Borland Laboratory Renovation

Senior Thesis – Spring 2007

Dustin Faust

Construction Management Option

The Pennsylvania State University
Borland Laboratory Renovation
University Park, PA

Project Team

Owner: The Pennsylvania State University
Construction Team: Leonard S. Fiore
Architects: Bower Lewis Thrower
LEED Team: Atelier Ten
Structural Engineer: Gannett Flemming
Mechanical Engineer: R.G. Vanderweil
Acoustics, AV/IT: Acentech Inc.

Project Overview

Location: Corner of Curtain Rd. and Shortlidge Rd.
Building size: 61,415 gross square feet

Estimated Cost: $15,000,000

Building Height: 3 Stories - 56'

Building Dates: December 1st, 2006 to April 23, 2008

Architectural Features

Renovating this 1930s building into classrooms, offices, and digital design studios for the College of Arts and Architecture

Will be the first LEED Certified project for an existing building on any Penn State Campus

MEP Systems

New HVAC system suplied by the University's High Pressure Steam and Chilled Water Systems

Primarily fluorescent lighting with occupancy sensors for LEEDs the certification

New underground utilities installed

Dustin Faust

Architectural Engineering
Construction Management
Capstone Project

Executive Summary

The Pennsylvania State University, Borland Laboratory Renovation has recently begun construction under the General Contractor of Leonard S. Fiore. The notice to proceed was given on December 1st, 2006, and the project has a substantial completion date of April 4th, 2008. Leonard S. Fiore, Inc. has worked on many astounding projects around the State College, Pa area, and has also completed many projects for Penn State. Some of their recent work for Penn State has been, Pattee Library, Community Arts Center, Research Center, and The Bryce Jordan Center Renovations.

During the Fall 2006 and Spring 2007 Semesters, I will be working on this project as an employee of The Pennsylvania State University Office of the Physical Plant (PSU OPP). Due to the tardiness in the completion of The University Creamery, there was a delay in removing production machinery from the Borland Laboratory. This caused the project start time to be pushed back drastically. However it has also allowed ample time for the Architects, Bower Lewis Thrower, to produce a 100% complete bid set. To date there has only been one minor set of revisions issued.

This renovation will be the first LEED rated project for an existing building on any Penn State Campus. Penn State has hired a construction group that specializes in designing LEED buildings. Atelier Ten has formed a list of the different LEED items they believe could be achievable for this project. This list if completed will give The Borland Laboratory Renovation a LEED Certification rating. In this review I will be looking at many different options, including a redesigned domestic water system as well as a redesign of the HCAV system. These items strive to make this renovation more Green to work towards the plans of the AIA 2030 Challenge which I will also be covering.

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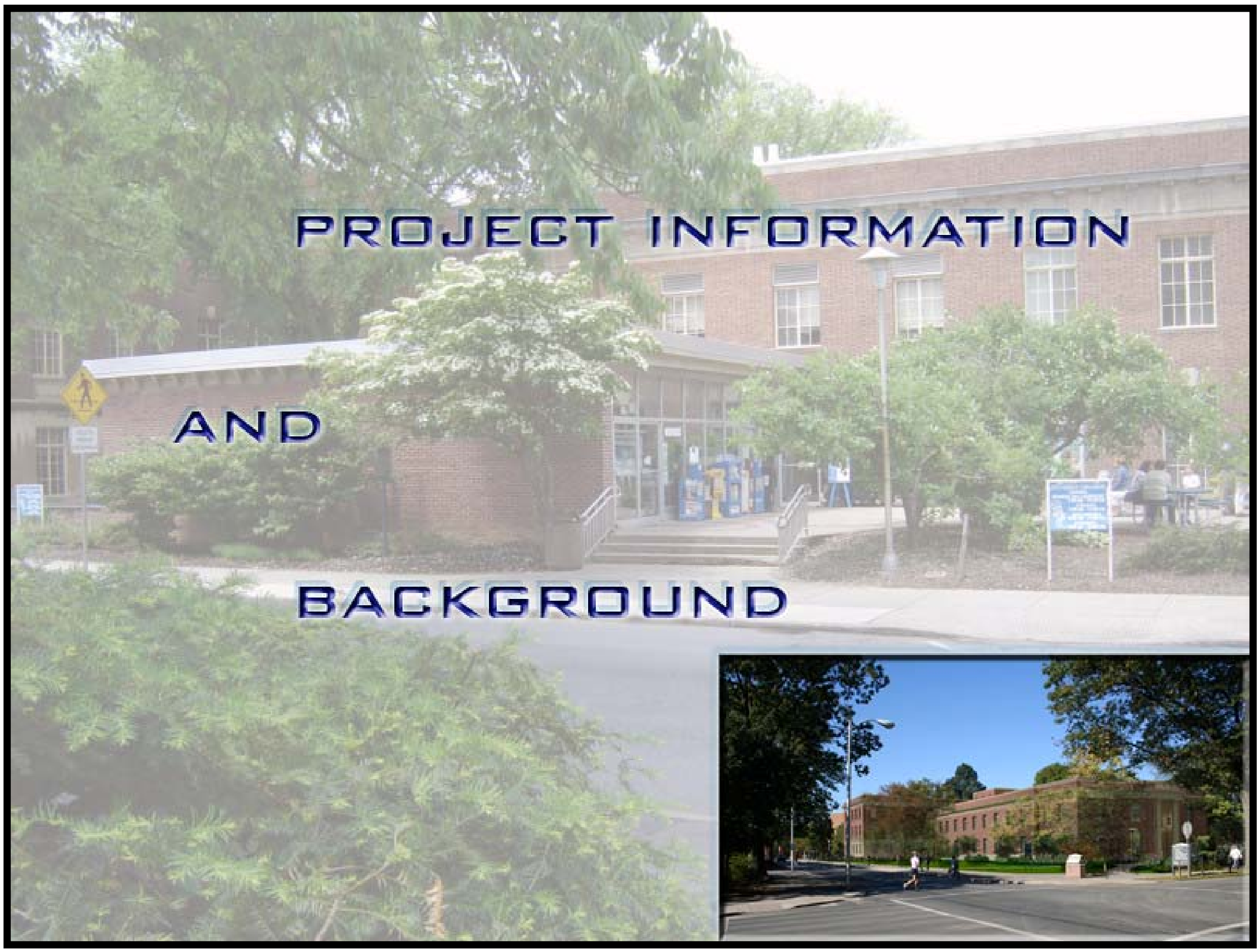

PROJECT INFORMATION
AND
BACKGROUND

Project Background

The Penn State Borland Laboratory housed the Penn State Creamery for over 73 years, making it one of the most popular buildings on the University Park Campus. It is due to this fact that newly named Borland Building is being renovated, and not torn down to make room for a new structure. The current state of the Borland Laboratory consists of three different periods of construction. The renovation will take this building back to its original footprint of 1932, when the construction of Borland Laboratory was completed. From 1932 till its current state, the building has gone threw many renovations, and 2 additions. In the years 1960 through 1961, a raw-milk receiving room was added onto the back (North Side) of the building, as well as the sales room that was added to the front (South Side) of the structure.

Project Information

The Borland Laboratory is being totally renovated from its original use as Dairy Science Classrooms, and the production and sales of dairy products. After the renovation is complete, this building will house the College of Arts and Architecture. This College is currently split up between many buildings, and will soon have a building to house everyone in one spot. The layout for this building has been designed with enough offices to hold the staff and faculty for Art History, E-Learning, and Integral Arts, as well as the Deans and Associate Deans for these majors. There is ample room left for a few classrooms on the second floor, as well as four large studios and two large lecture halls designed to hold 150 students each.

Client Information

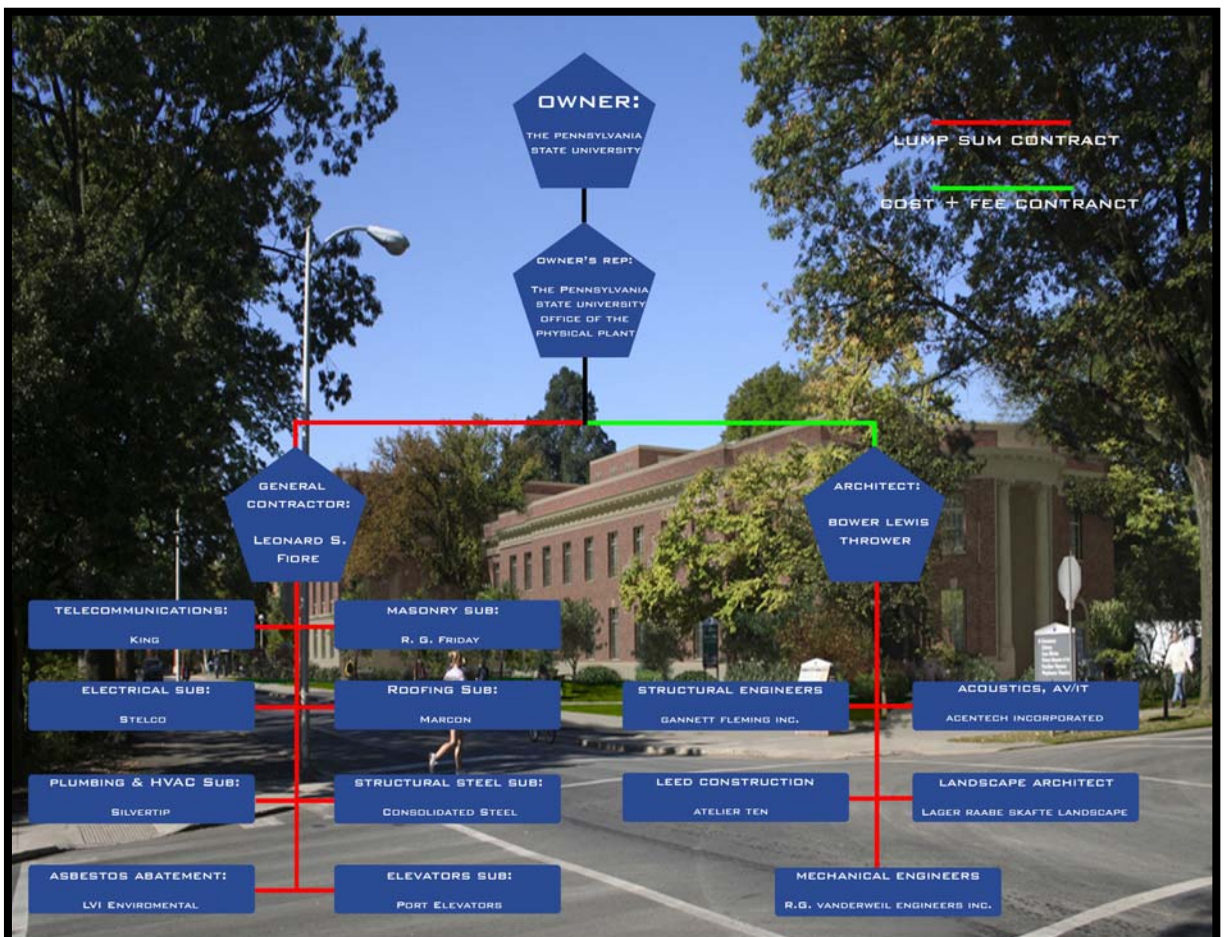
The Pennsylvania State University is ranked 40th among the world's top 100 global institutions. Penn State follows a list of very high quality standards that are backed up by the Office of the Physical Plant's Construction Services Unit. The Construction Services team is in charge of making sure that the project is a safe work environment for the workers and everyone on campus. Their job also consists of ensuring the Universities quality standards are met, that the job stays on schedule, and that the project is built to the specifications. The Construction Services Unit is a big part of any project on campus and more about their role in any project can be found in Appendix A on page 43.

Penn State has chosen to renovate this existing building instead of demolishing it and rebuilding. The main factor in this decision was to preserve a historical site. The Borland Laboratory was built in 1932 to enhance the research of dairy products. They also produced and sold ice-cream from this facility that has been known as the "University Creamery" ever since and has become a landmark at Penn State for anyone visiting. The creamery has just been moved one block East on Curtain road to the brand new Food Sciences building and the sales room has been renamed to the Berkey Creamery.

Then Pennsylvania State University has given a construction cost estimate of $11,800,000 and a total project cost of $15,000,000. This will include a lot of planning and scheduling on both sides of the project, because the campus is occupied by nearly 40,000 students almost everyday. This makes utility shutdowns and tie-ins very difficult to not disrupt the normal day activities of the students.

Staffing Plan and Project Delivery System

The staffing Plan located bellow shows all of the parties involved on the Borland Laboratory Renovation project. Also shown are the two types of contracts that have been utilized for this project. Penn State holds a cost and fee contract with Bower Lewis Thrower, the architect, who has sub-contracted out for all of the engineers, using a lump sum contract. Penn State also holds a lump sum contract with Leonard S. Fiore, the General Contractor. Fiore also holds a lump sum contract with all of the sub-contractors being utilized on the building.



Building Systems Summary

Demolition

Being a renovation of the existing Borland Laboratory, three months will be spent in the demolition and abatement phases for this project. All together, the interior walls on the ground, first, and second floors will be demolished to make room for a new floor plan. As an effect to this, the HVAC system will be totally removed from the building to make room for a new state of the art system. As for any Plumbing and Electrical fixtures, the supply lines will be cut and terminated at the entry point to the building. During the construction phase, the existing electrical supply to the building will be metered by Penn State University Office of the Physical Plant (OPP) and used for the temporary construction power. This will be used until the new electrical utility lines are installed across Shortlidge Road. The existing water supply will also be metered by OPP and used during the construction phase.

Along with the demolition phase comes a very large portion of this project. That is to remove the dairy products sales room on the South side of the building and also the raw-milk receiving room on the North side of the building. These two portions of the existing building where additions to the original structure. They will be removed and brick will be matched to the original to fill in any spaces needed. Also the beginning of the demolition phase will include asbestos abatement. Like many of the other older buildings on The Pennsylvania State University Campus, the Borland Laboratory contains asbestos fire proofing on the ceilings as well as pipe insulation, and floor tiles that must be abated. Before any other demolition or construction begins, the abatement crew will remove all of the harmful substances, following the Environmental Health and Safety Codes.

Structural Steel Frame

Since this project is a renovation of the Borland Laboratory, and the existing building envelope will be reused. There is a minimal amount of structural steel framing to be done on the first and second floors. Due to the relocation of duct banks, elevator shafts, and stairs, there will be an estimated 27.5 Tons of steel added to support the above floors. On the Second floor, in the existing attic, space will be made to allow for more offices and storage space. A skylight section will be cut into the roof to allow natural light to enter these areas. The majority of steel connections for this area have been designed for a double angle shear connections.

Cast in Place Concrete

The original project scope called for very little cast in place concrete aside from new sidewalks and patios in the landscape. During the demolition phase, a lot of unforeseen conditions were uncovered. During the construction of the original building, a base floor was poured and then the terracotta block walls were placed on top of this. After that was completed, a finish layer of concrete was placed on top partially burying the walls, and causing each room to have a different finished floor height. Due to this problem, a change order has been issued to place a flow able fill of concrete into each section in order to attempt to level out each floor.

Mechanical System

There are two mechanical rooms located in the basement. MB001 contains domestic water pumps, low pressure steam water heaters, and the hot water pumps. Located in MB002 are the chilled water pumps that take the University supplied chilled water and pumps it to the Air Handling Units (AHU) on the above floors.

This project requires 4 Air Handling Units. AHU1 and AHU2 are both located on the Second Floor in room M223. They are designed by Trane to have a maximum of 14,000 Cubic Feet per Minute (CFM) of air flow. The other two units (AHU3 and AHU4) are located on the room in on the Penthouse floor in room M301. These two units have also been designed by Trane and have a maximum CFM of 12,000.

There will be two different types of fire protection utilized on this project. A wet system will be used in all pipe spaces, common areas, offices, and classrooms. Due to some equipment that could be damaged by a water leak, in the mechanical rooms and computer labs, and dry system will be utilized using schedule 40 galvanized piping.

Electrical System

The Borland Laboratory power system is supplied by The Pennsylvania State University's power plant. Before entering the building, the power system will run through a transformer supplied by the University. Upon entering the building, the power supply is fed into a 280/120V, 3 phase, 4 wire, 2000 A switchgear. This switchgear then distributes the power to many different areas. The main switchgear carries a total connected and demanded load of 543.6 KW.

The emergency power is also being supplied from The Pennsylvania State University. It will come from the University’s campus emergency back-up system. The emergency power for this building is switched at a 240/120V, 2 phase, 3 wire, 150A transfer-switch. This switch will automatically transfer power to the Normal Emergency and Emergency circuits in the case of a power loss.

Masonry

A lot of careful work will be put into the masonry part of this project. Due to the two additions that were added onto the original building, a large amount of brick will need to be replaced to match the original façade. It will be attempted to salvage some of the original brick that is part of a retaining wall that is being removed. A sample of brick has also been picked out with a special colored mortar that has been placed into a mock-up and approved for use as well.

Excavation

There will be the usual excavation done to the exterior of the building for landscaping and other architectural features, as well as for the new utility lines. The only excavation needed for the building is a 8’x8’x10’ pit for the elevator shaft, and two sump pump pits 9 feet deep in the basement that will need to be hand dug..

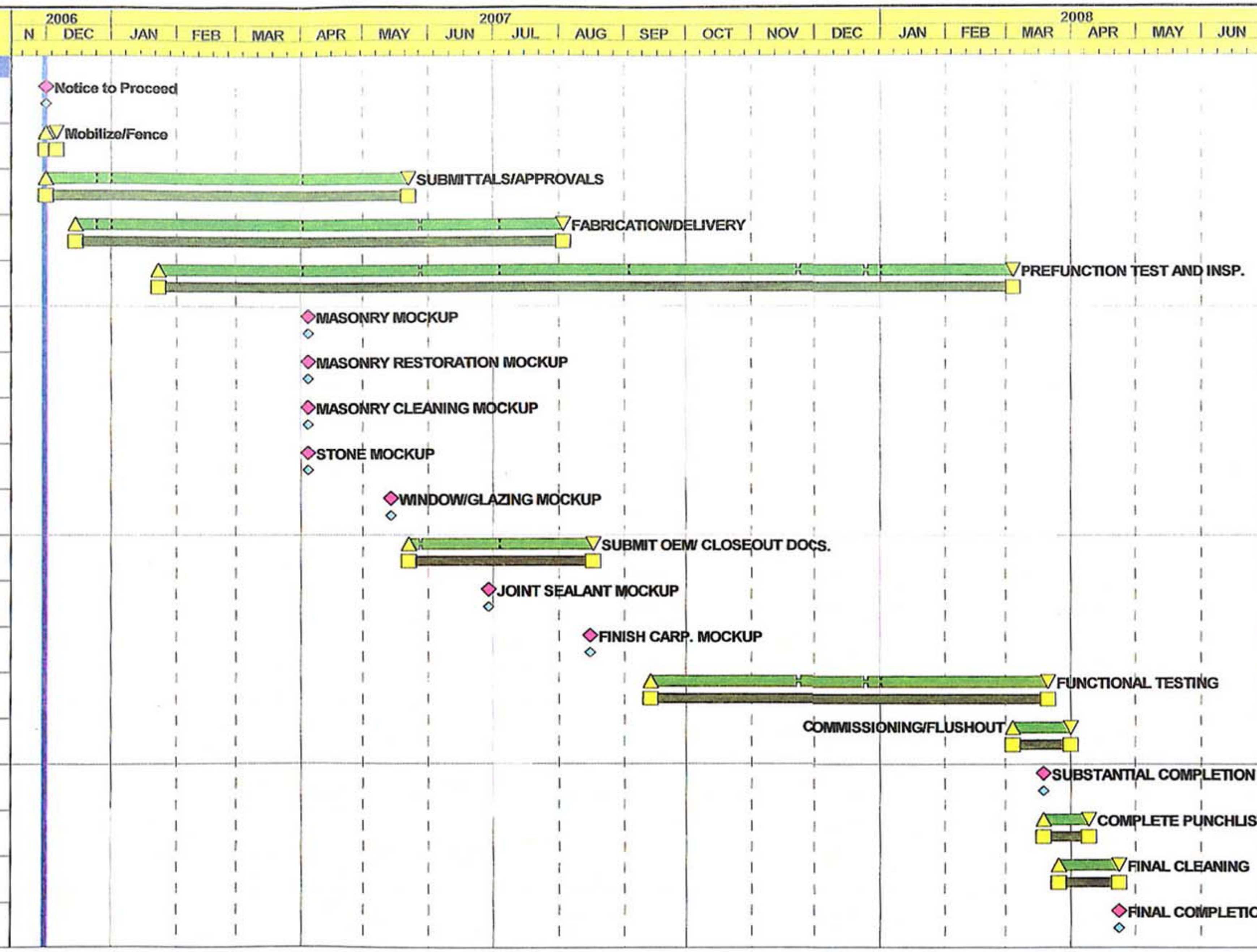
Project Schedule

Below is a schedule showing the administrative milestones for the Borland Laboratory Renovation. A detailed schedule has been included in Appendix B on pages 44-60. Some important milestones that I would like to point out are the all of the mockups. For a renovation project, mockups are a very important process. This is to ensure to the owner that the materials being used on the project match the original materials, which have been aged, as close as possible. Extensive research of bricks, stone, and joint sealant has been done to allow a wide variety of choices for the Penn State officials to choose from.

Two other very important mockups are for the masonry restoration, and the masonry cleaning process. There are many spots in the existing façade that contain damaged brick that must be delicately replaced, in order to not disturb the surrounding brick. In conjunction with this, all of the limestone on the building is being cleaned. Many test samples have been done to find a suitable acid wash that will not damage the nostalgic look of the limestone, or hurt the brick that is surrounding it. Penn State is very proud of the historical buildings on all of the campuses, and strive to keep them up to date while preserving their historical

Administrative Milestone Schedule

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
ADMINISTRATIVE						
10	Notice to Proceed	0	0	100	01DEC06A	
20	Mobilize/Fence	3	3	0	01DEC06	05DEC06
660	SUBMITTALS/APPROVALS	120	120	0	01DEC06	22MAY07
670	FABRICATION/DELIVERY	160	160	0	15DEC06	02AUG07
1860	PREFUNCTION TEST AND INSP.	280	280	0	24JAN07	03MAR08
2810	MASONRY MOCKUP	0	0	0	05APR07	
2820	MASONRY RESTORATION MOCKUP	0	0	0	05APR07	
2830	MASONRY CLEANING MOCKUP	0	0	0	05APR07	
2840	STONE MOCKUP	0	0	0	05APR07	
2870	WINDOW/GLAZING MOCKUP	0	0	0	14MAY07	
1750	SUBMIT OEM/ CLOSEOUT DOCS.	60	60	0	23MAY07	16AUG07
2860	JOINT SEALANT MOCKUP	0	0	0	29JUN07	
2850	FINISH CARP. MOCKUP	0	0	0	16AUG07	
1870	FUNCTIONAL TESTING	130	130	0	14SEP07	20MAR08
1800	COMMISSIONING/FLUSHOUT	20	20	0	04MAR08	31MAR08
1810	SUBSTANTIAL COMPLETION	0	0	0		18MAR08
1830	COMPLETE PUNCHLIST	15	15	0	19MAR08	08APR08
1850	FINAL CLEANING	20	20	0	26MAR08	22APR08
1840	FINAL COMPLETION	0	0	0	23APR08	



Start Date	01DEC06
Finish Date	22APR08
Data Date	01DEC06
Run Date	14FEB07 16:14

Early Bar
Target Bar
Progress Bar
Critical Activity

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BL1D

Sheet 1 of 17

Leonard S. Fiore, Inc.
Borland Lab Renovation
Target Schedule

Date	Revision	Checked	Approved
14FEB07	Revised to include site anc shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Project Cost Summary

ACTUAL COST ESTIMATE

The total area being renovated on this project is 76,000 sf. Below is a cost breakdown showing the estimated costs for this building, and unit costs.

- Base Building: **$10,365,600**
    - Unit Cost: **$136.40 /sf**
- Site Development: **$518,400**
    - Unit Cost: **5%**
- Utilities: **$360,000**
- Major Maintenance Upgrades: **$381,000**
- Telecommunications Networking: **$175,000**

- Total Estimated Construction Costs: **$11,800,000**
    - Unit Cost: **$155.30 /sf**
- Soft Costs: **$2,000,000**
    - Unit Cost: **16.9%**

- Total Estimated Project Costs (w/o FF&E): **$13,800,000**
  - Unit Cost: **$181.6 /sf**
- FF&E: **$1,200,000**
  - Unit Cost: **10.2%**
- <u>Total Estimated Project Costs (w/ FF&E):</u> **$15,000,000**
  - Unit Cost: **$197.4 /sf**

<u>Parametric Estimate using D4 Cost 2002</u>

Using this program I compared the Borland Laboratory Renovation to a College Expansion & Renovation at Brookhaven College located in Dallas, Texas. The estimate given for this college renovation was for a 20,000 square foot project. I adjusted the provided information to fit the Borland Laboratory project, and produced a fairly accurate estimate of $14,547,725. This estimate came within $400,000 of the actual predicted cost for this project.

<u>RS Means SF Estimate</u>

The estimate given by RS Means is about half of the actual cost for this building, coming in at $9,112,150. This is due to the extensive mechanical and AV/IT system that Borland Laboratory will hold.


2030
C
AIA 2030
CHALLENGE

Executive Summary

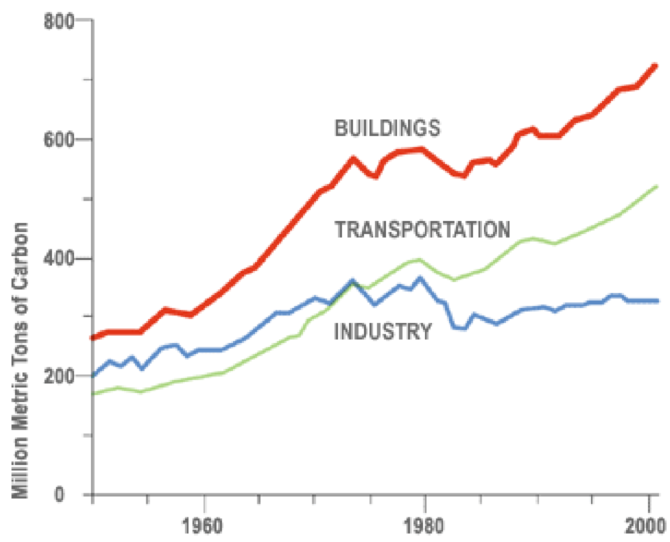
This proposal is a very critical issue in the construction industry. The following research done covers The American Institute of Architects (AIA) 2030 Challenge. The AIA was formed on February 23rd, 1857 by 13 architects, and has represented all of America's architects since. The AIA acts as the voice of the architectural profession, and provides many services and resources to its members. One goal of this group is to make the construction industry more eco friendly. Their way of doing this was to develop the AIA 2030 Challenge.

The 2030 challenge was founded by Edward Mazria from the AIA. He is an internationally known architect for his 30 years of work designing environmentally friendly structures. The AIA 2030 challenge was designed to be a flexible, non-traditional plan, with protecting Earth's environment being its primary goal.

The following research includes a background of the 2030 challenge, a list of problems that Earth is facing, and the solution to making this plan effective. Also included is a compilation of surveys taken from various architects in the field.

Background

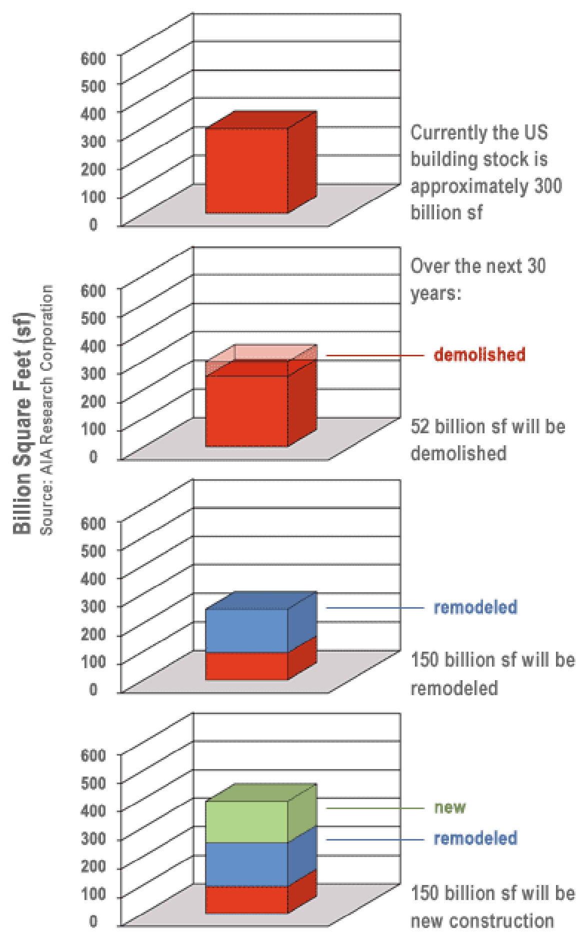
Everyone has heard about Global Greenhouse Gas Emissions, and the effects it has on our environment. The most commonly known causes to this problem are gas emissions, and power plants. However, Unknown to many people, the construction industry has posed a huge effect on the greenhouse gases that pollute this world. Bellow is a graph comparing the major carbon creating industries showing that the building industry has climbed to be the highest.



Source: U.S. Energy Information Administration statistics

The American Institute of Architects (AIA) has proposed a plan called The 2030 Challenge to fix this problem. An investigation done by the AIA Research Corporation has determined that by the year 2030, 150 billion square feet of building renovations will be completed. Along with another 150 billion square feet of new construction.

Since the Borland Laboratory Renovation is a remodeling project this proposal will look at how the construction industry can become greener with renovation projects. The goal is to reduce the use of fossil fuels to construct and operate all buildings by the year 2030, making them carbon-neutral. This must be completed by designing high-performance, carbon-neutral buildings as well as renovations. As seen bellow in a diagram done by the AIA research Corporation, the remodeling industry is a great part of the total construction done in the country.



Proposal

The main goal set by the AIA 2030 Challenge is that the fossil fuel reduction for all new and remodeled building increase to:

- 60% in 2010
- 70% in 2015
- 80% in 2020
- 90% in 2025
- Carbon Neutral by 2030.

There are many solutions possible to push the construction industry towards meeting these goals. The best place to start is at the source of the problem. That is in the design phase of all renovations. Architects and engineers must consider the Earth's environment when designing and building projects. To ensure this, a Green Design course should be administered to all architectural and engineering students.

A survey was conducted through the Architecture Faculty at Penn State. The results can be found in Appendix C on pages 61-63. These results show that none of the people surveyed have heard of the AIA 2030 Challenge. However when informed of the challenge, and its goals, they all feel that it is an excellent idea, and believe that it is achievable.

The survey shows that the AIA 2030 Challenge is an outstanding program, however, it is not widely known. This leads into the second part of the solution, education of the public. The best way to lead the public is by example. That is why I propose that Penn State put into effect a plan to meet the goals set by this challenge.

The Pennsylvania State University is a growing college community that is widely known for its State-of-the-Art facilities, and beautiful campuses. If a plan were implemented at this university to develop more green, and carbon neutral buildings, not only would it help the cause, but it would also set an example for other colleges, and builders across the country.

Possibly the biggest challenge for this project will be to convince the owners, and future builders to make their properties more carbon-neutral. In accordance with this, a resolution has been proposed to adopt the 2030 challenge in city buildings. Saying; The U.S. Conference of Mayors will encourage its members to adopt the following "2030 Challenge" for building performance targets. New construction, renovation projects, repairs and replacements of city buildings shall be designed to achieve a minimum delivered fossil-fuel energy consumption performance standard of one half the U.S. average for that building type as defined by the U.S. Department of Energy. Also to follow green building practices to the maximum extent possible. Resolution number 50 is located in Appendix D on page 64-66.

During the 1970's, a energy crisis led to a massive amount of research being developed on the materials used in the building industry. New materials such as high-performance glazing's for glass materials, more efficient and recycled insulating materials, and new geo-thermal mechanical systems were formed. A large part of the carbon being emitted comes from the production of energy which is used to produce green items. To further advance the 2030 challenge, more efficient ways of making energy must be used. Such as, photovoltaics, solar hot water, fuel cells, micro-hydro, wind, geo-exchange, etc.

Conclusions

In conclusion, the AIA 2030 challenge is well underway, however it is not on pace to achieving its upcoming goal of a 60% reduction by the year 2010. The solutions I proposed will help push this country towards the goals set. To date, the Mayors of Albuquerque, Seattle, Chicago, and Miami have accepted resolution #50 for their respective cities, and show how this can be put into effect world-wide.

The problem does not lie within the technology, we have the technologies to be able to produce carbon neutral buildings and energy. The obstacle is in the education of the public.


DOMESTIC WATER SYSTEM
RE-DESIGN

Executive Summary

The Borland Laboratory Renovation has been designed with a costly copper tubing domestic water system. Not only is this system expensive, but the soldered joints being used are very time intensive. This part of my research explores a cross-linked polyethylene tubing also known as PEX tubing, which is unfamiliar in larger buildings.

Extensive research has been done on PEX tubing including long-term pressure testing in extreme temperature and pressure conditions for more than 30 years. PEX tubing also undergoes extreme testing against the effects of chlorinated water to ensure it can withstand chlorines' effects on natural materials.

In order to ensure an accurate comparison between the design system, and the proposed system, a detailed take-off of each system has been completed. These take-offs were then estimated by Schuylkill Sales Company, a plumbing contractor in the Easter Pennsylvania area. All prices in the comparison are from APR Supply company, and do not include any markups. A labor savings has also been estimated for the comparison to show any schedule savings.

After comparing the two systems, a savings of $8,668.56 and 96 man hours has been estimated when using the proposed PEX tubing system. Further details will be covered in the following analysis.

Introduction

In concurrence with the 2030 challenge, this analysis will discuss redesigning the domestic water piping system to a more green material. The current piping system consists mostly of copper tubing. A new system has been designed using a cross-linked polyethylene tubing. Contrary to popular belief, this product also known as PEX is a green material. It is often confused with a normal polyethylene tubing called PE which causes many toxins when manufactured. Also PE tubing was unable to be ground up and recycled for new tubing. New developments allow the PEX tubing to be recycled and also give it a much longer life span. PEX tubing is manufactured cleanly and consumes far less energy than the manufacturing of metallic piping. Also the price of copper is very, high, and climbing.

Helping the environment isn't the only benefit to using this product. The Borland Laboratory Renovation is a perfect place for PEX tubing to be used. Since this is a plastic like material, it allows the tubing to be bent around corners and odd shapes without the use of extra fittings. This project is an existing building which would make it difficult to run ridged copper tubing around the many obstacles that exist in the floor and ceiling plenums.

The domestic water system that is currently being installed is an all copper system using soldered joints. The new proposed PEX system will look very similar to the designed system. Currently, the supplies for each floor have been designed to come from the basement through a floor penetration in the pipe space between each bathroom. A detail of this can be seen in Appendix E on page 67. From the penetration through the floor, the water is then distributed to of the necessary locations.

Solution

The price of copper tubing is at an all time high. My solution for this problem is something that has not been used in an commercial building sense before. PEX tubing is well know for being a cheap and effective way to supply domestic water, and hot water for heating purposes to residential buildings. However metallic piping is still preferred in larger buildings such as the Borland Laboratory Renovation.

There are many perks to using PEX tubing in a building such as this. They are as follows:

- PEX tubing is much cheaper compared to copper tubing.
- Due to flexibility, PEX tubing is easier to handle and install.
- PEX tubing is safe for the environment.
- PEX tubing is the most heavily tested piping material in the world.
- PEX tubing is much lighter than traditional metallic pipe, causing a reduction in the manufacturing and transportation of the material.
- A manifold system typically used with PEX tubing allows for all of the shut-off valves to be located in one spot rather than spread around the building.
- PEX tubing can be recycled into a variety of plastic fillers.

Comparison

Designed Copper Tubing System

The designed copper tubing system uses a rigid type L copper tubing, ranging in sizes from 3” to ½”. This tubing uses copper fittings which is joined by using a soldering operation. The soldering operation involves melting a non-lead material into the joints of the pipe making a air and water tight seal. This non-lead solder has a much lower melting temperature than the copper piping allowing it to flow into the very small gap between the tubing and the fitting, with-out damaging the piping.

The cost of this system with out any mark-ups has been compiled. A overview of this estimate is shown bellow. The detailed estimate that was done can be found in Appendix F on pages 68-72.

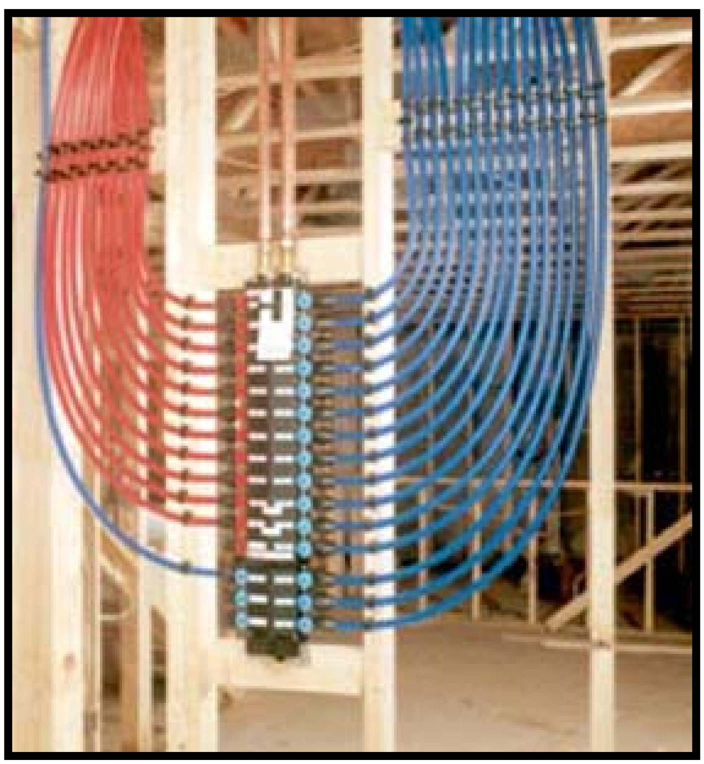
Copper Piping System			
	Copper Pipe Total Cost		$17,122.70
	Copper Fittings Total Cost		$3,839.57
	Total Cost		**$20,962.27**

Proposed PEX Tubing System

The Proposed PEX tubing system will consist of a combination of PEX tubing and copper tubing. This is because PEX tubing is only practically used in the sizes ranging from 1" – ½". In the newly designed system, copper piping will be run from the basement to a manifold on each floor that is located in the piping space between the bathrooms. The same area the designed risers are located.

PEX tubing is a flexible material that can be bent around corners with-out the need of a fitting. An example of this is demonstrated in the figure below. When a fitting is necessary, a brass fitting is used that has a set of reversed barbs on it to lock the pipe onto it. A cinch ring is then placed over the joint, and a specialized crimper is used to tighten this ring around the pipe and fitting making a air and water tight seal. This seal is unlike a soldered seal, and can be rotated easily to allow adjustments without compromising the seal of the joint.

One of the biggest differences between the designed copper system, and the proposed PEX system, is the new system uses a home-run manifold. With this system, the water supplies are run from the basement to each floor and then distributed from there. The pipes supplying each facility will go in the same path as the copper has been designed. However with the copper system, each faucet is supplied from the ceiling plenum, where the shut-off valve for it is located. One of the advantages to a manifold system is that all of the shut-off valves are located in a centralized location, at the manifold. This makes it extremely easier to isolate certain parts of a system. Due to the size of the pipe supplying each floor, a prefabricated manifold can not be utilized, and one will need to be made using copper fittings. An example of a prefabricated manifold can be seen below. The manifold made with copper fittings would look similar to this.



A detailed cost estimate of this system has been compiled, and is located in Appendix G on pages 73-77. Located bellow is an overview of this estimate showing just the rates of the materials with out any mark-ups. The same amount of piping is used for each system, however, the PEX system uses a combination of copper and PEX tubing. Due to this, there are some extra fitting that need to be utilized in order to adapt from PEX to copper pipe. However this extra cost is compensated by the elimination of many of the 90 º elbows that are used in the rigid piping system.

PEX Piping System		
PEX & Copper Pipe Total Cost		$10,866.84
PEX & Copper Fittings Total Cost		$1,426.84
Total Cost		**$12,293.71**

Conclusions

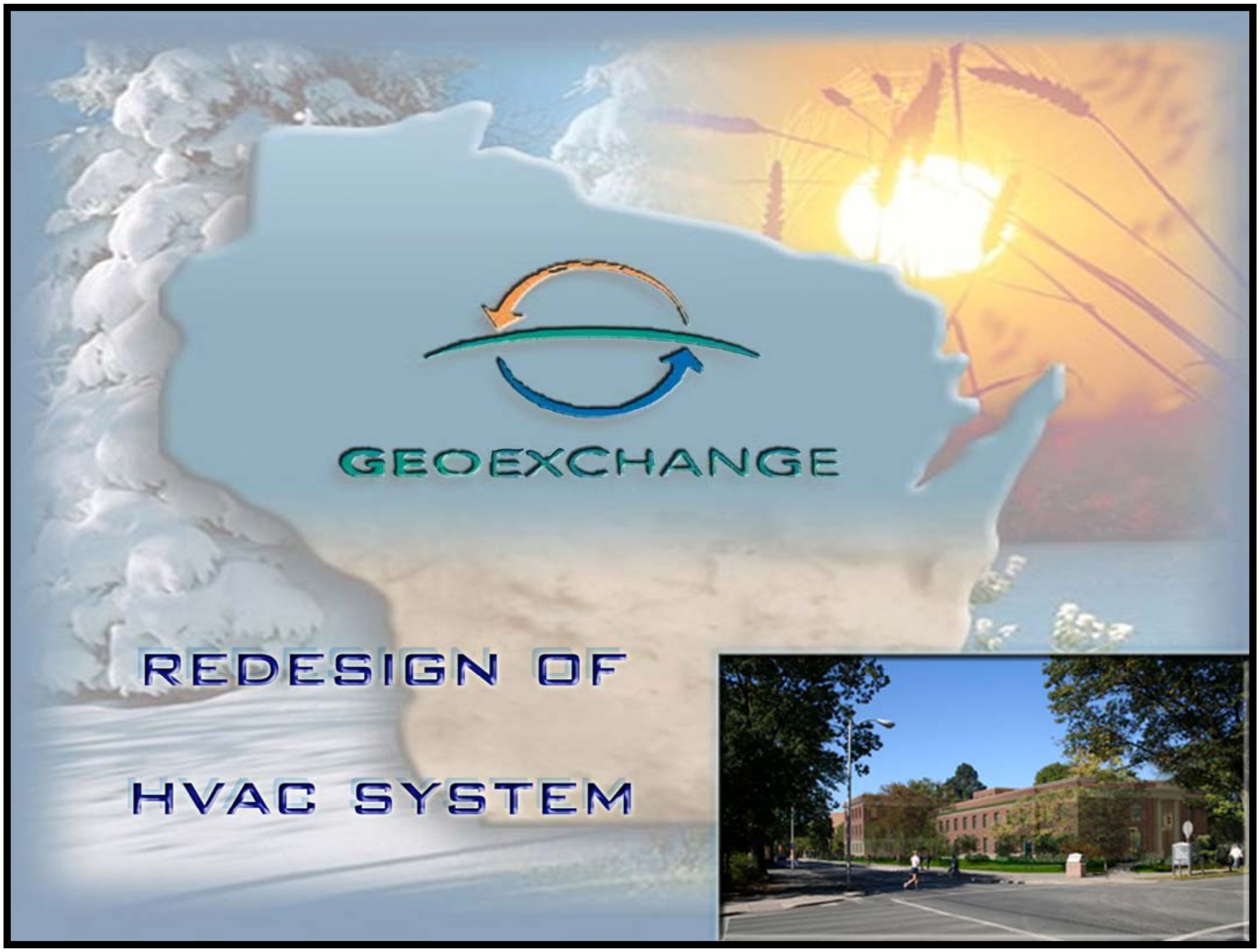
PEX vs. Copper Comparison

Aside from the advantages of using a PEX system that were covered above, there are two others that have a great impact on this project. That is the cost and schedule savings. The total cost savings between the two for just materials with no mark up is $8,668.56. Along with this, there is an estimated time savings of 96 man hours. This will add onto the cost savings, as well as have an effect on the construction schedule.

Recommendations

My recommendations for this project are based off of three different things. The first two are the obvious. That being the cost and schedule savings. They might seem miniscule on such a large project, however in the end, every penny, and hour counts. The third thing is my experience of working with PEX tubing. I worked with Schuylkill Sales Company for many years, and used PEX tubing extensively on many residential buildings. It was used successfully in new construction and renovations. I found this tubing very easy to work with, and in most times creates a better final product.

In conclusion I recommend using the PEX & Copper system for this project for all of the above stated reasons. I feel that in conjunction with the AIA 2030 challenge, and more and more buildings being build using green methods, that PEX tubing will be seen a lot in commercial buildings, and not just in a residential aspect.


GEOEXCHANGE
REDESIGN OF
HVAC SYSTEM

Executive Summary

Following with the same theme of the research on the Borland Laboratory Renovation, this analysis will cover a green option for the HVAC mechanical system. When designing the mechanical system for a building, there are many options. This analysis will compare two of them. Those two systems are, a geo-thermal system, and the designed system. The designed system uses steam supplied by the university for heat, and chilled water also supplied by the university.

The advances in geo-thermal systems have grown exponentially. This system is another example of the many things that the commercial buildings can learn from residential houses. Just like PEX tubing, geo-thermal HVAC systems were originally developed for and used primarily in residential houses. In the past 15 years, this type of system has grown more popular in federal and commercial sectors.

The standard system that has been designed for this project is very un-efficient. For the cooling, water is received from Penn State's chilled water system, and supplied to the Air Handling Units (AHUs) in the mechanical room. The heating system works the same way. Low Pressure steam is used to supply heat to the AHUs.

Introduction

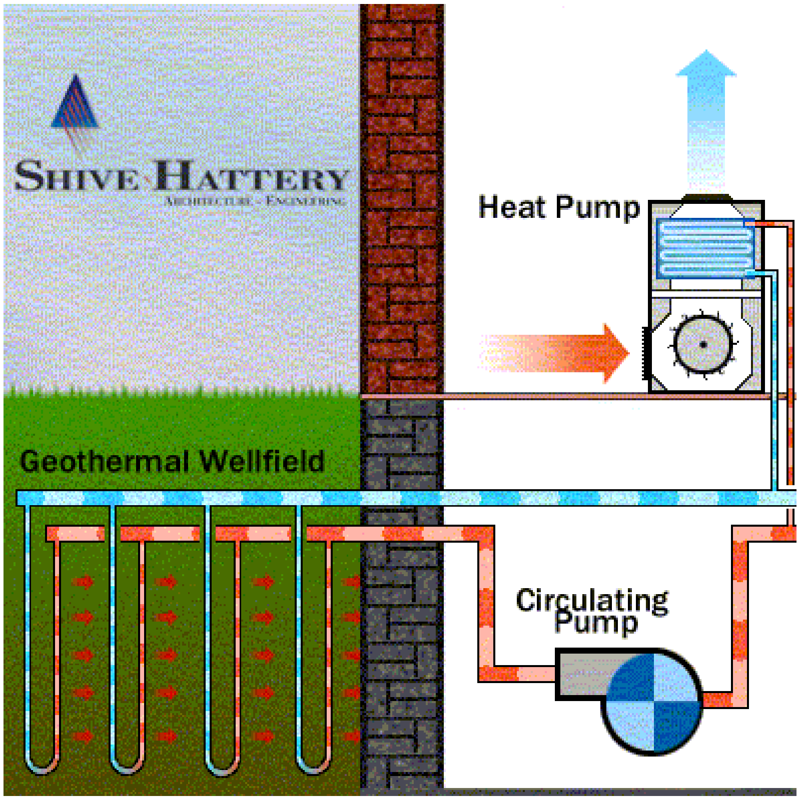
Following with the AIA 2030 Challenge, Penn State is trying to due its part. The Borland Laboratory Renovation will be the first renovated building on a Penn State Campus to be LEED Certified. The amount of points specified for this building is very close to obtaining a Silver LEED Rating. This could easily be accomplished by changing a few small things in the demolition phases of the project. However, a great way to work toward the 2030 challenge is to use a green mechanical system on this project.

The advances in geo-thermal heating and cooling have greatly increased in the past few years. A study has been completed that compares the existing HVAC system, to one that uses geo-thermal technologies. The coal burned in Penn State's power plant creates a great amount of the carbon that the AIA 2030 challenge is trying to eliminate. The use of a geo-thermal HVAC system on the Borland Laboratory Renovations would only be a start to fixing the carbon problem on the University Park Campus. However it is a step in the right direction.

Solution

The issue of green house gasses can not be fixed in one day. However, by using the energy that is readably supplied by the Earth, we can reach our goal. A geo-thermal HVAC system uses the natural heat and cooling that is trapped beneath the ground to heat and cool a building.

Unlike the air, water, and soil on the surface, underground, the earth and water stay at a very stable temperature of about 55 º F at a depth of 10 ft, or more. To capture this stored energy and use it in buildings, many feet of pipe are either vertically submerged in various wells in the ground, or run horizontally 10 or more feet under the ground. During the heating months, a specially formulated liquid is pumped through these pipes, which captures the heat from the soil, and circulated back to the AHUs in the mechanical room. During the cooling months, the same process is repeated, however the soil sucks the heat from the liquid, making it cooler, and sending it back to the AHUs. An example of these loops and how they work can be seen in the figures below.



Listed below are a few advantages of using a geo-thermal heat pump system over any standard HVAC system.

- A very durable piping with a life cycle of 30 to 50 years.
- A 25 to 40 percent savings in heating and cooling cost.
- A Earth friendly system.
- Very simple controls.
- No need to use the University's steam or chilled water systems.

Comparison

University Supplied HVAC System

The Pennsylvania State University, University Park, uses 270,000,000 kWh annually. Along with that outstanding amount of energy, 452,000 Mcf of natural gas, and 72,000 Tons of bituminous coal are used to run this campus. Most of the buildings on campus have systems in place that use the low pressure steam, and chilled water supplied. These systems account for most of this energy being used. With all of that natural gas, and coal being burned, this creates a very large amount of carbon that is being released into the Earth's atmosphere.

The System designed for the Borland Laboratory Renovation consists of 4 Trane AHUs. Two of these units are 35 tons and have a maximum of 14,000 Cubic Feet per Minute (CFM). The other two units are 30 tons and 12,000 CFMs. In most buildings, the HVAC systems are over designed to allow in extreme fluctuations in temperature, causing excessive energy consumption. However after speaking with the manager in charge of all heating and cooling systems on the University Park Campus, it was determined that due to a lack of funds, these 4 units are not over designed.

Geo-Thermal Heat Pump System

As explained above, a geo-thermal heat pump system requires a vast amount of tubing immersed in the soil or ground water for this to work efficiently. According to Schuylkill Sales Company, a rule of thumb for estimating the amount of tubing needed for a system is 200-250 ft/Ton. Using this rule, with the 4 units adding up to 130 Tons of heating a cooling, a maximum of 32,500 ft or 6.16 miles of tubing would be required.

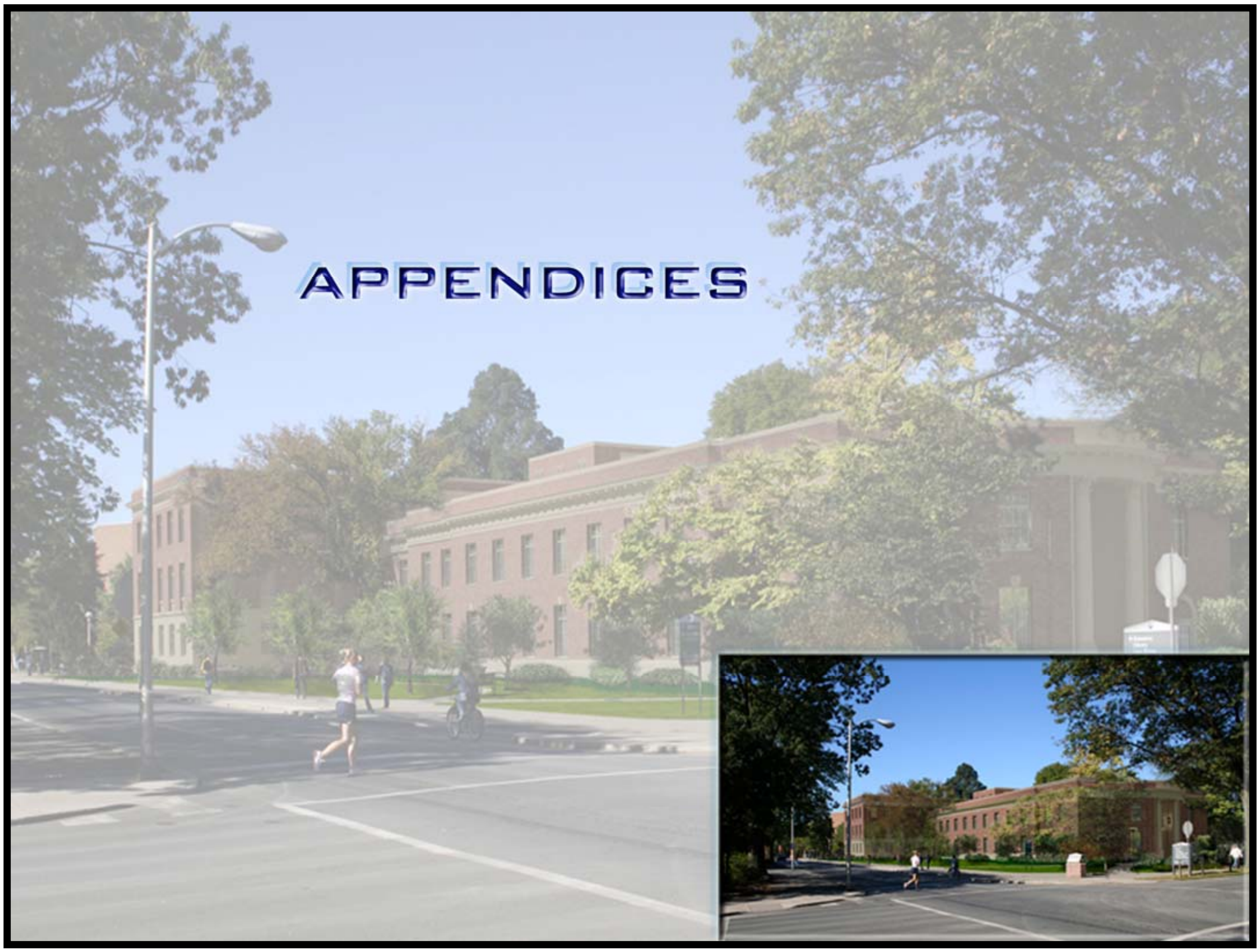
At this point in the analysis, it was determined that this type of system would not be feasible for the Borland Laboratory Renovation. The amount of piping needed to allow for this geo-thermal heat pump system to run efficiently would require a large amount of un-developed land. The area for this underground tubing can not have a parking lot or any other structure on top of it. This would cause all of the heat to be trapped underground for an extended period of time during climate changes. This would cause the system to not work properly. In the area around the Borland Laboratory Renovation, there is not enough green space to allow a system of this type. So the calculations stopped at this point.

Conclusions

Due to the lack of green space around the Borland Laboratory Renovation, the use of a geo-thermal heat pump system is not possible. In theory this system is a very good idea, and great for the environment. This type of system can and has worked very well for various buildings with a large amount of green space around.

With some planning from the Pennsylvania State University Office of the Physical Plant, and geo-thermal heat pump system could be utilized in all of the building on the University Park campus. This would eliminate a large amount of carbon that is being produce here, and save a large amount of money in the future. In order to make this work, the University would have to have a large amount of land that is used only for a geo-thermal well bed. I believe that with enough wells in place, the geo-thermally treated liquid could be circulated throughout the campus and to each building just like the existing steam and chilled water lines.

A plan like this is something for Penn State to consider in the future. This would require all of the HVAC systems on campus to be changed in every building. Along with a vast amount of underground piping, this would be a very costly campus wide renovation.


APPENDICES

Appendix A

QUALITY SERVICE ACTION PLAN
CONSTRUCTION SERVICES
OFFICE OF PHYSICAL PLANT

OUR CUSTOMERS: Facility Coordinators, Project Managers, Project Coordinators, Contractors, Parking Office, faculty, students, university personnel, community, L&I inspectors, local codes/zoning, police services, Accounting, Design Professionals, Design Services, building users, and other OPP departments.

OUR CUSTOMERS' EXPECTATIONS: Facilitation of the timely delivery of quality projects. They also expect us to be courteous and reliable while being committed to maintaining a positive and safe working environment.

OUR QUALITY SERVICE STANDARDS:

SAFE ENVIRONMENT:

1. Maintain organized and safe project sites.
2. Ensure installation of signage to communicate unsafe areas.
3. Ensure proper separation between occupied and non-occupied spaces.
4. Assure jobsite safety through inspection and observation.
5. Initiate and monitor corrective actions.
6. Focus on the environment around jobsite to ensure public safety.

SERVICE ATTITUDE:

1. Respond in a courteous, positive, and timely manner.
2. Empathetically listen to customers' needs and concerns.
3. Effectively communicate project information to all entities involved.

STEWARDSHIP:

1. Ensure contractors comply with contract requirements and quality standards.
2. Continuously inspect, monitor, and evaluate performance of contractor.
3. Coordinate project requirements to help facilitate the timely completion of the project.
4. Provide leadership at job conferences to resolve project issues.

EASE OF SERVICE:

1. Clearly identify all points of contacts for the work.
2. Ensure availability to allow timely resolution of project issues.
3. Provide continuous customer assistance throughout project process.
4. Pro-actively communicate project status.

EFFICIENCY:

1. Take a pro-active team approach maintaining positive relationships.
2. Establish a quality control action plan for the project.
3. Reduce rework through continuous monitoring of the work.
4. Attempt to review assigned projects during the pre-construction stage.
5. Periodically review and streamline the flow of communication.
6. Monitor project long-lead items to ensure timely delivery.
7. Track project schedule providing input throughout the project.
8. Commit to an efficient close-out/turnover of the project.

DEAR CUSTOMER,

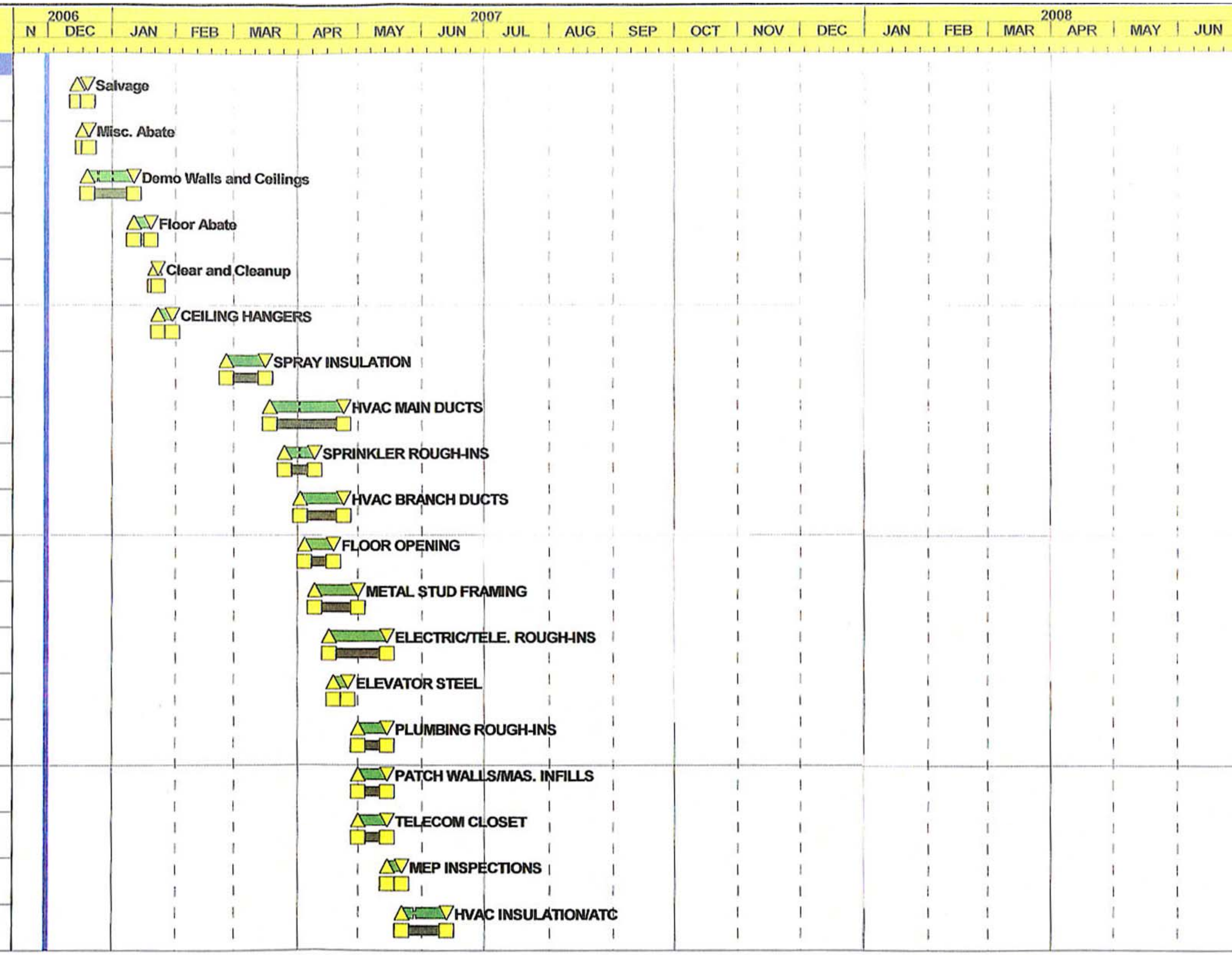
The Construction Services department within Design and Construction Services is committed to exceeding your expectations by providing a positive and safe working environment through leadership and collaborative efforts. We will continuously strive to ensure all contract requirements are met in a timely manner and at the highest quality.

Appendix B

Detailed Schedule

Detailed Schedule

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
2nd Floor West						
70	Salvage	3	3	0	15DEC06	19DEC06
80	Misc. Abate	3	3	0	18DEC06	20DEC06
90	Demo Walls and Ceilings	15	15	0	20DEC06	11JAN07
100	Floor Abate	6	6	0	12JAN07	19JAN07
110	Clear and Cleanup	2	2	0	22JAN07	23JAN07
890	CEILING HANGERS	5	5	0	24JAN07	30JAN07
260	SPRAY INSULATION	15	15	0	26FEB07*	16MAR07
490	HVAC MAIN DUCTS	25	25	0	19MAR07	23APR07
470	SPRINKLER ROUGH-INS	10	10	0	26MAR07	09APR07
1880	HVAC BRANCH DUCTS	15	15	0	03APR07	23APR07
140	FLOOR OPENING	10	10	0	05APR07	18APR07
460	METAL STUD FRAMING	15	15	0	10APR07	30APR07
500	ELECTRIC/TELE. ROUGH-INS	20	20	0	17APR07	14MAY07
230	ELEVATOR STEEL	5	5	0	19APR07	25APR07
480	PLUMBING ROUGH-INS	10	10	0	01MAY07	14MAY07
640	PATCH WALLS/MAS. INFILLS	10	10	0	01MAY07	14MAY07
930	TELECOM CLOSET	10	10	0	01MAY07	14MAY07
690	MEP INSPECTIONS	5	5	0	15MAY07	21MAY07
870	HVAC INSULATION/ATC	15	15	0	22MAY07	12JUN07



Start Date 01DEC06
Finish Date 22APR08
Data Date 01DEC06
Run Date 14FEB07 16:14

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Progress Bar
Critical Activity

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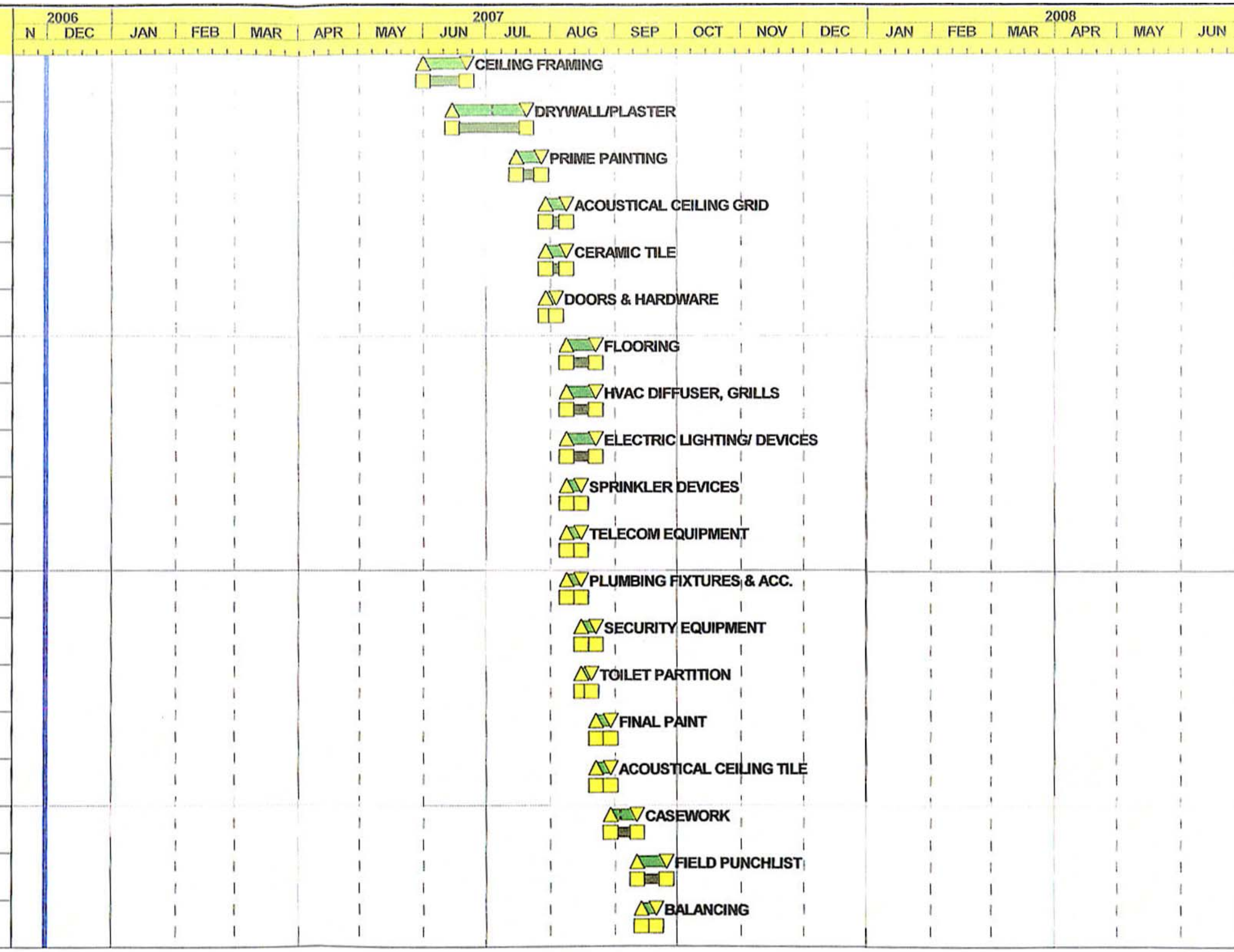
Leonard S. Fiore, Inc.
Borland Lab Renovation
Target Schedule

Sheet 2 of 17

Date	Revision	Checked	Approved
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
900	CEILING FRAMING	15	15	0	01JUN07	21JUN07
510	DRYWALL/PLASTER	25	25	0	15JUN07	20JUL07
530	PRIME PAINTING	10	10	0	16JUL07	27JUL07
540	ACOUSTICAL CEILING GRID	8	8	0	30JUL07	08AUG07
650	CERAMIC TILE	8	8	0	30JUL07	08AUG07
520	DOORS & HARDWARE	5	5	0	30JUL07	03AUG07
550	FLOORING	10	10	0	09AUG07	22AUG07
600	HVAC DIFFUSER, GRILLS	10	10	0	09AUG07	22AUG07
610	ELECTRIC LIGHTING/ DEVICES	10	10	0	09AUG07	22AUG07
580	SPRINKLER DEVICES	5	5	0	09AUG07	15AUG07
620	TELECOM EQUIPMENT	5	5	0	09AUG07	15AUG07
590	PLUMBING FIXTURES & ACC.	5	5	0	09AUG07	15AUG07
630	SECURITY EQUIPMENT	5	5	0	16AUG07	22AUG07
570	TOILET PARTITION	3	3	0	16AUG07	20AUG07
1760	FINAL PAINT	5	5	0	23AUG07	29AUG07
680	ACOUSTICAL CEILING TILE	5	5	0	23AUG07	29AUG07
560	CASEWORK	8	8	0	30AUG07	11SEP07
710	FIELD PUNCHLIST	10	10	0	12SEP07	25SEP07
880	BALANCING	5	5	0	14SEP07	20SEP07



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Data Date	01DEC06
Run Date	14FEB07 16:14

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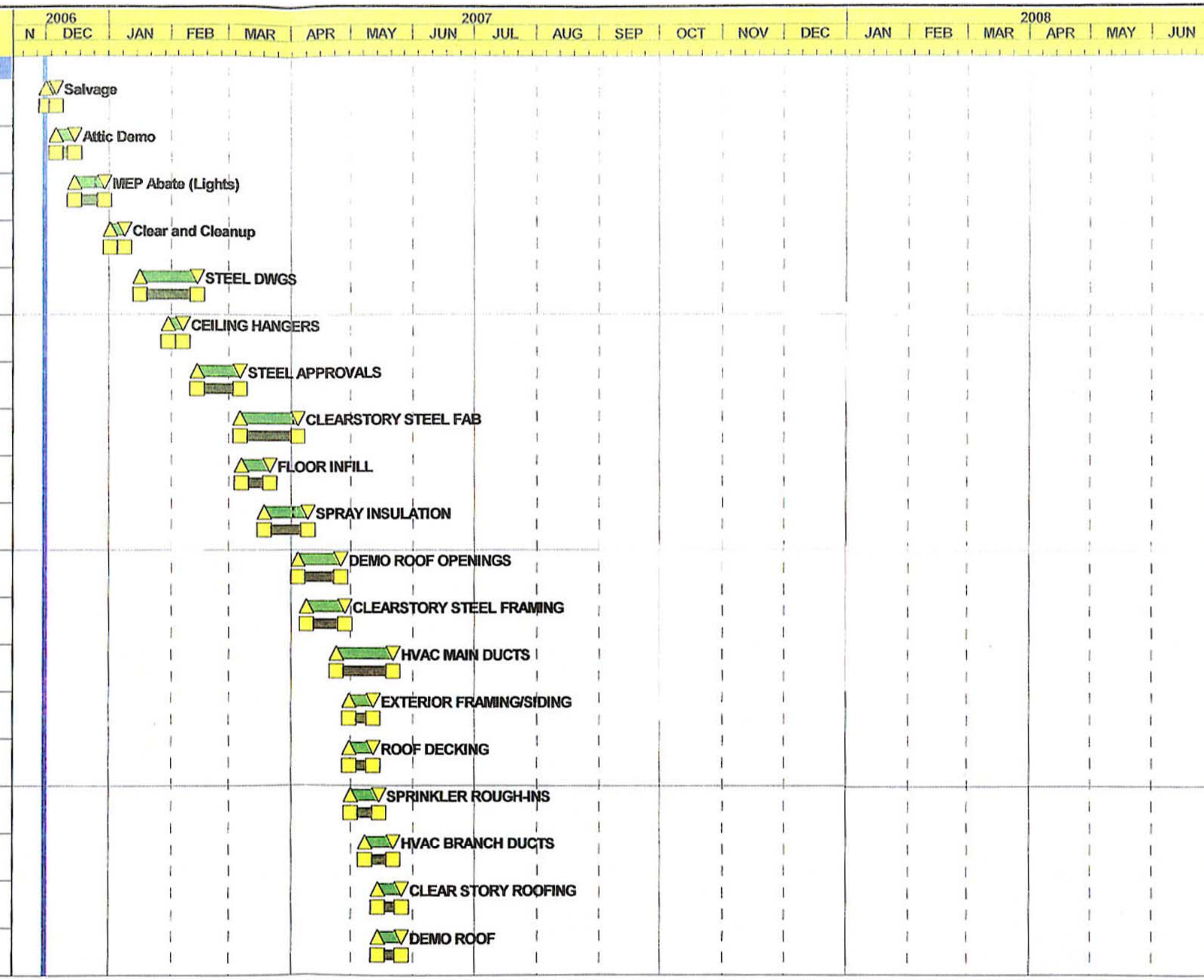
Leonard S. Fiore, Inc.
Borland Lab Renovation
Target Schedule

Sheet 3 of 17

Date	Revision	Checked	Approved
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
2nd Floor East						
30	Salvage	3	3	0	01DEC06	05DEC06
40	Attic Demo	7	7	0	06DEC06	14DEC06
50	MEP Abate (Lights)	10	10	0	15DEC06	29DEC06
60	Clear and Cleanup	5	5	0	02JAN07	08JAN07
940	STEEL DWGS	20	20	0	17JAN07*	13FEB07
1060	CEILING HANGERS	5	5	0	31JAN07	06FEB07
1120	STEEL APPROVALS	15	15	0	14FEB07	06MAR07
950	CLEARSTORY STEEL FAB	20	20	0	07MAR07	04APR07
1050	FLOOR INFILL	10	10	0	08MAR07	21MAR07
1080	SPRAY INSULATION	15	15	0	19MAR07	09APR07
960	DEMO ROOF OPENINGS	15	15	0	05APR07	25APR07
970	CLEARSTORY STEEL FRAMING	15	15	0	09APR07	27APR07
1100	HVAC MAIN DUCTS	20	20	0	24APR07	21MAY07
1000	EXTERIOR FRAMING/SIDING	10	10	0	30APR07	11MAY07
1040	ROOF DECKING	10	10	0	30APR07	11MAY07
1130	SPRINKLER ROUGH-INS	10	10	0	01MAY07	14MAY07
1890	HVAC BRANCH DUCTS	10	10	0	08MAY07	21MAY07
990	CLEAR STORY ROOFING	10	10	0	14MAY07	25MAY07
1030	DEMO ROOF	10	10	0	14MAY07	25MAY07



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Borland Lab Renovation
Target Schedule

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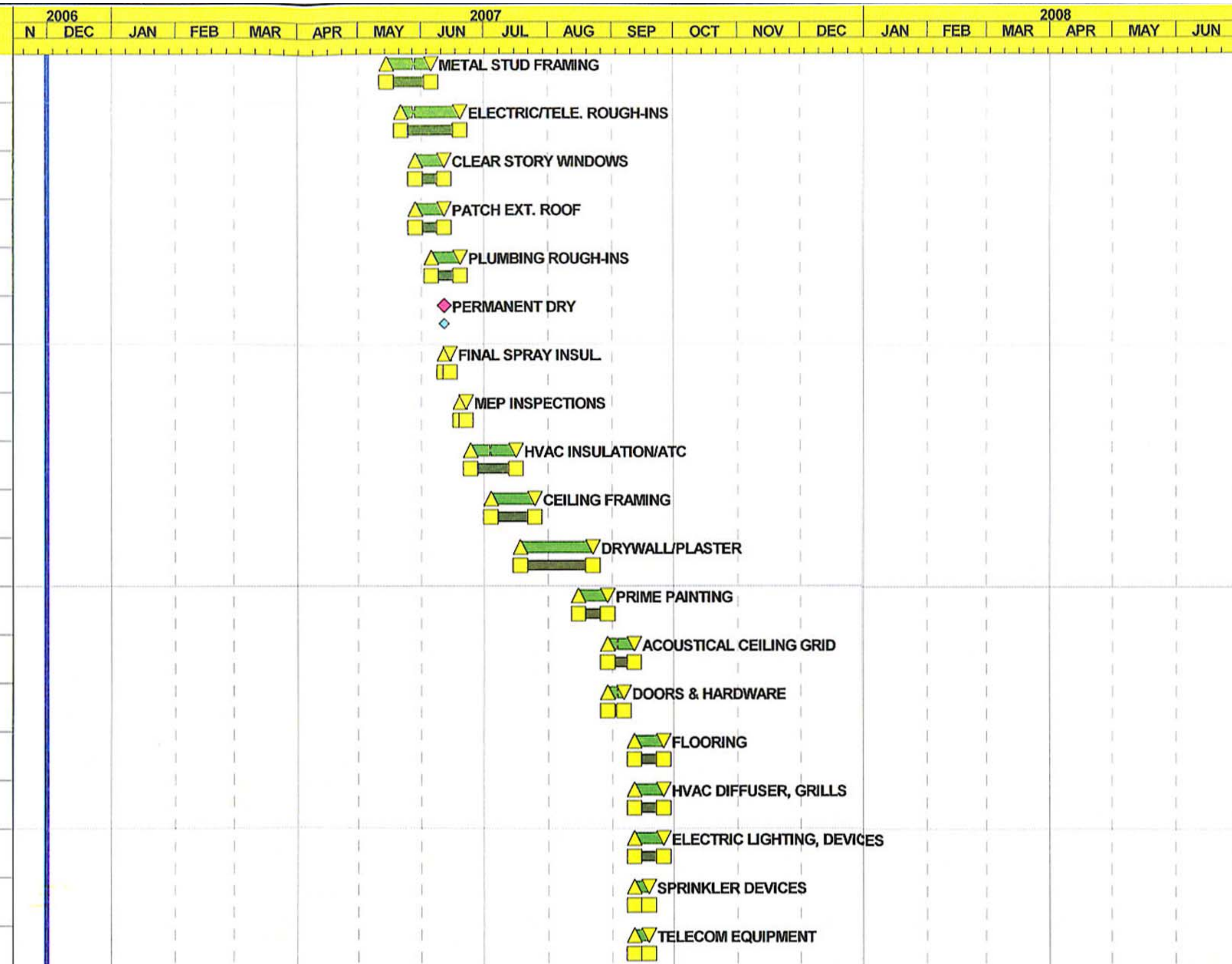
Date	Revision	Checked	Approved
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1110	METAL STUD FRAMING	15	15	0	15MAY07	05JUN07
1150	ELECTRIC/TELE. ROUGH-INS	20	20	0	22MAY07	19JUN07
980	CLEAR STORY WINDOWS	10	10	0	29MAY07	11JUN07
1010	PATCH EXT. ROOF	10	10	0	29MAY07	11JUN07
1140	PLUMBING ROUGH-INS	10	10	0	06JUN07	19JUN07
1020	PERMANENT DRY	0	0	0		11JUN07
1090	FINAL SPRAY INSUL.	3	3	0	12JUN07	14JUN07
1170	MEP INSPECTIONS	3	3	0	20JUN07	22JUN07
1160	HVAC INSULATION/ATC	15	15	0	25JUN07	16JUL07
1180	CEILING FRAMING	15	15	0	05JUL07	25JUL07
1190	DRYWALL/PLASTER	25	25	0	19JUL07	22AUG07
1200	PRIME PAINTING	10	10	0	16AUG07	29AUG07
1210	ACOUSTICAL CEILING GRID	8	8	0	30AUG07	11SEP07
1230	DOORS & HARDWARE	5	5	0	30AUG07	06SEP07
1270	FLOORING	10	10	0	12SEP07	25SEP07
1260	HVAC DIFFUSER, GRILLS	10	10	0	12SEP07	25SEP07
1290	ELECTRIC LIGHTING, DEVICES	10	10	0	12SEP07	25SEP07
1280	SPRINKLER DEVICES	5	5	0	12SEP07	18SEP07
1300	TELECOM EQUIPMENT	5	5	0	12SEP07	18SEP07



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Target Schedule

Date	Revision	Checked	Approved
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1320	SECURITY EQUIPMENT	5	5	0	19SEP07	25SEP07
1770	FINAL PAINT	5	5	0	26SEP07	02OCT07
1330	ACOUSTICAL CEILING TILE	5	5	0	26SEP07	02OCT07
1310	CASEWORK	8	8	0	03OCT07	12OCT07
1350	BALANCING	5	5	0	03OCT07	09OCT07
1340	FIELD PUNCHLIST	10	10	0	15OCT07	26OCT07
1st Floor West						
200	Salvage	3	3	0	19JAN07	23JAN07
210	Misc. Abate	3	3	0	19JAN07	23JAN07
270	Floor Abate	6	6	0	24JAN07	31JAN07
240	Clear and Cleanup	2	2	0	01FEB07	02FEB07
220	Demo Walls and Ceilings	20	20	0	05FEB07	02MAR07
250	Final Cleanup	2	2	0	05MAR07	06MAR07
1351	CEILING HANGERS	5	5	0	07MAR07	13MAR07
1360	FLOOR OPENING	10	10	0	05APR07	18APR07
1370	ELEVATOR STEEL	5	5	0	19APR07	25APR07
1400	HVAC MAIN DUCTS	25	25	0	22MAY07	26JUN07
1430	SPRINKLER ROUGH-INS	10	10	0	30MAY07	12JUN07
1900	HVAC BRANCH DUCTS	15	15	0	06JUN07	26JUN07
1410	METAL STUD FRAMING	15	15	0	13JUN07	03JUL07

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Borland Lab Renovation
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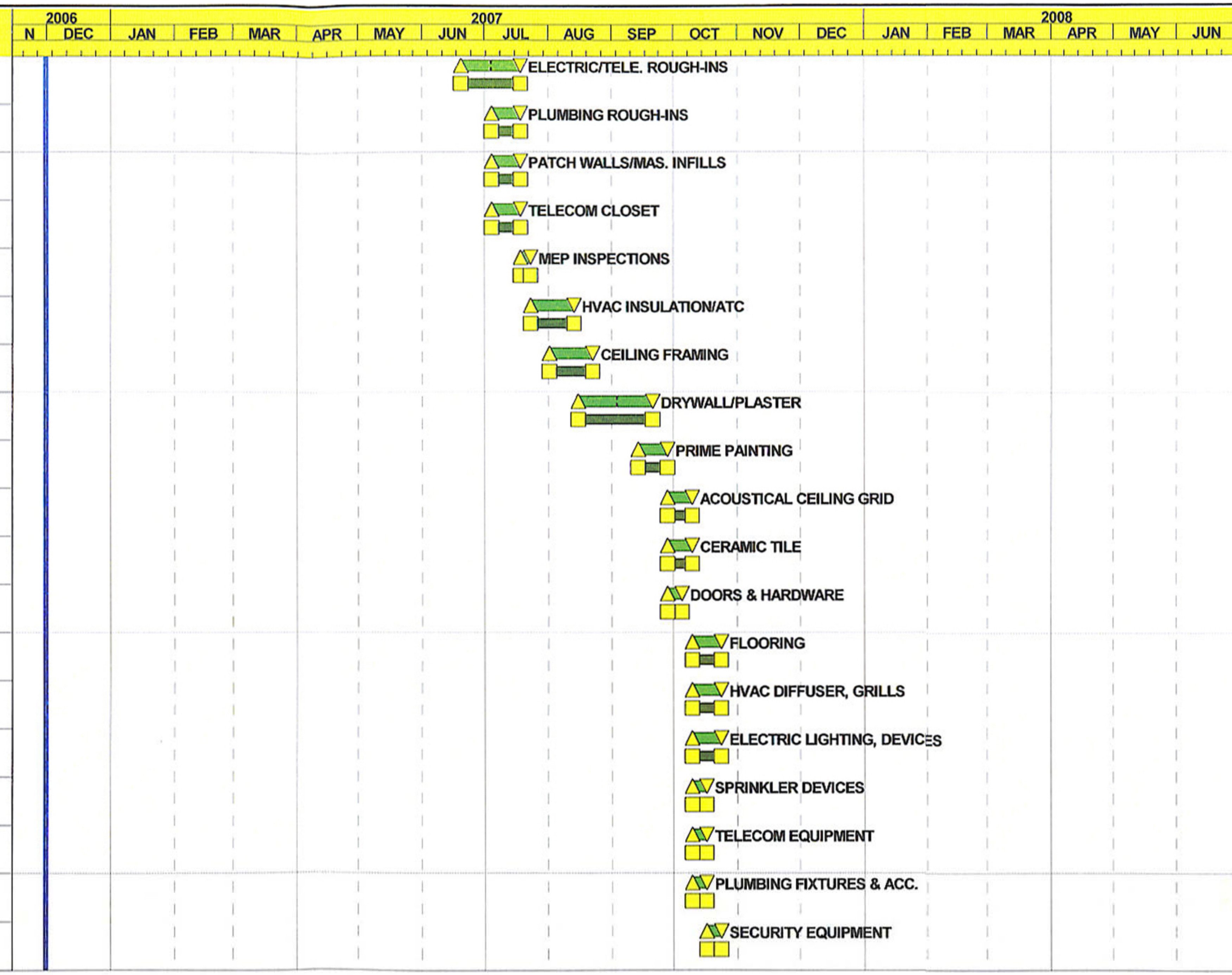
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1450	ELECTRIC/TELE. ROUGH-INS	20	20	0	20JUN07	18JUL07
1440	PLUMBING ROUGH-INS	10	10	0	05JUL07	18JUL07
1390	PATCH WALLS/MAS. INFILLS	10	10	0	05JUL07	18JUL07
1420	TELECOM CLOSET	10	10	0	05JUL07	18JUL07
1460	MEP INSPECTIONS	3	3	0	19JUL07	23JUL07
1470	HVAC INSULATION/ATC	15	15	0	24JUL07	13AUG07
1480	CEILING FRAMING	15	15	0	02AUG07	22AUG07
1490	DRYWALL/PLASTER	25	25	0	16AUG07	20SEP07
1500	PRIME PAINTING	10	10	0	14SEP07	27SEP07
1510	ACOUSTICAL CEILING GRID	8	8	0	28SEP07	09OCT07
1520	CERAMIC TILE	8	8	0	28SEP07	09OCT07
1530	DOORS & HARDWARE	5	5	0	28SEP07	04OCT07
1550	FLOORING	10	10	0	10OCT07	23OCT07
1560	HVAC DIFFUSER, GRILLS	10	10	0	10OCT07	23OCT07
1580	ELECTRIC LIGHTING, DEVICES	10	10	0	10OCT07	23OCT07
1570	SPRINKLER DEVICES	5	5	0	10OCT07	16OCT07
1590	TELECOM EQUIPMENT	5	5	0	10OCT07	16OCT07
1540	PLUMBING FIXTURES & ACC.	5	5	0	10OCT07	16OCT07
1610	SECURITY EQUIPMENT	5	5	0	17OCT07	23OCT07



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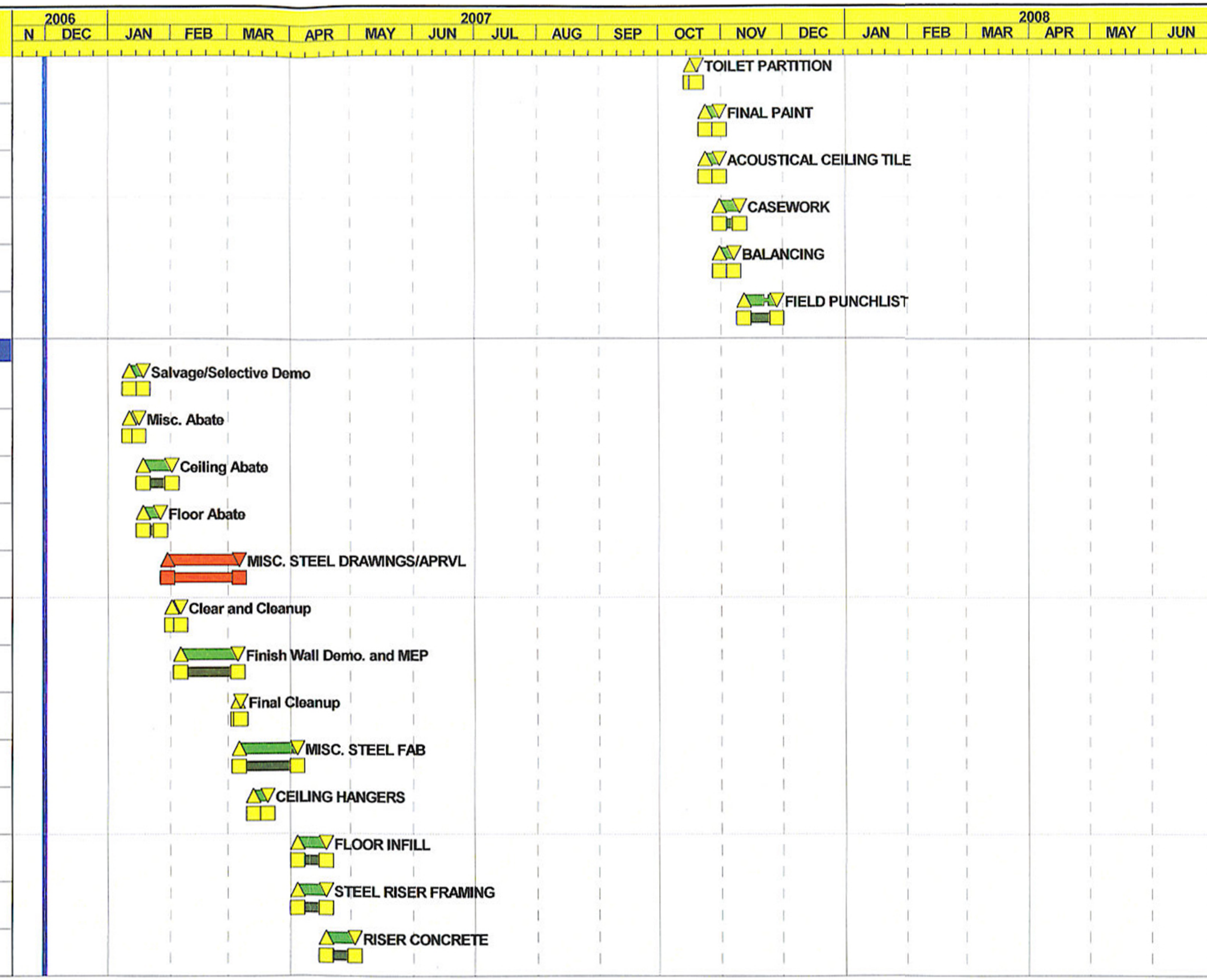
14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1600	TOILET PARTITION	3	3	0	17OCT07	19OCT07
1780	FINAL PAINT	5	5	0	24OCT07	30OCT07
1630	ACOUSTICAL CEILING TILE	5	5	0	24OCT07	30OCT07
1620	CASEWORK	8	8	0	31OCT07	09NOV07
1650	BALANCING	5	5	0	31OCT07	06NOV07
1640	FIELD PUNCHLIST	10	10	0	12NOV07	27NOV07
1st Floor East						
120	Salvage/Selective Demo	5	5	0	12JAN07	18JAN07
130	Misc. Abate	3	3	0	12JAN07	16JAN07
150	Ceiling Abate	10	10	0	19JAN07	01FEB07
190	Floor Abate	6	6	0	19JAN07	26JAN07
1220	MISC. STEEL DRAWINGS/APRVL	25	25	0	31JAN07*	06MAR07
160	Clear and Cleanup	2	2	0	02FEB07	05FEB07
170	Finish Wall Demo. and MEP	20	20	0	06FEB07	05MAR07
180	Final Cleanup	2	2	0	06MAR07	07MAR07
1990	MISC. STEEL FAB	20	20	0	07MAR07	04APR07
1980	CEILING HANGERS	5	5	0	14MAR07	20MAR07
1960	FLOOR INFILL	10	10	0	05APR07	18APR07
2080	STEEL RISER FRAMING	10	10	0	05APR07	18APR07
2090	RISER CONCRETE	10	10	0	19APR07	02MAY07



Start Date	01DEC06
Finish Date	22APR08
Data Date	01DEC06
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Leonard S. Fiore, Inc.
Borland Lab Renovation
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14FEB07	Revised to include site and shell		
08JAN07	Revised to include interior finishes		
10DEC06	Preliminary Demo/Abatement Plan		

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Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
2030	HVAC MAIN DUCTS	20	20	0	27JUN07	25JUL07
2040	SPRINKLER ROUGH-INS	10	10	0	05JUL07	18JUL07
2060	HVAC BRANCH DUCTS	10	10	0	12JUL07	25JUL07
2070	METAL STUD FRAMING	15	15	0	19JUL07	08AUG07
2110	ELECTRIC/TELE. ROUGH-INS	20	20	0	26JUL07	22AUG07
2100	PLUMBING ROUGH-INS	10	10	0	09AUG07	22AUG07
2050	PATCH WALLS/ MAS. INFILL	10	10	0	09AUG07	22AUG07
2140	MEP INSPECTIONS	3	3	0	23AUG07	27AUG07
2170	HVAC INSULATION/ATC	15	15	0	28AUG07	18SEP07
2180	CEILING FRAMING	15	15	0	07SEP07	27SEP07
2190	DRYWALL/PLASTER	25	25	0	21SEP07	25OCT07
2200	PRIME PAINTING	10	10	0	12OCT07	25OCT07
2210	ACOUSTICAL CEILING GRID	5	5	0	26OCT07	01NOV07
2220	DOORS & HARDWARE	5	5	0	26OCT07	01NOV07
2230	FLOORING	15	15	0	02NOV07	26NOV07
2240	HVAC DIFFUSER, GRILLS	10	10	0	02NOV07	15NOV07
2260	ELECTRIC LIGHTING, DEVICES	10	10	0	02NOV07	15NOV07
2250	SPRINKLER DEVICES	5	5	0	02NOV07	08NOV07
2270	TELECOM EQUIPMENT	5	5	0	02NOV07	08NOV07

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14FEB07	Revised to include site and shell		
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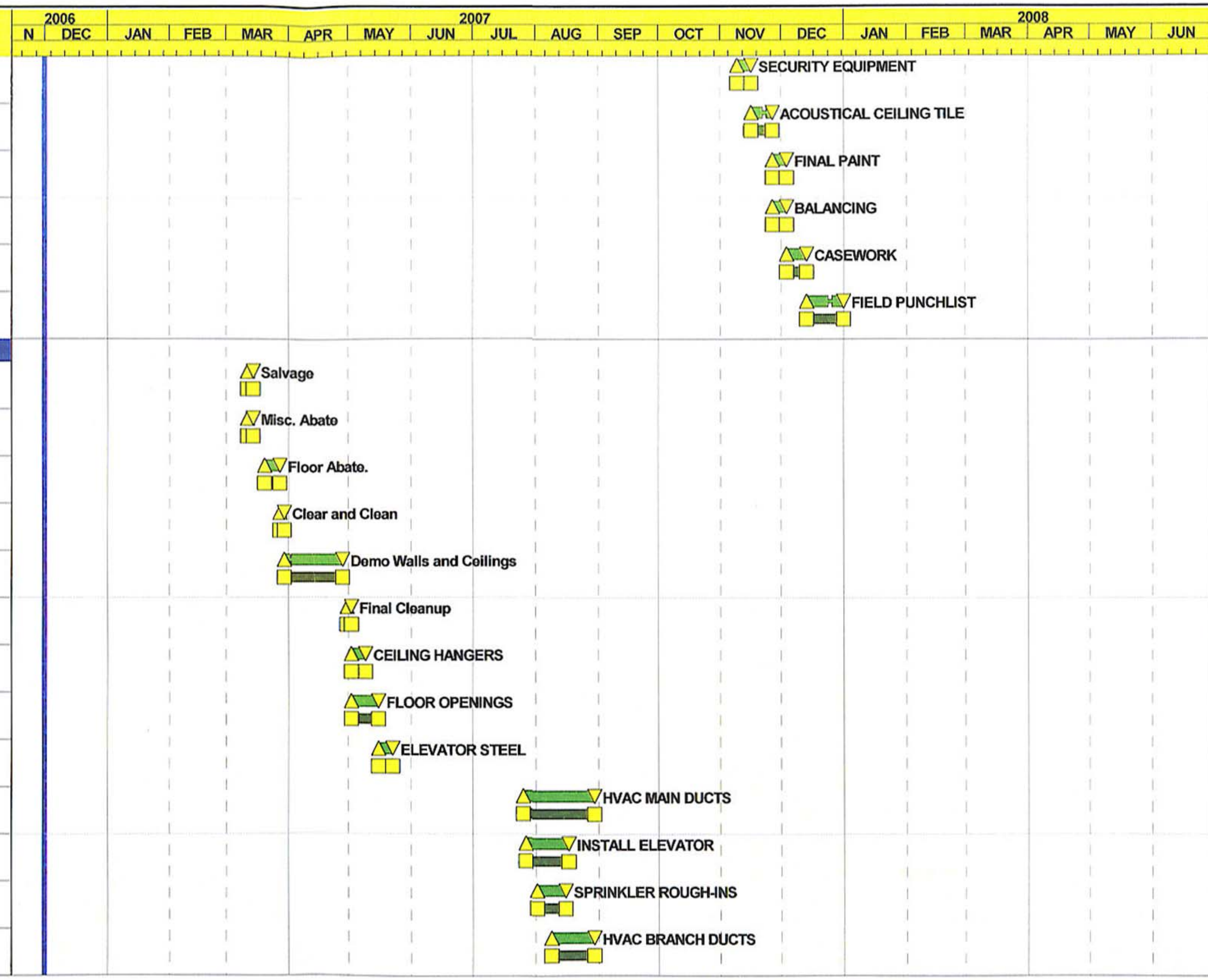
Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
2280	SECURITY EQUIPMENT	5	5	0	09NOV07	15NOV07
2300	ACOUSTICAL CEILING TILE	5	5	0	16NOV07	26NOV07
2340	FINAL PAINT	5	5	0	27NOV07	03DEC07
2320	BALANCING	5	5	0	27NOV07	03DEC07
2290	CASEWORK	8	8	0	04DEC07	13DEC07
2310	FIELD PUNCHLIST	10	10	0	14DEC07	31DEC07
Ground Floor West						
330	Salvage	3	3	0	12MAR07	14MAR07
340	Misc. Abate	3	3	0	12MAR07	14MAR07
360	Floor Abate.	6	6	0	20MAR07	27MAR07
370	Clear and Clean	2	2	0	28MAR07	29MAR07
350	Demo Walls and Ceilings	20	20	0	30MAR07	27APR07
450	Final Cleanup	2	2	0	30APR07	01MAY07
1651	CEILING HANGERS	5	5	0	02MAY07	08MAY07
1661	FLOOR OPENINGS	10	10	0	02MAY07	15MAY07
1671	ELEVATOR STEEL	5	5	0	16MAY07	22MAY07
1701	HVAC MAIN DUCTS	25	25	0	26JUL07	29AUG07
1681	INSTALL ELEVATOR	15	15	0	27JUL07	16AUG07
1731	SPRINKLER ROUGH-INS	10	10	0	02AUG07	15AUG07
1971	HVAC BRANCH DUCTS	15	15	0	09AUG07	29AUG07



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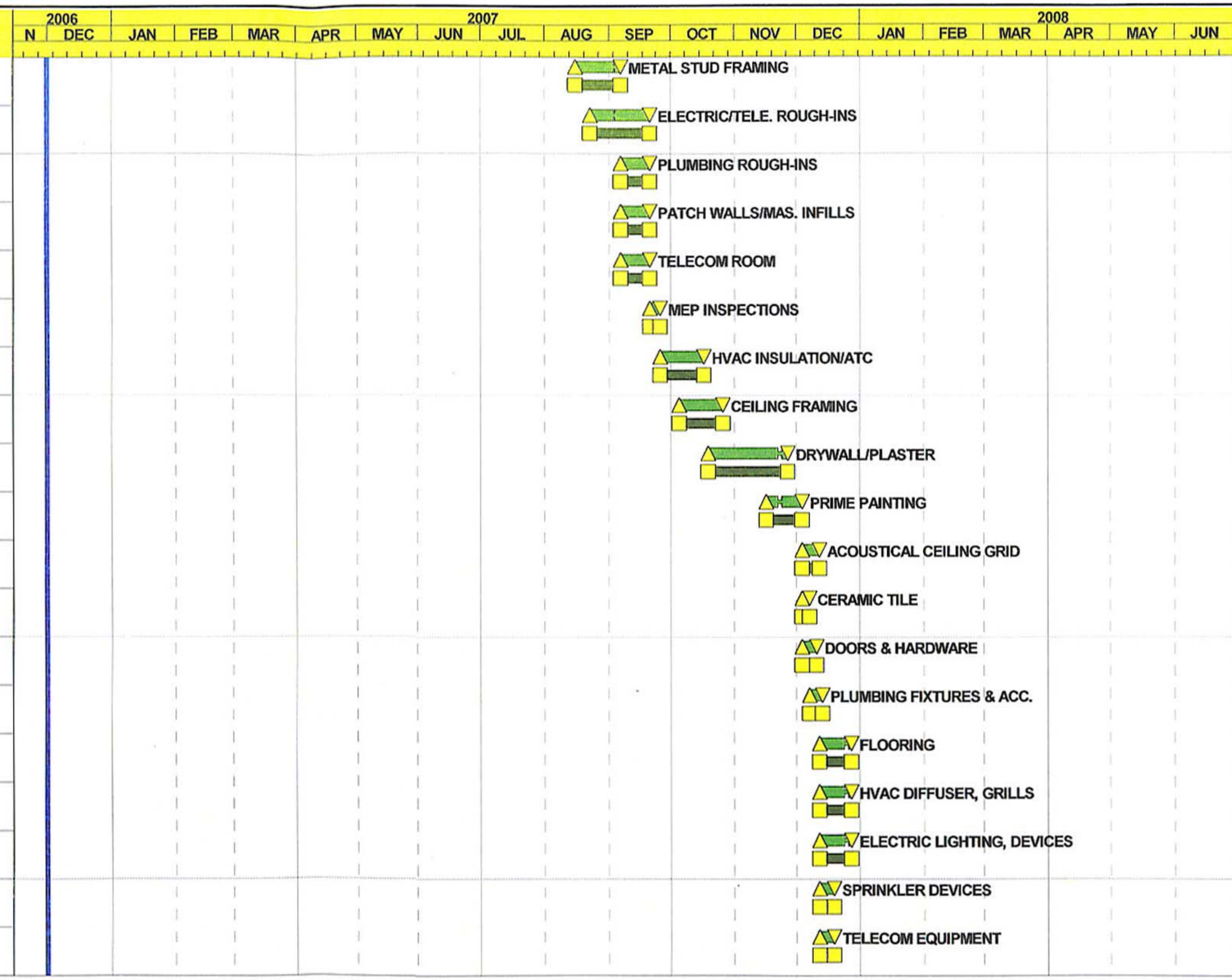
Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1711	METAL STUD FRAMING	15	15	0	16AUG07	06SEP07
1751	ELECTRIC/TELE. ROUGH-INS	20	20	0	23AUG07	20SEP07
1741	PLUMBING ROUGH-INS	10	10	0	07SEP07	20SEP07
1691	PATCH WALLS/MAS. INFILLS	10	10	0	07SEP07	20SEP07
1721	TELECOM ROOM	10	10	0	07SEP07	20SEP07
1761	MEP INSPECTIONS	3	3	0	21SEP07	25SEP07
1771	HVAC INSULATION/ATC	15	15	0	26SEP07	16OCT07
1781	CEILING FRAMING	15	15	0	05OCT07	25OCT07
1791	DRYWALL/PLASTER	25	25	0	19OCT07	26NOV07
1801	PRIME PAINTING	10	10	0	16NOV07	03DEC07
1811	ACOUSTICAL CEILING GRID	6	6	0	04DEC07	11DEC07
1821	CERAMIC TILE	3	3	0	04DEC07	06DEC07
1831	DOORS & HARDWARE	5	5	0	04DEC07	10DEC07
1841	PLUMBING FIXTURES & ACC.	5	5	0	07DEC07	13DEC07
1851	FLOORING	10	10	0	12DEC07	27DEC07
1861	HVAC DIFFUSER, GRILLS	10	10	0	12DEC07	27DEC07
1881	ELECTRIC LIGHTING, DEVICES	10	10	0	12DEC07	27DEC07
1871	SPRINKLER DEVICES	5	5	0	12DEC07	18DEC07
1891	TELECOM EQUIPMENT	5	5	0	12DEC07	18DEC07



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Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1901	TOILET PARTITION	3	3	0	14DEC07	18DEC07
1911	SECURITY EQUIPMENT	5	5	0	19DEC07	27DEC07
1961	FINAL PAINT	5	5	0	28DEC07	04JAN08
1931	ACOUSTICAL CEILING TILE	5	5	0	28DEC07	04JAN08
1921	CASEWORK	8	8	0	07JAN08	16JAN08
1951	BALANCING	5	5	0	07JAN08	11JAN08
1941	FIELD PUNCHLIST	10	10	0	17JAN08	30JAN08
Ground Floor East						
280	Salvage/ Selective Wall Demo	5	5	0	05MAR07	09MAR07
400	Misc. Abate	3	3	0	05MAR07	07MAR07
290	Ceiling Abate	15	15	0	12MAR07	30MAR07
300	Floor Abate	6	6	0	12MAR07	19MAR07
320	Clear and Cleanup	2	2	0	03APR07	04APR07
310	Finish Demo Walls and MEP	20	20	0	05APR07	02MAY07
410	Final Cleanup	2	2	0	03MAY07	04MAY07
2370	M015 FLOOR FRAMING	10	10	0	07MAY07	18MAY07
2350	CEILING HANGERS	5	5	0	09MAY07	15MAY07
2330	FLOOR INFILL	15	15	0	21MAY07	11JUN07
2380	M015 FLOOR SLAB	5	5	0	21MAY07	25MAY07
2390	T015/M015 ROOMS	15	15	0	29MAY07	18JUN07

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2400	HVAC MAIN DUCTS	20	20	0	30AUG07	27SEP07
2410	SPRINKLER ROUGH-INS	10	10	0	07SEP07	20SEP07
2430	HVAC BRANCH DUCTS	10	10	0	14SEP07	27SEP07
2440	METAL STUD FRAMING	15	15	0	21SEP07	11OCT07
2480	ELECTRIC/TELE. ROUGH-INS	20	20	0	28SEP07	25OCT07
2470	PLUMBING ROUGH-INS	10	10	0	12OCT07	25OCT07
2420	PATCH WALLS/MAS. INFILLS	10	10	0	12OCT07	25OCT07
2510	MEP INSPECTIONS	3	3	0	26OCT07	30OCT07
2540	HVAC INSULATION/ATC	15	15	0	31OCT07	20NOV07
2550	CEILING FRAMING	15	15	0	09NOV07	03DEC07
2560	DRYWALL/PLASTER	25	25	0	27NOV07	03JAN08
2570	PRIME PAINTING	10	10	0	18DEC07	03JAN08
2580	ACOUSTICAL CEILING GRID	15	15	0	04JAN08	24JAN08
2590	DOORS & HARDWARE	5	5	0	04JAN08	10JAN08
2600	FLOORING	15	15	0	25JAN08	14FEB08
2610	HVAC DIFFUSER, GRILLS	10	10	0	25JAN08	07FEB08
2630	ELECTRIC LIGHTING, DEVICES	10	10	0	25JAN08	07FEB08
2620	SPRINKLER DEVICES	5	5	0	25JAN08	31JAN08
2640	TELECOM EQUIPMENT	5	5	0	25JAN08	31JAN08

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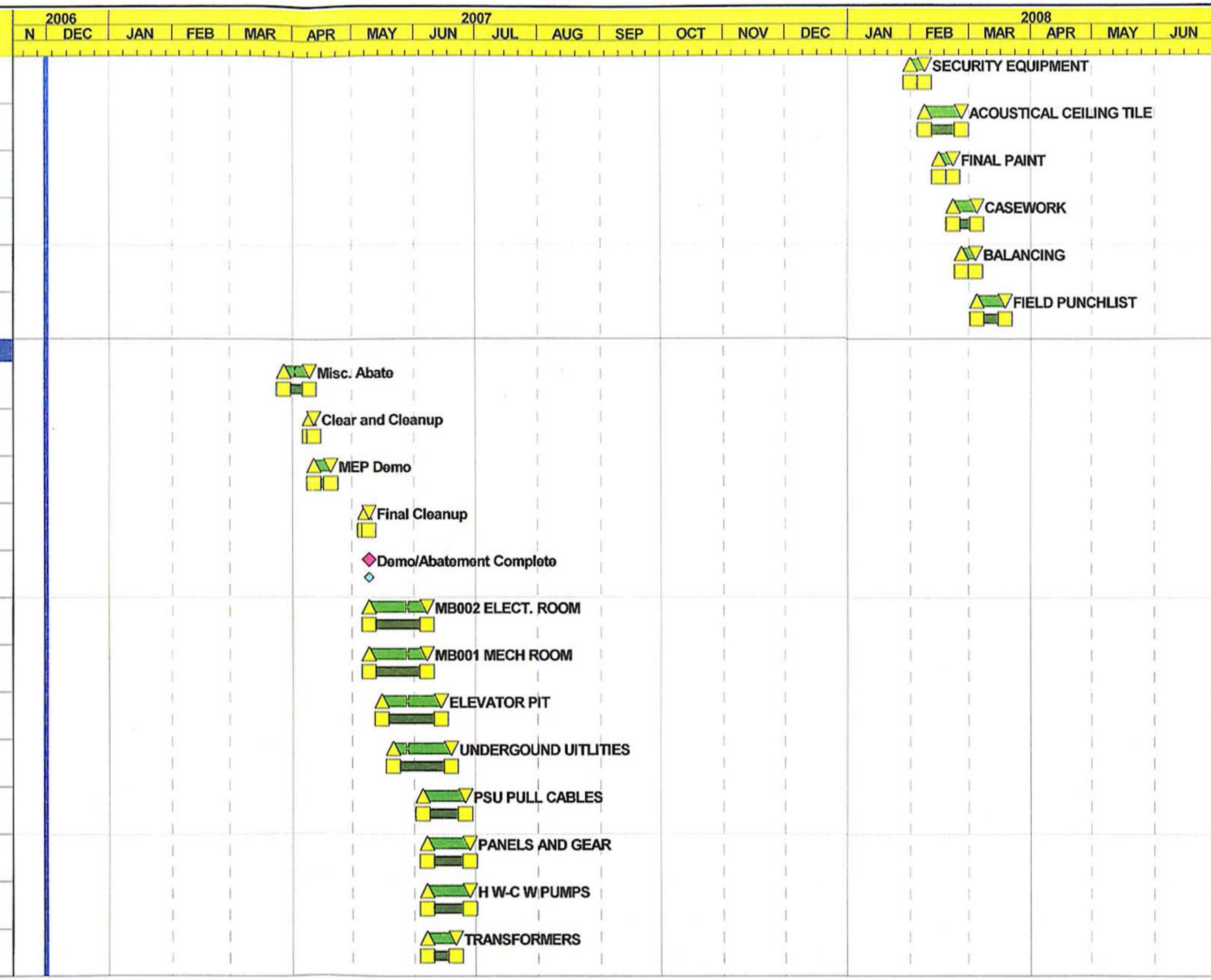
Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
2650	SECURITY EQUIPMENT	5	5	0	01FEB08	07FEB08
2670	ACOUSTICAL CEILING TILE	12	12	0	08FEB08	25FEB08
2700	FINAL PAINT	5	5	0	15FEB08	21FEB08
2660	CASEWORK	8	8	0	22FEB08	04MAR08
2690	BALANCING	5	5	0	26FEB08	03MAR08
2680	FIELD PUNCHLIST	10	10	0	05MAR08	18MAR08
Basement						
380	Misc. Abate	8	8	0	28MAR07	09APR07
440	Clear and Cleanup	2	2	0	10APR07	11APR07
390	MEP Demo	6	6	0	12APR07	19APR07
420	Final Cleanup	2	2	0	07MAY07	08MAY07
430	Demo/Abatement Complete	0	0	0		08MAY07
1700	MB002 ELECT. ROOM	20	20	0	09MAY07	06JUN07
1380	MB001 MECH ROOM	20	20	0	09MAY07	06JUN07
1240	ELEVATOR PIT	20	20	0	16MAY07	13JUN07
1820	UNDERGOUND UITLITIES	20	20	0	21MAY07*	18JUN07
1910	PSU PULL CABLES	15	15	0	05JUN07	25JUN07
1710	PANELS AND GEAR	15	15	0	07JUN07	27JUN07
1660	H W-C W PUMPS	15	15	0	07JUN07	27JUN07
1730	TRANSFORMERS	10	10	0	07JUN07	20JUN07



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Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1250	ELEVATOR STEEL	10	10	0	14JUN07	27JUN07
1720	WIRING AND DEVICES	15	15	0	28JUN07	19JUL07
1670	H W PIPING	20	20	0	28JUN07	26JUL07
1790	C W PIPING	10	10	0	28JUN07	12JUL07
1680	CONTROL WIRING	5	5	0	28JUN07	05JUL07
1740	PERMANENT POWER	5	5	0	20JUL07	26JUL07
1690	SYSTEM START UP/ADJUST	10	10	0	27JUL07	09AUG07
MECHANICAL PENTHOUSE						
860	STEEL DWGS/APPROVALS	25	25	0	10JAN07*	13FEB07
910	ATC DWGS/APPROVALS	20	20	0	05FEB07*	02MAR07
1930	ACF DRAWING APPROVAL	20	20	0	12FEB07*	09MAR07
850	STEEL FAB	20	20	0	14FEB07	13MAR07
920	ATC FAB AND DELIVERY	80	80	0	05MAR07	26JUN07
1940	ACF FAB AND DELIVERY	60	60	0	12MAR07	05JUN07
700	DEMO ROOF AND PARAPET	10	10	0	14MAR07	27MAR07
720	PENTHOUSE STEEL FRAMING	10	10	0	28MAR07	11APR07
760	SLAB ON DECK	5	5	0	12APR07	18APR07
1070	METAL DECK	5	5	0	12APR07	18APR07
740	MASONRY WALLS	15	15	0	19APR07	09MAY07
730	PENTHOUSE ROOF	5	5	0	10MAY07	16MAY07

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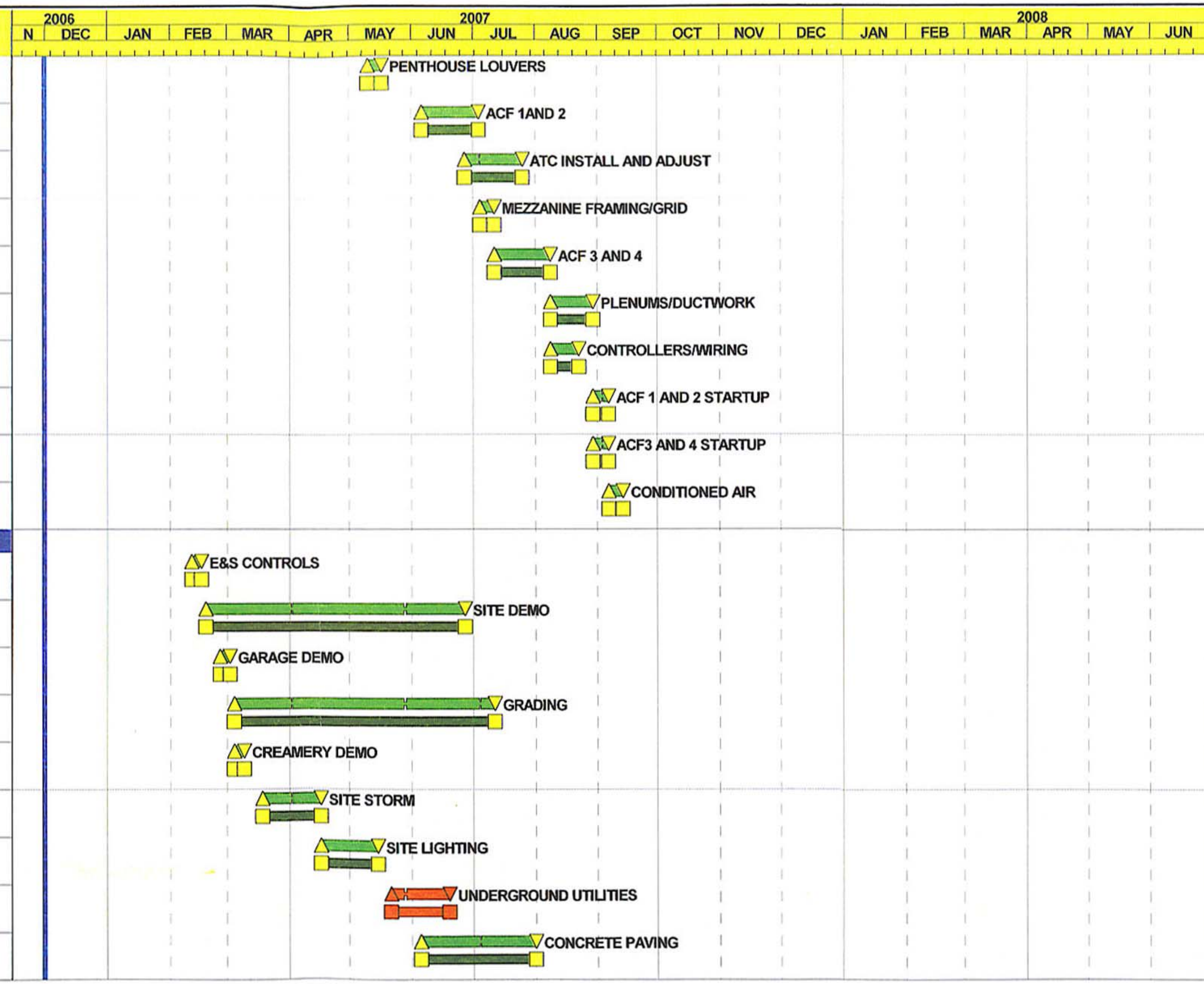
750	PENTHOUSE LOUVERS	5	5	0	10MAY07	16MAY07
780	ACF 1AND 2	20	20	0	06JUN07	03JUL07
1920	ATC INSTALL AND ADJUST	20	20	0	27JUN07	25JUL07
770	MEZZANINE FRAMING/GRID	5	5	0	05JUL07	11JUL07
790	ACF 3 AND 4	20	20	0	12JUL07	08AUG07
800	PLENUMS/DUCTWORK	15	15	0	09AUG07	29AUG07
810	CONTROLLERS/WIRING	10	10	0	09AUG07	22AUG07
820	ACF 1 AND 2 STARTUP	5	5	0	30AUG07	06SEP07
830	ACF3 AND 4 STARTUP	5	5	0	30AUG07	06SEP07
840	CONDITIONED AIR	5	5	0	07SEP07	13SEP07
SITEWORK						
2010	E&S CONTROLS	5	5	0	12FEB07*	16FEB07
1950	SITE DEMO	90	90	0	19FEB07	26JUN07
2000	GARAGE DEMO	5	5	0	26FEB07*	02MAR07
2020	GRADING	90	90	0	05MAR07	11JUL07
1970	CREAMERY DEMO	5	5	0	05MAR07	09MAR07
2460	SITE STORM	20	20	0	19MAR07	16APR07
2500	SITE LIGHTING	20	20	0	17APR07	14MAY07
2880	UNDERGROUND UTILITIES	20	20	0	21MAY07*	18JUN07
2130	CONCRETE PAVING	40	40	0	05JUN07	31JUL07



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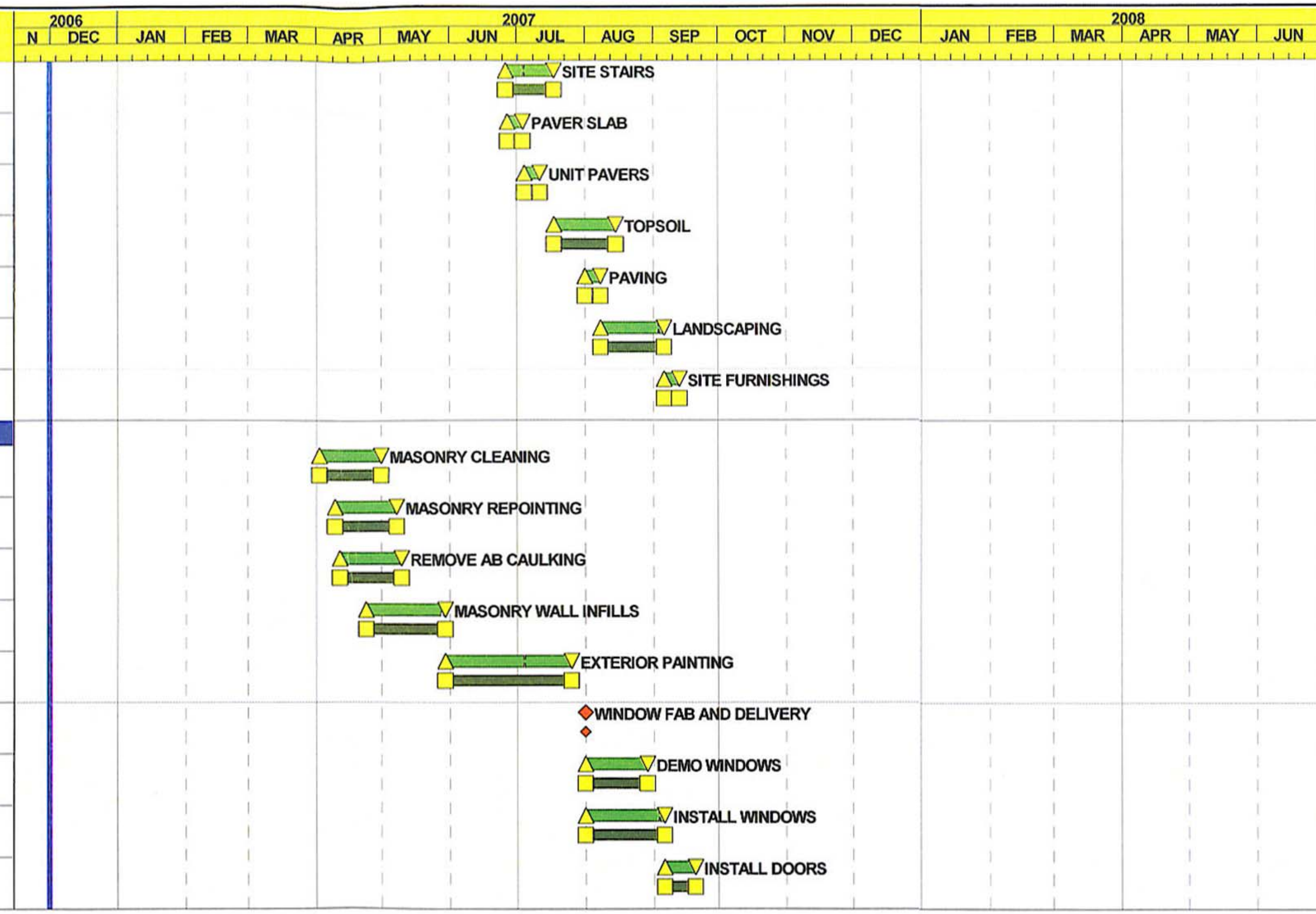
2450	SITE STAIRS	15	15	0	26JUN07	17JUL07
2490	PAVER SLAB	5	5	0	27JUN07	03JUL07
2520	UNIT PAVERS	5	5	0	05JUL07	11JUL07
2530	TOPSOIL	20	20	0	18JUL07	14AUG07
2120	PAVING	5	5	0	01AUG07	07AUG07
2710	LANDSCAPING	20	20	0	08AUG07	05SEP07
2720	SITE FURNISHINGS	5	5	0	06SEP07	12SEP07
BUILDING SHELL						
2790	MASONRY CLEANING	20	20	0	03APR07*	30APR07
2780	MASONRY REPOINTING	20	20	0	10APR07	07MAY07
2730	REMOVE AB CAULKING	20	20	0	12APR07	09MAY07
2770	MASONRY WALL INFILLS	25	25	0	24APR07	29MAY07
2800	EXTERIOR PAINTING	40	40	0	30MAY07	25JUL07
2890	WINDOW FAB AND DELIVERY	0	0	0	01AUG07*	
2740	DEMO WINDOWS	20	20	0	01AUG07	28AUG07
2750	INSTALL WINDOWS	25	25	0	01AUG07	05SEP07
2760	INSTALL DOORS	10	10	0	06SEP07	19SEP07



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Appendix C

Survey Results

1) Before Today, have you heard of the AIA 2030 Challenge?

- No
- No
- No
- No
- No
- No

2) What do you think of the challenge, is a good idea, and why?

- good idea, but poor execution...the less than rigorous coordination between hosts and presenters left me scrambling, and the Q&A at the end was painfully ephemeral
- good idea - it makes sense, is good for the environment, and engages externalities as an important issue for designers
- Something larger, more international is required, but that doesn't mean that this is a bad idea, just too small-scaled. What are the penalties for not doing it?
- Absolutely. We must act to deal with climate change.
- I think that it is an excellent idea since energy consumption from buildings are a major contributor to the problem.
- An excellent idea! While a lot of lip service goes into energy conservation in this country, we do very little to put existing means into practice.

3) Do you feel that Penn State should implement a program to work toward this challenge, and why?

- at least it should become a pet project for someone on the faculty in order to keep the torch burning and have someone to pass off to
- yes, as an institution in the public eye, leadership in this field is not only responsible, but arguably part of its mission
- Should be some further study, with positive interest developed in the broadest possible terms. It's not JUST a building problem.
- Yes. AE and Arch students need to be part of the solutions.
- Yes, Penn State as an educational and research institution should be spearheading such a challenge.
- I believe PSU should have such a program. We educate the policy makers of tomorrow and as a major university have the means to reach a large number of people.

4) Do you feel that the goals set by this challenge can be completed by the year 2030? and why.

- y'know other than for the sequestering carbon dioxide I can't even remember the damn goals
- About the challenge per the website:

1. Not enough info on what the goals are.
2. Unclear as to the means to achieve it.

Bigger problems: why should anyone adopt the standards voluntarily? The direct costs are higher, with no mechanism for internalizing the current externalities (such as the market-based solution seen in carbon trading). You can change behavior in three ways: legislate it (use of force), encourage it (the moral argument), or incentivize it (prod individuals to act in their self interest). The first is typical for planning efforts, the second is usually ineffective when the rubber hits the road (example: people bought SUVs knowing they were not 'green', they slowed down when gas prices rose); the third typically happens when the negative impact is directly impacting them (i.e. the ocean laps on the city limits of Santa Fe). This scheme needs to rely on the first, not the second or the third.

- Can't be done without broad popular and governmental support, also institutional involvements and, of course, cooperation by multi-national corporations, who are largely responsible for carbon emissions.
- Yes. They are pretty modest.
- Yes, they are reasonable and within reach.
- I think a lot of this depends on political will and economics. If there is a financial incentive to do something, people will do it. Politics must make this a number one priority.

Appendix D

U.S. Conference of Mayors – Resolution #50

Resolution No.50
Submitted By:
The Honorable Martin Chavez
Mayor of Albuquerque
The Honorable Greg Nickels
Mayor of Seattle
The Honorable Richard M. Daley
Mayor of Chicago
The Honorable Manuel A. Diaz
Mayor of Miami

ADOPTING THE "2030 CHALLENGE" FOR ALL BUILDINGS

WHEREAS, the U.S. Conference of Mayors has previously adopted strong policy resolutions for cities, communities, and the federal government to take actions to reduce fossil fuel consumption and global warming pollution; and

WHEREAS, the Inter-Governmental Panel on Climate Change (IPCC), the international community's most respected assemblage of scientists, has found that climate disruption is a reality and that human activities are largely responsible for increasing concentrations of global warming pollution; and

WHEREAS, the U.S. Building Sector has been shown to be the major consumer of fossil fuel and producer of global warming causing greenhouse gases; and

WHEREAS, the federal government through programs fostered within many of its key agencies and numerous state governments as well as municipalities across the U.S. have adopted high performance green building principles; and

WHEREAS, a recent study completed by Lawrence Berkeley National Laboratory, the most definitive cost-benefit analysis of green buildings ever conducted, concluded that the financial benefits of green design are between \$50 and \$70 per square foot, more than 10 times the additional cost associated with building green; and

WHEREAS, the large positive impact on employee productivity and health gains suggests that green building has a cost-effective impact beyond just the utility bill savings; and

WHEREAS, studies have indicated that student attendance and performance is higher in high performance school buildings; and

WHEREAS, recognizing that a building's initial construction costs represent only 20-30 percent of the building's entire costs over its 30 to 40 year life, emphasis should be placed on the "life cycle costs" of a public building rather than on solely its initial capital costs; and

WHEREAS, the construction industry in the U.S. represents a significant portion of our economy and a significant portion of the building industry is represented by small business and an increase in sustainable building practices will encourage and promote new and innovative small business development throughout the nation; and

WHEREAS, the American Institute of Architects (AIA), the national professional organization representing architects has adopted a position statement calling for the immediate energy reduction of all new and renovated buildings to one-half the national average for that building type, with increased reductions of 10% every five years so that by the year 2030 all buildings designed will be carbon neutral, meaning they will use no fossil fuel energy.

NOW, THEREFORE, BE IT RESOLVED that the U.S. Conference of Mayors will encourage its members to adopt the following "2030 Challenge" for building performance targets:

New construction of City buildings shall be designed to and achieve a minimum delivered fossil-fuel energy consumption performance standard of one half the U.S. average for that building type as defined by the U.S. Department of Energy.

Renovation projects of City buildings shall be designed to and achieve a minimum delivered fossil-fuel energy consumption performance standard of one half the U.S. average for that building type as defined by the U.S. Department of Energy.

All other new construction, renovations, repairs, and replacements of City buildings shall employ cost-effective, energy-efficient, green building practices to the maximum extent possible; and

NOW, THEREFORE, BE IT FURTHER RESOLVED that the U.S. Conference of Mayors will work to increase the fossil-fuel reduction standard for all new buildings to carbon neutral by 2030, in the following increments:

60% in 2010
70% in 2015
80% in 2020
90% in 2025

Carbon-neutral by 2030 (meaning new buildings will use no fossil fuel GHG emitting energy to operate); and

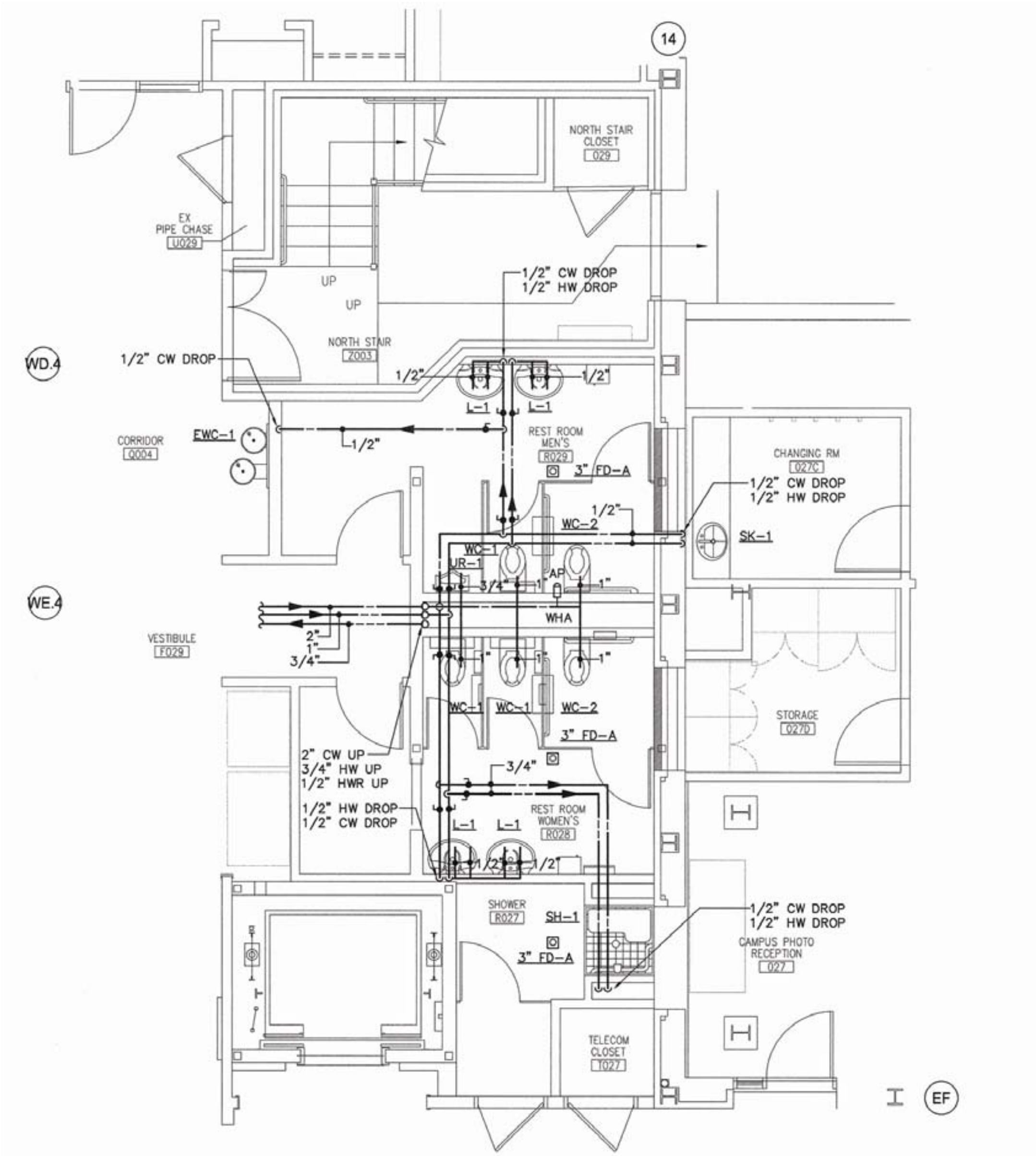
BE IT FURTHER RESOLVED that the U.S. Conference of Mayors will urge mayors from around the nation to join this effort by developing plans to fully implement the above mentioned targets as part of their procurement process and by establishing policies to insure compliance and measure results; and

BE IT FURTHER RESOLVED that the U.S. Conference of Mayors will urge mayors from around the nation to develop plans to fully implement the above mentioned targets for *all* new and renovated buildings within the City; and

BE IT FINALLY RESOLVED that the U.S. Conference of Mayors will work in conjunction with ICLEI Local Governments for Sustainability and other appropriate organizations to join this effort to develop plans to fully implement similar targets as mentioned above. Project cost: Unknown

Appendix E

Pipe-Space and Riser Detail



4 P302 GROUND FLOOR REST ROOM PARTIAL PLAN-DOMESTIC WATER
SCALE 1/4"=1'-0"

Appendix F

Detailed Copper Piping System Estimate

		Size of Pipe	Linear Ft.	Price per Foot		Total Cost
Basement						
	Cold Water					
		3"	129' 5"	$23.30		$3,029.00
		1 1/2"	5' 1"	$7.51		$37.55
	Hot Water					
		1 1/2"	53' 3"	$7.51		$398.03
	Hot Water Return					
		1"	53' 3"	$4.23		$224.19
Ground Floor						
	Cold Water					
		3"	123' 5"	$23.30		$2,865.90
		1"	201' 8"	$4.23		$854.46
		3/4"	438' 6"	$2.94		$1,290.66
	Hot Water					
		1 1/2"	122' 6"	$7.51		$923.73
		1"	3' 7"	$4.23		$16.92
		3/4"	114' 10"	$2.94		$338.10
	Hot Water Return					
		1"	121' 6"	$4.23		$516.06
		3/4"	73'	$2.94		$214.62

Dustin Faust
Construction Management

		Size of Pipe	Linear Ft.	Price per Foot		Total Cost
Ground Floor Bathroom Area						
	Cold Water					
		2"	41' 3"	$11.69		$479.29
		1"	40' 10"	$4.23		$173.43
		3/4"	65' 4"	$2.94		$191.10
		1/2"	108' 0"	$1.85		$199.80
	Hot Water					
		1"	29' 5"	$4.23		$126.90
		3/4"	68' 1"	$2.94		$199.92
		1/2"	91' 8"	$1.85		$170.20
	Hot Water Return					
		3/4"	27' 2"	$2.94		$79.38
1st Floor						
	Cold Water					
		3/4"	96' 5"	$2.94		$285.18
		1/2"	12'	$1.85		$22.20
	Hot Water					
		3/4"	98' 2"	$2.94		$288.12
		1/2"	12'	$1.85		$22.20
	Hot Water Return					
		1/2"	90' 4"	$1.85		$166.50

		Size of Pipe	Linear Ft.	Price per Foot		Total Cost
First Floor Bathroom Area						
	Cold Water					
		2"	25' 3"	$11.69		$292.25
		1"	15' 8"	$4.23		$67.68
		3/4"	34' 7"	$2.94		$102.90
		1/2"	140' 7"	$1.85		$260.85
	Hot Water					
		3/4"	31' 10"	$2.94		$94.08
		1/2"	130' 5"	$1.85		$242.35
	Hot Water Return					
		1'2"	14' 3"	$1.85		$25.90
2nd Floor						
	Cold Water					
		3/4"	244' 10"	$2.94		$720.30
		1/2"	36'	$1.85		$66.60
	Hot Water					
		3/4"	241' 7"	$2.94		$711.48
		1/2"	36'	$1.85		$66.60
	Hot Water Return					
		1/2"	222' 3"	$1.85		$410.70

		Size of Pipe	Linear Ft.	Price per Foot		Total Cost
Second Floor Bathroom Area						
	Cold Water					
		2"	25' 4"	$11.69		$292.25
		1"	24'	$4.23		$101.52
		3/4"	46' 1"	$2.94		$135.24
		1/2"	106' 6"	$1.85		$197.95
	Hot Water					
		3/4"	14' 4	$2.94		$41.16
		1/2"	82' 10"	$1.85		$153.55
	Hot Water Return					
		1/2"	14' 4"	$1.85		$25.90
				Copper Piping Total		**$17,122.70**

Copper Fittings

	Description	Quantity	Price		Total Cost
	3" x 2" x 3" Cp. T	1	$72.30		$72.30
	3" x 3" x 2" Cp. T	2	$71.25		$142.50
	3" x 2" x 1" Cp. T	1	$81.93		$81.93
	3" Cp. 90 º	9	$47.84		$430.56
	2" x 2" x 1" Cp. T	12	$23.57		$282.84
	2" x 2" x 3/4" Cp. T	7	$22.85		$159.95
	2" Cp. 90 º	2	$16.26		$32.52
	2" Male IP x Cp. Adpt.	2	$18.89		$37.78
	1 1/2" Cp. T	2	$19.41		$38.82
	1 1/2" x 1 1/2" x 3/4" Cp. T	4	$14.44		$57.76
	1 1/2" Cp. 90 º	17	$8.10		$137.70
	1 1/2" Male IP x Cp. Adpt.	2	$9.22		$18.44
	1" FM IP x Cp. Adpt.	15	$6.29		$94.35
	3'4" FM IP x Cp. Adpt.	9	$2.58		$23.22
	3/8" FM IP x 1/2" Cp. Eared Els	52	$7.79		$405.08
	1/2" FM IP x Cp. Eared Els	6	$3.97		$23.82
	Misc. Cp. Fittings (1" - 3/4" - 1/2")				$1,800.00
			Copper Fittings Total		**$3,839.57**
			Copper Piping Total		**$17,122.70**
			Copper System Total		**$20,962.27**

Appendix G

Detailed PEX Piping System Estimate

	Size of Pipe	Linear Ft.	Price per Foot	Total Cost
Basement				
Cold Water				
	3"	129' 5"	$23.30	$3,029.00
	1 1/2"	5' 1"	$7.51	$37.55
Hot Water				
	1 1/2"	53' 3"	$7.51	$398.03
Hot Water Return				
	1"	53' 3"	$1.35	$71.55
Ground Floor				
Cold Water				
	3"	123' 5"	$23.30	$2,865.90
	1"	201' 8"	$1.35	$272.70
	3/4"	438' 6"	$0.86	$377.11
Hot Water				
	1 1/2"	122' 6"	$7.51	$923.73
	1"	3' 7"	$1.35	$4.73
	3/4"	114' 10"	$0.86	$98.90
Hot Water Return				
	1"	121' 6"	$1.35	$164.03
	3/4"	73'	$0.86	$62.78

	Size of Pipe	Linear Ft.	Price per Foot	Total Cost
Ground Floor Bathroom Area				
Cold Water				
	2"	41' 3"	$11.69	$479.29
	1"	40' 10"	$1.35	$55.35
	3/4"	65' 4"	$0.86	$55.90
	1/2"	108' 0"	$0.47	$50.76
Hot Water				
	1"	29' 5"	$1.35	$39.83
	3/4"	68' 1"	$0.86	$58.48
	1/2"	91' 8"	$0.47	$43.24
Hot Water Return				
	3/4"	27' 2"	$0.86	$23.22
1st Floor				
Cold Water				
	3/4"	96' 5"	$0.86	$82.56
	1/2"	12'	$0.47	$5.64
Hot Water				
	3/4"	98' 2"	$0.86	$84.28
	1/2"	12'	$0.47	$5.64
Hot Water Return				
	1/2"	90' 4"	$0.47	$42.30

	Size of Pipe	Linear Ft.	Price per Foot	Total Cost
First Floor Bathroom Area				
Cold Water				
	2"	25' 3"	$11.69	$292.25
	1"	15' 8"	$1.35	$21.60
	3/4"	34' 7"	$0.86	$29.67
	1/2"	140' 7"	$0.47	$66.27
Hot Water				
	3/4"	31' 10"	$0.86	$27.52
	1/2"	130' 5"	$0.47	$61.34
Hot Water Return				
	1'2"	14' 3"	$0.47	$6.58
2nd Floor				
Cold Water				
	3/4"	244' 10"	$0.86	$210.70
	1/2"	36'	$0.47	$16.92
Hot Water				
	3/4"	241' 7"	$0.86	$208.12
	1/2"	36'	$0.47	$16.92
Hot Water Return				
	1/2"	222' 3"	$0.47	$104.34

	Size of Pipe	Linear Ft.	Price per Foot	Total Cost
Second Floor Bathroom				
Cold Water				
	2"	25' 4"	$11.69	$292.25
	1"	24'	$1.35	$32.40
	3/4"	46' 1"	$0.86	$39.56
	1/2"	106' 6"	$0.47	$50.06
Hot Water				
	3/4"	14' 4	$0.86	$12.04
	1/2"	82' 10"	$0.47	$39.01
Hot Water Return				
	1/2"	14' 4"	$0.47	$6.82
			PEX & Copper Piping Total	**$10,866.87**

PEX & Copper Fittings

Description	Quantity	Price	Total Cost
3" x 2" x 3" Cp. T	1	$72.30	$72.30
3" x 3" x 2" Cp. T	2	$71.25	$142.50
3" x 2" x 1" Cp. T	1	$81.93	$81.93
2" x 2" x 1" Cp. T	12	$23.57	$282.84
2" x 2" x 3/4" Cp. T	7	$22.85	$159.95
2" Male IP x Cp. Adpt.	2	$18.89	$37.78
1 1/2" Cp. T	2	$19.41	$38.82
1 1/2" x 1 1/2" x 3/4" Cp. T	4	$14.44	$57.76
1 1/2" Male IP x Cp. Adpt.	2	$9.22	$18.44
1" PEX x 1" FM IP	15	$5.89	$88.35
3/4" PEX x 3/4" FM IP	9	$2.82	$25.38
1/2" PEX x 1/2" FM IP Eared Els	58	$4.06	$235.48
1" PEX x 1" CP sweat	15	$2.43	$36.45
3/4" PEX x 3/4" CP sweat	9	$1.50	$13.50
1/2" PEX x 1/2" CP sweat	58	$0.83	$48.14
1" Cinch Rings	30	$0.70	$21.00
3/4" Cinch Rings	18	$0.65	$11.70
1/2" Cinch Rings	116	$0.47	$54.52

PEX & Copper Fittings Total	**$1,426.84**
PEX & Copper Piping Total	**$10,866.87**
PEX System Total	**$12,293.71**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- Dr. Riley – The Pennsylvania State University, Construction Management Faculty
- Steve Howel – APR Supply Company

Borland Laboratory Renovation Weight Matrix					
Description	**Research**	**Value Engineering**	**Constructability Review**	**Schedule Reduction**	**Total**
AIA 2030 Challenge	30%	0%	10%	0%	40%
Domestic Water Re-Design	5%	20%	10%	5%	40%
HVAC Re-Design	5%	10%	5%	0%	20%
Total	40%	30%	25%	5%	100%