Warrenton Aquatics and Recreation Facility

Warrenton, Virginia

Derek DiPiazza

Construction Management

Spring 2007

Department of Architectural Engineering
The Pennsylvania State University

Warrenton Aquatic and Recreation Facility

Warrenton, Virginia

www.arche.psu.edu/thesis/eportfolio/2007/portfolios/dnd122

Project Team

Owner:	Warrenton Public Works
Architect:	Parker & Grimm Architects
General Contractor:	Forrester Construction Co.
MEP Design:	B2E Consulting Engineers
Recreation Consultant:	The Sports Management Group

Project Overview

Delivery Method:	Design-Bid-Build
Total Square Footage:	59,738 ft²
Total Cost:	22 Million Dollars
Floors:	Two + Penthouse
Schedule Duration:	18 Months

Architecture & Building Envelope

- Mixed use Recreational Building Containing a competition pool, Leisure Pool, Fitness Center, and Offices
- Cylindrical Entrance Vestibule
- Standing Seam Metal Roofing Systems
- Light Beige Brick & Stone Veneer Façade

Structural

- 101'6" Long Roof Truss System Above Pools
- W-shaped Beams and Girders for Floor Support
- Composite Concrete Metal Deck Floor
- Slab-on-Grade Pools (3500psi)
- Continuous and Spread Footings (3500psi)
- Structural Steel and Concrete Columns
- Brick & Stone Veneer Walls with Concrete Masonry

Electrical/Lighting

- 480/277V 3ø, 4-Wire System
- 3000A main Breaker
- 85 kw Emergency Generator
- Typical 277V lighting
- Metal Halide Above Pool Areas
- Typical T-8 Fluorescent bulbs in hallways and fitness rooms

Mechanical

- 4 Air Handling Units, 3 Energy Recovery Units
- 15 water pumps (20-1400GPM)
- 2 Chiller units (415 & 98.3 Tons)
- Hot Water Unit Heaters for Penthouse

Derek DiPiazza
Construction Management
The Pennsylvania State University

Table of Contents

Acknowledgments

I would like to take this opportunity to thank the following people for their guidance and support during my senior thesis project:

- **The Penn State Architectural Engineering Faculty**
  - Dr. Michael Horman
  - Dr. John Messner
  - Dr. David Riley
  - Prof. Kevin Parfitt
  - Prof. Robert Holland
- **Forrester Construction Company**
  - John Diggs
  - Gary Dean
  - Ian McDonald
  - Pavlo Villhauer
  - Raissa Wetcher
- **DuctSox Inc.**
- **Rickmond Engineering, Inc.**
- **B2E Consulting Engineers**
- **Grimm and Parker Architects**
- **Architectural Engineering Students**
  - Tom Sabol
  - Rod Crousey
  - Thad Maugle
  - Dave Potchack
  - Tyler Swartzwelder
  - CM's
- **My Friends**
- **Family**
  - Joanne and Bill- Parents
  - Cristina and Roman- Siblings
- **And the one who helped me the most**
  - Katelyn Baker

Executive Summary

The following document is a thesis report that focuses on the in-depth study of the Warrenton Aquatic and Recreation Facility. The report is divided into four major sections: Project Overview, Construction Ethics Research, Fabric Duct Mechanical Breadth, and Structural Column Breadth.

The project overview portion of the paper is designed to give the reader an introduction to the projects systems and construction components. This portion of the project contains project systems descriptions, the project team summary, local conditions, site layout planning, and project estimate and schedule logistics.

The second portion of this report is designed to take a detailed look at the practice of ethics in the construction industry. The analysis highlights ethical problems within the industry, shows results from an ethical need survey, details the creation of the construction ethics program, and quantifies the results of using the program before making a final recommendation based on the collective research.

Fabric ductwork analysis is the subject of the first breadth. This section describes the different advantages of fabric duct compared to the prescribed double walled spiral aluminum ductwork that is currently in the Warrenton Aquatic and Recreation Facility. Also contained in this portion of the report is a cost analysis, schedule analysis, structural impacts analysis, and finally a conclusion based on the findings.

The last portion of the report is a detailed design and comparative analysis comparing the specified cast in place concrete columns, structural steel columns, and reinforced masonry pilasters. The comparisons consist of cost analysis, schedule analysis, and constructability analysis. A conclusion is then made based on the best possible structural column for the aquatic spaces of the building.

Project Overview

The Warrenton Aquatic and Recreation Facility is located on Old Waterloo Road in the town of Warrenton, Virginia. This building will be an indoor swimming facility for not only competition purposes, but for leisure also. To do this the building incorporates exercise facilities, a competition pool, leisure pool, administrative office space, and snack bars. The project is being delivered by the traditional Design-Bid-Build with a CM Agent representing the owner, Warrenton Public Works.

Project Systems Description

ARCHITECTURE

Function

The new building is designed to provide a recreation facility for the town of Warrenton. It will consist of a competition swimming pool with spectator seating, leisure pool complete with waterslide and lounge areas, juice bars, fitness rooms, and office space to run the facility. It also features a cylindrical entrance vestibule on the upper floor as its main entrance which enhances this aesthetically pleasing building.

Design

The architecture of the building combines different types of building materials to enhance the building's appearance. The light beige brick on the exterior walls cover the main building while the vivid red brick defines the cylindrical entrance vestibule. On top of the building, the standing seam metal roof is colored to be consistent with the metal shingles

on top of the exterior walls as well as the architectural exposed steel members that support the roof. The base of the building is covered in a stone veneer that matches the surrounding site's retaining walls. The interior spaces are naturally lit by large, light glazed window systems that will give the building an open feeling.

Building Envelope

The building envelope consists of multiple materials on each exterior wall. These walls primarily consist of CMU block backing with a stone veneer base followed by brick veneer and metal shingles above. The walls also use aluminum framed, glazed curtain wall window system, cast stone sills, and architectural steel to complete its structure. To compliment this, the architect chose three types of roofing systems to accommodate the buildings needs. The bulk of the roof consists of a standing seam metal system on all the sloped and curved roofs, while a built-up roof resides on the upper, flat roofs. Also incorporated into the building is a small green roof located in the plaza area just outside the entrance vestibule that will be covered with grass.

Construction Description

The construction of the Warrenton Aquatic & Recreation Facility has some challenging tasks to be completed to ensure that the project runs smoothly and is a success. Construction starts in January of 2006 with excavation of the site in order to place the concrete foundation. The steel superstructure and metal roof and floor decks are set before the concrete is pumped in to complete the floor systems in the main building. To top out the competition and leisure pool areas, a series of eight 101'6" prefabricated

steel roof trusses will be set via mobile crane, which had to be shipped in halves and welded on site before being placed. The trusses were prefabricated to speed up installation, ensure proper assembly in a controlled environment, and also to reduce safety hazards during installation. After the roof is in place, the buildings CMU walls and brick façade will be put into place using hydraulic scaffolding as well as the MEP rough-in will be taking place. The pool areas are the last portion of the building to be constructed. Their concrete pours will be in the winter months of 2007, so the building will have to have temporary heating to ensure proper construction. Because the leisure pool has so many curves and turns, elevation and location points will be set by modern surveying equipment for proper placement. The 19 month construction is planned to end in July with building turnover planned for the first of August.

Mechanical System Description

The climate conditions in the building are supplied by four air handling units (AHU) and three energy recovery units (PHU & HRU). These units are housed in both penthouses while AHU-4 and HRU-1 are located in the lower level mechanical room. The two AHU's in Penthouse 2 service single zones only (Fitness (4800cfm) and Multi-Purpose Rooms(5500cfm)) while the PHU's are used primarily to save energy and supply heating and cooling to the competition and leisure pool areas (38,000cfm). The remaining air handler services the administration area of the building (14,575cfm). Also, hot water unit heaters are used to heat the penthouse areas while duct mounted reheat coils and air terminal units are being used to control air temperature in the common areas of the building. A series of fifteen pumps ranging in size from 20-1400gpm are used to supply water to the aforementioned air units. This water will come from five separate boilers during heating months and two chillers during the summer to cool the building.

The chillers are two different types, one being an air-cooled system rated at 415 tons while the water-cooled system is rated at 98.3 tons. Finally, the two pools use a series of 12 pumps, circulating water anywhere from 200gpm (main drain) to 1750gpm (current channel) to meet the respective needs.

Structural System Description

The structural system for the building starts at the foundation with both continuous and spread footings. These footings are made of 3500psi concrete while the slab-on-grade concrete floors are also made of 3500psi. The upper level and penthouse floor systems are supported by W-shaped beams. The floor itself is a composite slab and deck system with concrete specified at 3000psi. Throughout the non-pool areas load from the W-shaped beams and girders are transferred to the steel columns that support the gravity load while the moment frames resist the lateral load. The pool area columns are constructed of typical concrete columns with concrete masonry units for walls. Above the pool areas, anchor bolts on top of the concrete columns connect the 101’6” long roof trusses to the structural system (8 total) that support the standing seam metal roof above. Over the non-pool areas the roof also consists of standing seam metal but these areas are supported by W-shaped members instead of the large prefabricated trusses.

Electrical System Description

The electricity that is being brought into the Warrenton Aquatic and Recreation Facility is a 480/277V, 3-Phase 4 wire system. After entering the building the feeder goes

to a 3000A main distribution switchboard where it is split up to service the main building systems. The panel boards that are serviced from the main feeder supply power to the pool pumps, air handling units, future building expansion slots, and other local panel boards. To further supply power to the building, eight step-down transformers are used for panel boards that supply power to the elevators and typical lighting and receptacle spaces. A 30kva K13 transformer is used to step down the power for the facility's office space to control the unbalanced loads produced by computers. Finally, an 85 KW emergency generator supplies power to the elevator, fire alarm system, and emergency lighting in the event of an emergency.

Lighting System Description

The lighting inside of the Warrenton Aquatic and Recreation Center consists of metal halide, fluorescent, and incandescent lights. Most of these lights run off of 277V power with the exception of some specialty lighting that runs on 120V. The perimeter of the pool is interesting to note because the lighting is recessed in the walls, so to change the bulbs the pool will not have to be drained. Typical 32W T-8 fluorescent bulbs are used throughout the building in the locker rooms, fitness areas, and mechanical rooms, while metal halides are used in the entrance vestibule with the area above the pool being indirect metal halide lighting. The wattages for these lights typically range from 70W to 150W with the lights above the pool being 1000W.

Fire Protection Description

The fire protection system for the building incorporates both ceiling and duct mounted smoke detectors as well as manual pull stations and heat detectors as protection triggering devices. To alert the population of an emergency, audio-visual devices will be used incorporating strobes and alarms. All of these systems are wired to both a central fire alarm controlled panel and an annunciator panel that have integral battery backup systems. To extinguish fires the building will use a wet-pipe sprinkler system that will be located on the upper floor and supplied with water through an outside stem and yoke valve.

Building Transportation Description

The Warrenton Aquatic and Recreation facility employs one elevator to service the building. It is centrally located for ease of accessibility and is operated using an under-the-car single cylinder hydraulic system. The elevator cab is rated for 2500lbs and transports passengers at 100fpm. Three stair cases are also used to navigate through the building. These are located at the center of the building as well as the end of the west and south east corridors, respectively.

Competition & Leisure Pool Description

The main attractions of the Warrenton Aquatic and Recreation Facility are the competition and leisure pools. Each pool is slab-on-grade concrete and is cast-in-place. The competition pool is an 8 lane, 25 meter pool with timing devices for competition and also features two, one meter diving boards. The leisure area contains a 143’6” waterslide that is just under 20’ tall, spa, vortex pool, current channel, and a child amusement station. Both pools also have a handicap lift for ADA approved pool access as well as stairs, sloped grade entry, or ladders for easy pool access.

Project Team Summary

Client Information

The owner of the project is the town of Warrenton. Because the owner is not a single entity and does not have a large amount of construction experience, they hired a construction management agency to represent their best interests in the project.

The town decided to construct this project for multiple reasons. The first is because it is part of a plan to provide recreation facilities to the town of Warrenton. The facility fits in perfect with the surrounding baseball and soccer fields as well as the skateboard park and bike riding/hiking paths. The next reason is that the mayor and town councilmen wanted to provide the town of Warrenton with one of the best recreational facilities in the area. This is necessary because the town is primarily a rural area, so a development of this type will provide an entertaining venue for the town. The last reason for construction is to attract potential citizens to the area. The Washington D.C. area is continuously growing and Warrenton will use this building to help attract future citizens.

The expectations of the owner are high considering the amount of financial resources they are putting into the project. With regards to the budget, the public works department feels that the project will go over the $22 million budget because of a few change orders. However, the project should stay well below the industry average of 6-8%. The public works department feels that the construction will finish early and turnover should be possible before July. The owner points out that the early completion will not sacrifice quality, however, they mentioned that they are very pleased with how the construction is progressing. The last expectation that the town has is that safety should be the first priority and no injuries or accidents should take place on the site. To make sure safety comes first, Forrester Construction (GC) has hired an independent safety inspector to perform random inspections as well as having their own OSHA certified employees and CM-agent employees inspect the site on a daily basis.

Finally, the owner mentioned the one key issue for a successful and satisfactory completion of the project. That is that they want to receive the highest value for the amount of money they have invested. To guarantee that this happens, Forrester

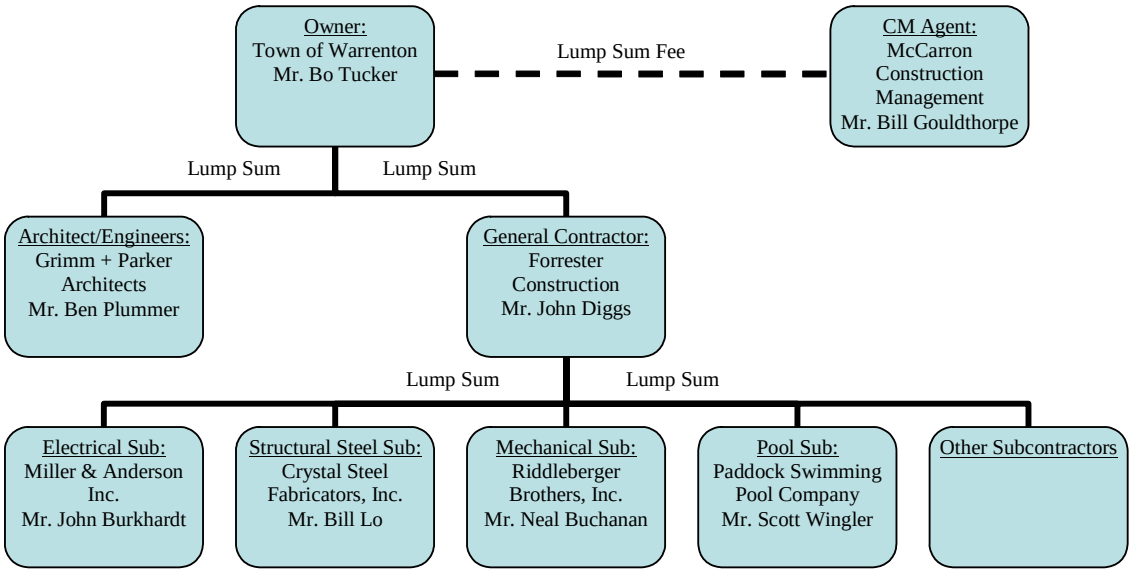
Construction has hired some of the areas finest subcontractors to ensure that the quality of work is of award winning craftsmanship. If a sub is not performing to the owners or their own high standards, Forrester has and will replace the subcontractor to make sure that the end product is well above the owner's satisfaction level.

Project Delivery System

The Warrenton Aquatic and Recreation Facility is being delivered as a Design-Bid-Build job. The owner, the town of Warrenton, is holding Lump Sum contracts with the architect/engineers, general contractor, and also with a construction management agent. Forrester Construction Company was the low bidder and therefore became the general contractor.

The contracts through Forrester construction were also handled in a similar fashion. Bid packs were created to split up the work and the purchasing department sent out bid invitations to the local contractors. The bids were then awarded based on the bid price and qualifications of the subcontractor. After the appropriate subcontractors were selected they signed a master subcontract agreement with Forrester as well as a Lump Sum project contract.

Project Delivery Chart



Project Staffing Plan

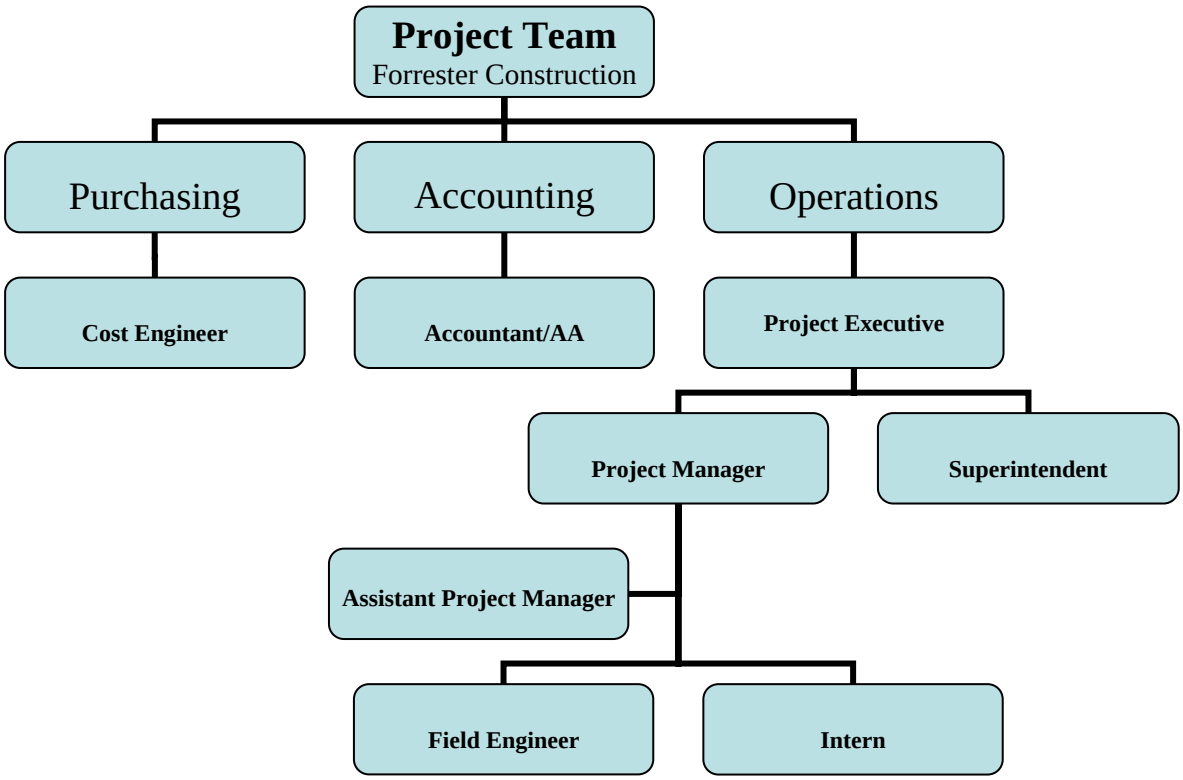
The staff on the Warrenton Aquatic and Recreation Center was organized by the general contractor into three groups based on their company structure. These departments are the purchasing group, accounting group, and the operations group, with an administrative assistant to help process paperwork.

The purchasing group consisted of one cost engineer who was responsible for contacting subcontractors with different bid packages. The cost engineer would then compare bids and based on the companies system for selecting subcontractors, would award the appropriate subcontractor the contract. This process started after the general contractor was selected and has continued through the first eight months of the schedule. The cost engineer also worked with the project manager (PM) and assistant project manager (APM) to try and make sure all work and materials were accounted for.

The accounting group consists of one accountant who devotes a portion of time to processing the financials of the project. These responsibilities include tracking payments and work-in-place, processing payments to subcontractors and suppliers, and logging losses and gains compared to the estimate. The PM also works with the accountant to help keep the numbers as realistic and up to date as possible as well as to keep the cash flow moving and positive.

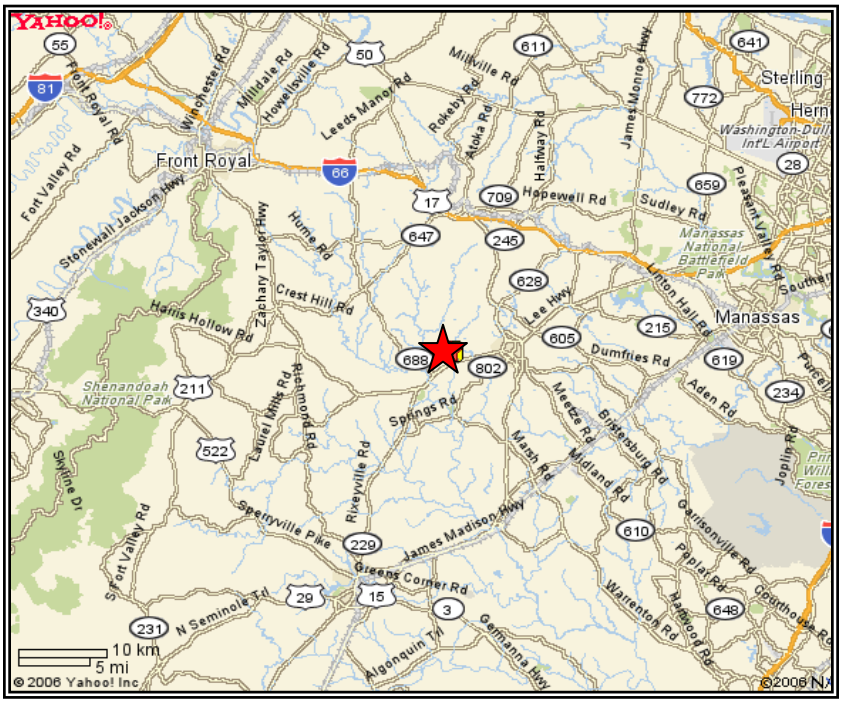
The largest part of the project staff is the operations group. At the head of the group is the project executive. This person is responsible for general project oversight and project troubleshooting while providing communication between the client and the rest of the project team. The next level in the staff is the PM and superintendent. The superintendent's primary responsibilities are project safety, the project schedule, construction coordination, and quality control of work being done. The project manager's responsibilities include negotiating contracts and change orders, subcontractor correspondence, material delivery log, and the aforementioned accounting and purchasing work. The APM assists the PM in all his duties as well as maintains meeting minutes and monthly project reports, submittal logs, and quality control. Finally, the field engineer and intern keep track of the site deliveries, conduct coordination and safety meetings, process RFI's, update drawings, and complete the misc. project tasks.

Project Staffing Chart



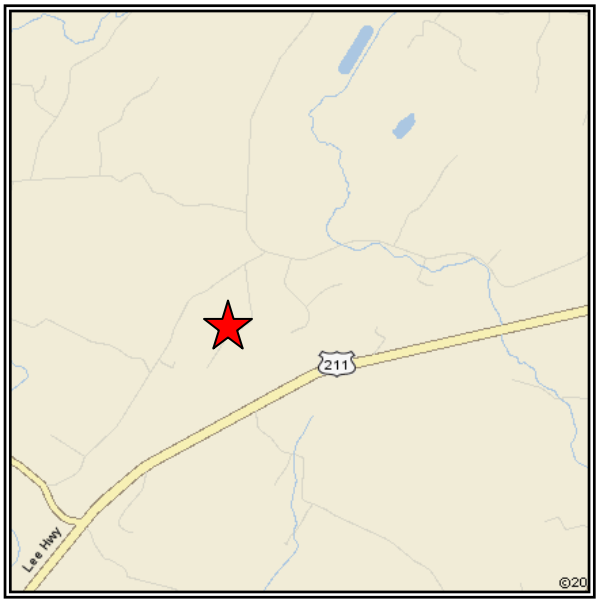
Local Conditions

The construction site is located in the town of Warrenton, Virginia, across the street from the Fauquier High School. Typically in the local area concrete is used to for the structural systems, however the owner and architect decided for the majority of the structural system to be steel with a composite deck floor system.



Town of Warrenton

Construction congestion around the project should not be an issue at all due to the fact of it being located in a large field with no close neighbors. Contractors have the option of using sea containers for storage around the large open site and there is a variety of areas available for steel staging. The mobile crane that is used for the erection of the steel will have no problem navigating through the site also as a result of the open space. With regards to site traffic and parking, one of the parking lots and access roads were paved early to provide parking for the construction workers and will also allow for a clear route for site deliveries. Pedestrian traffic



Project Location

is not an issue because of the remoteness of the site. In the final months of the project the remaining parking lot will be paved along with an access road connecting route 211 to the Warrenton Aquatic parking lots and Old Waterloo Road. Waste from the project is being removed via dumpsters provided by Waste Management Inc. who is contracted through the general contractor

The soil at the site consists of three primary types. The first type is the top soil which is an average of 12 inches deep and will be removed and used later for grading. The second type of soil is silty/sandy clay and fine sandy silt. Because this soil has low plasticity it is considered to be suitable for structural fill. The last type of soil is "Greenstone" bedrock. This soil can be excavated easily in the top layers but may produce difficulties when excavating the competition pool areas because of the increased depth. This stone can be crushed and processed to 3" and mixed with soil fines in order to be considered suitable for structural fill and backfill.

Site Layout Plan

The site plans will show that the site for the Warrenton Aquatic and Recreation Facility is favorable for all phases of construction. This is because the site is located in the middle of former recreational fields which provide the project with large amounts of open space for layout and storage. To illustrate this, the structural erection plan was highlighted to show how the project will be erected, which can be seen in Appendix A. As you can see in the plans, as well as the schedule, the construction is broken into zones, and then starting with the east of zone A, the structure will be set into place. It is important to note that while the erection of the last two zones do not appear to have total crane coverage, it is still possible for the steel to be set properly. This can be explained because the only major steel members that will need to be set in these two phases are the steel trusses that span the width of each building.

The structural erection drawings along with the schedule can be used as a tool to visualize how the building will be erected, not only structurally but through all phases of construction.

Project Logistics

Detailed Project Schedule

The Warrenton Aquatic and Recreation Center's schedule consists of 199 activities that are arranged chronologically so that the sequence of construction can be conveyed easily. The project was started on January 10, 2006 and is projected to finished and turned over on August 1, 2007. For the purposes of this assignment and also to help with the ease of legibility, relationship lines have been left off to make the schedule clearer. This schedule is located in Appendix B.

Project Cost Summary

The following project cost data is the estimated cost of the Warrenton Aquatic and Recreation Facility. All numbers were compiled using R.S. Means 2005 and include location modifiers. The table is provided as a reference to the scale of the project and in now way is associated with the actual cost of the project.

Warrenton Aquatic Cost Data		
Description	Cost ($)	Cost ($)/ft2
Construction Cost	19,738,474	330.42
Total Project Cost	22,430,111	375.47
Building Systems	Cost ($)	Cost ($)/ft2
Site Work	$ 2,000,000	33.48
Concrete	$ 1,875,000	31.39
Masonry & Stone	$ 2,350,000	39.34
Metals	$ 2,300,000	38.50
Rough & Finish Carpentry	$ 250,000	4.19
Thermal & Moisture Protection	$ 800,000	13.39
D/F/H, Glass, Glazing, Windows	$ 800,000	13.39
Drywall, Flooring, Finishes	$ 720,000	12.05
Specialties	$ 115,000	1.93
Equipment & Appliances	-	
Furnishings	$ 180,000	3.01
Special Constructions	$ 1,950,000	32.64
Conveying Systems	$ 40,000	0.67
Plumbing, HVAC, Sprinkler Systems	$ 4,900,000	82.03
Electrical Systems	$ 1,400,000	23.44
Special Systems	$ 16,000	0.27

Analysis #1

Construction Ethics

Problem

Ethics in the construction industry is an issue that is never clear cut. What companies view as ethical differs greatly and can have a significant impact on their competitive advantage. As a result, the industry suffers from a poor image and an uneven playing field. Formulating an interactive training tool to develop and implement ethics into a company would improve the industry's image, level the competitive playing field, and increase social responsibility among its employees.

Goal

The goal of the proposed research is to identify and develop an ethics training program that would become part of a company's employee training program and also be able to be used on students entering the industry. With the acquired knowledge from surveying industry members and students, an informational training program would be developed for companies and students to use. This will provide the industry with a solution to increase the ethical performance of its respective companies and personnel entering the industry.

Methodology

1. Complete a literature review on construction ethics focusing on prevailing ideals and codes
2. Develop and distribute a survey to the respective companies employees and students that will identify the different companies corporate ethical strengths and weaknesses as well as the success of their implementation
3. Use the results from the survey to decide what the best ethical implementation tool would be appropriate
4. Define the most common ethical transgressions
5. Develop the program and conduct an exit survey to analyze results

6. Research construction ethics awards and identify defining criteria
7. Relate the program to the Warrenton Aquatic Facility by communicating with project staff
8. Create final depth report from results

Tools

1. ASCE Code of Ethics
2. CMAA Code of Ethics
3. Ethical Need Survey
4. Exit Survey
5. National Capital Business Ethics Association
6. Penn State AE Faculty
7. Strategic Management Materials
8. Microsoft Excel
9. Microsoft PowerPoint

Expectations

The expected outcome of this research is to produce a training program that will help ingrain a standard of ethical values into industry members and students. This tool will be used to improve the industry's image, level the competitive playing field, and increase social responsibility among industry members and students alike.

Initial Research

After contacting different construction companies who offer training programs to their employees, I found that most companies do not offer a course on ethics. And as I have stated before, the industry is marred by unethical behavior. Therefore, a training program to develop better ethical practices by incoming and current industry members will help clean up this preposterous problem. The following is the research that I have conducted that will: illustrate the need and want for the training guide, define the industry identified ethical problems that will aid in developing the training guide, and quantify and draw conclusions from the training program.

Ethical Need Survey

A survey was compiled and distributed to construction management firms and students to determine how important industry members think ethics are. The survey consists of eleven yes/no questions and can be found in Appendix C. The percentages were determined from the 45 surveys that were returned. From the results, the following data was formatted to create the subsequent Table 1.1 (charts of the results can be found in Appendix D):

Question Description	Yes (%)	No (%)
Consider Ethics Vital to Job	95	5
Ethical Transgressions more Likely in Construction Industry	45	55
Consider Ethics a Competitive Advantage	74	26
Ethical Transgressions a Necessity to Maintain Competitive Advantage	32	68
Bottom Line more Important than Ethical Practices	21	79
Promotion based on Schedule and Budget Performance over Ethics	42	58
Rewarded for Ethical Job Performance	42	58
Behave More Ethically if Rewarded	87	13
Company Conducts Employee Training	89	11
Company Offers Ethics Training	16	84
Would like to have Course on Construction Ethics	73	27

Table 1.1

Ethical Need Survey Analysis

Industry Comparison

The results from the survey confirmed my initial expectations. The answer to the first question shows that nearly all members of the industry consider ethics to be a vital part of their job. This allows the conclusion to be drawn that ethics should be addressed in the industry whether by the individual company, university, on their own accord, or by the industry as a whole.

The next question shows nearly a split when considering whether or not ethical transgressions are more frequent and likely to happen in the construction industry when compared to business as a whole. The business industry already has programs that teach ethics to its employees. The advantages of this are that by providing training on ethics, the companies shed liability with regards to lawsuits based on employee ethical transgressions such as sexual harassment, discrimination, financial misrepresentation, etc. Because the numbers are so similar, the construction industry should also take steps to develop and implement an ethics training program. This could also help the industry with ethical lawsuits but more importantly would help clean up the industry's reputation.

Competitive Advantage

The next section of the survey correlates ethics to competitive advantage within the industry. As you can see, 74% of those surveyed considered ethics to be a competitive advantage over their company's competitors. This statistic may be skewed because the survey did not identify whether or not it was good or bad ethical practices to gain competitive advantage.

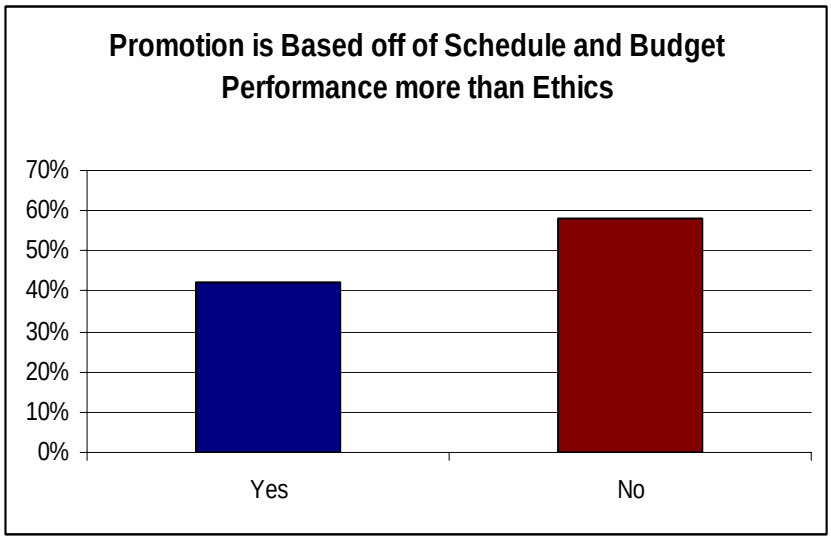
However, the next question of the survey did identify that only 32% of the industry members said that ethical transgressions were necessary to maintain a competitive advantage in their respective markets. This statistic shows that people knowingly behave unethical, which further demands that ethics be taught and developed within the industry. As I mentioned before this would level the playing field and the

competitive advantages would solely be gained by owners only wanting to conduct business with ethical companies.

Ethics and Career Advancement

Ethics within a company are strongly influenced by how the company conducts business. The first question that addresses this in the survey asks whether or not the bottom line is more important in a company than ethical behavior. Only 21% of those surveyed said that the bottom line was more important than behaving ethically. This statistic is encouraging, but should still be lower.

To incorporate this into individual careers and company practices, the responses from the survey show that 42% of industry members feel that schedule and budget performance will help them get promoted within the company rather than behaving ethically. The survey does not ask whether or not to achieve a better budget and schedule if the individuals were behaving unethical. However, coupled with data from the ethical transgressions survey found in table 1.2, I am assuming that to achieve a better schedule and budget, unethical practices such as front-end loading and bid shopping are two of the more common methods to increase project performance. Therefore it can be concluded that 42% of companies are rewarding unethical practices which is unacceptable.



An interesting statistic that contradicts this is that 42% of construction employees report that their company does reward them for behaving ethically. What was not indicated however was what type of reward was received by the employees. Informal

interviews with industry members however revealed examples of these rewards being in the form of monetary bonuses and awards.

The last portion of the survey that deals with company practices shows that 87% of industry members would behave more ethically if they were to be rewarded Most companies conduct performance reviews of their employees and therefore if they included a review of ethical practices for their employees, they could reward ethical practices through standard employee bonuses. So in conclusion, this is a corporate strategy that should be considered by companies to increase ethical practice.

Company Training and Ethics

The last and most important portion of this survey deals with company training and ethics. It was found that 89% of companies offered training courses to their employees. Of those 89% however, only 16% of the companies offered any type of training on ethics. This alone could be responsible for the bad ethical practices of employees and ultimately the industry as a whole. However, 73% of those surveyed said that they would like their company or university to offer a course on professional ethics as it relates to the construction industry. This shows that not only does the industry need a training program on ethics, but it also *wants* it.

Ethical Need Survey Conclusions

In conclusion from the Ethical Need Survey, I have found that industry members find ethics to be a vital portion of their job and they consider ethics to be a competitive advantage. Ethics can strongly influence individual's careers and how companies operate.

Incentives can be given and thus strategies developed by companies to create better ethical conduct within the industry. Finally, because companies generally use training programs to develop employees and instill corporate policies from within, a corporate training program that teaches ethics is a great method to develop ethics in the industry. Furthermore, my survey results show that the industry not only needs ethical training, but again, they more importantly *want* ethical training.

Ethical Training Guide Development

Research

The first step to develop the construction ethics training program is to identify the ethical transgressions that plague the industry. To do this, I have researched many different publishings on construction ethics to determine which are the prevailing ethical issues. However, while conducting my research, I found a study conducted by Barbara Jackson of the California Polytechnic State University that identified and defined the top transgressions in the industry. To do this, Barbara used a survey among random project managers to document the industry identified fifteen most frequent transgressions as well as ranking them according to the seriousness of the transgression. Therefore, for the purposes of the research and development of the ethics training program, these top fifteen transgressions will be the focus of the issues that need to be addressed in the program. The results of the survey can be seen in Table 1.2 which follows:

Contractor Perceptions of Frequency and Seriousness of Ethical Transgressions

Number	Frequency Issue	Mean	Seriousness Issue	Mean
1.	Improper or Questionable Bidding	3.3178	Alcohol and Drug Abuse	4.0870
2.	Misrepresentation of Completed Work or Value of Work	3.3031	Improper or Questionable Bidding	3.9437
3.	Poor Quality Control or Quality of Work	3.1063	Failure to Protect Public Health, Safety, or Welfare	3.8750
4.	Technical Incompetence or Misrepresentation of Competence	3.0063	Poor Quality Control or Quality of Work	3.8213
5.	Abuse of Company Resources	2.9969	Abuse of Client Resources	3.6677
6.	Alcohol and Drug Abuse	2.7262	Improper Relations with Clients, Contractors, etc.	3.6270
7.	Failure to Reconcile Employee or Subcontractor Concerns	2.7081	Conflicts of Interest, Improper Political/Community Involvement	3.5696
8.	Abuse of Client Resources	2.6563	Misrepresentation of Financial Status or Records	3.5688
9.	Conflict of Interest, Improper Political/Community Involvement	2.6375	Technical Incompetence or Misrepresentation of Competence	3.5643
10.	Mishandling Sensitive Information	2.4769	Failure to Protect the Environment	3.5497
11.	Failure to Protect Public Health, Safety, or Welfare	2.4594	Failure to Reconcile Employee or Subcontractor Concerns	3.4563
12.	Discrimination, Favoritism, or Harassment	2.4206	Mishandling Sensitive Information	3.4517
13.	Misrepresentation of Financial Status or Records	2.4149	Discrimination, Favoritism, or Harassment	3.4222
14.	Failure to Protect the Environment	2.3673	Abuse Company Resources	3.3836
15.	Improper Relations with Clients, Contractors, etc.	2.3187	Misrepresentation of Completed Work or Value of Work	3.0503
	Average Mean	**2.7277**		**3.6025**

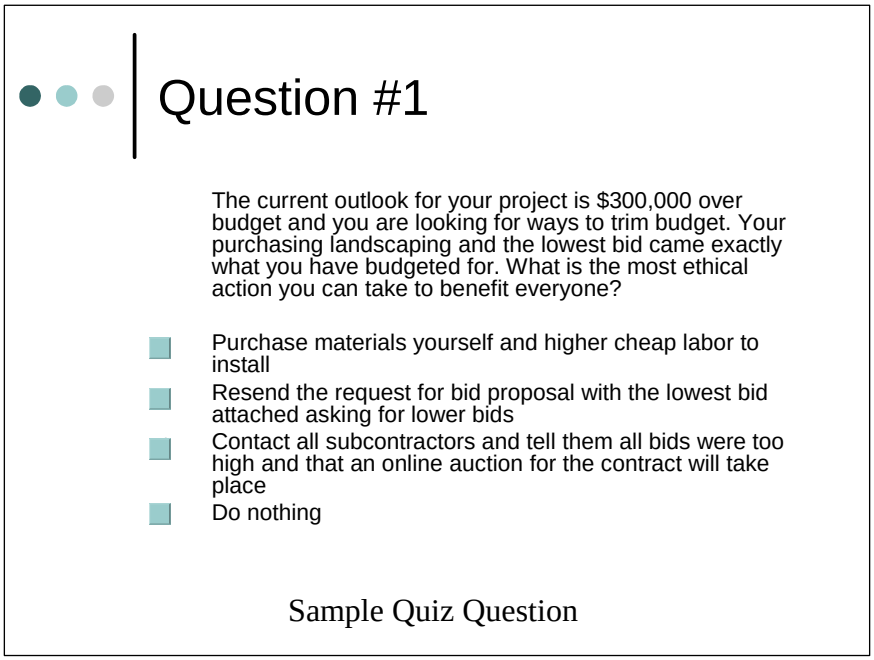
Table 1.2

Note: A mean of 1.0 for frequency represents the transgression never happening, and a mean of 5.0 represents the transgression happening very often. A mean of 1.0 for seriousness represents the transgression being perceived as not serious at all, and a mean of 5.0 represents the transgression being perceived as extremely serious.

Training Guide Setup

The instrument used to develop the construction ethics training guide was Microsoft PowerPoint. The fifteen transgressions, as mentioned earlier, were used to create the topics for training. Due to the potential length of the program, the fifteen transgressions were divided into three modules based on similarities. Each transgression topic was identified, key forms of violations noted and explained, and finally solutions proposed for each transgression.

At the end of each module, a five question quiz was developed from the learning portion of the module. The quiz questions defined situations that commonly have unethical practices associated with them. If any of the five questions are missed, the program takes the user back to the beginning of the module to review the material again. Upon successful completion of the quiz, the user will advance to the next module until all three modules are completed successfully.



Sample Quiz Question

The final portion of the training program is the final examination. The exam features a question modeled from each respective topic section totaling fifteen questions. The requirement to pass the course is an 85%, or thirteen out of fifteen correct. If more than two are missed, then the program will take the user back to the beginning of the exam until it is successfully completed.

Ethics Training Program Results

To evaluate the effectiveness of the construction ethics program a sample group of eleven people, including both students and industry members, completed the course. These eleven people were then asked to fill out an eight question exit survey evaluating the effectiveness of the construction ethics program, which can be found in Appendix E. The results of this survey were taken and compiled into Table 1.3:

No.	Question	Yes	No
1.	Do you consider the program to be a valid tool for ethical training?	100%	0%
2.	Would you recommend this program to your coworkers/peers?	91%	9%
3.	After completion of the program, would you act more ethically within the construction industry?	73%	27%
4.	Would you like your company/university to use this program as its means to train employees on ethical practices?	82%	18%
5.	Do you think that the program would fit into your companies/universities training program or learning curriculum?	73%	27%
6.	Is the benefit of taking the program worth the cost of it to your employer?	82%	18%
7.	Is the benefit of taking the program worth the time invested by the employees/students?	73%	27%
8.	Do you consider this training program to be a better alternative to your company's current method of addressing ethical practices?	91%	9%

Table 1.3

Exit Survey Analysis

The response from the program was extremely positive. As you can see from the table, all eleven of the participants who took the survey confirmed its validity as a training tool while all but one would recommend it.

Program Purpose

The question that defines the purpose of the program is "would you act more ethically within the construction industry after completion of the program?" The results show that eight of the eleven test subjects would act differently after the completion of the program. This demonstrates that the program is an effective tool to curb unethical practices in the construction industry. The ideal result would be for all test subjects to act ethically, but a reason that not all would act more ethically is that some believe they already behave in an acceptable manner.

The participants in the survey further demonstrated the program's validity by saying they would like their company to offer this program as the training guide on ethics in their company/university. 82% of those who participated in the course attested to this and feel that it would fit into their company's/university's training program.

Cost/Benefit Ratio

The next portion of the exit survey is with regards to the cost. Although the cost of the program to companies/universities was never revealed, 18% of those who participated felt that it would not be worth the price. Informal questioning afterwards revealed that the two participants who felt it would not be worth the cost said that they presumed the cost of the program to be in the $10,000 range. Although the program would cost less, if it did cost over $10,000 the potential benefits to your company would be far more reaching. The most important benefit perhaps to any company would be the question of liability in the event of a lawsuit involving ethical transgressions. Most companies have found that although the plaintiff usually files suit against the company as well as the defendant, the company usually is found not liable if they provided the correct and appropriate ethical training. One lawsuit against the company alone would make this program worth every penny spent on it.

The opportunity cost of taking the time to take the test is the next question posed by the exit survey to employees and students. As you can see, 73% of those surveyed said that the program was indeed worth the time it took to complete it. This number reveals that most individuals felt that the quality, material, and difficulty were worth the amount

of time it took to complete the program. Possible reasons for those who said that the program was not worth their time, identified from questioning following the survey, include the length of the program and the lack of depth of learning material. These two statements lead me to believe, by their contradictory meanings, that the program has close to, if not the right amount of length and depth of learning material.

The last question of the exit survey reveals a resounding yes for the ethics training program that I have developed over the current company/university method for addressing ethical practices. The 91% who said yes realize that this program defines, teaches, offers solutions, and finally tests the subject matter in an appropriate way. This program is found superior by those 91% because most likely their company/university does not offer appropriate ethics training material, as demonstrated earlier in the ethical need survey. This allows us to recommend to all companies and universities that the construction ethics training program is a smart, viable method for training a company's employees as well as a university's students.

Exit Survey Conclusions

In conclusion to the exit survey, I have found that the test subjects find this program to be a valid tool for training construction ethics. Not only would they like their company/university to offer the program, but they also feel that it would fit right in to the current methods of training or learning. Furthermore, the test subjects found that the cost of the program would be worth the investment to the company as well as worth the investment of the individual employee's time to complete the training. Those surveyed also indicated that this program was superior to their company's or university's current method for training ethics. Lastly, and most importantly, the majority of those who completed the course felt that they would act more ethically in the construction industry. This is the defining characteristic of the program and illustrates the program's validity by showing that it actually taught and influenced the industry members and students ethical solutions to ethical problems. Therefore, again I strongly recommend this program for training in construction management companies, universities, and the industry as a whole.

Ethics and the Warrenton Aquatic and Recreation Facility

Ethics can determine whether a project is successful or not, and the Warrenton Aquatic and Recreation Facility is no different. There are many corollaries that relate ethics and the construction of the facility. Perhaps the most important of these is the general contractor/project management team spearheaded by Forrester Construction Company.

Forrester Construction Company recently earned the National Capital Business Ethics Award. This award is judged and based off of the following criteria:

- A clear demonstration of the company's executive commitment to business ethics as demonstrated by speeches or other correspondence and communications from the CEO and other senior officers.
- A corporate code of ethics, credo, code of conduct, mission statement or philosophy that clearly communicates the company's requirement for honesty, integrity and compliance with the law in all business dealings.
- A means for employees, customers and other parties to bring ethical problems or conflicts to the attention of management and a mechanism for resolution that ensures fair and consistent treatment of the parties involved.
- A clear communication of the company's ethical standards, corporate culture, and expectations of employee behavior in company publications, employee handbooks, training courses and other materials.
- A clear indication that employees throughout the organization understand and accept the company's ethical standards, as indicated by survey results or internal audits.
- A narrative description of business ethics in action demonstrated by the company's response to a specific challenge affecting its operations or its industry, or by evidence of how ethical decision making is a part of the company's everyday operations, philosophy and culture.
- A consistently high quality of products, services, business and production practices, including demonstrated awareness of environmental impact, if appropriate.
- A corporate commitment to providing a work environment that is safe, free from harassment or inappropriate discriminatory behavior of any kind, and that fosters growth and opportunity.
- A community commitment that is demonstrated by involvement in local, regional and/or national issues, corporate philanthropy, support of civic and charitable endeavors through foundation grants, contributions, or gifts of time and materials.

Currently, Forrester does not offer a training program on ethics. Their strategy to this point in time has been to develop and instill a corporate mission and value statement that their employees believe in. This statement, "Through teamwork, we do the right thing to make it happen," is the backbone of Forrester's corporate strategy towards ethics which they display everywhere. They created posters with it, put it on their business cards, attached it to company emails, displayed it in every field office trailer, and posted it on their website. As if this is not enough to market the ethics within the company, all new employees must go through an orientation that highlights the value statement at least twenty times and then again they have to repeat it during their employment review sessions that the company holds.

These criteria relate to every portion of the company, including the aforementioned project team found in the project staffing portion of this report. The project team has reported that the project is running smoothly with little ethical transgressions, mainly front end loading of the schedule by subcontractors. The project management portion of the team is working hard to deter this behavior and maintain an ethical project, which they seem to be doing a good job of.

Conclusion

The Warrenton Aquatic and Recreation Facility is a project that is not plagued by the many ethical transgressions that are so common in the construction industry. This is because the personnel in charge have a strong background in ethical practices that has been developed by their company, Forrester Construction Company. The company demonstrates that by addressing ethics in their corporate strategy and performing ethically they can still be a competitive general contractor/construction management firm. Their performance in the industry has earned them the National Capital Business Ethics Award and rightfully so for how much effort they have put towards acting ethically.

Ethics is a problem and always will be as long as people are more concerned with the bottom line rather than doing the right thing. A training program for employees does not have to be the solution to your companies or industries ethical problems. Developing

a mission or value statement that incorporates ethical practices into your company or following ethical codes laid out by the industry such as the ASCE Code of Ethics are viable strategies to make a company behave more ethically. All successful companies develop and maintain strategies the make them successful and ethics should be one of the key items that is addressed.

The construction ethics program that I developed is a viable training program that would teach proper construction ethics to industry members and students alike. The program identifies and teaches about the top fifteen industry identified ethical transgressions and then tests the knowledge of the subject matter through situational and informational questioning. Many companies do not offer training on ethics, in fact most do not offer any ethical information or development at all such as codes for example. The construction ethics training program will fit into the average construction company's training regiment as well as any university's curriculum. Therefore it is my recommendation that this tool be used by all industry members and universities alike who have interest in constructing projects ethically.

Analysis 2

Fabric Duct System Mechanical Breadth

Problem

The ductwork above the competition and leisure pools of the Warrenton Aquatic and Recreation Center consists of large exposed metal duct. From a cost and schedule perspective, this system is expensive and time consuming to install.

Goal

The goal of this analysis is to conclude whether or not a fabric duct system will save money and reduce installation time as well as supply the desired air to the space. In addition, by analyzing the duct support structure, determine if the members can be resized to reduce cost.

Methodology

1. Determine the sizes and quantities current ductwork
2. Verify accuracy of quantities with project personnel
3. Estimate the cost and duration of the metal duct system
4. Design the fabric duct system to maintain space requirements
5. Estimate the cost and duration of the fabric duct system
6. Do a comparative analysis between fabric duct vs. metal duct with regards to chemicals, humidity, temperature, etc.
7. Analyze the support structure for the duct to see if members can be resized
8. Compare cost savings and installation time of the respective systems and make the appropriate recommendation

Tools

1. Warrenton Aquatic and Recreation Center Construction Documents
2. R.S. Means 2006
3. UPS Cost and Time Estimator
4. Penn State Architectural Engineering Faculty

5. Forrester Construction Company
6. DuctSox Engineering and Design Manual
7. DuctSox Installation Estimator

Expectations

From the aforementioned methodology I expect to conclude that the fabric duct system will be cheaper for material, faster to install, and provide better air quality to the space.

Fabric Duct Advantages

The reason for the selection of the redesign is due to the many advantages of fabric duct over metal ductwork, especially considering the spaces being natatoriums. The first and foremost advantage of fabric duct is that it is not corrosive in the humid, chemical filled air that natatoriums contain from their pools. The fabric duct also can be cleaned easily by taking it down and washing it in the laundry. The specific type of fabric I have chosen also contains anti-microbial properties that kill bacteria and improve the air quality in the space. Metal ductwork is a hassle to clean and often goes overlooked through the operational period of a building. Furthermore there is no condensation on fabric duct because of the uniform air dispersion throughout the space and minimal dust collects on the ductwork as a result of the breatheability of the material.

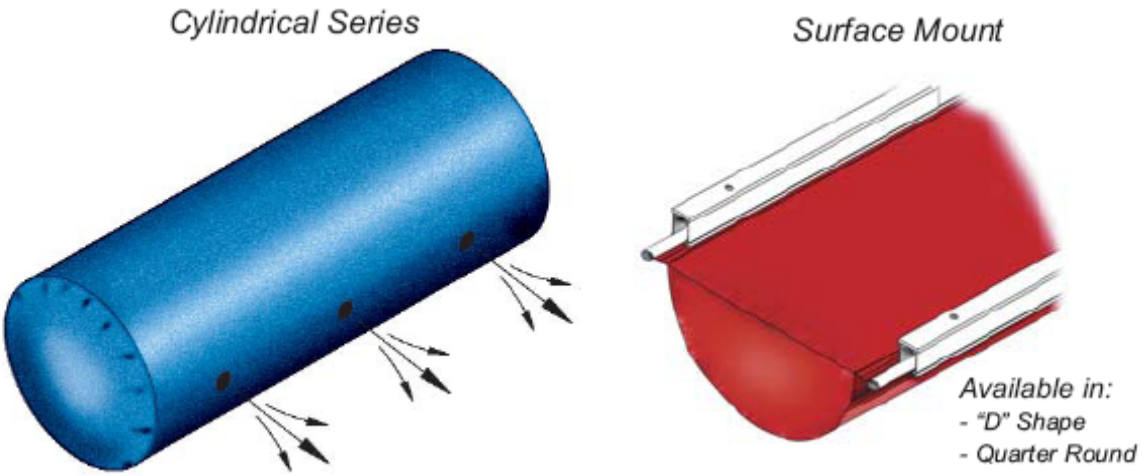
Fabric Duct System Design

The design of the fabric duct system is a simple, five step process. These steps are: selecting the shape for the space, determining the duct layout and size, selecting which type of fabric for the system, determine the type of dispersion system, and finally select the suspension for support. The following portion of this paper documents this design process for one of the duct runs.

Duct Run Design Example

Step 1: Duct Series/Shape Selection

The decision to be made in this portion of the design is the shape of the fabric duct. The options are either the cylindrical series or the surface mount series. This decision is easy because surface series are typically installed on a wall or against a ceiling. The ductwork for this space is running through the open trusses so the cylindrical series is the shape that is required.



Step 2: Design Layout

The first part of the design layout is to determine the duct diameter based on the amount of airflow required to the space and the inlet conditions. From the construction documents and the DuctSox design team, the numbers used to determine the diameter are an inlet velocity of 1600 fpm and a room capacity of 25,000 cfm. Using the manufacturers design tables, a diameter of 54" is sufficient to supply the required air to the space as seen below

50	13,635	16,362	19,090	21,817
52	14,748	17,698	20,647	23,597
54	15,904	19,085	22,266	25,447
56	17,104	20,525	23,946	27,367
58	18,348	22,017	25,687	29,356

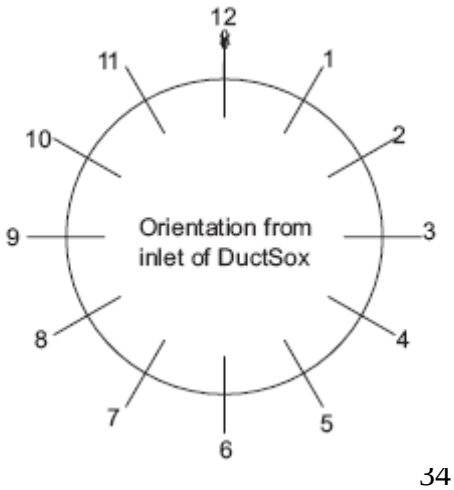
The next portion of the layout process is to determine the length of the run. From measurements around the pool, it was determined that 232' is the total length of fabric duct required. The length of allowable section of straight duct that corresponds to the 54" diameter is 25'. Therefore ten pieces of fabric duct are required. The layout for the space can be found in Appendix F. You will notice that the run of duct outlines the pool area. This is done so that when the system needs maintenance, easy access can be guaranteed and no special equipment is needed to service the duct

Step 3: Fabric Selection

To determine the type of fabric for the ductwork, the manufacturer offers many types. Each type has its own corresponding properties and usual types of spaces it is used for. For natatorium or pool areas however, either the Sedona-Xm or the Verona are generally preferred. Each type are sufficient for the space, but for this project I am selecting the Sedona-Xm because it has everything the Verona material offers, but comes with a 10 year warranty instead of a five and also is made of anti microbial material to improve air quality.

Step 4: Air Dispersion Design

The airflow through the duct will be what the manufacturer considers to be as "comfort flow." To design the air dispersion, you must first select the orientation of the vents along the diameter of the duct. Because the ceilings are high and we want to direct airflow downward, we will select the five and seven o'clock orientation of the vents.



The next steps are to calculate the airflow through the fabric, calculate the total vent size, select

the vent sizes, and finally specify the vent orientation. The equations used are as follows:

Pressure Review

$$AP = ISP_1 + 0.66x(VP-FL)$$

ISP_1 = Inlet Static Pressure
VP = Velocity Pressure = $(Velocity/4005)^2$
FL = Frictional Pressure Loss

AP= .1276 +.66((1600/4005)2 - .055)

AP= .1966 w.g.

Fabric Breathe-ability

$$Q_{fabric} = FP \times SA \times (AP/0.5) \quad (CFM)$$

FP = Fabric Porosity (rated) (CFM/ft^2)
SA = Surface Area (all fabric) (ft^2)
AP = Average Pressure (inch/w.g.)

Q_{fabric}= 1.5 x 3689.8 x (.1966/.5)

Q_{fabric}= 2176.2cfm

Using the table provided by the manufacturer, the

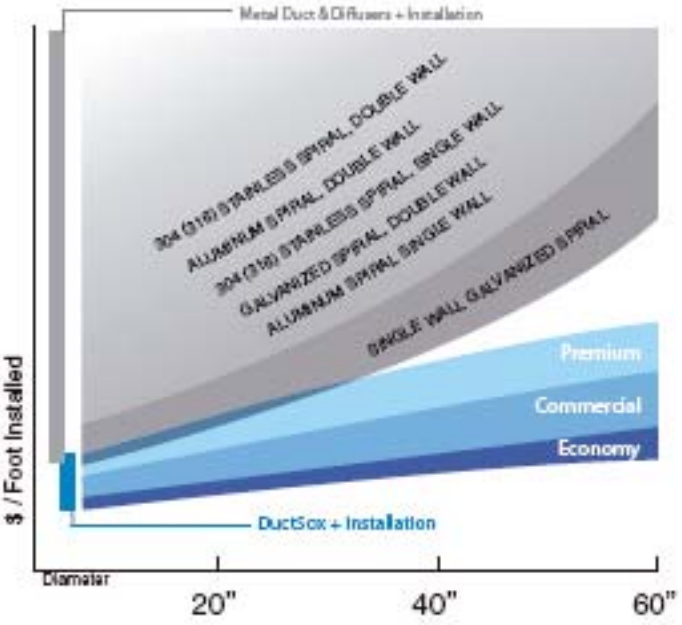
Step 5: Suspension System Design

The last portion of the design process for the duct system is to determine the suspension system that will support the duct. Three options are offered from the manufacturer: tension cable, suspended H-track, and flush mounted. The suspended H-track offers parts that are available in stainless steel, which is advantageous to combat the chemicals and humidity in the spaces. Because of this, the selection for the suspension system is the H-track.

The design of the duct system is now nearly complete, with one small item left, the filter. For fabric duct, the filter comes in three sizes, M, L, and X. Which on is chosen is based upon filtration quality desired and pressure loss. Because this run of duct is lengthy, the smaller filter is chosen, M. The filter is a cone shaped material that fits directly into the inner diameter of the fabric duct. The size is 4.5 x the diameter or 20.25' in length.

Cost Comparison

Typically, fabric ductwork costs on average 20-80% less than the average metal ductwork system. The adjacent graph depicts the typical costs based on diameter size for a total system comparing both fabric ductwork (blue) and metal ductwork (grey). The original design for the aquatic facility called for the second most expensive material, aluminum spiral, double walled duct. For an actual comparison within the aquatic facility, the following Table 2.1 is used for cost comparison.



Ductwork Pricing Comparison					
Area	Type of Duct	Quantity	Mat. Cost	Labor Cost	Total Cost
Competition Pool	Double Walled Aluminum	10876.78 lbs	$1.10	$5.05	$66,892.20
Competition Pool	Fabric Duct	307 ft	$52.12	$2.60	$16,799.04
Leisure Pool	Double Walled Aluminum	7896.52 lbs	$1.10	$5.05	$48,563.60
Leisure Pool	Fabric Duct	172 ft	$52.12	$2.60	$9,411.84

Table 2.1

Shipping cost

One further analysis with regards to cost that needs to be considered is how the change in weight will reduce shipping costs. With the original system, almost 19,000 lbs of ductwork were going to have to be shipped in. Using fabric duct, the shipment would weigh 600 lbs. To ship this ductwork you could use UPS freight service and receive the entire duct for the system in two days for only $1,900 by air. If you shipped ground, which is a distinct possibility with the time saved from installation, you could ship it for less than $500. The aforementioned spiral ductwork would take at least three truckload shipments and has an estimated cost of $2,900. Therefore, the savings in shipping can be a considerable $2,400, which could be the difference in being over budget.

Cost Summary

The total cost of the spiral metal duct system, including shipping, is $118,355.80 while the total cost for the fabric duct system including shipping is only $26,710.88. This shows that the total savings of the fabric system is $91,644.92. This amount saved corresponds to roughly a 2% savings in the mechanical contract.

Schedule Comparison

As you may have noticed from the cost comparison, the time and labor costs for standard metal ductwork is significantly higher than the fabric duct system. Furthermore research has shown that up to a 90% reduction in labor costs can be achieved. For this project, the following comparison was constructed using the actual data for the metal ductwork that was installed and data calculated using the DuctSox Installation Estimator. Results can be seen in Table 2.2. It is easy to see where the 90% savings can come into play as the reduction in installation time is almost 80% itself. A few reasons that the installation of the metal duct takes so long is because you have to lift every piece up in the lift which takes significantly longer than the duct, then after it is installed the crews have to provide a polished finish and install the vents and diffusers. With the fabric duct it is just attach the hanging track to the truss and clip the duct in, that simple. This reduces the installation time significantly as can be seen below.

Estimate of Duct Installation Time						
Type	Quantity	Daily Output/Quantity	Typical Crew Size	Number of Crews	Total Hours	Total Days
Spiral Aluminum Double Walled Duct	18773.3lbs	145 lbs	3	3	345.2	43.15
Sedona-XM Fabric Duct	479 ft	53.7'	3	1	63.2	7.9

Table 2.2

Schedule Summary

As you can see, the fabric duct system only takes 7.9 days to install compared to the 43.15 of the metal system. This is a savings of more than 35 days in the mechanical portion of the schedule.

Structural Analysis

The third portion of the breadth on the mechanical ductwork analyzes the effect of the lost weight of the double walled aluminum spiral duct after it is replaced with the fabric duct on the roof trusses. Quantity takeoffs were completed to determine the difference in the loading on the support structure (prefabricated roof truss.) The following Table 2.3 is a summary of the loads obtained:

Competition & Leisure Duct Totals			
Area	Length	Weight	Avg. lb/Lin. ft
Competition	1098.5	10876.78	9.90
Leisure	819	7896.52	9.64
Totals	1917.5	18773.30	9.79

Table 2.3

Fabric duct offers an average lb/Lin. ft of less than one. Therefore, to complete the analysis, each total would be divided by the area of the space it serves to determine the load/s.f. After doing this I obtained loads that were less than 1lb/s.f. in difference, which would obviously not be enough to influence a change in size of the roof truss members. Therefore, although the fabric duct weighs on average $1/10^{th}$ of the weight of spiral ductwork, I conclude that in a structure of this size that the ductwork redesign has no structural impact.

Breadth Conclusion

The fabric duct is a good product to be considered in open spaces, especially spaces with uncommon air properties such as a natatorium. It offers many benefits to the air quality of the space as well as to the O&M of the building as well. Through my analysis and comparison of the two systems, I have found that the fabric duct that I designed for these two spaces is superior in every aspect. It cuts a significant portion of the cost out, reduces the schedule drastically, and reduces the load on the roof truss members by nearly a factor of ten compared to the double walled aluminum duct. Therefore, it is my recommendation that the fabric duct system that I have designed be considered for installation in my building and in projects of similar scope.

Analysis 3

Structural Column Redesign Breadth

Problem

The main structural system in the Warrenton Aquatic and Recreation Center is steel. However, the architect chose to use cast in place concrete for the structural columns in the two aquatic portions of the building. From construction standpoint this increases coordination and congestion problems on site and adds duration to the schedule.

Goal

The goal of this analysis is to decide whether there is a viable alternative to the cast in place concrete columns in the pool area. The proposed alternatives that will be analyzed are structural steel columns and masonry pilasters. To conclude this I will compare total cost, schedule durations, column sizes, and constructability.

Methodology

1. Determine the building loads that the cast in place columns support
2. Design a steel system with the calculated loads
3. Design the reinforced masonry pilasters
3. Analyze the systems based on the cost, schedule, and constructability
4. Select the best structural system

Tools

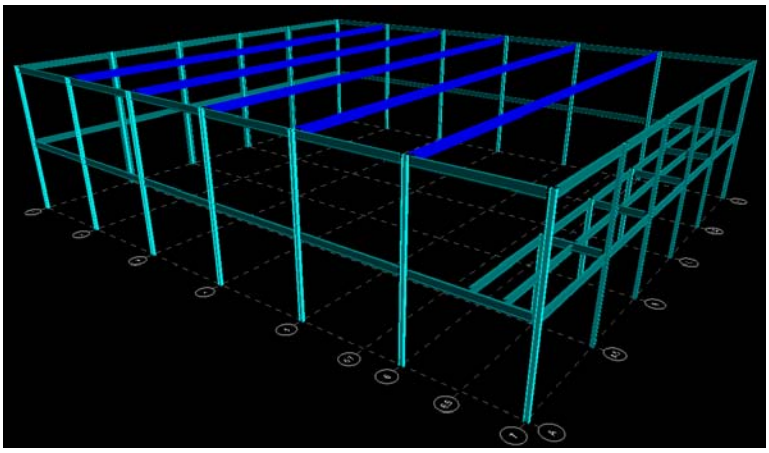
1. Warrenton Aquatic and Recreation Center Construction Documents
2. R.S. Means 2006
3. Penn State Architectural Engineering Faculty
4. Forrester Construction Company
5. Microsoft Excel
6. AISC Steel Construction Manual 13th ed.
7. RAM Model
8. Masonry Designer's Guide, 4th ed.

Expectations

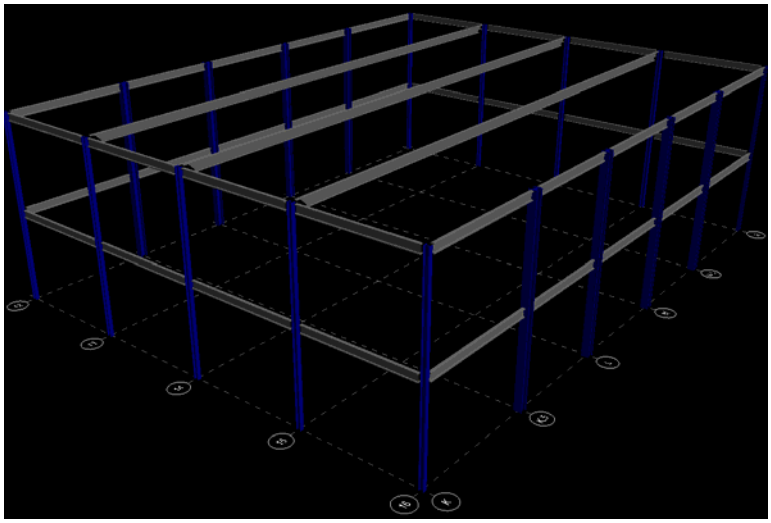
The expected outcome of this analysis should indicate that the proposed steel structural system will save money, reduce installation time, and improve constructability with the pilaster also being more economical than the concrete system.

Structural Steel Design

The selection of steel for the redesign is based upon the uniformity of the building. All other structural members in the building are steel shapes, so therefore to reduce site congestion and coordination issues, steel should be considered as a possible alternative. To conduct the steel redesign of the concrete columns, the Ram structural system application was used. Using the axial loads given by the structural engineer as well as the column heights taken from the construction documents, I was able to enter the data into the program for the steel column generation. Upon completing this task, two types of columns were generated for the competition and leisure pool rooms, W10x33 and W10x39. Both columns were checked for slenderness and load capacity using the AISC Steel Construction Manual to ensure proper design was obtained. The following three dimensional models are the results of the design process. You will notice that the roof truss members were modeled as joists with the same loading properties for simplicity. Also it should be noted that the current roof truss system connection is a steel plate that will be welded to the top of the structural steel columns



Competition Pool Structural Steel Design



Leisure Pool Structural Steel Design

Masonry Pilaster Design

The reason for the design of the masonry pilaster is because concrete masonry units are already being placed in between and around the concrete columns. Having the masons put the pilaster directly into the wall will again reduce site congestion and coordination issues because it lessens the subcontractors on site. To actually calculate the size of the pilaster, again the loads and heights were taken from the structural engineer and construction documents. The calculations were then conducted based on the Masonry Designers Guide, section 12.3.3, design considerations for reinforced pilasters. The appropriate calculations can be found in Appendix G. After completing the design, it was determined that a 24”x 24” reinforced masonry pilaster would support the required loading. This size was maintained so as to not disrupt the current spacing of the current concrete columns.

Cost Comparison

The cost of switching the systems can be based on the structure alone for the two alternative solutions because the means and methods of installing the pilaster and steel are already on site. As a result, the following Table 3.1 is a cost comparison with values from R.S. Means and Contractors from the Warrenton Aquatic and Recreation Facility.

Structural Column Cost Comparison				
Type of Column	Quantity	Material Cost	Labor Cost	Total Cost
Concrete	156.4	$305.00	$365.00	$104,788.00
Steel	1056	$40.00	$2.37	$44,742.72
Pilaster	1056	$37.00	$25.00	$65,472.00

Table 3.1

As you can see, the cast in place concrete system is the most expensive by nearly double. The pilaster installation price is significantly higher than the steel labor cost because the amount of time to install and the number of crew members it takes is significantly reduced by using steel. From a cost perspective, the steel is the most viable alternative.

Schedule Comparison

Being on schedule is one of the most important aspects to a project and finding a way to cut schedule to get ahead on a project is extremely valuable. For this purpose, I have compared the durations for each type of structural column in the aquatic portions of the building. The results can be found in the following Table 3.2

Structural Column Schedule Comparison

Type of Column	Quantity	Daily Output/Crew	No. Crews	Total Duration
Concrete	156.4cy	17.7cy	1.0	8.8
Steel	1056lf	1025lf	1.0	1.0
Pilaster	1056vlf	18vlf	3.0	19.6

Table 3.2

As you can see, the erection time for the steel columns is by far the most efficient with the ability to place all the columns in one day. This can be attributed to the ease of

connection of members with a crane and small crew. The placement of the concrete columns is the second quickest, followed by the erection of the pilasters. The problem with the pilaster is that erection of the CMU wall is also going on at the same time, reducing efficiency of work on pilasters and increasing site congestion with increased crew sizes. Therefore, steel is the fastest and most beneficial to the schedule.

Constructability Comparison

The three systems in question require different means of construction to erect the columns. The original cast in place concrete column requires formwork, a pump for placement, and scaffolding for erection. The problem that arises from this is that the scaffolding used will be different than the scaffolding used by the masons which means it will have to be set up, torn down, and then different scaffolding will be put into place. This results in wasted labor and cost. The formwork is also an additional cost compared to both the steel and masonry systems.

To erect the structural steel columns, the first item to be addressed is the crane size. The weight of the proposed steel columns however will not increase the crane size because the members are significantly lighter than the roof trusses that rest on top. Furthermore, the columns will use the same bearing plates to attach to the substructure and roof truss system, the only difference being that the plate on top is welded to the column, which is a minimal schedule increase. The concern of corrosion to the members is not a factor because concrete masonry units will surround the column exactly like the current concrete system.

The masonry pilaster construction requires scaffolding, but this will already be in place while the masons construct the joining concrete masonry walls that are in between columns. This will not significantly impact the schedule in terms of duration of installation, but the masons schedule will have to start earlier to accommodate the setting of the roof trusses. Like the concrete columns system, the masonry pilasters will be joined to the substructure and roof truss system using the exact same bearing plates and anchoring systems.

Breadth Conclusion

The structural steel column is the most efficient in terms of schedule duration, cost, and causes no constructability issues. The savings from the current concrete system total $60,045. The change in schedule erection time will also allow for the roof truss members to be erected earlier, saving eight days of crane rental costs as well. The pilaster system is also a viable alternative compared to the concrete system, saving a total of $39,316. However this change would cause a delay in the schedule of eleven days, which would be unacceptable to the project. Therefore, my recommendation is that the structural steel column should be used for the columns located in the aquatic spaces of the facility.

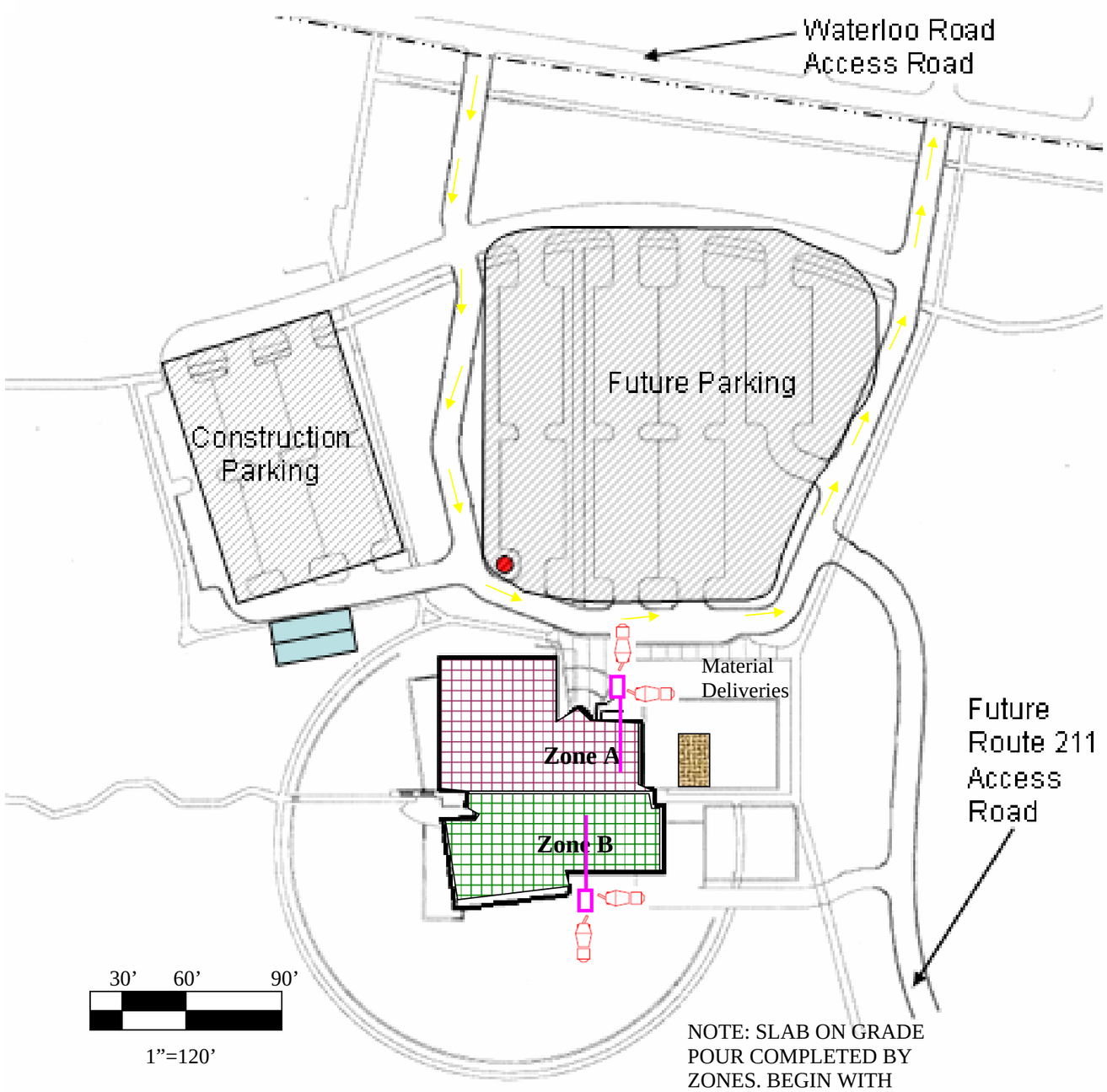
Thesis Recommendations

The information obtained from my research on ethics showed that there is a definite need for ethical training within the construction industry and universities alike. The research conducted to identify the top ethical transgressions coupled with the need for an ethical training method gave me to the need to develop my construction ethics training program. This program defines the top fifteen industry identified ethical transgressions, teaches about each, and then provides testing material to ensure the material is learned. The results from the training program showed that the training program was valid, the cost/benefit ration was very positive, and most importantly those who participated said they would act more ethically after the completion of the program. Therefore, it is my recommendation that this training program be used by both industry members and universities. This would improve the industry's image, level the competitive playing field, and increase social responsibility among its employees.

The first breadth topic analyzed was a fabric ductwork system which compared the cost, schedule duration, structural impacts, and highlighted advantages of the material. It was found that the cost and schedule performance of the fabric duct system was far superior to the spiral metal ductwork. In conclusion, I recommend that the fabric duct system be installed into the Warrenton Aquatic and Recreation Facility in the aquatic spaces as well as also considering this material in similar projects.

The last portion of my thesis analyzed the structural columns in the competition and leisure pool areas. The current system is cast in place concrete, while I chose to analyze both structural steel columns and masonry pilasters. The steel showed to be the most cost effective and shortest in installation time, while the pilaster was less expensive but added eleven days to the schedule. Finally, it is my recommendation that structural steel members be installed into the aquatic portion of the Warrenton Aquatic and Recreation Facility.

APPENDIX A



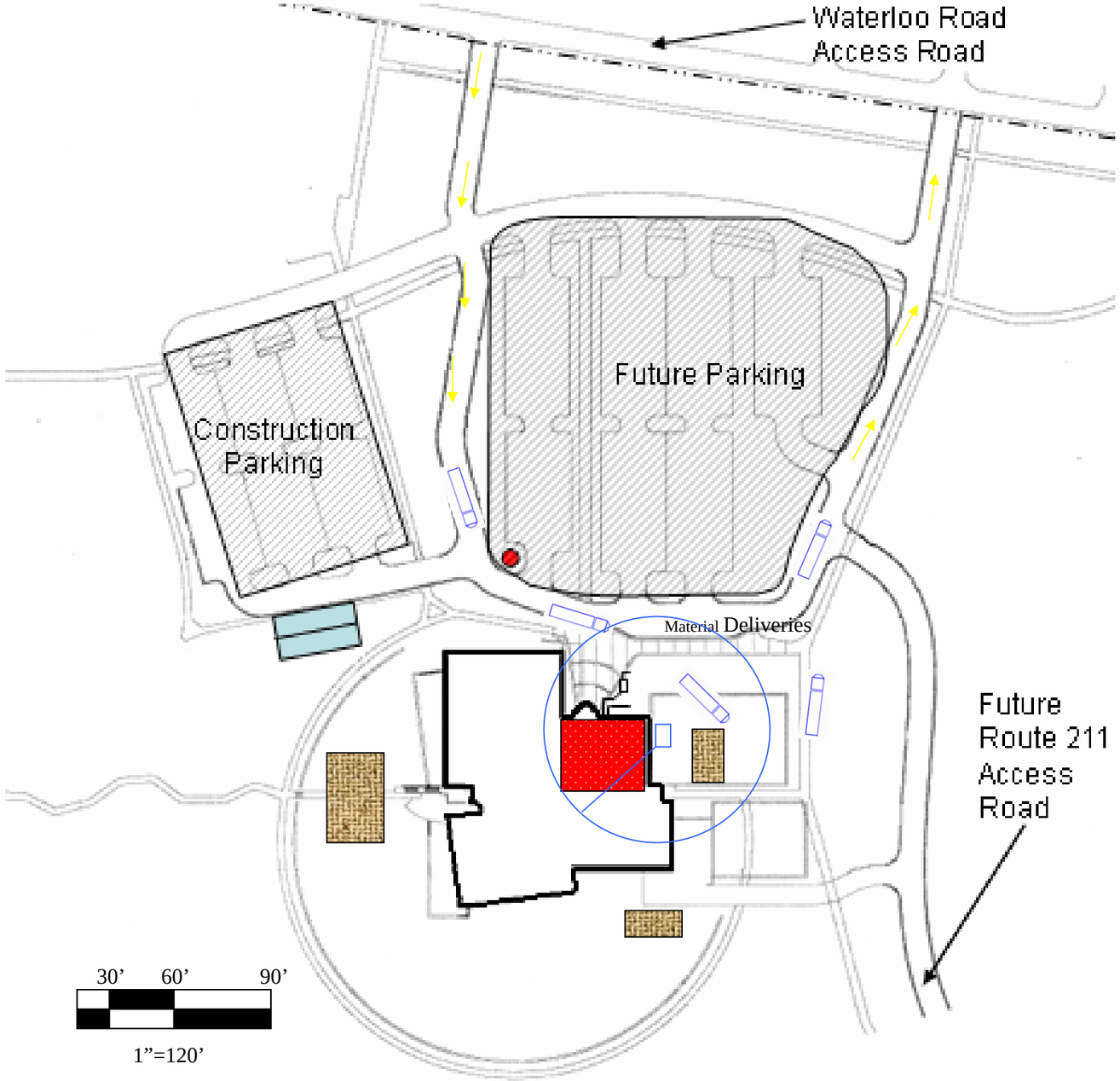
NOTE: SLAB ON GRADE POUR COMPLETED BY ZONES. BEGIN WITH ZONE A

LEGEND

- Concrete Truck
- Steel Delivery Trailer
- Site Trailer
- Parking
- Steel Delivery
- Property Line
- Fire Hydrant
- Crawler Crane
- Steel Shakeout
- Erection Complete
- Erection in Progress

N

WARRENTON AQUATIC AND RECREATION FACILITY	
STRUCTURE SITE PLAN-SOG	
DATE: 10/30/06	APPD. BY:
DRAWN BY: DEREK DIPIAZZA	DWG. No. SE-1



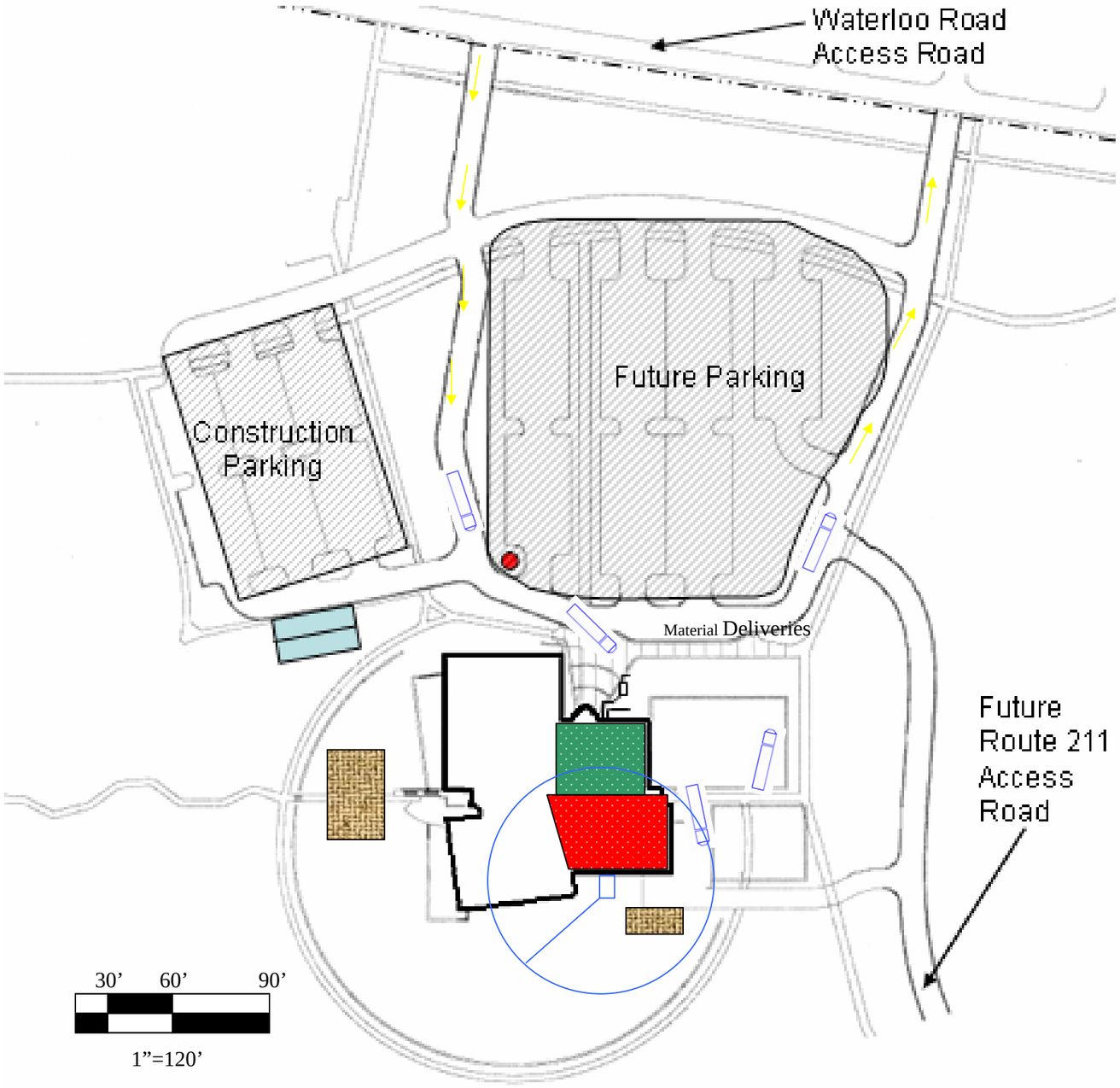
LEGEND

- Concrete Truck
- Steel Delivery Trailer
- Site Trailer
- Parking
- Steel Delivery
- Property Line
- Fire Hydrant
- Crawler Crane
- Steel Shakeout
- Erection Complete
- Erection in Progress

WARRENTON AQUATIC AND RECREATION FACILITY

STRUCTURE SITE PLAN- STEEL 1

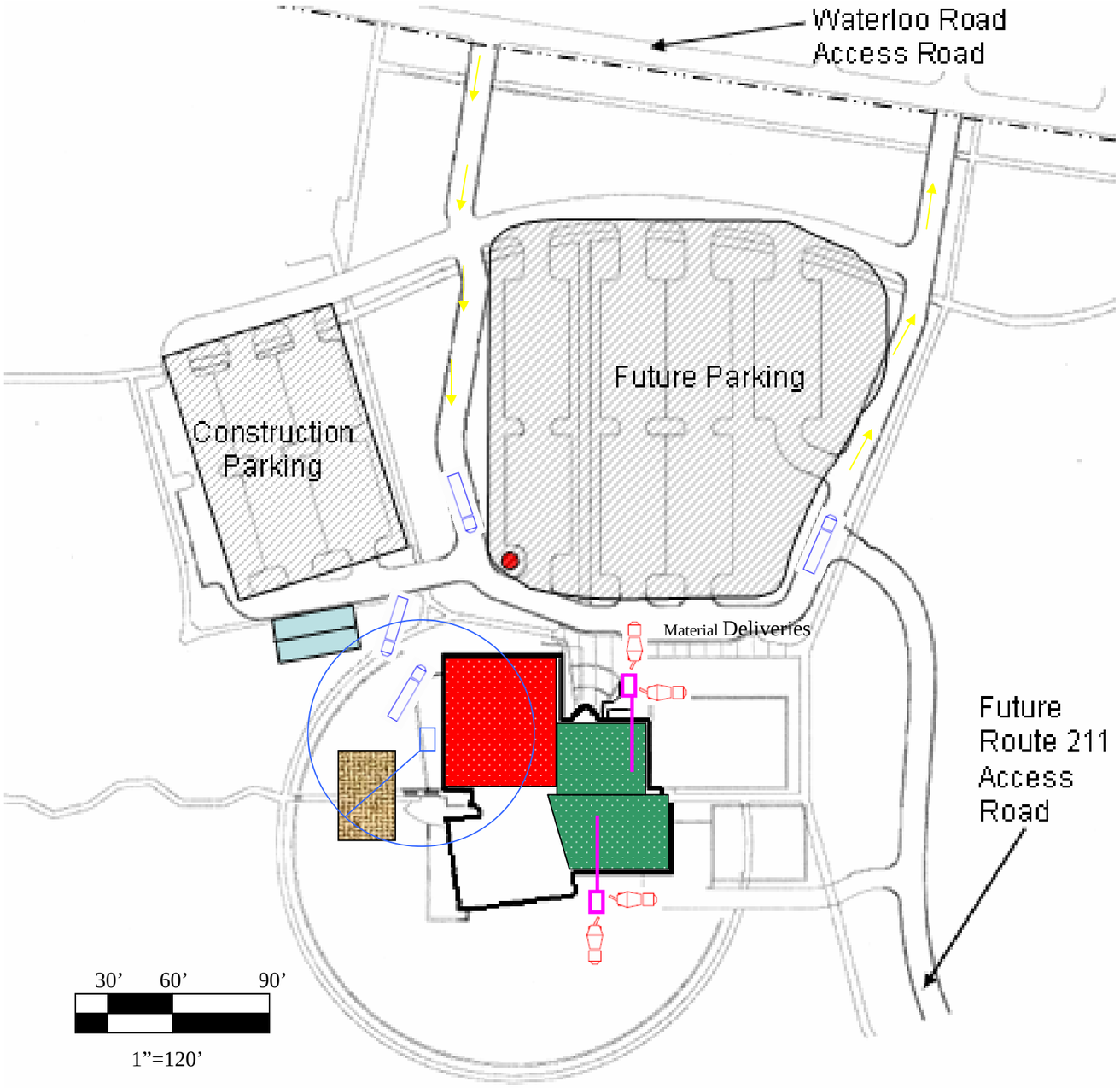
DATE: 10/30/06	APPD. BY:
DRAWN BY: DEREK DIPIAZZA	DWG. No. SE-2



LEGEND

- Concrete Truck
- Steel Delivery Trailer
- Site Trailer
- Parking
- Steel Delivery
- Property Line
- Fire Hydrant
- Crawler Crane
- Steel Shakeout
- Erection Complete
- Erection in Progress

WARRENTON AQUATIC AND RECREATION FACILITY	
STRUCTURE SITE PLAN- STEEL 2	
DATE: 10/30/06	APPD. BY:
DRAWN BY: DEREK DIPIAZZA	DWG. No. SE-3



LEGEND

- Concrete Truck
- Steel Delivery Trailer
- Site Trailer
- Parking
- Steel Delivery
- Property Line
- Fire Hydrant
- Crawler Crane
- Steel Shakeout
- Erection Complete
- Erection in Progress

WARRENTON AQUATIC AND RECREATION FACILITY

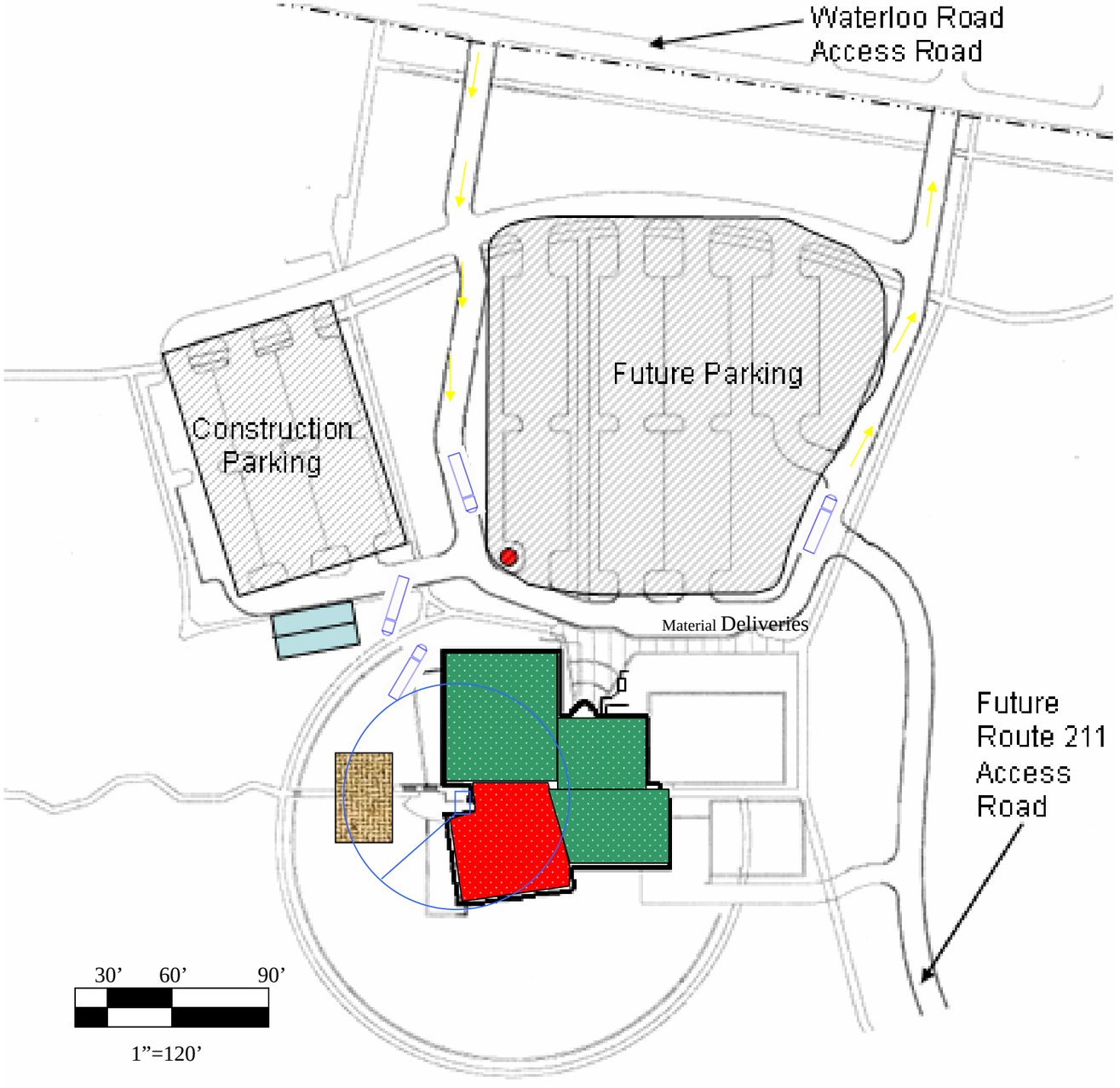
STRUCTURE SITE PLAN- STEEL 3

DATE: 10/30/06

APPD. BY:

DRAWN BY: DEREK DIPIAZZA

DWG. No. SE-4

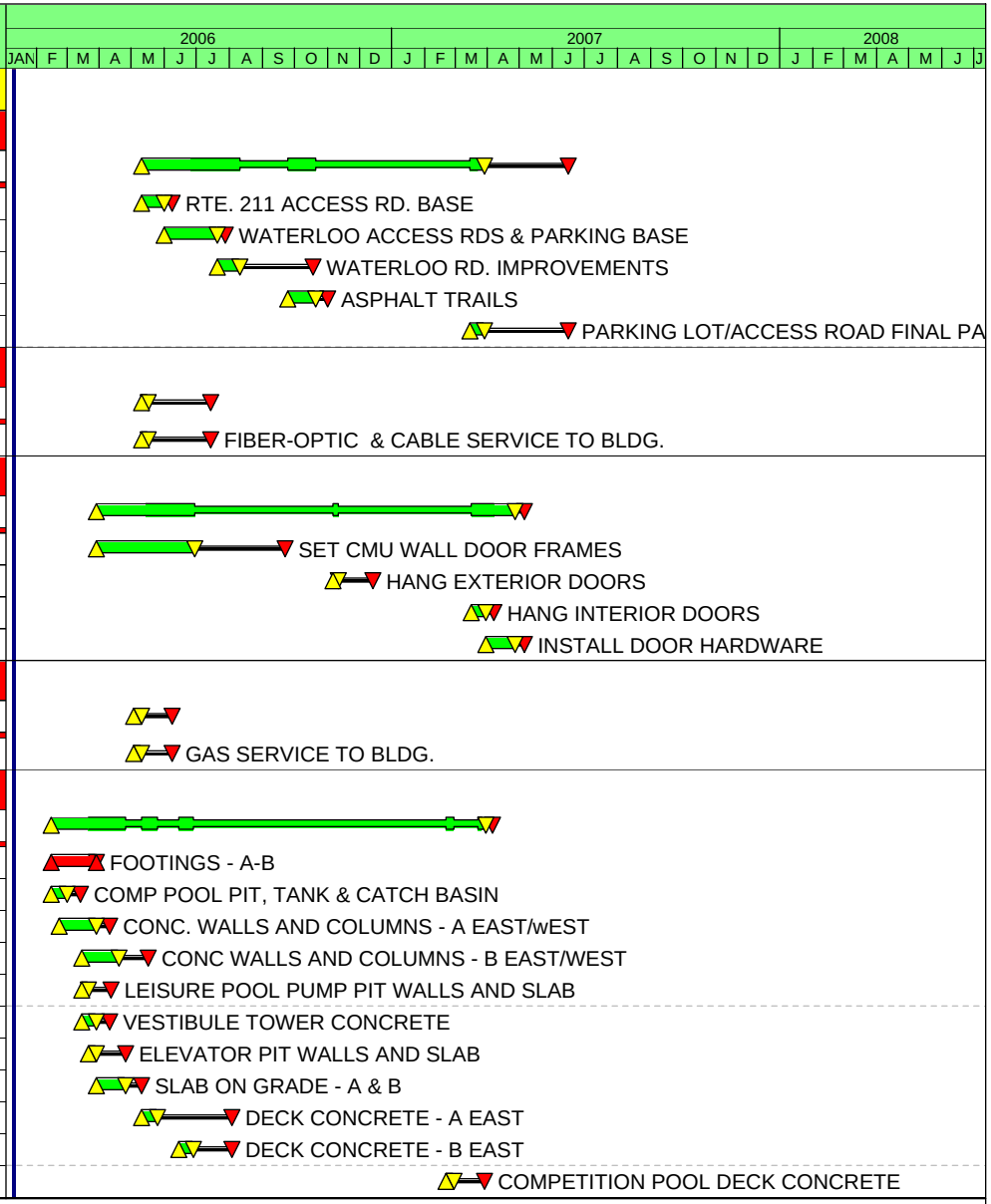


LEGEND

- Concrete Truck
- Steel Delivery Trailer
- Site Trailer
- Parking
- Steel Delivery
- Property Line
- Fire Hydrant
- Crawler Crane
- Steel Shakeout
- Erection Complete
- Erection in Progress

WARRENTON AQUATIC AND RECREATION FACILITY	
STRUCTURE SITE PLAN- 4	
DATE: 10/30/06	APPD. BY:
DRAWN BY: DEREK DIPIAZZA	DWG. No. SE-5

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
WARRENTON AQUATICS AND RECR FACILITY						
ASPHALT						
		224	224	10MAY06	28MAR07	56d
1430	RTE. 211 ACCESS RD. BASE	15	15	10MAY06	31MAY06	5d
1420	WATERLOO ACCESS RDS & PARKING	35	35	01JUN06	20JUL06	5d
1360	WATERLOO RD. IMPROVEMENTS	15	15	21JUL06	10AUG06	48d
1400	ASPHALT TRAILS	20	20	25SEP06	20OCT06	8d
1380	PARKING LOT/ACCESS ROAD FINAL	10	10	15MAR07	28MAR07	56d
CABLE						
		5	5	10MAY06	16MAY06	40d
1240	FIBER-OPTIC & CABLE SERVICE TO	5	5	10MAY06	16MAY06	40d
CARPENTRY						
		275	275	29MAR06	26APR07	6d
3725	SET CMU WALL DOOR FRAMES	65	65	29MAR06	28JUN06	60d
3731	HANG EXTERIOR DOORS	5	5	06NOV06	10NOV06	21d
3730	HANG INTERIOR DOORS	10	10	16MAR07	29MAR07	6d
3740	INSTALL DOOR HARDWARE	20	20	30MAR07	26APR07	6d
COLUMBIA GAS						
		5	5	03MAY06	09MAY06	20d
1210	GAS SERVICE TO BLDG.	5	5	03MAY06	09MAY06	20d
CONCRETE						
		285	285	15FEB06	29MAR07	5d
2110	FOOTINGS - A-B	30	30	15FEB06	28MAR06	0
2130	COMP POOL PIT, TANK & CATCH BASIN	10	10	15FEB06	28FEB06	9d
2120	CONC. WALLS AND COLUMNS - A	25	25	22FEB06	28MAR06	9d
2010	CONC WALLS AND COLUMNS - B	25	25	15MAR06	18APR06	20d
2012	LEISURE POOL PUMP PIT WALLS AND	5	5	15MAR06	21MAR06	15d
2135	VESTIBULE TOWER CONCRETE	10	10	15MAR06	28MAR06	9d
2020	ELEVATOR PIT WALLS AND SLAB	5	5	22MAR06	28MAR06	20d
2190	SLAB ON GRADE - A & B	20	20	29MAR06	25APR06	10d
2200	DECK CONCRETE - A EAST	10	10	11MAY06	24MAY06	49d
2090	DECK CONCRETE - B EAST	10	10	14JUN06	27JUN06	26d
2240	COMPETITION POOL DECK CONCRETE	5	5	21FEB07	27FEB07	21d



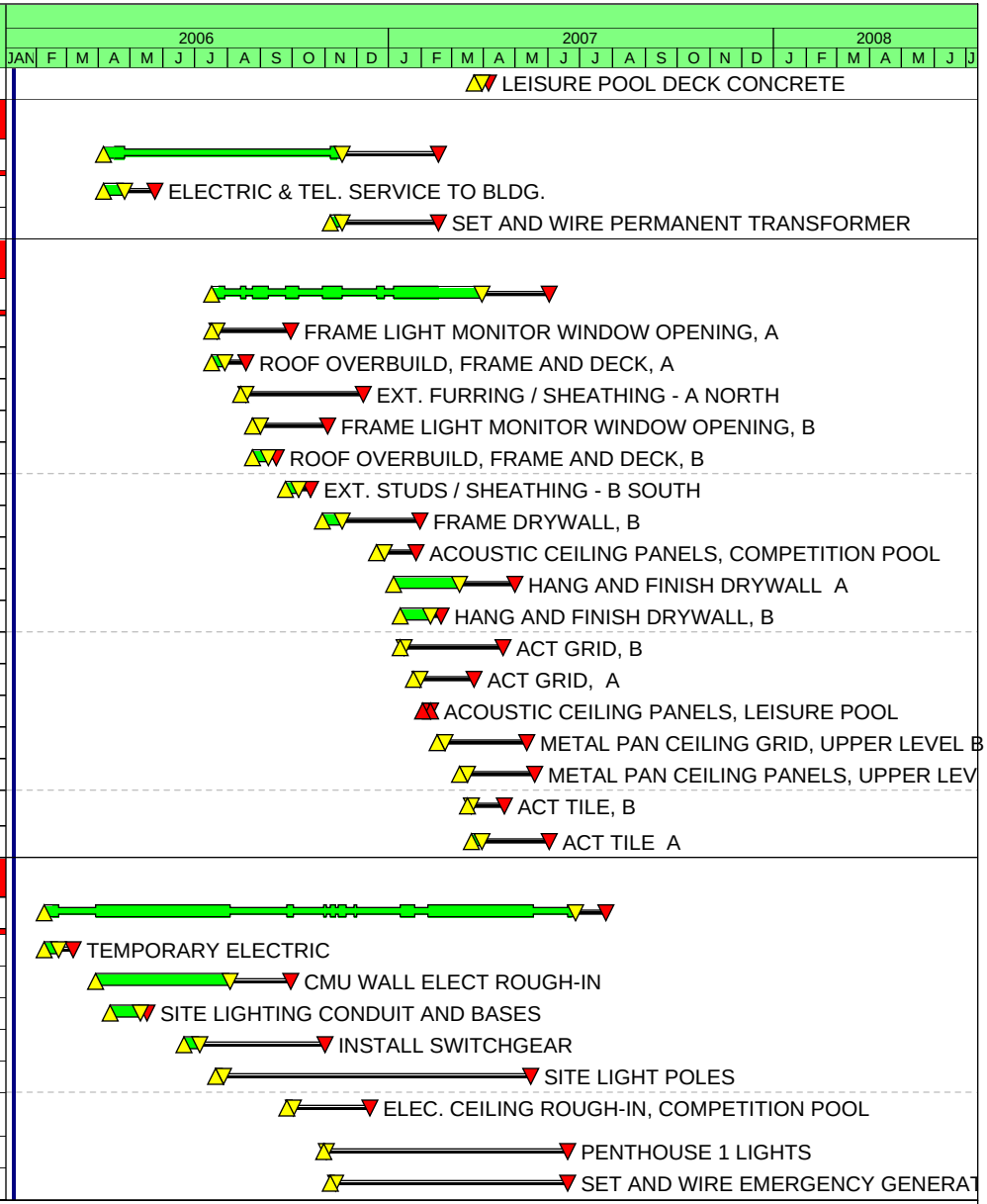
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	1A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
2250	LEISURE POOL DECK CONCRETE	5	5	23MAR07	29MAR07	5d
DOMINION RESOURCES						
		160	160	05APR06	17NOV06	61d
1220	ELECTRIC & TEL. SERVICE TO BLDG.	15	15	05APR06	25APR06	20d
1221	SET AND WIRE PERMANENT	10	10	06NOV06	17NOV06	61d
DRYWALL						
		179	179	17JUL06	29MAR07	45d
3340	FRAME LIGHT MONITOR WINDOW	5	5	17JUL06	21JUL06	49d
3360	ROOF OVERBUILD, FRAME AND DECK, A	10	10	17JUL06	28JUL06	14d
3330	EXT. FURRING / SHEATHING - A NORTH	5	5	14AUG06	18AUG06	76d
3350	FRAME LIGHT MONITOR WINDOW	5	5	25AUG06	31AUG06	45d
3370	ROOF OVERBUILD, FRAME AND DECK, B	10	10	25AUG06	08SEP06	5d
3310	EXT. STUDS / SHEATHING - B SOUTH	10	10	25SEP06	06OCT06	8d
3384	FRAME DRYWALL, B	15	15	30OCT06	17NOV06	47d
3374	ACOUSTIC CEILING PANELS,	5	5	20DEC06	27DEC06	21d
3385	HANG AND FINISH DRYWALL A	45	45	05JAN07	08MAR07	37d
3387	HANG AND FINISH DRYWALL, B	20	20	12JAN07	08FEB07	7d
3395	ACT GRID, B	2	2	12JAN07	15JAN07	67d
3391	ACT GRID, A	5	5	24JAN07	30JAN07	37d
3375	ACOUSTIC CEILING PANELS, LEISURE	5	5	02FEB07	08FEB07	0
3372	METAL PAN CEILING GRID, UPPER	5	5	16FEB07	22FEB07	56d
3373	METAL PAN CEILING PANELS, UPPER	5	5	09MAR07	15MAR07	46d
3396	ACT TILE, B	2	2	16MAR07	19MAR07	24d
3392	ACT TILE A	8	8	20MAR07	29MAR07	45d
ELECTRICAL						
		352	352	08FEB06	26JUN07	20d
1060	TEMPORARY ELECTRIC	10	10	08FEB06	21FEB06	10d
5560	CMU WALL ELECT ROUGH-IN	90	90	29MAR06	03AUG06	40d
5520	SITE LIGHTING CONDUIT AND BASES	20	20	12APR06	09MAY06	5d
5570	INSTALL SWITCHGEAR	10	10	21JUN06	05JUL06	83d
5540	SITE LIGHT POLES	5	5	21JUL06	27JUL06	202d
5500	ELEC. CEILING ROUGH-IN, COMPETITION	5	5	26SEP06	02OCT06	50d
5670	PENTHOUSE 1 LIGHTS	3	3	31OCT06	02NOV06	158d
5535	SET AND WIRE EMERGENCY	5	5	06NOV06	10NOV06	151d



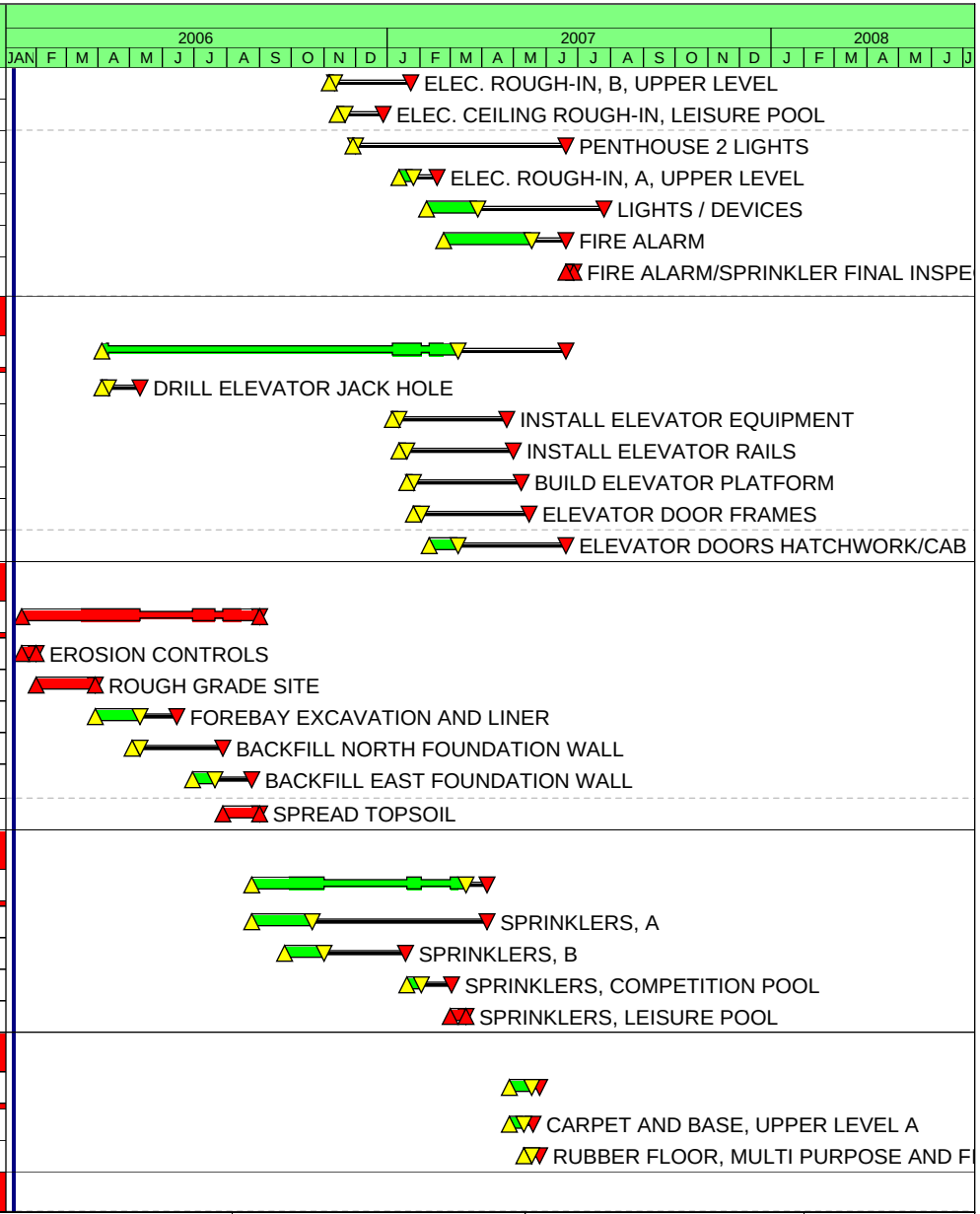
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	2A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
5590	ELEC. ROUGH-IN, B, UPPER LEVEL	5	5	06NOV06	10NOV06	47d
5510	ELEC. CEILING ROUGH-IN, LEISURE	5	5	14NOV06	20NOV06	24d
5680	PENTHOUSE 2 LIGHTS	3	3	29NOV06	01DEC06	139d
5580	ELEC. ROUGH-IN, A, UPPER LEVEL	10	10	12JAN07	25JAN07	16d
5610	LIGHTS / DEVICES	35	35	07FEB07	27MAR07	84d
5600	FIRE ALARM	60	60	23FEB07	17MAY07	22d
5551	FIRE ALARM/SPRINKLER FINAL	5	5	20JUN07	26JUN07	0
ELEVATOR						
		236	236	04APR06	08MAR07	72d
2002	DRILL ELEVATOR JACK HOLE	5	5	04APR06	10APR06	21d
2003	INSTALL ELEVATOR EQUIPMENT	5	5	05JAN07	11JAN07	72d
2004	INSTALL ELEVATOR RAILS	5	5	12JAN07	18JAN07	72d
2005	BUILD ELEVATOR PLATFORM	5	5	19JAN07	25JAN07	72d
2006	ELEVATOR DOOR FRAMES	5	5	26JAN07	01FEB07	72d
2007	ELEVATOR DOORS HATCHWORK/CAB	10	20	09FEB07	08MAR07	72d
EXCAVATION						
		160	160	18JAN06	31AUG06	0
1040	EROSION CONTROLS	10	10	18JAN06	31JAN06	0
1300	ROUGH GRADE SITE	40	40	01FEB06	28MAR06	0
1310	FOREBAY EXCAVATION AND LINER	30	30	29MAR06	09MAY06	25d
1550	BACKFILL NORTH FOUNDATION WALL	5	5	03MAY06	09MAY06	55d
1551	BACKFILL EAST FOUNDATION WALL	15	15	29JUN06	20JUL06	25d
1560	SPREAD TOPSOIL	25	25	28JUL06	31AUG06	0
FIRE PROTECTION						
		140	140	25AUG06	15MAR07	15d
5820	SPRINKLERS, A	40	40	25AUG06	20OCT06	115d
5830	SPRINKLERS, B	27	27	25SEP06	31OCT06	52d
5800	SPRINKLERS, COMPETITION POOL	10	10	19JAN07	01FEB07	21d
5810	SPRINKLERS, LEISURE POOL	10	10	02MAR07	15MAR07	0
FLOOR COVERINGS						
		15	15	27APR07	17MAY07	6d
9050	CARPET AND BASE, UPPER LEVEL A	10	10	27APR07	10MAY07	6d
9051	RUBBER FLOOR, MULTI PURPOSE AND	5	5	11MAY07	17MAY07	6d
FORRESTER						



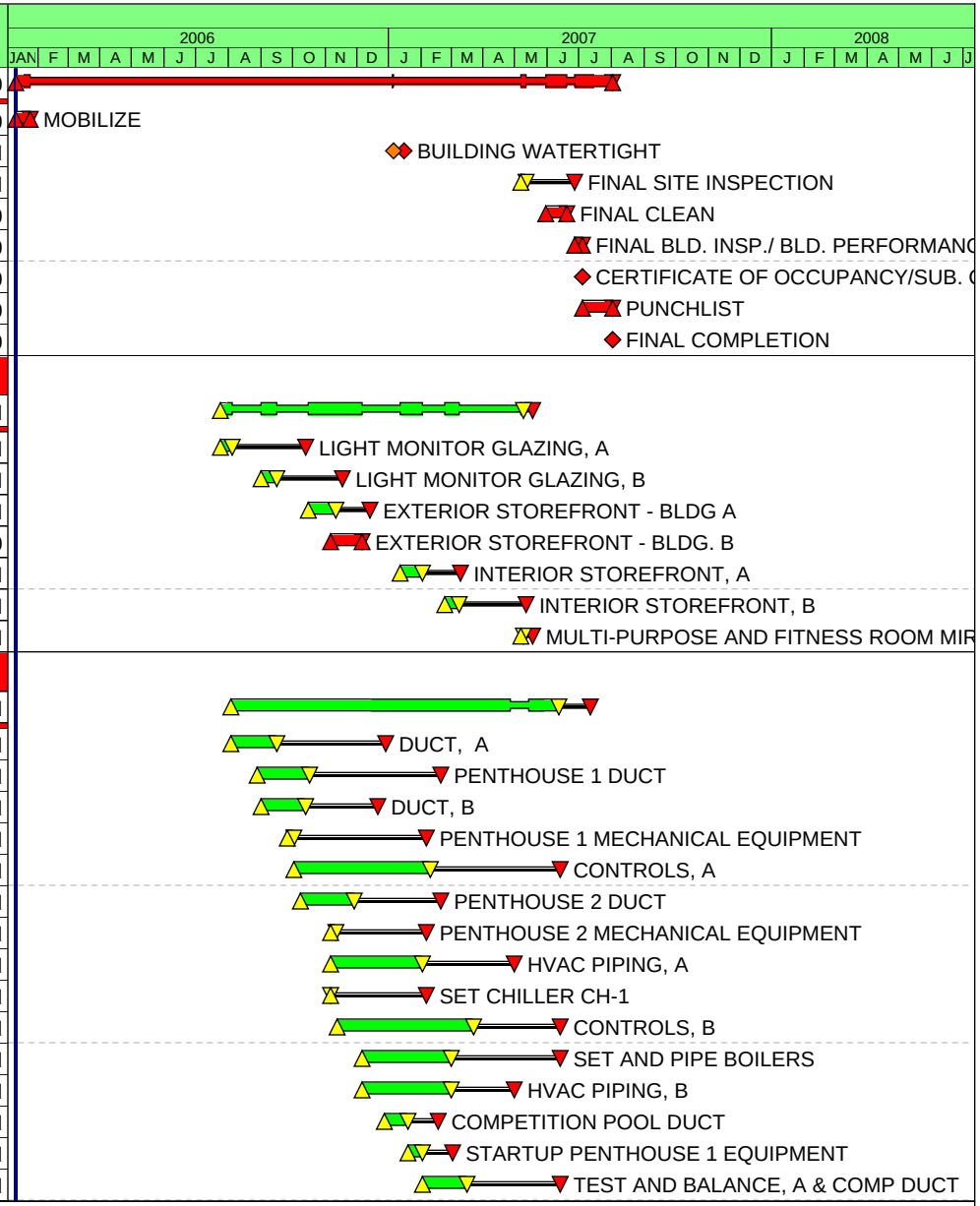
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	3A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
		398	398	10JAN06	01AUG07	0
1010	MOBILIZE	10	10	10JAN06	23JAN06	0
3603	BUILDING WATERTIGHT	0	0		04JAN07	7d
1006	FINAL SITE INSPECTION	5	5	07MAY07	11MAY07	31d
1016	FINAL CLEAN	15	15	30MAY07	19JUN07	0
1011	FINAL BLD. INSP./ BLD. PERFORMANCE	5	5	27JUN07	03JUL07	0
1012	CERTIFICATE OF OCCUPANCY/SUB.	0	0		03JUL07	0
1014	PUNCHLIST	20	20	05JUL07	01AUG07	0
1015	FINAL COMPLETION	0	0		01AUG07	0
GLASS AND GLAZING						
		202	202	24JUL06	08MAY07	7d
3660	LIGHT MONITOR GLAZING, A	10	10	24JUL06	04AUG06	49d
3670	LIGHT MONITOR GLAZING, B	10	10	01SEP06	15SEP06	45d
3610	EXTERIOR STOREFRONT - BLDG A	20	20	16OCT06	10NOV06	21d
3600	EXTERIOR STOREFRONT - BLDG. B	20	20	06NOV06	05DEC06	0
3620	INTERIOR STOREFRONT, A	5	15	12JAN07	01FEB07	26d
3640	INTERIOR STOREFRONT, B	10	10	23FEB07	08MAR07	46d
3651	MULTI-PURPOSE AND FITNESS ROOM	2	2	07MAY07	08MAY07	7d
MECHANICAL HVAC						
		216	216	04AUG06	11JUN07	21d
5080	DUCT, A	30	30	04AUG06	15SEP06	71d
5010	PENTHOUSE 1 DUCT	35	35	28AUG06	16OCT06	86d
5100	DUCT, B	30	30	01SEP06	13OCT06	47d
5020	PENTHOUSE 1 MECHANICAL	5	5	26SEP06	02OCT06	86d
5300	CONTROLS, A	90	90	03OCT06	09FEB07	86d
5050	PENTHOUSE 2 DUCT	35	35	09OCT06	28NOV06	57d
5060	PENTHOUSE 2 MECHANICAL	5	5	06NOV06	10NOV06	57d
5200	HVAC PIPING, A	60	60	06NOV06	01FEB07	62d
5205	SET CHILLER CH-1	1	1	06NOV06	06NOV06	61d
5310	CONTROLS, B	90	90	13NOV06	22MAR07	57d
5065	SET AND PIPE BOILERS	60	60	06DEC06	01MAR07	72d
5210	HVAC PIPING, B	60	60	06DEC06	01MAR07	42d
5000	COMPETITION POOL DUCT	15	15	28DEC06	18JAN07	21d
5320	STARTUP PENTHOUSE 1 EQUIPMENT	10	10	19JAN07	01FEB07	21d
5340	TEST AND BALANCE, A & COMP DUCT	30	30	02FEB07	15MAR07	62d



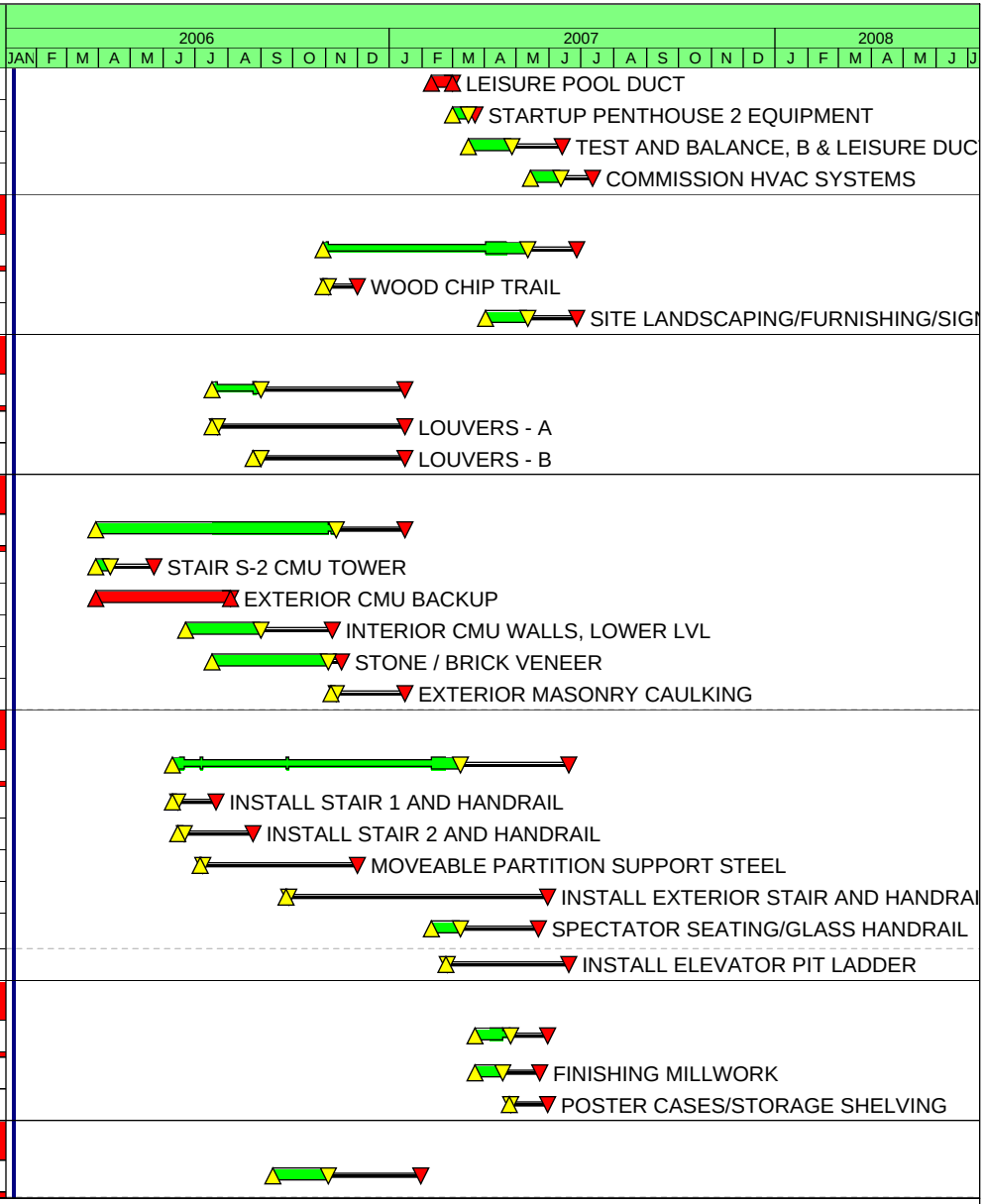
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	4A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
5040	LEISURE POOL DUCT	15	15	09FEB07	01MAR07	0
5330	STARTUP PENTHOUSE 2 EQUIPMENT	10	10	02MAR07	15MAR07	5d
5350	TEST AND BALANCE, B & LEISURE DUCT	30	30	16MAR07	26APR07	32d
5360	COMMISSION HVAC SYSTEMS	20	20	14MAY07	11JUN07	21d
LANDSCAPING						
		136	136	30OCT06	11MAY07	31d
1480	WOOD CHIP TRAIL	5	5	30OCT06	03NOV06	17d
1490	SITE	30	30	02APR07	11MAY07	31d
LOUVERS						
		34	34	17JUL06	31AUG06	92d
3710	LOUVERS - A	5	5	17JUL06	21JUL06	121d
3700	LOUVERS - B	5	5	25AUG06	31AUG06	92d
MASONRY						
		160	160	29MAR06	10NOV06	42d
2035	STAIR S-2 CMU TOWER	10	10	29MAR06	11APR06	29d
7050	EXTERIOR CMU BACKUP	70	70	29MAR06	03AUG06	0
7010	INTERIOR CMU WALLS, LOWER LVL	50	50	22JUN06	31AUG06	47d
3110	STONE / BRICK VENEER	79	79	17JUL06	03NOV06	9d
3601	EXTERIOR MASONRY CAULKING	5	5	06NOV06	10NOV06	42d
MISCELLANEOUS METALS						
		189	189	09JUN06	08MAR07	72d
2152	INSTALL STAIR 1 AND HANDRAIL	3	3	09JUN06	13JUN06	26d
2151	INSTALL STAIR 2 AND HANDRAIL	5	5	14JUN06	20JUN06	46d
2156	MOVEABLE PARTITION SUPPORT STEEL	2	2	06JUL06	07JUL06	101d
2153	INSTALL EXTERIOR STAIR AND	3	3	25SEP06	27SEP06	169d
2155	SPECTATOR SEATING/GLASS HANDRAIL	20	20	09FEB07	08MAR07	52d
2154	INSTALL ELEVATOR PIT LADDER	1	1	23FEB07	23FEB07	81d
MILLWORK						
		24	24	23MAR07	25APR07	24d
9153	FINISHING MILLWORK	18	18	23MAR07	17APR07	25d
9156	POSTER CASES/STORAGE SHELVING	2	2	24APR07	25APR07	24d
METAL SIDING						
		39	39	12SEP06	03NOV06	57d



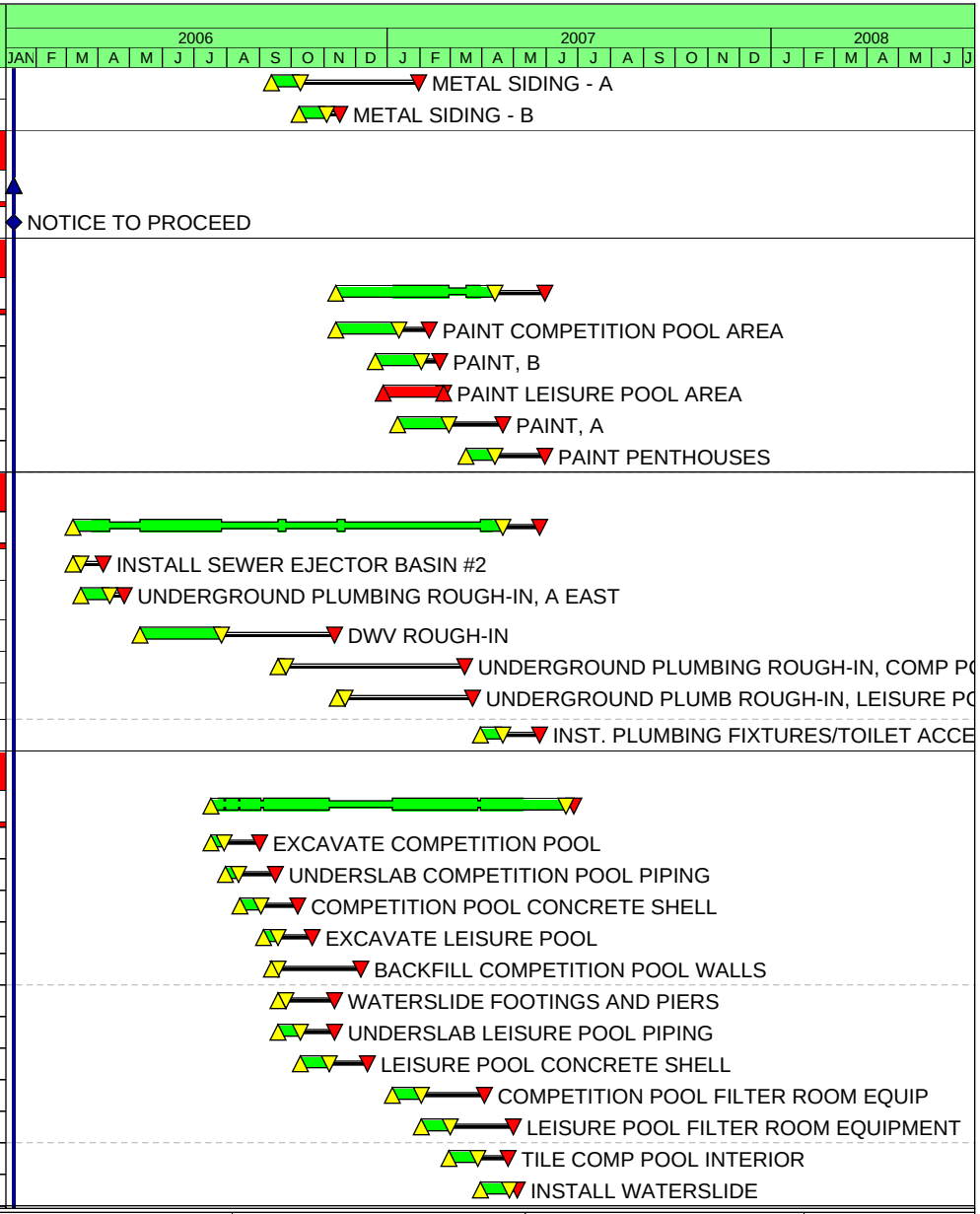
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	5A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
3430	METAL SIDING - A	20	20	12SEP06	09OCT06	76d
3410	METAL SIDING - B	20	20	09OCT06	03NOV06	8d
OWNER						
		0	0	10JAN06	10JAN06	
1000	NOTICE TO PROCEED	0	0	10JAN06		
PAINT						
		105	105	13NOV06	12APR07	32d
6000	PAINT COMPETITION POOL AREA	40	40	13NOV06	11JAN07	21d
6050	PAINT, B	30	30	20DEC06	01FEB07	12d
6010	PAINT LEISURE POOL AREA	40	40	28DEC06	22FEB07	0
6040	PAINT, A	35	35	10JAN07	27FEB07	37d
6100	PAINT PENTHOUSES	20	20	16MAR07	12APR07	32d
PLUMBING						
		285	285	08MAR06	19APR07	25d
2013	INSTALL SEWER EJECTOR BASIN #2	5	5	08MAR06	14MAR06	15d
8000	UNDERGROUND PLUMBING ROUGH-IN, A	20	20	15MAR06	11APR06	10d
8020	DWV ROUGH-IN	53	53	11MAY06	26JUL06	76d
8050	UNDERGROUND PLUMBING ROUGH-IN,	5	5	19SEP06	25SEP06	118d
8060	UNDERGROUND PLUMB ROUGH-IN,	5	5	14NOV06	20NOV06	84d
8090	INST. PLUMBING FIXTURES/TOILET	15	15	30MAR07	19APR07	25d
POOLS						
		236	236	17JUL06	19JUN07	5d
4100	EXCAVATE COMPETITION POOL	10	10	17JUL06	28JUL06	24d
4110	UNDERSLAB COMPETITION POOL PIPING	10	10	31JUL06	11AUG06	24d
4120	COMPETITION POOL CONCRETE SHELL	15	15	14AUG06	01SEP06	24d
4000	EXCAVATE LEISURE POOL	10	10	05SEP06	18SEP06	24d
4190	BACKFILL COMPETITION POOL WALLS	5	5	12SEP06	18SEP06	55d
4005	WATERSLIDE FOOTINGS AND PIERS	5	5	19SEP06	25SEP06	34d
4010	UNDERSLAB LEISURE POOL PIPING	15	15	19SEP06	09OCT06	24d
4020	LEISURE POOL CONCRETE SHELL	20	20	10OCT06	06NOV06	24d
4075	COMPETITION POOL FILTER ROOM	20	20	05JAN07	01FEB07	42d
4070	LEISURE POOL FILTER ROOM	20	20	02FEB07	01MAR07	42d
4140	TILE COMP POOL INTERIOR	20	20	28FEB07	27MAR07	21d
4040	INSTALL WATERSLIDE	20	20	30MAR07	26APR07	5d



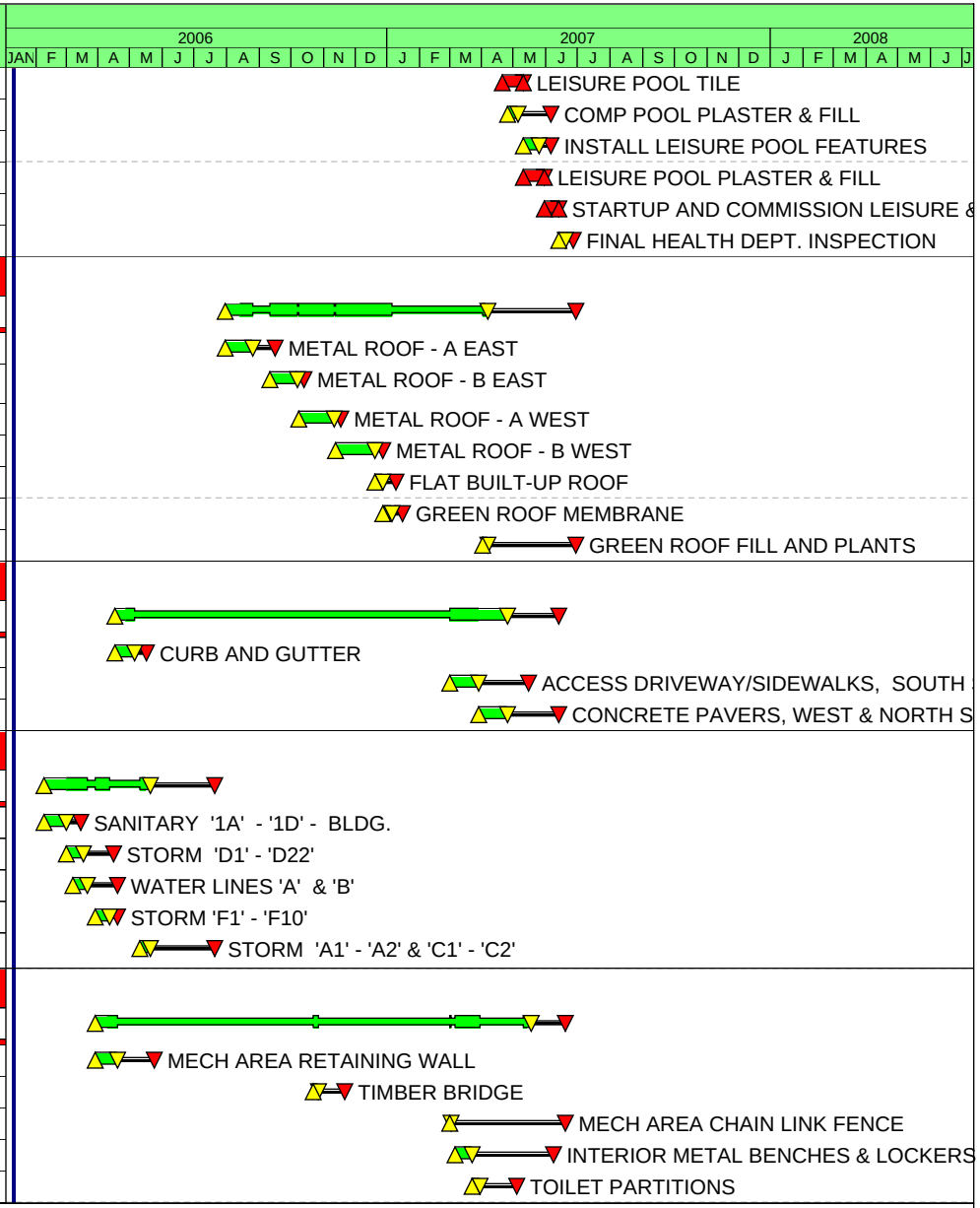
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	6A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
4035	LEISURE POOL TILE	15	15	20APR07	10MAY07	0
4150	COMP POOL PLASTER & FILL	8	8	25APR07	04MAY07	21d
4045	INSTALL LEISURE POOL FEATURES	10	10	11MAY07	24MAY07	7d
4048	LEISURE POOL PLASTER & FILL	12	12	11MAY07	29MAY07	0
4180	STARTUP AND COMMISSION LEISURE &	10	10	30MAY07	12JUN07	0
4181	FINAL HEALTH DEPT. INSPECTION	5	5	13JUN07	19JUN07	5d
ROOFING						
		175	175	31JUL06	06APR07	59d
3520	METAL ROOF - A EAST	20	20	31JUL06	25AUG06	14d
3500	METAL ROOF - B EAST	20	20	11SEP06	06OCT06	5d
3530	METAL ROOF - A WEST	25	25	09OCT06	10NOV06	5d
3510	METAL ROOF - B WEST	25	25	13NOV06	19DEC06	5d
3540	FLAT BUILT-UP ROOF	5	5	20DEC06	27DEC06	7d
3550	GREEN ROOF MEMBRANE	5	5	28DEC06	04JAN07	7d
3560	GREEN ROOF FILL AND PLANTS	5	5	02APR07	06APR07	59d
SITE CONCRETE						
		261	261	17APR06	25APR07	33d
1450	CURB AND GUTTER	15	15	17APR06	05MAY06	7d
1454	ACCESS DRIVEWAY/SIDEWALKS,	20	20	01MAR07	28MAR07	33d
1452	CONCRETE PAVERS, WEST & NORTH	20	20	29MAR07	25APR07	33d
SITE UTILITIES						
		73	73	08FEB06	19MAY06	42d
1190	SANITARY '1A' - '1D' - BLDG.	15	15	08FEB06	28FEB06	10d
1150	STORM 'D1' - 'D22'	13	13	01MAR06	17MAR06	20d
1100	WATER LINES 'A' & 'B'	10	10	08MAR06	21MAR06	20d
1160	STORM 'F1' - 'F10'	10	10	29MAR06	11APR06	5d
1120	STORM 'A1' - 'A2' & 'C1' - 'C2'	8	8	10MAY06	19MAY06	42d
SPECIALTY						
		290	290	29MAR06	17MAY07	22d
9111	MECH AREA RETAINING WALL	15	15	29MAR06	18APR06	25d
1470	TIMBER BRIDGE	5	5	23OCT06	27OCT06	17d
9106	MECH AREA CHAIN LINK FENCE	1	1	02MAR07	02MAR07	76d
9101	INTERIOR METAL BENCHES & LOCKERS	12	12	07MAR07	22MAR07	54d
9104	TOILET PARTITIONS	5	5	23MAR07	29MAR07	25d



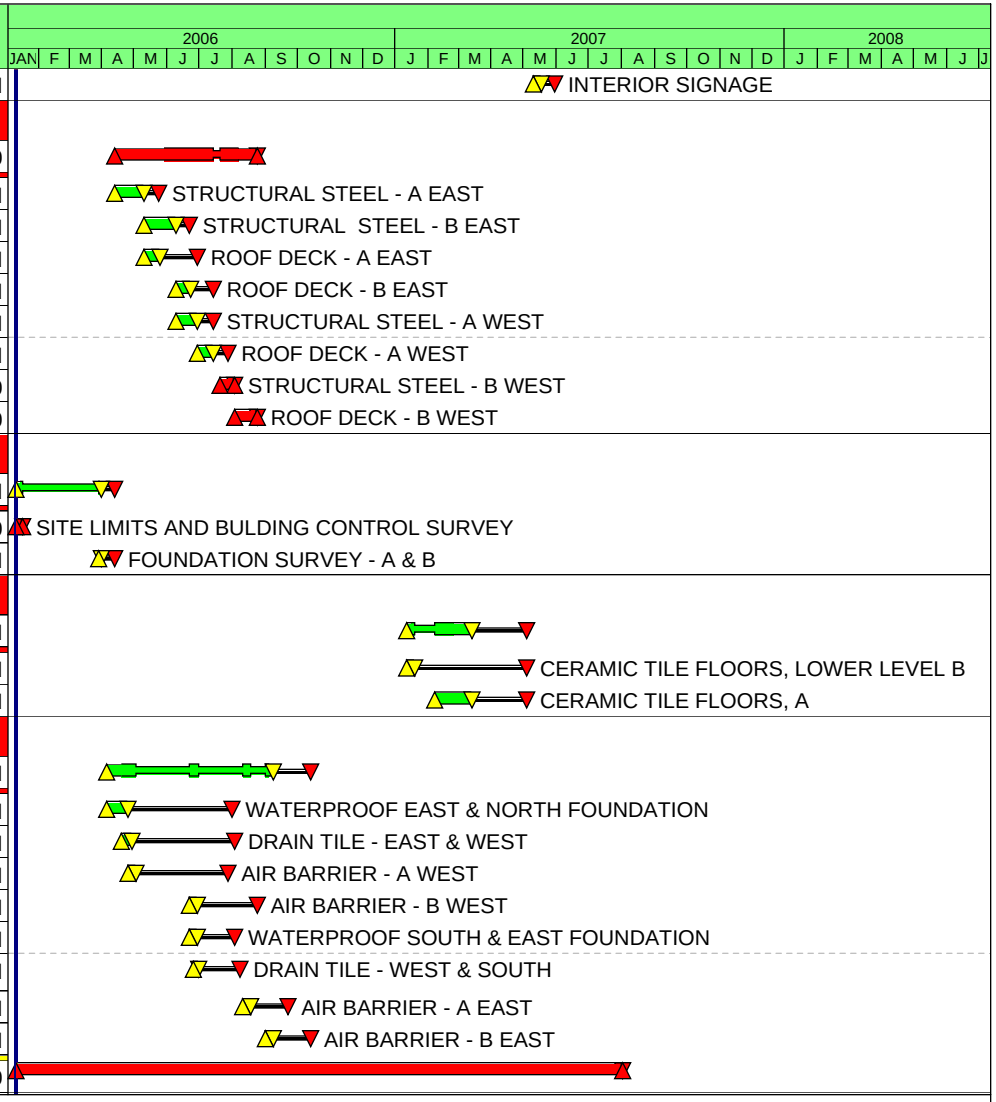
FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	7A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Act ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float
9108	INTERIOR SIGNAGE	5	5	11MAY07	17MAY07	7d
STRUCTURAL STEEL						
		94	94	13APR06	24AUG06	0
2160	STRUCTURAL STEEL - A EAST	20	20	13APR06	10MAY06	9d
2050	STRUCTURAL STEEL - B EAST	20	20	11MAY06	08JUN06	9d
2180	ROOF DECK - A EAST	10	10	11MAY06	24MAY06	24d
2070	ROOF DECK - B EAST	10	10	09JUN06	22JUN06	14d
2170	STRUCTURAL STEEL - A WEST	15	15	09JUN06	29JUN06	9d
2185	ROOF DECK - A WEST	10	10	30JUN06	14JUL06	9d
2060	STRUCTURAL STEEL - B WEST	10	10	21JUL06	03AUG06	0
2075	ROOF DECK - B WEST	15	15	04AUG06	24AUG06	0
SURVEY						
		58	58	10JAN06	30MAR06	9d
1020	SITE LIMITS AND BULDING CONTROL	5	5	10JAN06	16JAN06	0
2150	FOUNDATION SURVEY - A & B	2	2	29MAR06	30MAR06	9d
CERAMIC TILE						
		43	43	12JAN07	13MAR07	37d
9002	CERAMIC TILE FLOORS, LOWER LEVEL	5	5	12JAN07	18JAN07	75d
9001	CERAMIC TILE FLOORS, A	25	25	07FEB07	13MAR07	37d
WATERPROOFING						
		110	110	05APR06	08SEP06	25d
3280	WATERPROOF EAST & NORTH	15	15	05APR06	25APR06	67d
3290	DRAIN TILE - EAST & WEST	8	8	19APR06	28APR06	67d
3250	AIR BARRIER - A WEST	5	5	26APR06	02MAY06	60d
3220	AIR BARRIER - B WEST	5	5	22JUN06	28JUN06	40d
3265	WATERPROOF SOUTH & EAST	5	5	22JUN06	28JUN06	25d
3295	DRAIN TILE - WEST & SOUTH	5	5	26JUN06	30JUN06	26d
3230	AIR BARRIER - A EAST	5	5	11AUG06	17AUG06	25d
3200	AIR BARRIER - B EAST	5	5	01SEP06	08SEP06	25d
		398	398	10JAN06	01AUG07	0



FORRESTER CONSTRUCTION COMPANY
WARRENTON AQUATICS AND RECR FACILITY

Start date	10JAN06
Finish date	01AUG07
Data date	10JAN06
Run date	25OCT06
Page number	8A

Calculate: Total
Display: Quantity
Interval: Month
Total cumulative curve

Early start point
Early finish point
Early bar
Total float point
Total float bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Appendix C

Ethical Need Survey

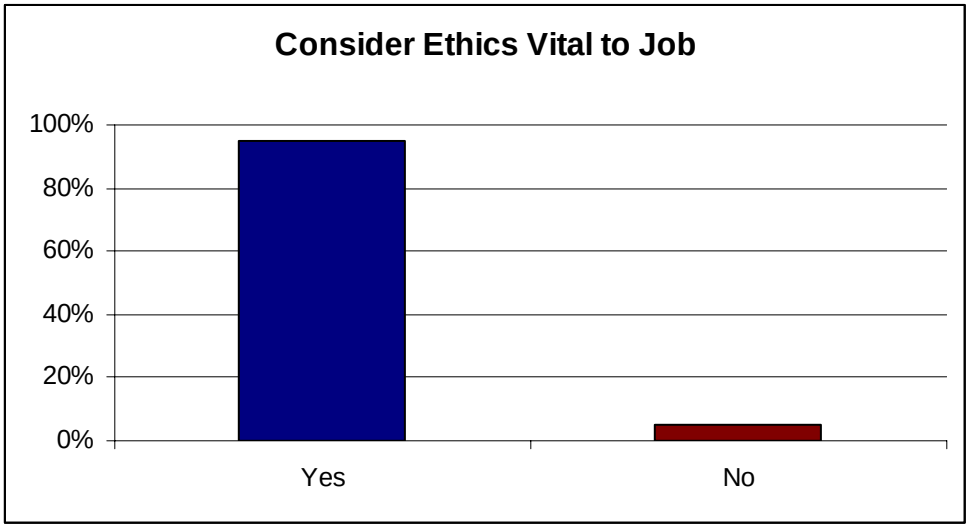
The following survey is for information purposes only. All individual surveys will be kept confidential, with the cumulative results being tabulated and published in correspondence with my senior thesis project. Thank you for your time and honesty.

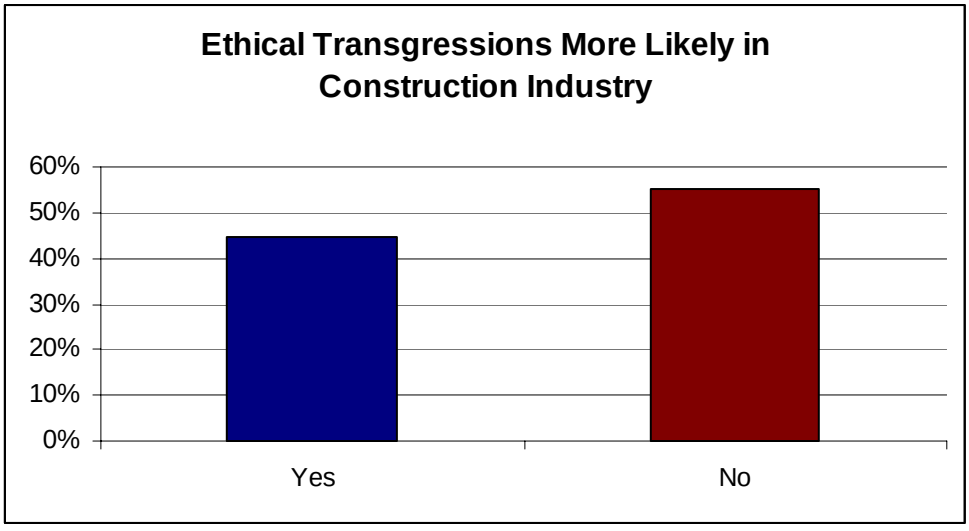
1.	Do you consider ethics to be a vital part of your job?	YES	NO
2.	Do you feel that ethical transgressions are more prevalent in the construction industry than others?	YES	NO
3.	Do you consider the ethics of your company to be a competitive advantage?	YES	NO
4.	Are ethical transgressions a necessity in order to maintain a competitive advantage in your field?	YES	NO
5.	Do you feel in your company that you should work towards a better bottom line rather than behave ethically?	YES	NO
6.	In order to get promoted, do you think that better schedule and budget performance are more important than acting in an ethical way?	YES	NO
7.	Does your company reward its employees for performing their job ethically?	YES	NO
8.	Would people in your company act more ethical if they were to be rewarded?	YES	NO
9.	Does your company conduct employee training? (i.e. safety or materials courses)	YES	NO
10.	Do they offer a course on ethical behavior?	YES	NO
11.	If not, would you like your company to offer a course on professional ethics as it relates to the construction industry?	YES	NO

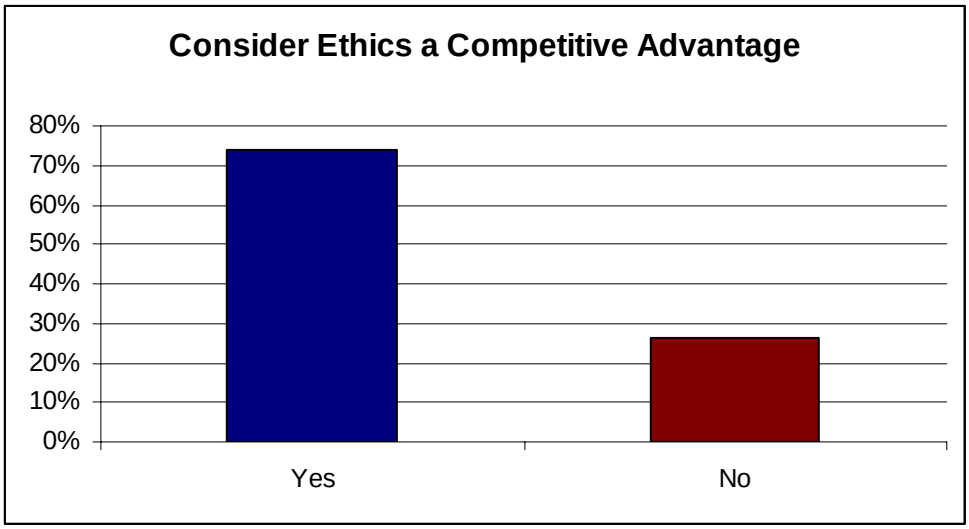
Please save the completed survey as your name and email it to dnd122@psu.edu.
Thank you for your time and efforts.

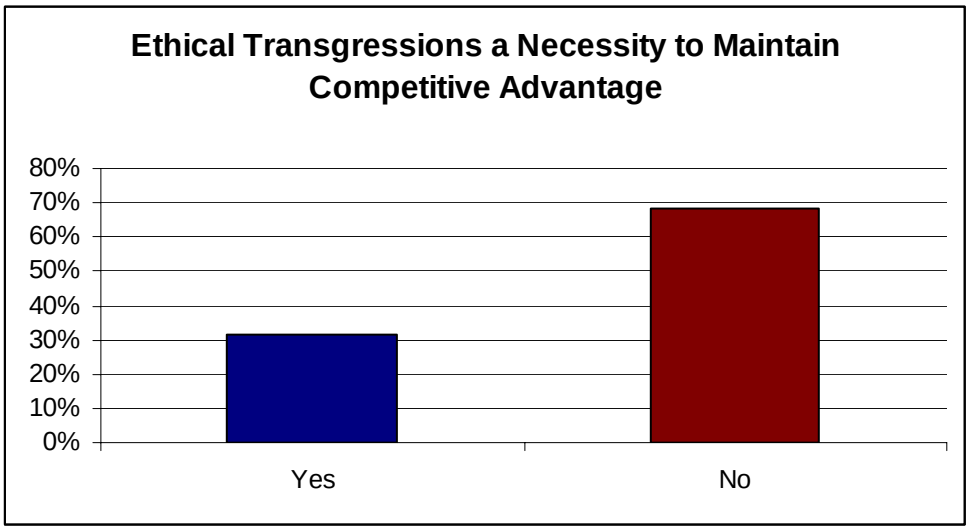
Appendix D

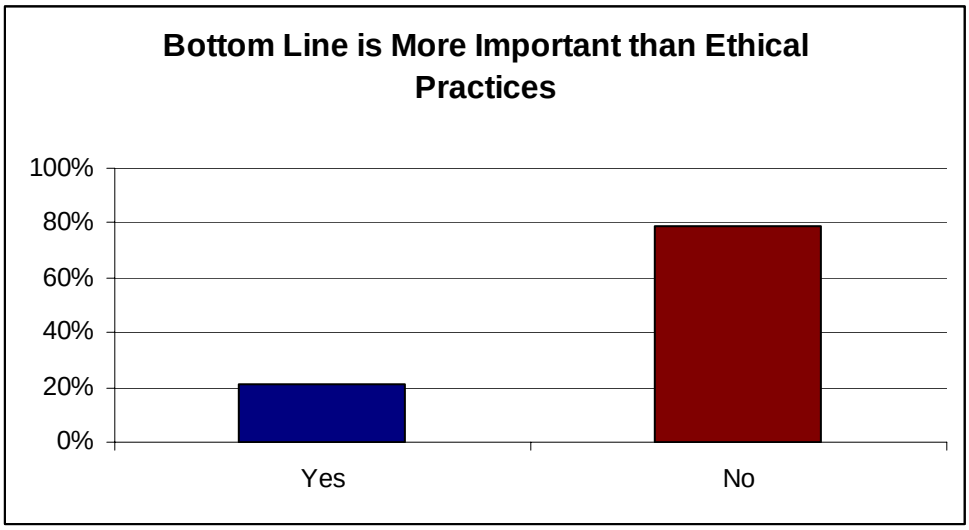
Ethical Need survey results:

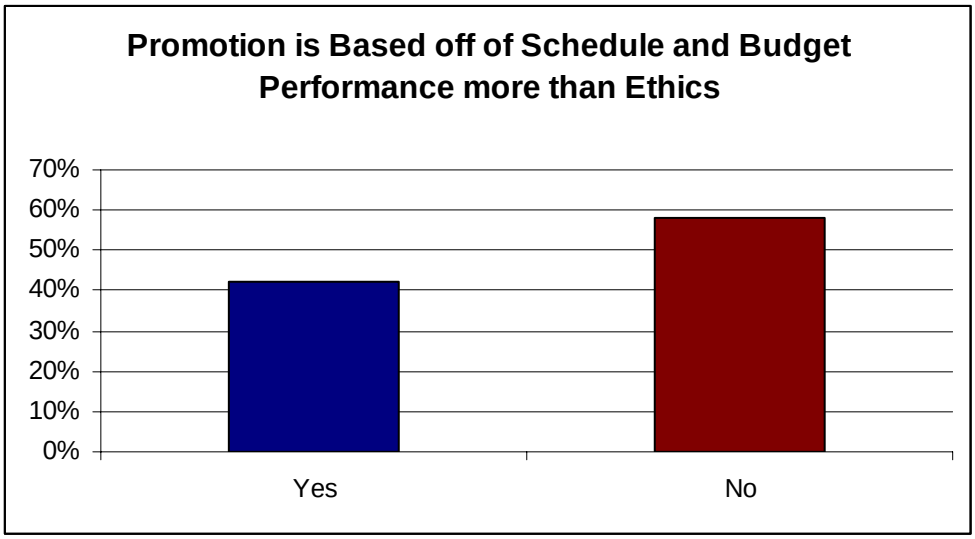


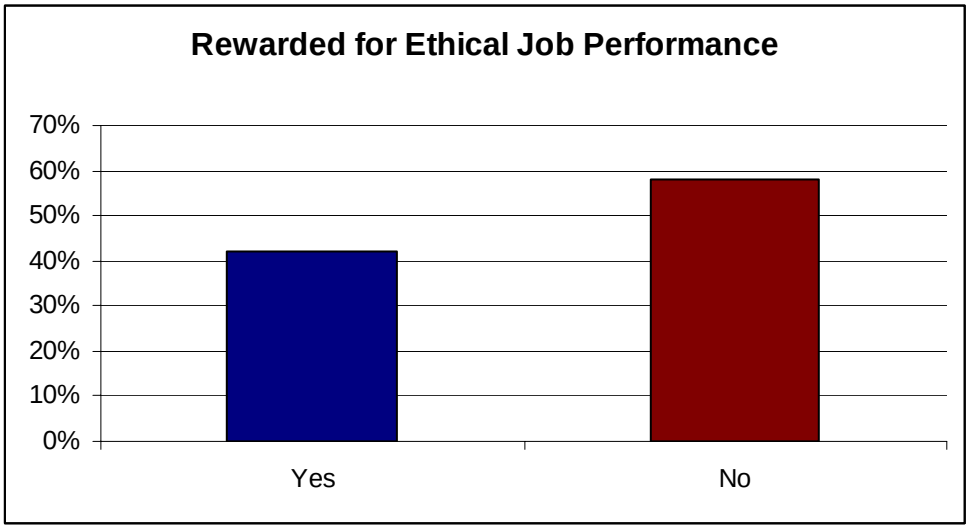


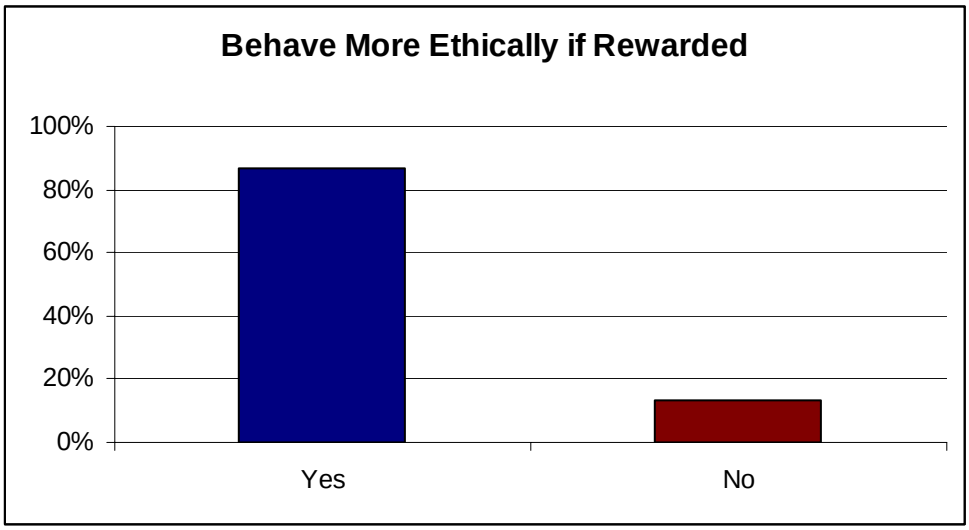

Consider Ethics a Competitive Advantage
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No

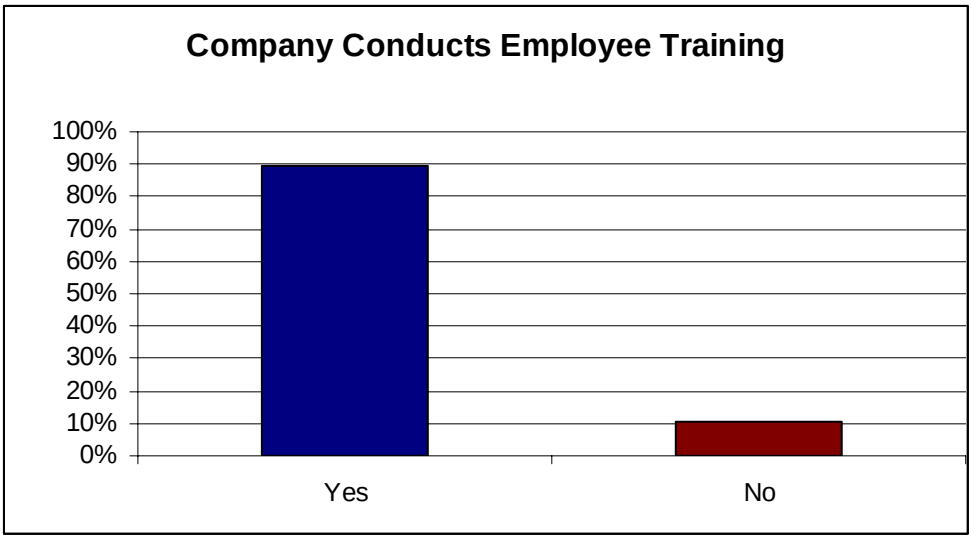

Ethical Transgressions a Necessity to Maintain Competitive Advantage
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No


Bottom Line is More Important than Ethical Practices
100%
80%
60%
40%
20%
0%
Yes
No

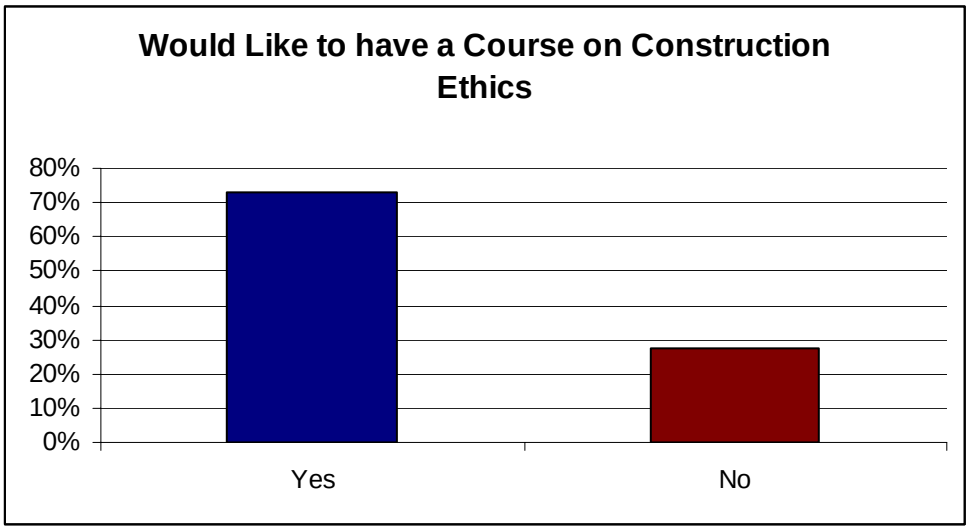

Promotion is Based off of Schedule and Budget Performance more than Ethics
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No


Rewarded for Ethical Job Performance
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No


Behave More Ethically if Rewarded
100%
80%
60%
40%
20%
0%
Yes
No


Company Conducts Employee Training
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No


Company Offers Training on Ethical Practices
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No


Would Like to have a Course on Construction Ethics
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No

Appendix E

Construction Ethics Training Program Exit Survey

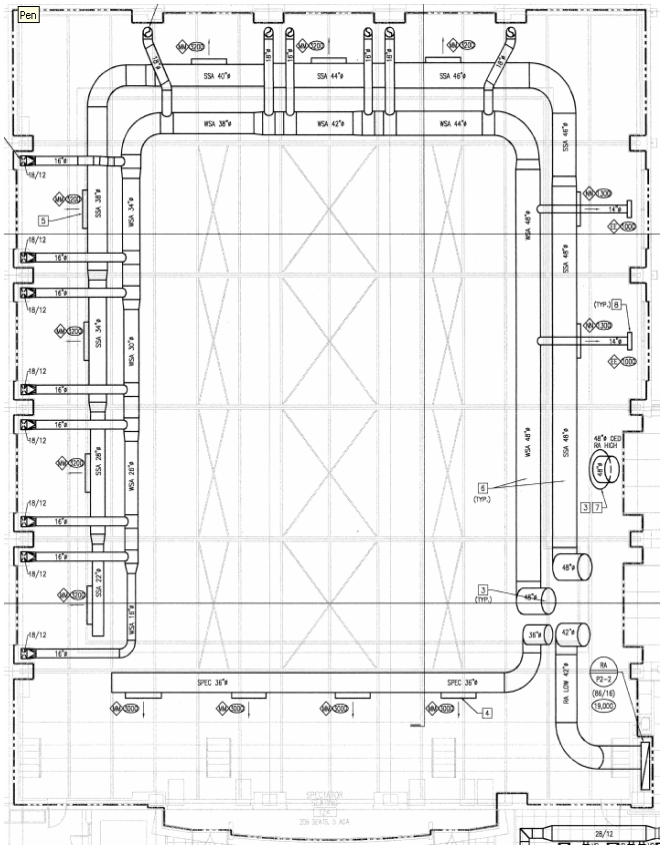
The following survey is for information purposes only. All individual surveys will be kept confidential, with the cumulative results being tabulated and published in correspondence with my senior thesis project. Thank you for your time and honesty.

1.	Do you consider the program to be a valid tool for ethical training?	YES	NO
2.	Would you recommend this program to your coworkers/peers?	YES	NO
3.	After completion of the program, would you act more ethically within the construction industry?	YES	NO
4.	Would you like your company/university to use this program as its means to train employees on ethical practices?	YES	NO
5.	Do you think that the program would fit into your companies/universities training program or learning curriculum?	YES	NO
6.	Is the benefit of taking the program worth the cost of it to your employer?	YES	NO
7.	Is the benefit of taking the program worth the time invested by the employees/students?	YES	NO
8.	Do you consider this training program to be a better alternative to your company's current method of addressing ethical practices?	YES	NO

Please save the completed survey as your name and email it to dnd122@psu.edu.
Thank you for your time and efforts.

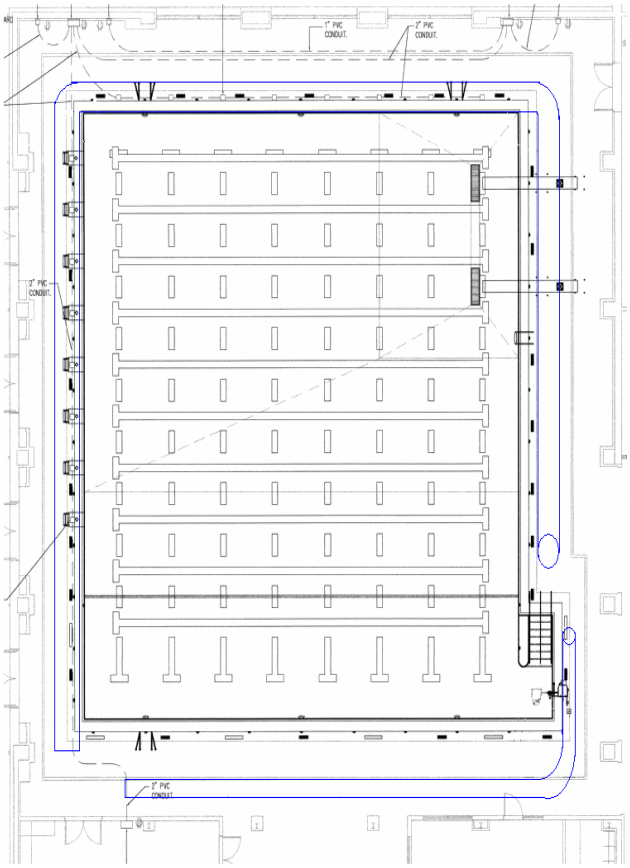
Appendix F

Duct Design Layouts

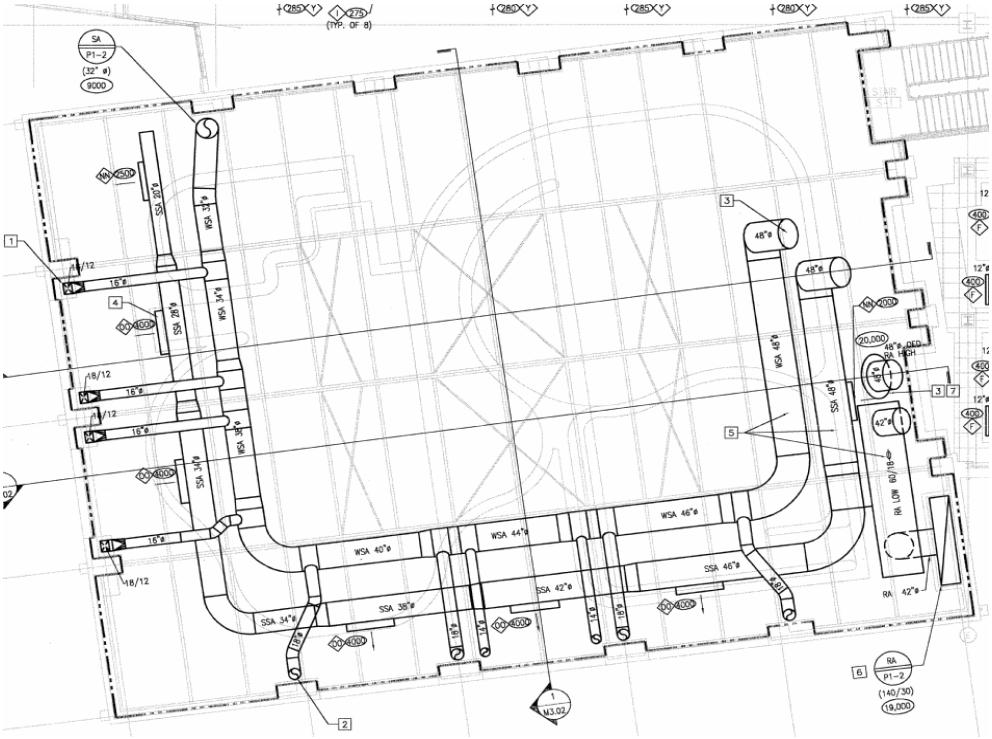


Initial Ductwork Design
Competition Pool

Fabric Duct Redesign
Competition Pool

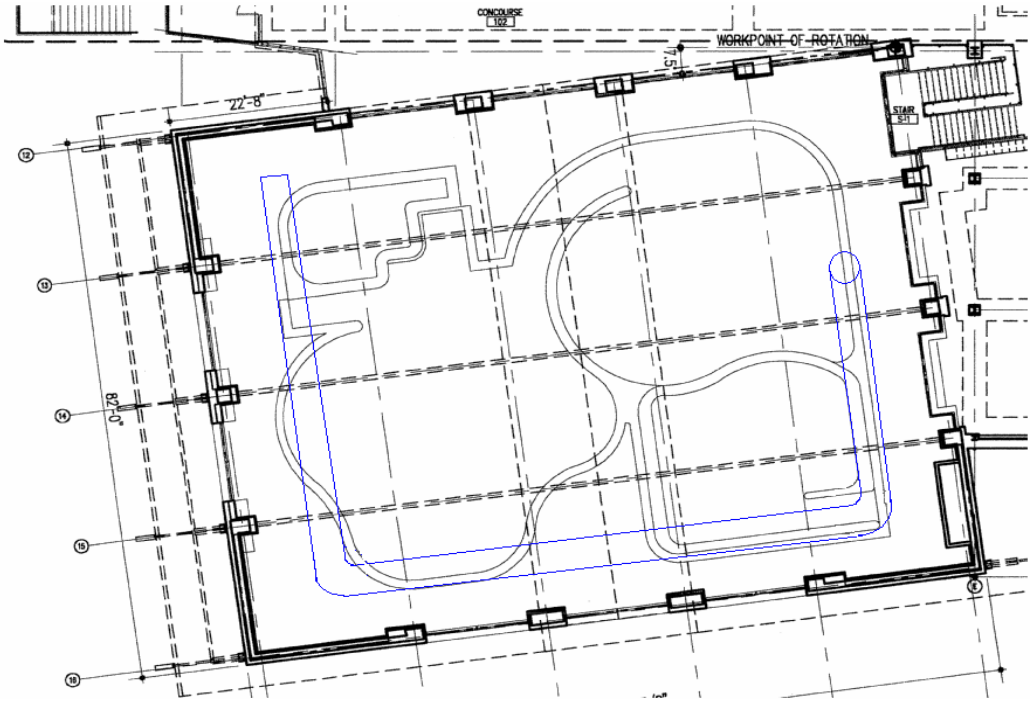


Duct Design Layouts



Initial Ductwork Design
Leisure Pool

Fabric Duct Redesign
Leisure Pool



Appendix G
Pilaster Calculation

Masonry Pilaster

Worst Case Loading

$P = 177\ k$

$m = 35.4\ ^{'k}$

Trial Size $= \frac{177000\ lb}{(345\ psi)} = (492\ in^2) \approx 22" \rightarrow try\ 24" \times 24"$

Use 4 #7's

$A_s = .60 \times 4 = 2.40\ in^2$

$A_g = 24 \times 24 = 576\ in^2$

$F_s = 24000$

$h = 384"$

$r = .3D = 7.2$

Axial Force Capacity

$$P = \left(.25\, f'm\, A_g + .65\, A_s F_s\right)\left(1 - \left(\frac{h}{140r}\right)^2\right)$$

$$= \left(.25(1500)(576) + .65(2.40)(24000)\right)\left(1 - \left(\frac{384}{140 \cdot 7.2}\right)^2\right)$$

$= 215.4\ K_{ins} > 177\ K_{ins} \quad \therefore\ OK$

Check Moment Capacity

$A_s = 2.40\ in^2 \quad n = 21.5$

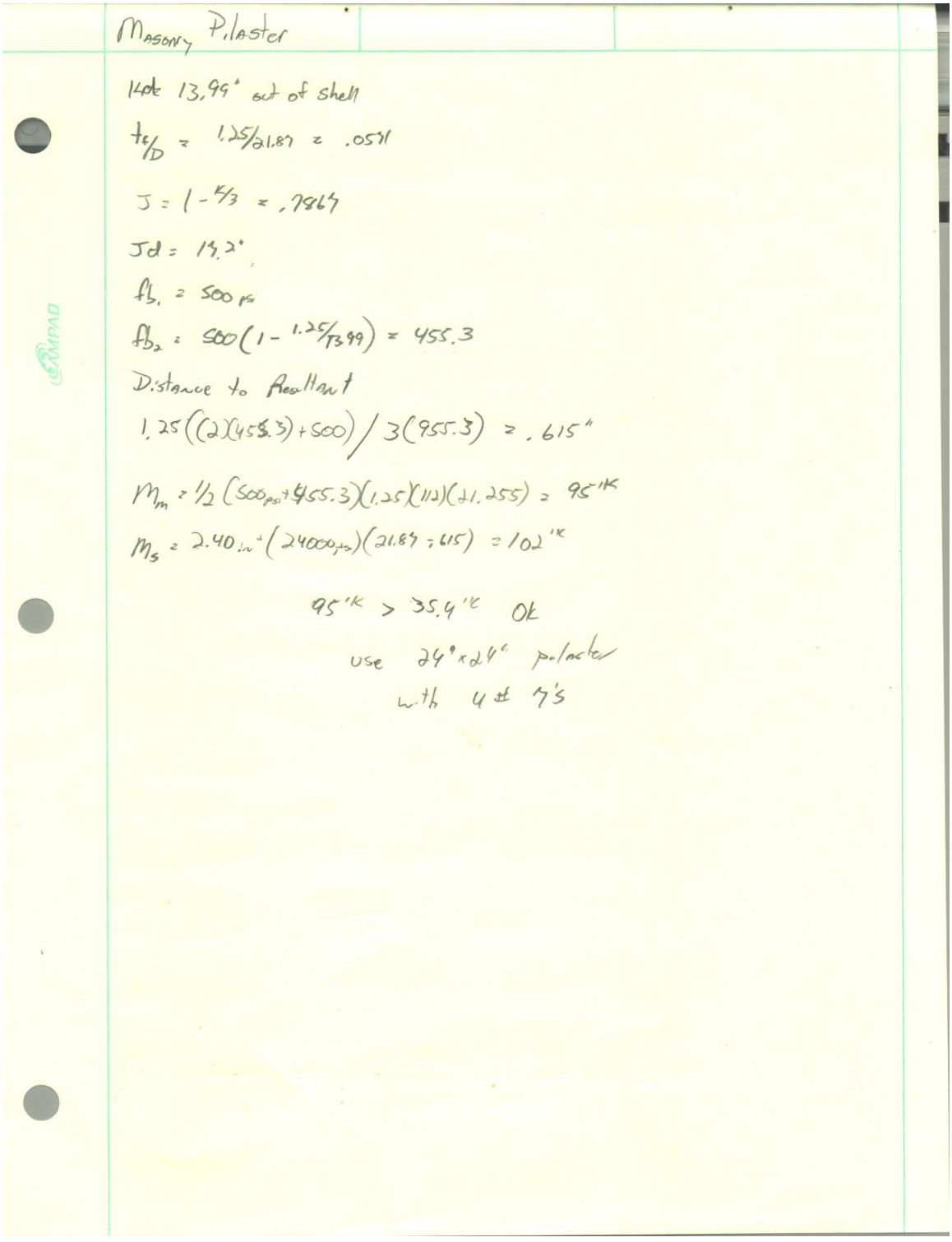
$d = 23.625 - 1.25 - 1.5" = 21.87$

$$\rho = \frac{A_s}{BD} = \frac{2.40}{(24)(21.87)} = .0046$$

$\rho_n = .0983$

$$K = \frac{\rho_n + \frac{1}{2}\left(\frac{t}{D}\right)^2}{\rho_n + \left(\frac{t}{D}\right)} = \frac{.0983 + \frac{1}{2}\left(\frac{1.25}{21.87}\right)^2}{.0983 + \left(\frac{1.25}{21.87}\right)} = .6399$$

Pilaster Calculation



Masonry Pilaster

Kpk 13.99° out of shell

$t_s/D = 1.25/21.87 = .057$

$J = 1 - K/3 = .7869$

$Jd = 13.2"$

$fb_1 = 500\ psi$

$fb_2 = 500(1 - 1.25/13.99) = 455.3$

Distance to Resultant

$1.25((2)(455.3) + 500) / 3(955.3) = .615"$

$M_m = 1/2\,(500_{psi} + 455.3)(1.25)(112)(21.255) = 95^{'k}$

$M_s = 2.40_{in^2}(24000_{psi})(21.87 - .615) = 102^{'k}$

$95^{'k} > 35.4^{'k}$ OK

use 24"x24" pilaster

with 4 #7's