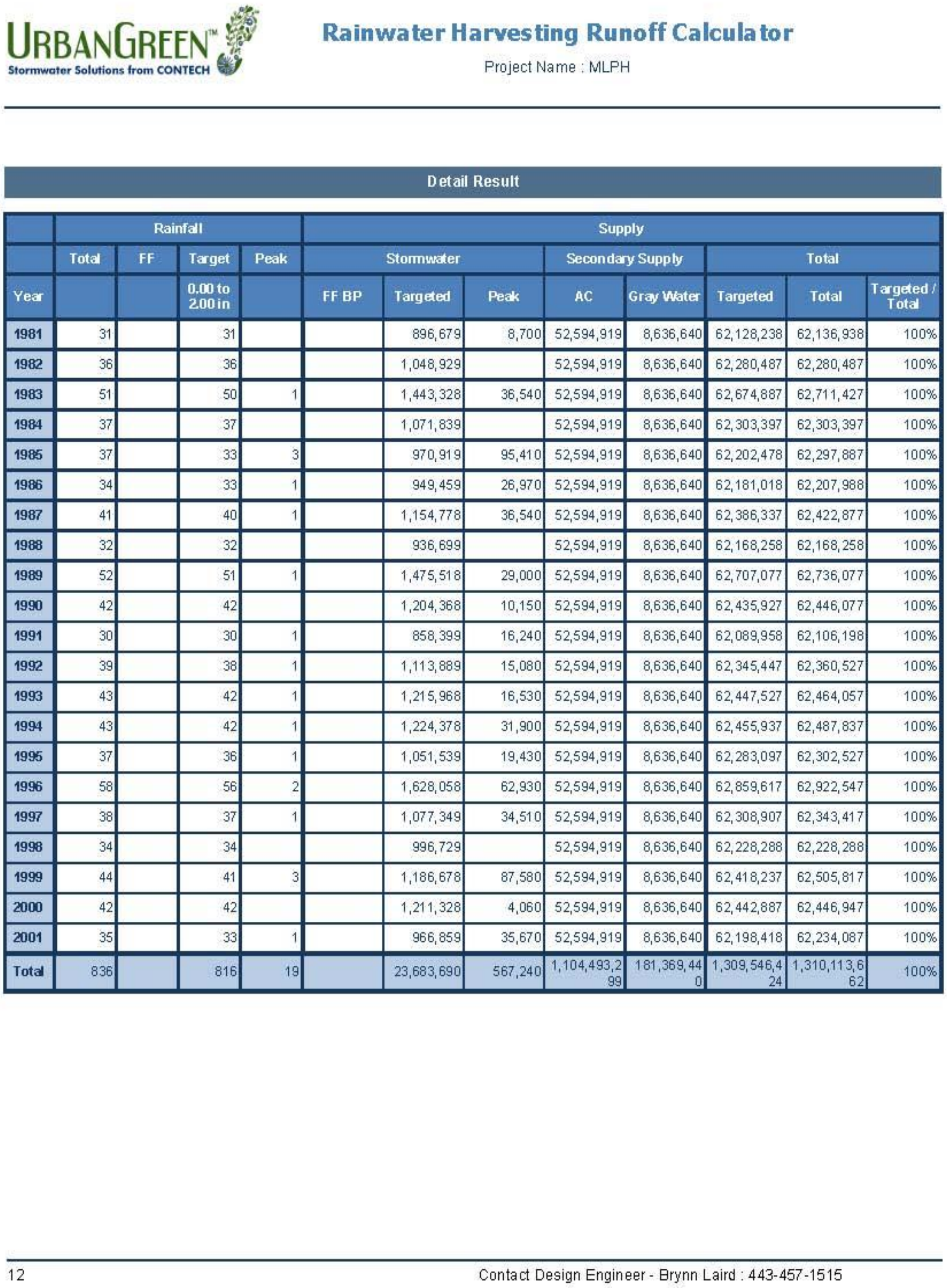

URBANGREEN™ Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

Detail Result

	Rainfall				Supply							
	Total	FF	Target	Peak	Stormwater			Secondary Supply		Total		
Year			0.00 to 2.00 in		FF BP	Targeted	Peak	AC	Gray Water	Targeted	Total	Targeted / Total
1981	31		31			896,679	8,700	52,594,919	8,636,640	62,128,238	62,136,938	100%
1982	36		36			1,048,929		52,594,919	8,636,640	62,280,487	62,280,487	100%
1983	51		50	1		1,443,328	36,540	52,594,919	8,636,640	62,674,887	62,711,427	100%
1984	37		37			1,071,839		52,594,919	8,636,640	62,303,397	62,303,397	100%
1985	37		33	3		970,919	95,410	52,594,919	8,636,640	62,202,478	62,297,887	100%
1986	34		33	1		949,459	26,970	52,594,919	8,636,640	62,181,018	62,207,988	100%
1987	41		40	1		1,154,778	36,540	52,594,919	8,636,640	62,386,337	62,422,877	100%
1988	32		32			936,699		52,594,919	8,636,640	62,168,258	62,168,258	100%
1989	52		51	1		1,475,518	29,000	52,594,919	8,636,640	62,707,077	62,736,077	100%
1990	42		42			1,204,368	10,150	52,594,919	8,636,640	62,435,927	62,446,077	100%
1991	30		30	1		858,399	16,240	52,594,919	8,636,640	62,089,958	62,106,198	100%
1992	39		38	1		1,113,889	15,080	52,594,919	8,636,640	62,345,447	62,360,527	100%
1993	43		42	1		1,215,968	16,530	52,594,919	8,636,640	62,447,527	62,464,057	100%
1994	43		42	1		1,224,378	31,900	52,594,919	8,636,640	62,455,937	62,487,837	100%
1995	37		36	1		1,051,539	19,430	52,594,919	8,636,640	62,283,097	62,302,527	100%
1996	58		56	2		1,628,058	62,930	52,594,919	8,636,640	62,859,617	62,922,547	100%
1997	38		37	1		1,077,349	34,510	52,594,919	8,636,640	62,308,907	62,343,417	100%
1998	34		34			996,729		52,594,919	8,636,640	62,228,288	62,228,288	100%
1999	44		41	3		1,186,678	87,580	52,594,919	8,636,640	62,418,237	62,505,817	100%
2000	42		42			1,211,328	4,060	52,594,919	8,636,640	62,442,887	62,446,947	100%
2001	35		33	1		966,859	35,670	52,594,919	8,636,640	62,198,418	62,234,087	100%
Total	836		816	19		23,683,690	567,240	1,104,493,299	181,369,440	1,309,546,424	1,310,113,662	100%

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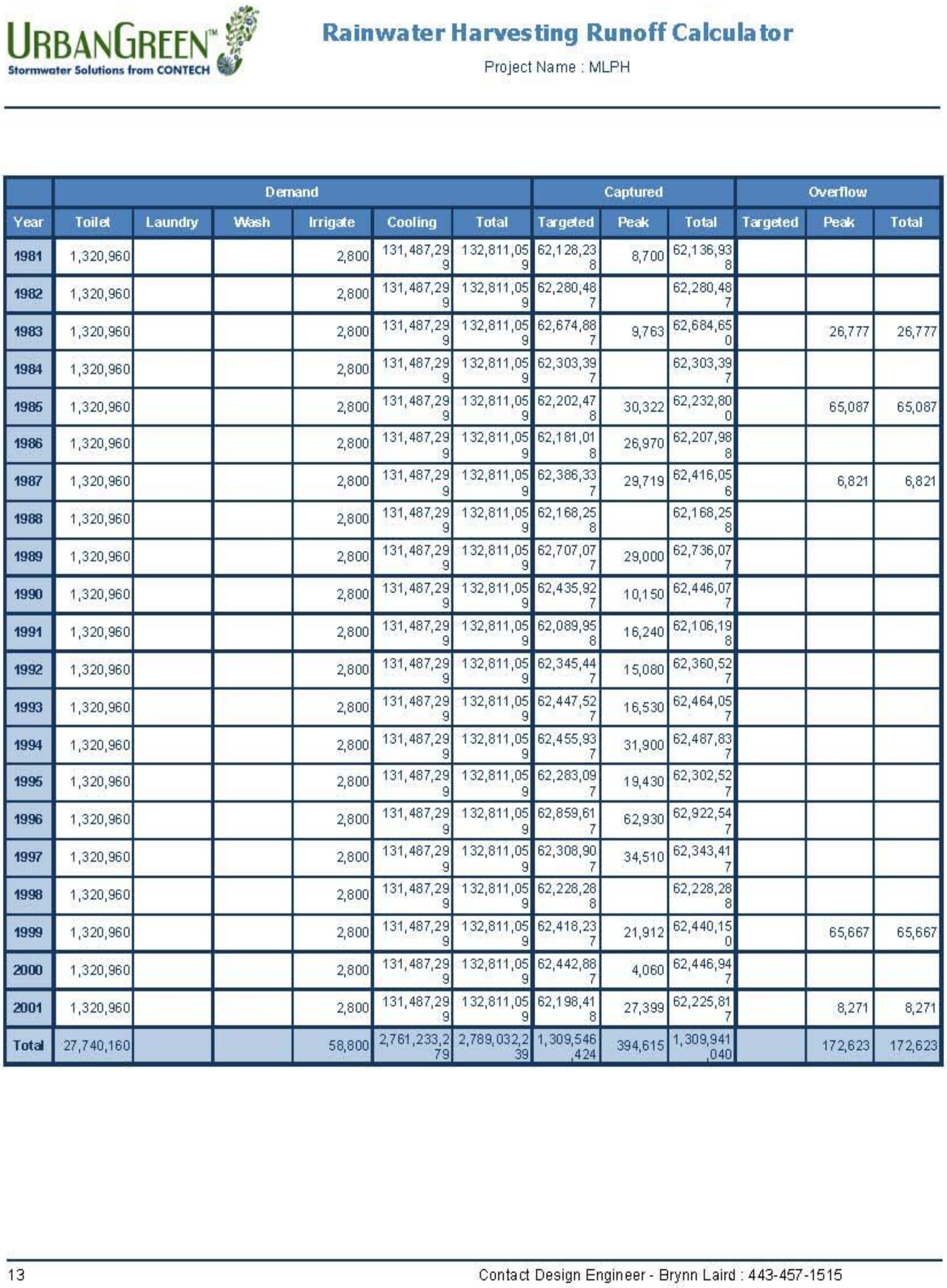
Contact Design Engineer - Brynn Laird : 443-457-1515



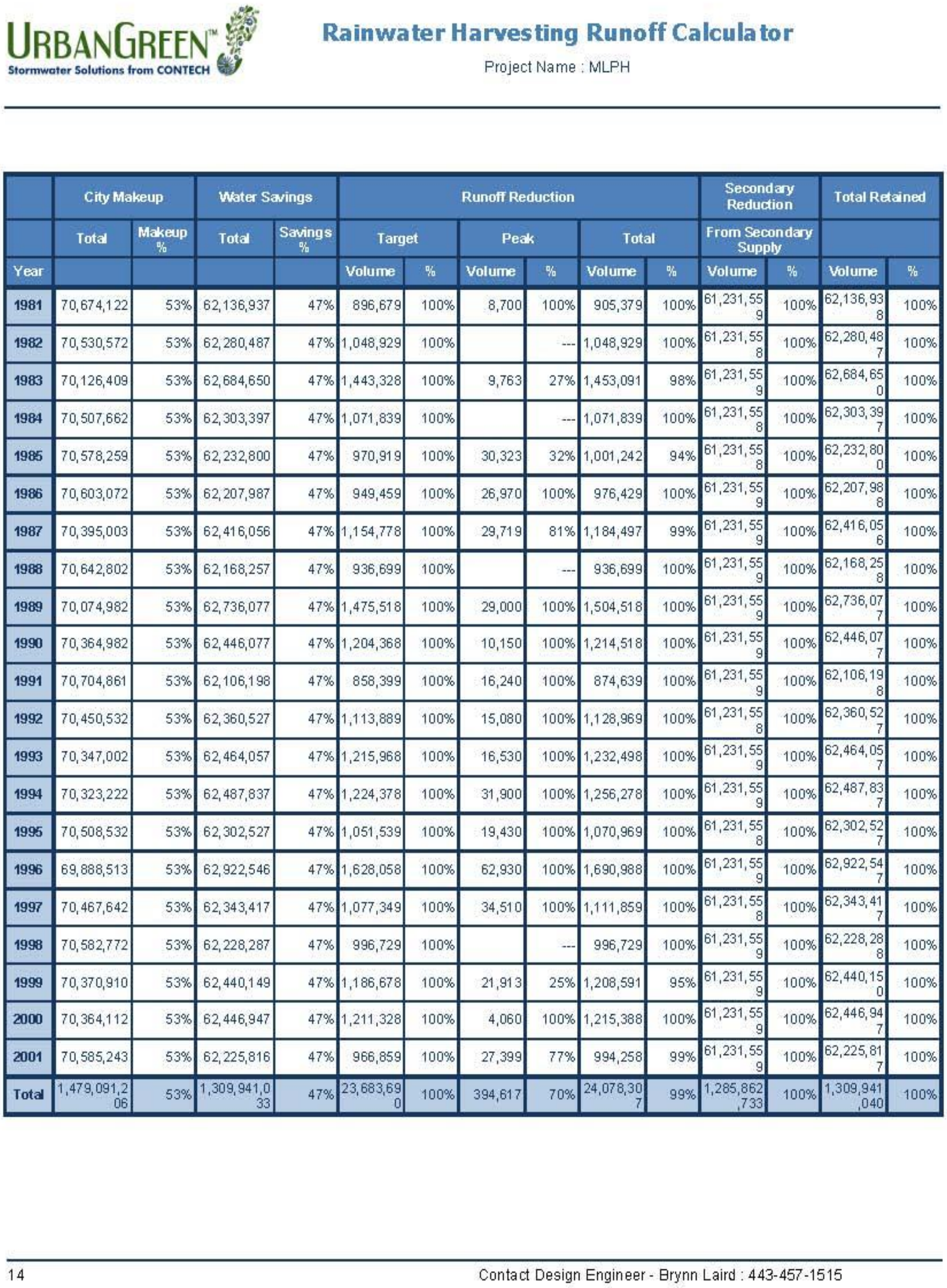
URBANGREEN™ Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

	Demand						Captured			Overflow		
Year	Toilet	Laundry	Wash	Irrigate	Cooling	Total	Targeted	Peak	Total	Targeted	Peak	Total
1981	1,320,960			2,800	131,487,299	132,811,059	62,128,238	8,700	62,136,938			
1982	1,320,960			2,800	131,487,299	132,811,059	62,280,487		62,280,487			
1983	1,320,960			2,800	131,487,299	132,811,059	62,674,887	9,763	62,684,650		26,777	26,777
1984	1,320,960			2,800	131,487,299	132,811,059	62,303,397		62,303,397			
1985	1,320,960			2,800	131,487,299	132,811,059	62,202,478	30,322	62,232,800		65,087	65,087
1986	1,320,960			2,800	131,487,299	132,811,059	62,181,018	26,970	62,207,988			
1987	1,320,960			2,800	131,487,299	132,811,059	62,386,337	29,719	62,416,056		6,821	6,821
1988	1,320,960			2,800	131,487,299	132,811,059	62,168,258		62,168,258			
1989	1,320,960			2,800	131,487,299	132,811,059	62,707,077	29,000	62,736,077			
1990	1,320,960			2,800	131,487,299	132,811,059	62,435,927	10,150	62,446,077			
1991	1,320,960			2,800	131,487,299	132,811,059	62,089,958	16,240	62,106,198			
1992	1,320,960			2,800	131,487,299	132,811,059	62,345,447	15,080	62,360,527			
1993	1,320,960			2,800	131,487,299	132,811,059	62,447,527	16,530	62,464,057			
1994	1,320,960			2,800	131,487,299	132,811,059	62,455,937	31,900	62,487,837			
1995	1,320,960			2,800	131,487,299	132,811,059	62,283,097	19,430	62,302,527			
1996	1,320,960			2,800	131,487,299	132,811,059	62,859,617	62,930	62,922,547			
1997	1,320,960			2,800	131,487,299	132,811,059	62,308,907	34,510	62,343,417			
1998	1,320,960			2,800	131,487,299	132,811,059	62,228,288		62,228,288			
1999	1,320,960			2,800	131,487,299	132,811,059	62,418,237	21,912	62,440,150		65,667	65,667
2000	1,320,960			2,800	131,487,299	132,811,059	62,442,887	4,060	62,446,947			
2001	1,320,960			2,800	131,487,299	132,811,059	62,198,418	27,399	62,225,817		8,271	8,271
Total	27,740,160			58,800	2,761,233,279	2,789,032,239	1,309,546,424	394,615	1,309,941,040		172,623	172,623

13 Contact Design Engineer - Brynn Laird : 443-457-1515



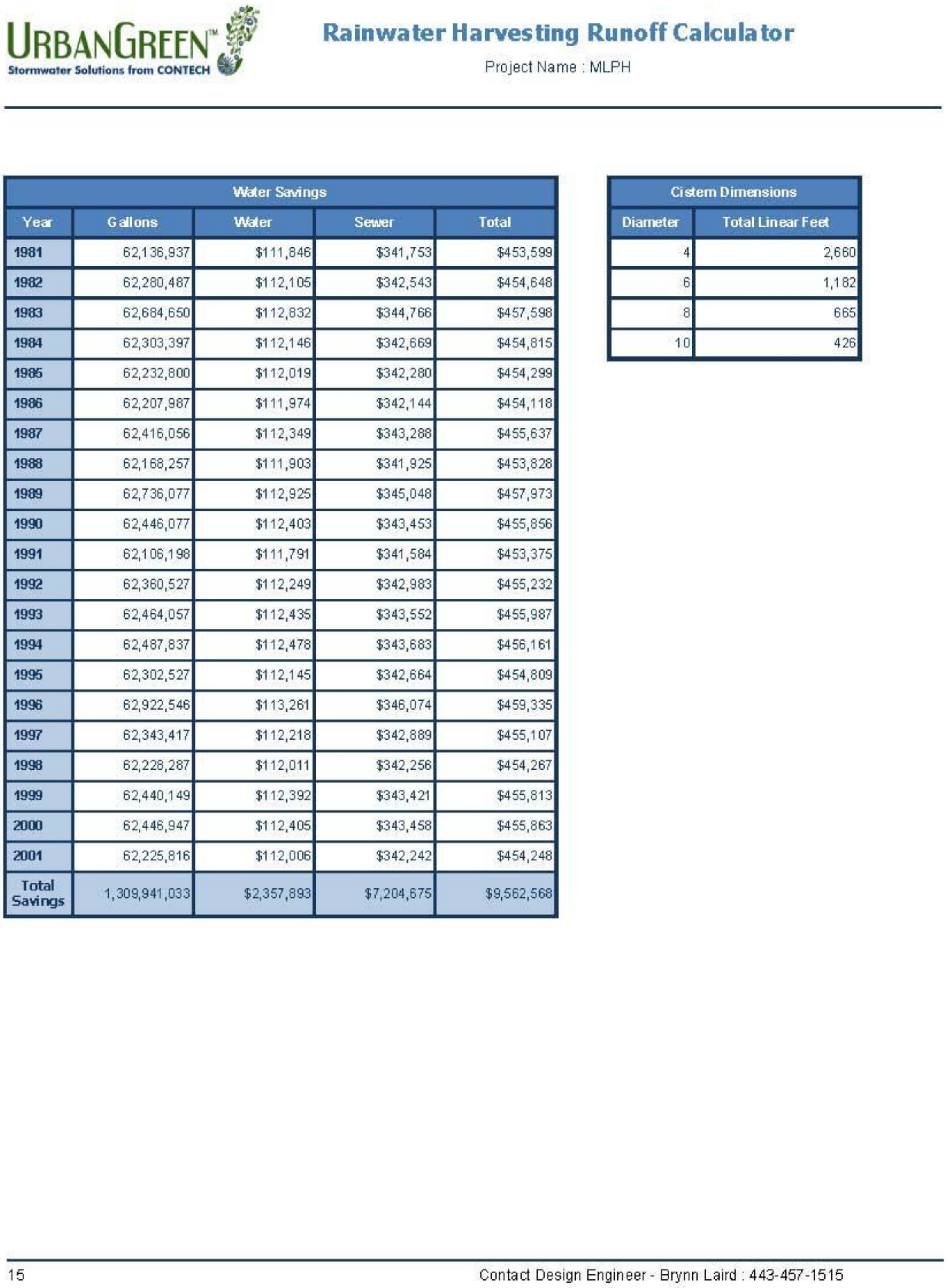
URBANGREEN™
Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

	City Makeup		Water Savings		Runoff Reduction						Secondary Reduction		Total Retained	
	Total	Makeup %	Total	Savings %	Target		Peak		Total		From Secondary Supply			
Year					Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
1981	70,674,122	53%	62,136,937	47%	896,679	100%	8,700	100%	905,379	100%	61,231,559	100%	62,136,938	100%
1982	70,530,572	53%	62,280,487	47%	1,048,929	100%		---	1,048,929	100%	61,231,558	100%	62,280,487	100%
1983	70,126,409	53%	62,684,650	47%	1,443,328	100%	9,763	27%	1,453,091	98%	61,231,559	100%	62,684,650	100%
1984	70,507,662	53%	62,303,397	47%	1,071,839	100%		---	1,071,839	100%	61,231,558	100%	62,303,397	100%
1985	70,578,259	53%	62,232,800	47%	970,919	100%	30,323	32%	1,001,242	94%	61,231,558	100%	62,232,800	100%
1986	70,603,072	53%	62,207,987	47%	949,459	100%	26,970	100%	976,429	100%	61,231,559	100%	62,207,988	100%
1987	70,395,003	53%	62,416,056	47%	1,154,778	100%	29,719	81%	1,184,497	99%	61,231,559	100%	62,416,056	100%
1988	70,642,802	53%	62,168,257	47%	936,699	100%		---	936,699	100%	61,231,559	100%	62,168,258	100%
1989	70,074,982	53%	62,736,077	47%	1,475,518	100%	29,000	100%	1,504,518	100%	61,231,559	100%	62,736,077	100%
1990	70,364,982	53%	62,446,077	47%	1,204,368	100%	10,150	100%	1,214,518	100%	61,231,559	100%	62,446,077	100%
1991	70,704,861	53%	62,106,198	47%	858,399	100%	16,240	100%	874,639	100%	61,231,559	100%	62,106,198	100%
1992	70,450,532	53%	62,360,527	47%	1,113,889	100%	15,080	100%	1,128,969	100%	61,231,558	100%	62,360,527	100%
1993	70,347,002	53%	62,464,057	47%	1,215,968	100%	16,530	100%	1,232,498	100%	61,231,559	100%	62,464,057	100%
1994	70,323,222	53%	62,487,837	47%	1,224,378	100%	31,900	100%	1,256,278	100%	61,231,559	100%	62,487,837	100%
1995	70,508,532	53%	62,302,527	47%	1,051,539	100%	19,430	100%	1,070,969	100%	61,231,558	100%	62,302,527	100%
1996	69,888,513	53%	62,922,546	47%	1,628,058	100%	62,930	100%	1,690,988	100%	61,231,559	100%	62,922,547	100%
1997	70,467,642	53%	62,343,417	47%	1,077,349	100%	34,510	100%	1,111,859	100%	61,231,558	100%	62,343,417	100%
1998	70,582,772	53%	62,228,287	47%	996,729	100%		---	996,729	100%	61,231,559	100%	62,228,288	100%
1999	70,370,910	53%	62,440,149	47%	1,186,678	100%	21,913	25%	1,208,591	95%	61,231,559	100%	62,440,150	100%
2000	70,364,112	53%	62,446,947	47%	1,211,328	100%	4,060	100%	1,215,388	100%	61,231,559	100%	62,446,947	100%
2001	70,585,243	53%	62,225,816	47%	966,859	100%	27,399	77%	994,258	99%	61,231,559	100%	62,225,817	100%
Total	1,479,091,206	53%	1,309,941,033	47%	23,683,690	100%	394,617	70%	24,078,307	99%	1,285,862,733	100%	1,309,941,040	100%

14 Contact Design Engineer - Brynn Laird : 443-457-1515



URBANGREEN™
Stormwater Solutions from CONTECH

Rainwater Harvesting Runoff Calculator

Project Name : MLPH

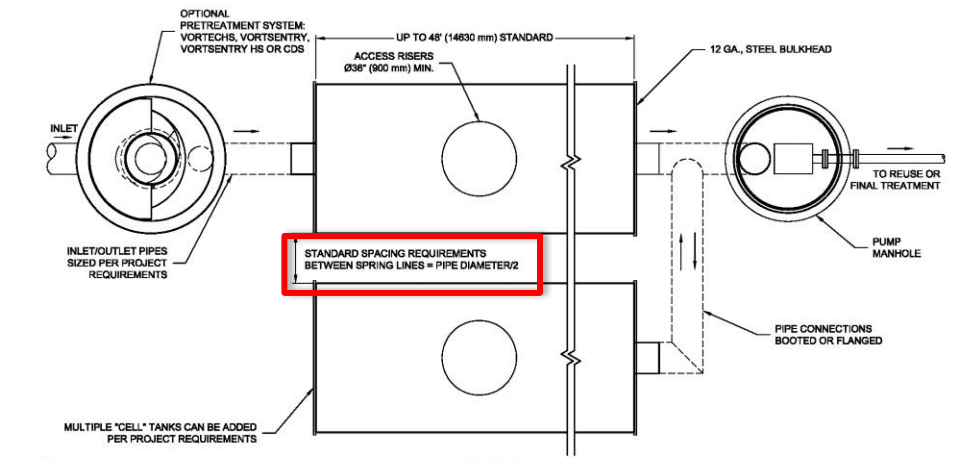
Water Savings				
Year	**Gallons**	**Water**	**Sewer**	**Total**
1981	62,136,937	$111,846	$341,753	$453,599
1982	62,280,487	$112,105	$342,543	$454,648
1983	62,684,650	$112,832	$344,766	$457,598
1984	62,303,397	$112,146	$342,669	$454,815
1985	62,232,800	$112,019	$342,280	$454,299
1986	62,207,987	$111,974	$342,144	$454,118
1987	62,416,056	$112,349	$343,288	$455,637
1988	62,168,257	$111,903	$341,925	$453,828
1989	62,736,077	$112,925	$345,048	$457,973
1990	62,446,077	$112,403	$343,453	$455,856
1991	62,106,198	$111,791	$341,584	$453,375
1992	62,360,527	$112,249	$342,983	$455,232
1993	62,464,057	$112,435	$343,552	$455,987
1994	62,487,837	$112,478	$343,683	$456,161
1995	62,302,527	$112,145	$342,664	$454,809
1996	62,922,546	$113,261	$346,074	$459,335
1997	62,343,417	$112,218	$342,889	$455,107
1998	62,228,287	$112,011	$342,256	$454,267
1999	62,440,149	$112,392	$343,421	$455,813
2000	62,446,947	$112,405	$343,458	$455,863
2001	62,225,816	$112,006	$342,242	$454,248
Total Savings	1,309,941,033	$2,357,893	$7,204,675	$9,562,568

Cistern Dimensions	
Diameter	**Total Linear Feet**
4	2,660
6	1,182
8	665
10	426

15

Contact Design Engineer - Brynn Laird : 443-457-1515

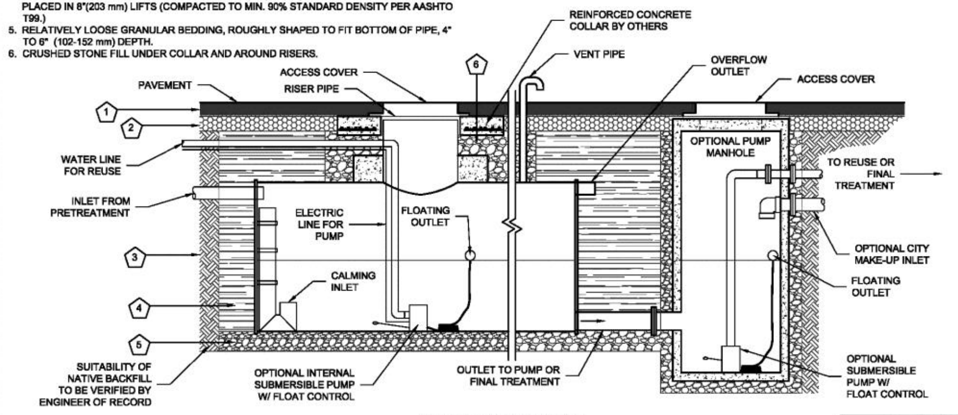
Appendix U: Cistern & Prefiltraion Specifications



PLAN VIEW

KEY

1. RIGID OR FLEXIBLE PAVEMENT.
2. GRANULAR COMPACTED ROAD BASE.
3. ANY SUITABLE NATIVE OR GENERAL BACKFILL, SEE ENGINEER PLANS.
4. SELECT GRANULAR FILL PER AASHTO M145 A1, A2, OR A3, OR APPROVED EQUAL. PLACED IN 8"(203 mm) LIFTS (COMPACTED TO MIN. 90% STANDARD DENSITY PER AASHTO T99.)
5. RELATIVELY LOOSE GRANULAR BEDDING, ROUGHLY SHAPED TO FIT BOTTOM OF PIPE, 4" TO 6" (102-152 mm) DEPTH.
6. CRUSHED STONE FILL UNDER COLLAR AND AROUND RISERS.

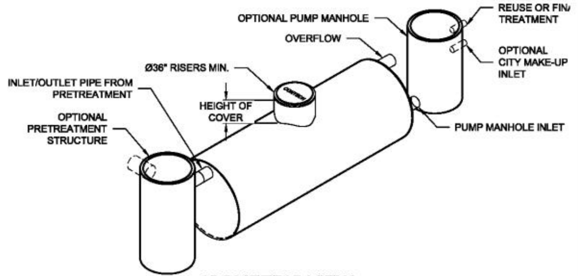


ELEVATION DETAIL

URBANGREEN™

STORAGE AVAILABILITY PER DIAMETER

DIAMETER in / mm	AVAILABLE STORAGE PER L.F. (C.F. / m³)	AVAILABLE STORAGE PER L.F. (GAL. / L)
48 / 1200	12.57 / 0.35	94.00 / 356
54 /1350	15.90 / 0.45	118.97 / 450
60 / 1500	19.63 / 0.55	146.88 / 556
72 / 1800	28.27 / 0.8	211.51 / 800
84 / 2100	38.48 / 1.09	287.88 / 1090
96 / 2400	50.27 / 1.42	376 / 1423



ISOMETRIC VIEW

GENERAL NOTES

1. CONTECH TO PROVIDE ALL MATERIALS UNLESS NOTED OTHERWISE.
2. FOR SITE SPECIFIC DRAWINGS WITH DETAILED STRUCTURE, CAPACITY AND BACKFILL DETAILS, PLEASE CONTACT YOUR CONTECH CONSTRUCTION PRODUCTS INC REPRESENTATIVE. www.contech-cpi.com
3. ALL ELEVATIONS, DIMENSIONS AND LOCATIONS OF RISERS AND INLETS SHALL BE VERIFIED BY THE ENGINEER OF RECORD.
4. PRIOR TO INSTALLATION OF THE SYSTEM A PRE-CONSTRUCTION MEETING SHALL BE CONDUCTED. THOSE REQUIRED TO ATTEND ARE THE SUPPLIER OF THE SYSTEM, THE GENERAL CONTRACTOR, SUB-CONTRACTORS AND THE ENGINEER.
5. THE CISTERN SHALL BE MANUFACTURED WITH THE APPLICABLE REQUIREMENTS OF AASHTO M36 OR ASTM A760
6. THE CISTERN SYSTEM TO MEET AASHTO HS20/HS25 LIVE LOADING, PER AASHTO LRFD SECTION 12.
7. ACCESS COVERS TO MEET AASHTO M306 LOAD RATING.
8. MINIMUM COVER IS EQUAL TO TANK DIAMETER/5 AND NO LESS THAN 12-INCHES (305 mm) FROM TOP OF TANK TO BOTTOM OF PAVEMENT.
9. FOR INFORMATION ON PRE-TREATMENT SYSTEMS, REFERENCE CONTECH PRE-TREATMENT SYSTEM STANDARD DETAILS OR CONTACT YOUR LOCAL CONTECH REPRESENTATIVE.

INSTALLATION NOTES

A. INSTALLATION GUIDE TO BE REVIEWED BY CONTRACTOR PRIOR TO INSTALLATION.
B. CONTRACTOR TO PROVIDE, INSTALL AND GROUT ALL INLET AND OUTLET PIPES.
C. CONTRACTOR TO PROVIDE AND INSTALL ALL BEDDING AND BACKFILL MATERIAL.
D. PRIOR TO PLACING BEDDING, THE FOUNDATION MUST BE CONSTRUCTED TO A UNIFORM AND STABLE GRADE. IN THE EVENT THAT UNSUITABLE FOUNDATION MATERIALS ARE ENCOUNTERED DURING EXCAVATION, A TENSAR BX GEOGRID SHALL BE UTILIZED OR UNSUITABLE MATERIAL SHALL BE REMOVED AND BROUGHT BACK TO GRADE WITH FILL MATERIAL AS APPROVED BY THE ENGINEER OF RECORD. ONCE THE FOUNDATION PREPARATION IS COMPLETE, THE BEDDING MATERIAL CAN BE PLACED.
E. THE BACKFILL SHALL BE AN A1, A2, OR A3 GRANULAR FILL PER AASHTO M145, OR A WELL GRADED GRANULAR FILL AS APPROVED BY THE SITE ENGINEER (SEE INSTALLATION GUIDELINES). THE MATERIAL SHALL BE PLACED IN 8" (203 mm)
LOOSE LIFTS AND COMPACTED TO 90% AASHTO T99 STANDARD PROCTOR DENSITY. WHEN PLACING THE FIRST LIFTS OF BACKFILL IT IS IMPORTANT TO MAKE SURE THAT THE BACKFILL IS PROPERLY COMPACTED UNDER AND AROUND THE TANK HAUNCHES. BACKFILL SHALL BE PLACED SUCH THAT THERE IS NO MORE THAN A TWO LIFT (16" / 406 mm) DIFFERENTIAL BETWEEN ANY TWO OF THE TANKS AT ANY TIME DURING THE BACKFILL PROCESS. THE BACKFILL SHALL BE ADVANCED ALONG THE LENGTH OF THE TANKS AT THE SAME RATE TO AVOID DIFFERENTIAL LOADING ON THE TANK.
F. REFER TO INSTALLATION GUIDE FOR TEMPORARY CONSTRUCTION LOADING GUIDELINES.
G. IT IS ALWAYS THE RESPONSIBILITY OF THE CONTRACTOR TO FOLLOW OSHA GUIDELINES FOR SAFE PRACTICES.
H. GENERAL INSTALLATION METHODS AND MATERIALS TO BE IN ACCORDANCE WITH ASTM D2321.

CONTECH®
CONSTRUCTION PRODUCTS INC.
www.contech-cpi.com
9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069
800-338-1122 513-645-7000 513-645-7993 FAX

URBANGREEN UNDERGROUND METAL CISTERN
STANDARD DETAIL

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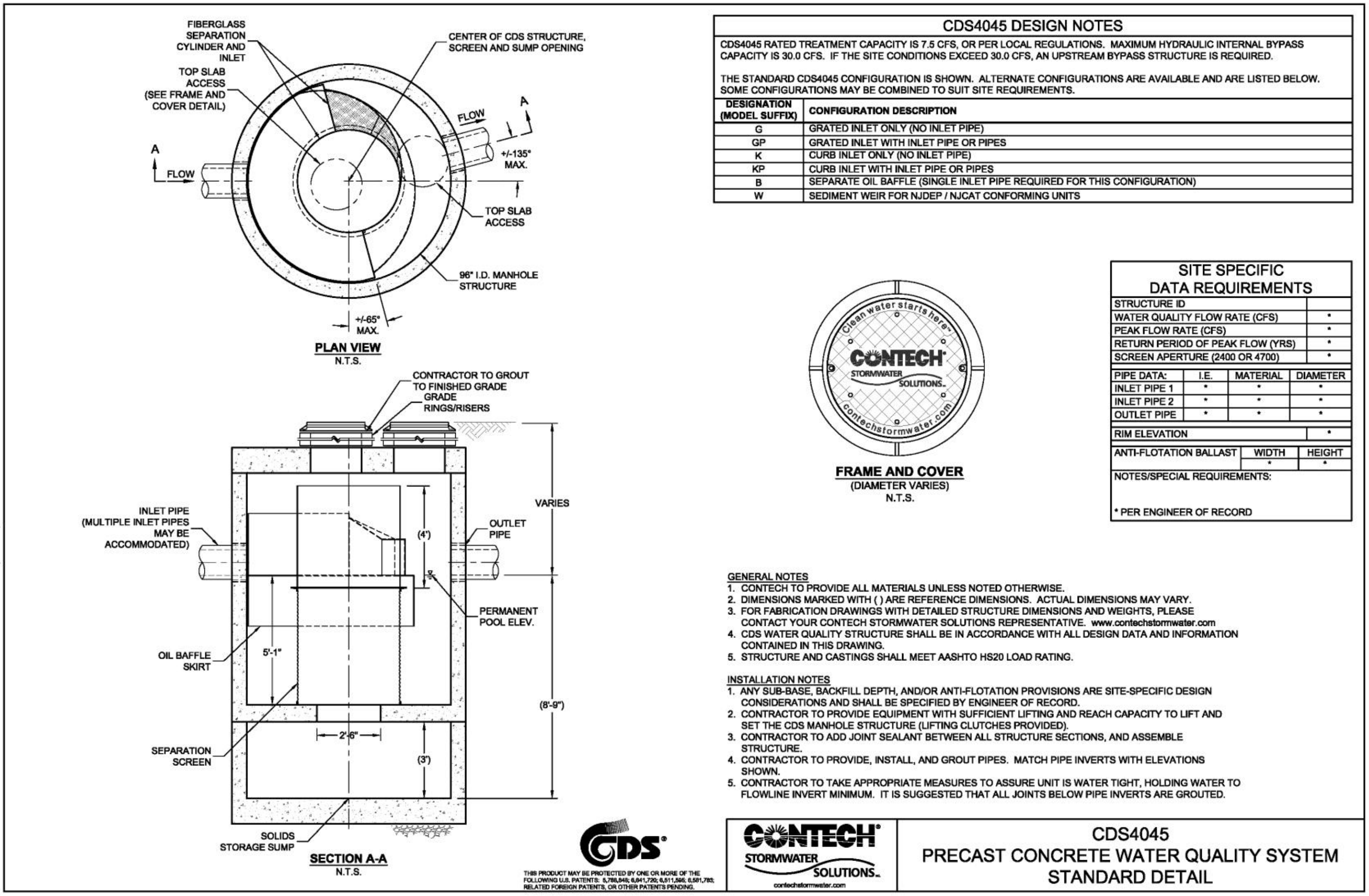


CDS4045 DESIGN NOTES

CDS4045 RATED TREATMENT CAPACITY IS 7.5 CFS, OR PER LOCAL REGULATIONS. MAXIMUM HYDRAULIC INTERNAL BYPASS CAPACITY IS 30.0 CFS. IF THE SITE CONDITIONS EXCEED 30.0 CFS, AN UPSTREAM BYPASS STRUCTURE IS REQUIRED.

THE STANDARD CDS4045 CONFIGURATION IS SHOWN. ALTERNATE CONFIGURATIONS ARE AVAILABLE AND ARE LISTED BELOW. SOME CONFIGURATIONS MAY BE COMBINED TO SUIT SITE REQUIREMENTS.

DESIGNATION (MODEL SUFFIX)	CONFIGURATION DESCRIPTION
G	GRATED INLET ONLY (NO INLET PIPE)
GP	GRATED INLET WITH INLET PIPE OR PIPES
K	CURB INLET ONLY (NO INLET PIPE)
KP	CURB INLET WITH INLET PIPE OR PIPES
B	SEPARATE OIL BAFFLE (SINGLE INLET PIPE REQUIRED FOR THIS CONFIGURATION)
W	SEDIMENT WEIR FOR NJDEP / NJCAT CONFORMING UNITS

SITE SPECIFIC DATA REQUIREMENTS

STRUCTURE ID			
WATER QUALITY FLOW RATE (CFS)			*
PEAK FLOW RATE (CFS)			*
RETURN PERIOD OF PEAK FLOW (YRS)			*
SCREEN APERTURE (2400 OR 4700)			*
PIPE DATA:	I.E.	MATERIAL	DIAMETER
INLET PIPE 1	*	*	*
INLET PIPE 2	*	*	*
OUTLET PIPE	*	*	*
RIM ELEVATION			*
ANTI-FLOTATION BALLAST		WIDTH	HEIGHT
		*	*

NOTES/SPECIAL REQUIREMENTS:

* PER ENGINEER OF RECORD

GENERAL NOTES

1. CONTECH TO PROVIDE ALL MATERIALS UNLESS NOTED OTHERWISE.
2. DIMENSIONS MARKED WITH ( ) ARE REFERENCE DIMENSIONS. ACTUAL DIMENSIONS MAY VARY.
3. FOR FABRICATION DRAWINGS WITH DETAILED STRUCTURE DIMENSIONS AND WEIGHTS, PLEASE CONTACT YOUR CONTECH STORMWATER SOLUTIONS REPRESENTATIVE. www.contechstormwater.com
4. CDS WATER QUALITY STRUCTURE SHALL BE IN ACCORDANCE WITH ALL DESIGN DATA AND INFORMATION CONTAINED IN THIS DRAWING.
5. STRUCTURE AND CASTINGS SHALL MEET AASHTO HS20 LOAD RATING.

INSTALLATION NOTES

1. ANY SUB-BASE, BACKFILL DEPTH, AND/OR ANTI-FLOTATION PROVISIONS ARE SITE-SPECIFIC DESIGN CONSIDERATIONS AND SHALL BE SPECIFIED BY ENGINEER OF RECORD.
2. CONTRACTOR TO PROVIDE EQUIPMENT WITH SUFFICIENT LIFTING AND REACH CAPACITY TO LIFT AND SET THE CDS MANHOLE STRUCTURE (LIFTING CLUTCHES PROVIDED).
3. CONTRACTOR TO ADD JOINT SEALANT BETWEEN ALL STRUCTURE SECTIONS, AND ASSEMBLE STRUCTURE.
4. CONTRACTOR TO PROVIDE, INSTALL, AND GROUT PIPES. MATCH PIPE INVERTS WITH ELEVATIONS SHOWN.
5. CONTRACTOR TO TAKE APPROPRIATE MEASURES TO ASSURE UNIT IS WATER TIGHT, HOLDING WATER TO FLOWLINE INVERT MINIMUM. IT IS SUGGESTED THAT ALL JOINTS BELOW PIPE INVERTS ARE GROUTED.

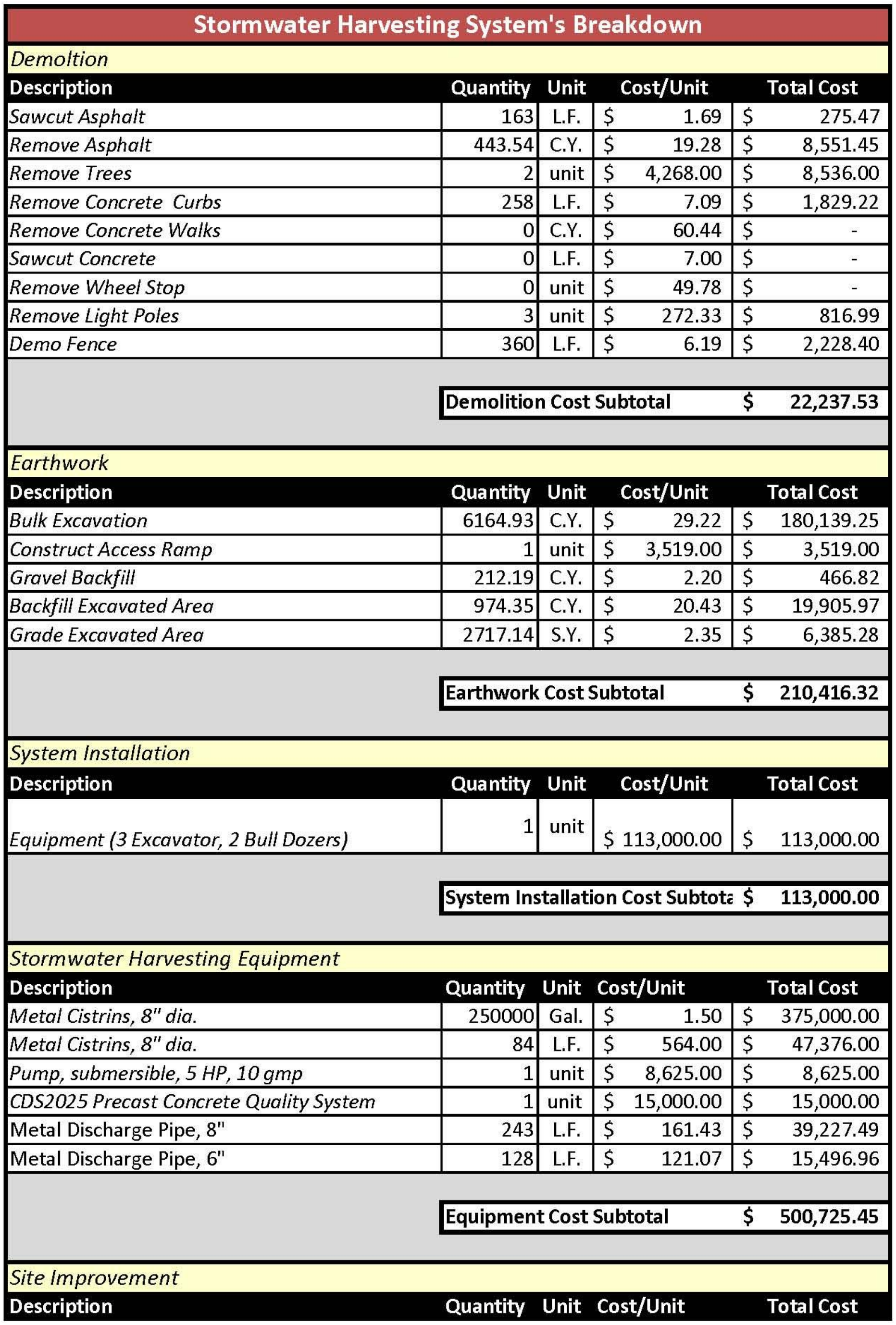
CDS®

THIS PRODUCT MAY BE PROTECTED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS: 5,788,848; 6,641,720; 6,511,595; 6,581,783; RELATED FOREIGN PATENTS, OR OTHER PATENTS PENDING.

CONTECH® STORMWATER SOLUTIONS™
contechstormwater.com

CDS4045
PRECAST CONCRETE WATER QUALITY SYSTEM
STANDARD DETAIL

Appendix V: Stormwater Harvesting Cost Breakdown



Stormwater Harvesting System's Breakdown

Demoltion

Description	Quantity	Unit	Cost/Unit	Total Cost
Sawcut Asphalt	163	L.F.	$ 1.69	$ 275.47
Remove Asphalt	443.54	C.Y.	$ 19.28	$ 8,551.45
Remove Trees	2	unit	$ 4,268.00	$ 8,536.00
Remove Concrete Curbs	258	L.F.	$ 7.09	$ 1,829.22
Remove Concrete Walks	0	C.Y.	$ 60.44	$ -
Sawcut Concrete	0	L.F.	$ 7.00	$ -
Remove Wheel Stop	0	unit	$ 49.78	$ -
Remove Light Poles	3	unit	$ 272.33	$ 816.99
Demo Fence	360	L.F.	$ 6.19	$ 2,228.40
		Demolition Cost Subtotal		**$ 22,237.53**

Earthwork

Description	Quantity	Unit	Cost/Unit	Total Cost
Bulk Excavation	6164.93	C.Y.	$ 29.22	$ 180,139.25
Construct Access Ramp	1	unit	$ 3,519.00	$ 3,519.00
Gravel Backfill	212.19	C.Y.	$ 2.20	$ 466.82
Backfill Excavated Area	974.35	C.Y.	$ 20.43	$ 19,905.97
Grade Excavated Area	2717.14	S.Y.	$ 2.35	$ 6,385.28
		Earthwork Cost Subtotal		**$ 210,416.32**

System Installation

Description	Quantity	Unit	Cost/Unit	Total Cost
Equipment (3 Excavator, 2 Bull Dozers)	1	unit	$ 113,000.00	$ 113,000.00
		System Installation Cost Subtota		**$ 113,000.00**

Stormwater Harvesting Equipment

Description	Quantity	Unit	Cost/Unit	Total Cost
Metal Cistrins, 8" dia.	250000	Gal.	$ 1.50	$ 375,000.00
Metal Cistrins, 8" dia.	84	L.F.	$ 564.00	$ 47,376.00
Pump, submersible, 5 HP, 10 gmp	1	unit	$ 8,625.00	$ 8,625.00
CDS2025 Precast Concrete Quality System	1	unit	$ 15,000.00	$ 15,000.00
Metal Discharge Pipe, 8"	243	L.F.	$ 161.43	$ 39,227.49
Metal Discharge Pipe, 6"	128	L.F.	$ 121.07	$ 15,496.96
		Equipment Cost Subtotal		**$ 500,725.45**

Site Improvement

Description	Quantity	Unit	Cost/Unit	Total Cost