
# Multi-Use High Rise | Washington D.C. Area

Penn State Architectural Engineering 2014 Senior Thesis

Ryan MacNichol | Construction Option

Ray Sowers | Faculty Advisor

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## Presentation Outline



Photo Credit: donohoeconstruction.com

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## Project Background

- Location: Washington D.C Area
- Occupancy Type: Mixed-Use High Rise
- Height :
  - Underground Parking: 2 Stories
  - Building A: 10 Stories
  - Building B: 6 Stories
- Size: 214,768 SF
- Total Cost: $44,000,000
- Cost Per Square Foot: $204.87
- Dates of Construction: July, 2012 – July, 2014


Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


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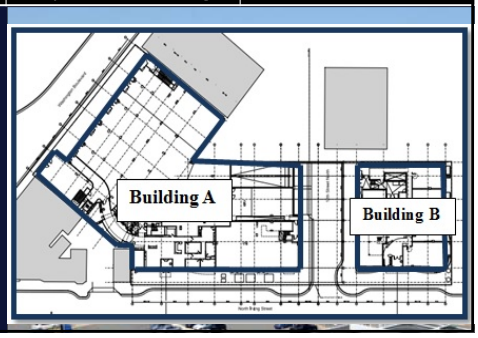

## Project Team

DONOHOE
Integrity and Vision Since 1884
Credit: donohoeconstruction.com

- **Owner**: USAA Real Estate
- **Developer**: ZOM Mid-Atlantic
- **Architect**: Esocoff & Associates
- **General Contractor**: Donohoe Construction Company

USAA®
Credit: USAA.com



## Project Delivery Method

DONOHOE
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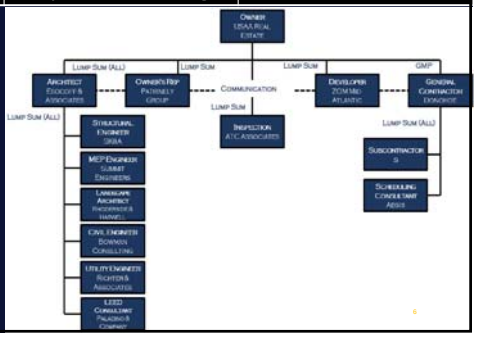
Design – Bid – Build

GMP Contract: Donohoe Construction Company

Lump Sum Contract: Other Parties




## Cost & Schedule Overview

- **24 Month Construction Schedule (7/2012 – 7/2014)**
  - Enclosure is longest phase: 250 days
- **$44 Million Project**
  - General Conditions: $4,131,858.75
  - Structural: $4,391,165.75
  - MEP Assemblies: $3,563,211.00

| | Duration | Start Date | Finish Date |
|---|---|---|---|
| Notice To Proceed | - | 07/24/2012 | - |
| Preconstruction | 110 Days | 07/24/2012 | 12/24/2012 |
| Procurement | 277 Days | 07/24/2012 | 08/14/2013 |
| MEP Coordination | 277 Days | 07/24/2012 | 08/14/2013 |
| Initial Site Work | 120 Days | 08/06/2012 | 01/18/2013 |
| Foundation & Structure | 152 Days | 12/28/2012 | 07/29/2013 |
| Garage | 109 Days | 12/28/2012 | 05/29/2013 |
| Building 1 | 99 Days | 05/14/2013 | 09/27/2013 |
| Building 2 | 51 Days | 05/20/2013 | 07/29/2013 |
| Enclosure | 250 Days | 07/30/2013 | 07/14/2014 |
| Building 1 | 250 Days | 07/30/2013 | 07/14/2014 |
| Building 2 | 93 Days | 06/28/2013 | 11/05/2013 |
| Rough-In | 167 Days | 07/05/2013 | 02/24/2014 |
| Garage | 167 Days | 07/05/2013 | 02/24/2014 |
| Building 1 | 151 Days | 07/09/2013 | 02/04/2014 |
| Building 2 | 122 Days | 07/09/2013 | 12/25/2013 |
| Finishes | 244 Days | 07/18/2013 | 06/24/2014 |
| Garage | 133 Days | 07/18/2013 | 01/20/2012 |
| Building 1 | 179 Days | 10/17/2013 | 06/24/2014 |
| Building 2 | 133 Days | 11/29/2013 | 06/03/2014 |
| Project Closeout | 201 Days | 10/01/2013 | 07/08/2014 |
| Substantial Completion | - | - | 07/29/2014 |
| Total | 735 Days | 07/24/2012 | 07/29/2014 |

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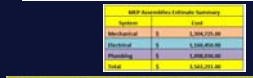
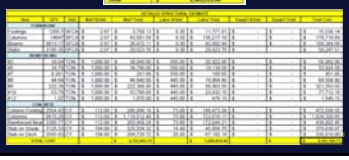
  - Structural: $4,391,165.75
  - MEP Assemblies: $3,563,211.00

General Conditions Summary

| General Breakdown | Cost/Week | Total Cost |
|---|---|---|
| Jobsite Management | $ 27,913.15 | $ 2,930,681.25 |
| Equipment & Facilities | $ 2,668.10 | $ 280,150.00 |
| Temporary Utilities | $ 2,869.79 | $ 301,327.50 |
| Insurance, Permits, & Bonds | $ 5,900.00 | $ 619,500.00 |
| Total | $ 39,351.04 | $ 4,131,858.75 |






# Analysis 1:

# Mobile Technology Integration


Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


## Analysis Background

- **Problem Identification:**
  - Significant Change Orders
  - Schedule Difficulties
- **Goals:**
  - Reduce Delays in Construction
  - Generate Cost Savings
  - Provide Industry Leading Expertise

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Credit: Google Images

Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


Credit: LATISTA

## LATISTA

- **Advantages**
  - Decrease Site Congestion
  - Increase Efficiency
  - Preconstruction Benefits
  - Material Organization
  - Drawing Cost Savings
  - Material Delivery Traceability
- **Disadvantages**
  - Up Front Cost
  - Lack of Knowledge
  - Software Defect Potential


Credit: LATISTA

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## Industry Research

- **Case Study 1: ASCE Journal Article**
  - Clear Barriers
  - Successful Practice
  - "People Issue"
- **Case Study 2: Eli Lilly & Company**
  - The Project
  - LATISTA Integration
  - Improved Rework, Schedule, Budget, and Quality

- *Making the Case for Mobile IT*
  - Quick and Easy Reports
  - Better Customer Service
  - Identification of Trends
  - Efficient Task Allocation
  - Reduced Turn Around Time
  - Improved Quality of Work
  - Increased Staff Accountability
  - Rework Avoidance

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| | | |
|---|---|---|
| IMPROVED REWORK | - | Rework savings of 46%, an estimated $4.3 million |
| | - | Rework addressed by contractors, not Lilly |
| IMPROVED SCHEDULE | - | Project delivered 2.5 months ahead of schedule |
| | - | Issues identified during construction, not operations |
| IMPROVED BUDGET | - | Under budget on quality delivery |
| | - | Under budget on overall project cost |
| IMPROVED QUALITY | - | Only 0.49% of 10,000 identified issues affected quality |
| | - | Zero punch list items open at final turnover |

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## Proposed Implementation

Direct Costs of Tablet Computer Implementation

| Description | Quantity | Cost/Unit | Cost |
|---|---|---|---|
| Tablet Computers | 4 | $500/iPad | -($2,000) |
| Contingency for Software & Add-ons | 4 | $500/iPad | -($1,200) |
| Training Project Manager | 6 hours | - | -($624) |
| Training Assistant Project Manager | 6 hours | - | -($408) |
| Training Superintendent | 6 hours | - | -($624) |
| Training Project Engineer #2 | 6 hours | - | -($408) |
| Training Project Engineer #2 | 6 hours | - | -($408) |
| Total | - | - | -($5,672) |

Direct Cost: ($5,672)

- **Implementation Tasks:**
  - Accessibility to Drawings in the Field
  - Coordination in the Field
  - Documenting Field Issues
  - Email and Correspondence
  - Safety Evaluations
  - Daily Forms and Checklists

Human Resource Costs of Tablet Integration (weekly)

| Description | Quantity | Cost/Unit | Cost |
|---|---|---|---|
| Costs | | | |
| Project IT Consultant | 2 hours | $68/hour | ($136) |
| Savings | | | |
| Project Manager Time | 4 hours | - | $416 |
| Assistant Project Manager Time | 5 hours | - | $340 |
| Superintendent Time | 7 hours | - | $728 |
| Project Engineer #1 Time | 5 hours | - | $340 |
| Project Engineer #2 Time | 5 hours | - | $340 |
| Total | - | - | $2,028/week |

Human Resource Cost: $2,028/week

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Human Resource Cost: $2,028/week

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## Proposed Implementation

Direct Costs of Tablet Computer Implementation

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|---|---|---|---|
| Tablet Computers | 4 | $500/iPad | -($2,000) |
| Contingency for Software & Add-ons | 4 | $500/iPad | -($1,200) |
| Training Project Manager | 8 hours | - | -($424) |
| Training Assistant Project Manager | 8 hours | - | -($408) |
| Training Superintendent | 8 hours | - | -($424) |
| Training Project Engineer #1 | 8 hours | - | -($408) |
| Training Project Engineer #2 | 8 hours | - | -($408) |
| Total | - | - | ($5,672) |

Direct Cost: ($5,672)

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Human Resource Savings: $2,028/week






## Conclusion & Recommendation

- Payback Period: 3 Weeks
- Cost Savings: $210,912.00
- Valuable Knowledge

**Recommended!**


Credit: Donohue

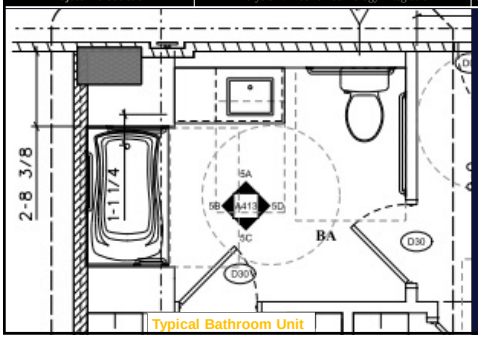
# Analysis 2:

# Bathroom Modularization


Credit: Google Images





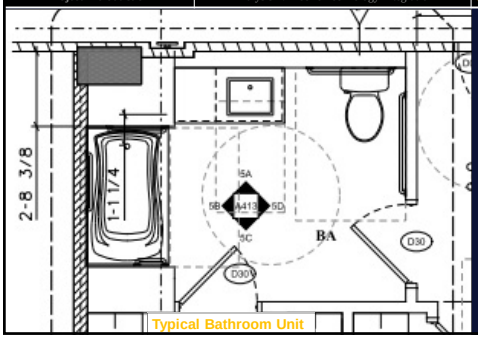


Typical Bathroom Unit

## Analysis Background

- **Problem Identification:**
  - Schedule Difficulties
  - Congested Site
- **Goals:**
  - Schedule Acceleration
  - Reduce Site Congestion
  - Provide Cost Comparison

| Bathroom Unit Breakdown | |
|---|---|
| *Building 1* | |
| 2nd Floor | 28 Bathroom Units |
| 3rd Floor | 28 Bathroom Units |
| 4th Floor | 28 Bathroom Units |
| 5th Floor | 28 Bathroom Units |
| 6th Floor | 28 Bathroom Units |
| 7th Floor | 28 Bathroom Units |
| *Building 2* | |
| 2nd Floor | 8 Bathroom Units |
| 3rd Floor | 8 Bathroom Units |
| 4th Floor | 8 Bathroom Units |
| 5th Floor | 8 Bathroom Units |
| 6th Floor | 8 Bathroom Units |



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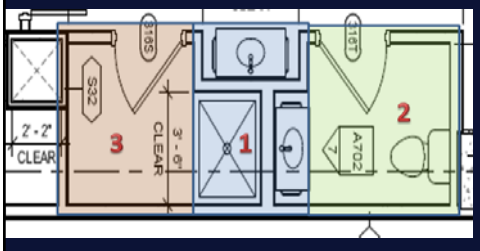
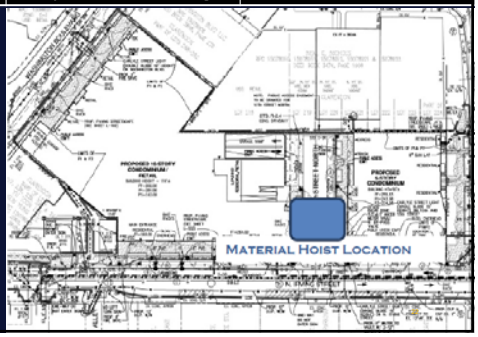
## Bathroom Modules



3 Modules per Bathroom Unit

- **Module Constraints**
  - Fit On Trucks
  - Fit Through Unfinished Corridors
  - Handled and Moved Easily
- **Logistics**
  - Warehouse Location and Size
  - Material Hoist Location



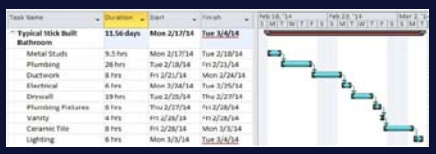
## Schedule Comparison

| | Single Unit | | Typical Floor (36 units) | |
|---|---|---|---|---|
| | *Modularized* | *Stick Built* | *Modularized* | *Stick Built* |
| Duration (days) | 4.50 | 11.56 | 30.00 | 83.66 |
| Savings (days) | 7.06 | | 53.66 | |

- **Modular Constructed Unit: 4.5 Days**

- **Modular Assumptions**
  - Modules will be shipped in groups of six bathroom units (18 modules)
  - Three days duration are allotted for each group of six modules
- **Stick-Built Assumptions**
  - Each bathroom construction will begin once the previous unit has been under construction for 2 days

- **Stick-Built Constructed Unit: 11.56 Days**








## Cost Comparison

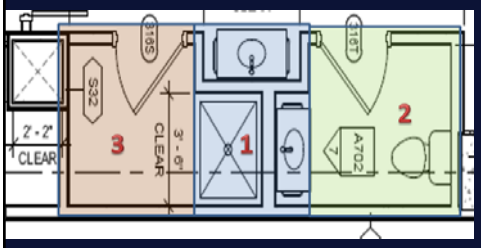
| | Single Unit | Typical Floor (36 Units) | Entire Project (208 Units) |
|---|---|---|---|
| Modular | $ 17,057.44 | $ 614,827.84 | $ 3,547,947.52 |
| Stick-Built | $ 16,969.22 | $ 610,855.92 | $ 3,529,597.76 |
| Difference | $ 88.22 | $ 3,159.16 | $ 18,349.76 |

- **Modular Construction**

| | Single Unit | Typical Floor (36 Units) | Entire Project (208 Units) |
|---|---|---|---|
| Modularized Bathroom | $ 16,837.44 | $ 598,947.84 | $3,460,587.52 |
| Shipping | $ 110.00 | $ 5,400.00 | $ 31,200.00 |
| Warehouse | $ 270.00 | $ 6,480.00 | $ 56,160.00 |
| Total | $ 17,057.44 | $ 614,827.84 | $ 3,547,947.52 |

- **Stick-Built Construction**

| | Material Cost | Labor Cost | Equipment Cost | Total |
|---|---|---|---|---|
| Single Unit | $ 9,079.82 | $ 7,889.40 | $ -- | $ 16,969.22 |
| Typical Floor | $ 326,873.52 | $ 284,018.40 | $ -- | $ 610,855.92 |
| Entire Project | $ 1,888,602.56 | $ 1,640,995.20 | $ -- | $ 3,529,597.76 |




## Conclusion & Recommendation

- Duration Saved: 55 Days
- Minimal Cost Increase: $18,349.76
- Site Congested Cleared

**Recommended!**





## Analysis 3:

## Façade Prefabrication


## Analysis Background

- **Problem Identification:**
  - Schedule Difficulties
  - Congested Site
  - Project Quality and Productivity
- **Goals:**
  - Schedule Acceleration
  - Reduce Site Congestion
  - Provide Cost Comparison
  - Structural Breadth – Load Calculations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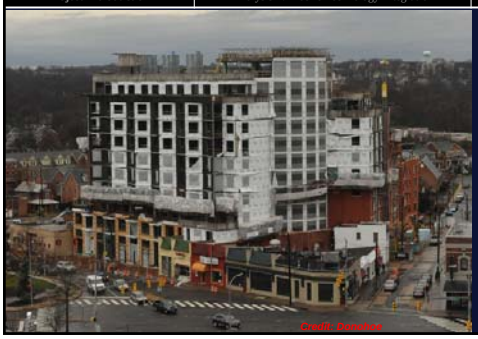
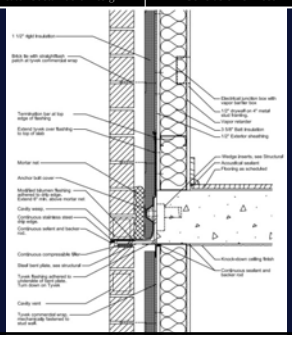



## Current Facade

- Palmetto Brick
- 1” Void Space
- 1 ½” Rigid Insulation
- ½” Exterior Sheathing
- Tyvek Wrap
- 3 5/8” Batt. Insulation
- 4” Metal Stud Framing
- ½” Drywall








## Current Facade

- Façade Coverage Area: 75,000 SF
  - Building 1: 62,000 SF
  - Building 2: 13,000 SF
- Palmetto Brick: 56,225 Bricks
  - Building 1: 41,600 Bricks
  - Building 2: 14,625 Bricks

## Current Facade

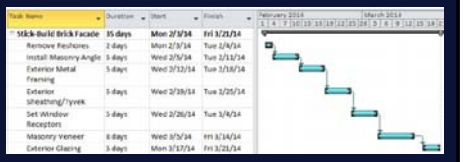
- Cost: $1,801,145.20

**Façade Cost Breakdown**

| Item | Floors | Cost/Floor | Total Cost |
|---|---|---|---|
| Building 1 Façade | 10 | $ 148,132.78 | $ 1,481,327.80 |
| Building 2 Façade | 6 | $ 53,302.98 | $ 319,917.40 |
| Total Cost | | | $ 1,801,145.20 |

Credit: Donohoe

- Schedule: 35 Days








## Prefabricated Facade

NITTERHOUSE CONCRETE PRODUCTS

Credit: Nitterhouse

**Panel Information**

| Type | Size | Quantity |
|---|---|---|
| A | 10' x 23' | 120 |
| B | 8' x 23' | 57 |
| C | 4' x 10' | 16 |
| D | 10' x 10' | 16 |
| E | 8' x 10' | 2 |
| F | 14' x 10' | 1 |
| G | 14' x 2' | 1 |
| H | 4' x 10' | 1 |
| I | 4' x 8' | 1 |
| J | 14' x 23' | 94 |
| Total | | 209 |

- 209 - 9" Insulated Panel w/ Thin Brick Veneer
  - 3" Concrete Inner Face
  - 2" Rigid Insulation
  - 4" Concrete Outer Face
  - Thin Brick

- Total Cost: $2,631,450
  - $35 /SF of Panel
  - 74,670 SF
  - Crane Cost: $18,000

- Total Duration: 15 Working Days
  - 15 Panels Erected/Day

## Prefabricated Facade

NITTERHOUSE CONCRETE PRODUCTS

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Panel Information

| Type | Size | Quantity |
|---|---|---|
| A | 10' x 23' | 120 |
| B | 3' x 23' | 17 |
| C | 4' x 10' | 14 |
| D | 10' x 10' | 15 |
| E | 8' x 10' | 2 |
| F | 14' x 10' | 1 |
| G | 14' x 3' | 1 |
| H | 6' x 10' | 1 |
| I | 4' x 8' | 2 |
| J | 14' x 23' | 36 |
| Total | | 209 |

- 209 - 9" Insulated Panel w/ Thin Brick Veneer
  - 3" Concrete Inner Face
  - 2" Rigid Insulation
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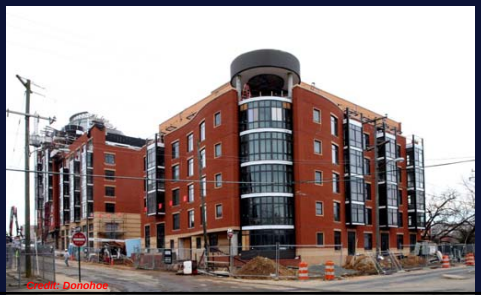
## Cost & Schedule Comparison

- Cost

**Stick-Built vs. Prefabricated Cost Estimate**

| | Cost |
|---|---|
| Stick-Built Façade | $ 1,801,145.20 |
| Prefabricated Facade | $ 2,631,450.00 |
| **Difference** | **$ 830,304.80** |



Credit: Donohoe

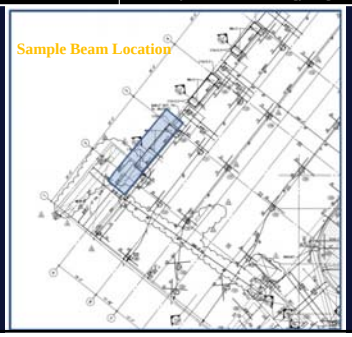
- Schedule

**Stick-Built vs. Prefabricated Schedule**

| | Duration (weeks) |
|---|---|
| Stick-Built Façade | 50 Weeks |
| Prefabricated Facade | 3 Weeks |
| **Difference** | **47 Weeks** |


# Structural Breadth



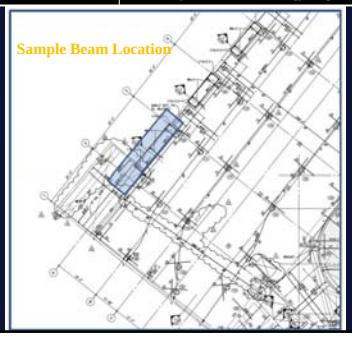




## Structural Breadth

| Beam Size | Length | Max Allowable Moment ($\varphi M_n$) | Max Allowable Deflection | Max Allowable Deflection due to Live Load |
|---|---|---|---|---|
| 16" x 30" | 26' | 212.6 k-ft | 1.3" | 0.866" |

- Maximum Allowable Moment ($\varphi M$)
  - $\varphi M_n = \varphi \left[ f_y A_s \left( d - \frac{a}{2} \right) \right] = 212.6\ k - ft.$
- Maximum Allowable Deflection
  - $\Delta_{TL\ max} = {}^{L}/_{240} = 1.3"$
- Maximum Deflection Due to Live Load
  - $\Delta_{LL\ max} = {}^{L}/_{360} = 0.866"$

- Original Façade
  - Dead Loads = 120 psf
  - Live Load = 60 psf
  - $w = 2.27\ klf$
  - $M_u = \frac{wL^2}{8} = 191.82\ k - ft.$
  - $\Delta_{TL} = \frac{5wL^4}{384EI} = 0.268"$
  - $\Delta_{LL} = \frac{5wL^4}{384EI} = 0.066"$




## Structural Breadth

| Beam Size | Length | Max Allowable Moment ($\varphi M_n$) | Max Allowable Deflection | Max Allowable Deflection due to Live Load |
|---|---|---|---|---|
| 16" x 30" | 26' | 212.6 k-ft | 1.3" | 0.866" |

- Maximum Allowable Moment ($\varphi M$)
  - $\varphi M_n = \varphi\left[f_y A_s\left(d - \frac{a}{2}\right)\right] = 212.6\ k - ft.$
- Maximum Allowable Deflection
  - $\Delta_{TL\ max} = {}^{L}/_{240} = 1.3"$
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- Original Façade
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  - $M_u = \frac{wL^2}{8} = 191.82\ k - ft.$
  - $\Delta_{TL} = \frac{5wL^4}{384EI} = 0.268"$
  - $\Delta_{LL} = \frac{5wL^4}{384EI} = 0.066"$

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## Structural Breadth

- Prefabricated Façade
  - Dead Loads = 153 psf
  - Live Load = 60 psf
  - $w = 1.61\ klf$
  - $P = 28.6\ kip\ (adds\ w = 0.37\ klf)$
  - $M_u = \frac{wL^2}{8} = 321.95\ k - ft.$
  - $\Delta_{TL} = \frac{5wL^4}{384EI} = 0.207"$
  - $\Delta_{LL} = \frac{5wL^4}{384EI} = 0.066"$

| Beam Size | Length | Max Allowable Moment ($\varphi M_n$) | Max Allowable Deflection | Max Allowable Deflection due to Live Load |
|---|---|---|---|---|
| 16" x 30" | 26' | 212.6 k-ft | 1.3" | 0.866" |

- Maximum Allowable Moment ($\varphi M$)
  - $\varphi M_n = \varphi\left[f_y A_s\left(d - \frac{a}{2}\right)\right] = 212.6\ k - ft.$
- Maximum Allowable Deflection
  - $\Delta_{TL\ max} = {}^{L}/_{240} = 1.3"$
- Maximum Deflection Due to Live Load
  - $\Delta_{LL\ max} = {}^{L}/_{360} = 0.866"$

| | Total Load w (klf) | Point Load (kip) | Total Moment $M_u$ (k-ft) | Total Deflection (in.) | Live Load Deflection (in.) |
|---|---|---|---|---|---|
| Original Façade | 2.27 | - | 191.82 | 0.268 | 0.066 |
| Prefabricated Façade | 1.98 | 28.6 | 321.95 | 0.207 | 0.066 |
| Increase/Decrease | 13% | - | 40% | 23% | - |

13% Decrease In Load

40% Increase in $M_u$

23% Decrease in $\Delta_{TL\ max}$

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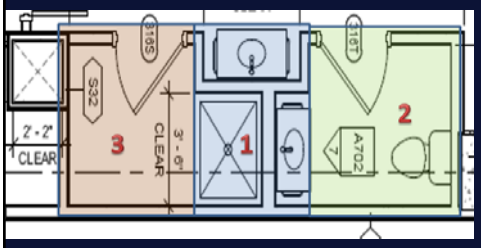


## Conclusion & Recommendation

- Positive
  - Duration Saved: 47 Weeks
  - Site Congested Cleared
- Negative
  - Cost Increase: $830,000
  - Structural Unsuitability

**Not Recommended!**




## Analysis 4:

## Greater Sustainable Design


Credit: LEED

## Analysis Background

- **Problem Identification:**
  - Minimum LEED Certification
  - Room For Improvement
- **Goals:**
  - Implement Greater Sustainable Strategies
  - Increase LEED Rating
  - Mechanical Breadth – Grey-Water Recapture


Credit: LEED

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Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


Credit: LEED

## Analysis Background

- **Problem Identification:**
  - Minimum LEED Certification
  - Room For Improvement
- **Goals:**
  - Implement Greater Sustainable Strategies
  - Increase LEED Rating
  - Mechanical Breadth – Grey-Water Recapture


Credit: LEED

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Credit: LEED

## LEED Certified

| | Points Earned | Possible Points |
|---|---|---|
| Sustainable Sites | 9 | 14 |
| Water Efficiency | 1 | 5 |
| Energy & Atmosphere | 1 | 17 |
| Materials & Resources | 4 | 13 |
| Indoor Environmental Quality | 8 | 15 |
| Innovation & Design | 5 | 5 |
| Total | 28 | 69 |

Credit: LEED





Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
| **Storm Water Collection** | **4** | **$200,000** | **70,000+ gal Harvested** |
| Grey Water Recapture | 1 | $1,497,577.41 | $34,081.70/yr. Utility Savings |
| Upgrade Core Lighting | 1 | Negligible | $5,112/yr. Utility Savings |
| Reduce Garage Lighting Power Density | - | Negligible | $14,912/yr. Utility Savings |
| Add Garage Occupancy Sensors | 1 | Negligible | $5,022/yr. Utility Savings |
| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| CO Monitoring | 1 | $10,000 | Life Safety |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |

| | # gal/sf for 1" rainfall | Avg. Yearly Rainfall | Net Roof Area (SF) | Yearly Gallons Harvested | Monthly Gallons Harvested |
|---|---|---|---|---|---|
| Building 1 | 0.625 | 42.05 | 25747 | 679,996.34 | 56,666.36 |
| Building 2 | 0.625 | 42.05 | 7884 | 207,201.36 | 17,266.78 |
| Total | | | | 860,581.79 | 71,715.15 |

Storm Water Cost Breakdown

| Item | QTY | Unit | Mat'l $/Unit | Mat'l Total | Labor $/Unit | Labor Total | Equip $/Unit | Equip Total | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| Rainmaster Fiberglass Tank | 3 | Ea. | $ 59,974.95 | $ 179,924.85 | $ 950.00 | $ 2,850.00 | $ - | $ - | $ 182,774.85 |
| 4" PVC Piping | 450 | LF | $ 0.58 | $ 261.00 | $ 2.82 | $ 1,269.00 | $ - | $ - | $ 1,530.00 |
| Crane Rental | 4 | hrs | $ - | $ - | $ - | $ - | $ 1,500.00 | $ 6,000.00 | $ 6,000.00 |
| Rainmaster Pump Station | 3 | Ea. | $ 3,490.95 | $ 10,490.85 | $ - | $ - | $ - | $ - | $ 10,490.85 |
| Filter | 3 | Ea. | $ 423.33 | $ 1,269.99 | $ - | $ - | $ - | $ - | $ 1,269.99 |
| Rainwater Guage | 3 | Ea. | $ 59.99 | $ 179.97 | $ - | $ - | $ - | $ - | $ 179.97 |
| Total Cost | | | | $ 192,135.66 | | $ 4,119.00 | | $ 6,000.00 | $ 202,254.66 |

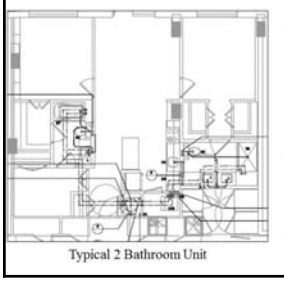

## Obtainable Credits

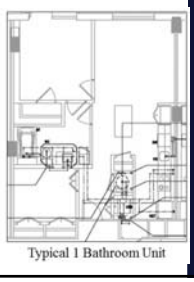
| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
| **Grey Water Recapture** | **1** | **$1,497,577.41** | **$34,081.70/yr. Utility Savings** |
| Upgrade Core Lighting | 1 | Negligible | $5,112/yr. Utility Savings |
| Reduce Garage Lighting Power Density | - | Negligible | $14,912/yr. Utility Savings |
| Add Garage Occupancy Sensors | 1 | Negligible | $5,022/yr. Utility Savings |
| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| CO Monitoring | 1 | $10,000 | Life Safety |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |

## Mechanical Breadth



Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


Typical 2 Bathroom Unit


Typical 1 Bathroom Unit

## Current Mechanical System

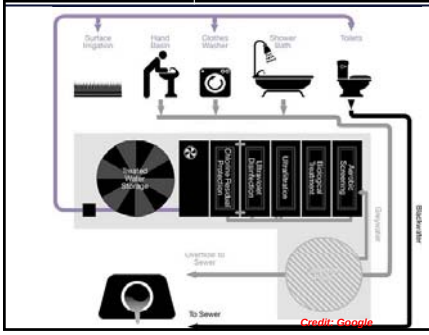
- Typical System
- 130- One Bathroom Units
- 30- Two Bathroom Units
- Total System Cost: $3,625,247.85

Total Gallons/Year: 2,702,752 gal.

| | GPM | Approx. Min/Use | Use/Day | Units | Gal./Day | Gal./Month | Gal./Year |
|---|---|---|---|---|---|---|---|
| Toilet | 1.28 | 5 | 2 | 160 | 204.8 | 6,229.33 | 74,752 |
| Shower | 1.8 | 10 | 2 | 160 | 5,760 | 175,200 | 2,102,400 |
| Faucet | 1.8 | 1 | 5 | 160 | 1,440 | 43,800 | 525,600 |
| Total | | | | | 7,404.8 | 225,229.33 | 2,702,752 |

Potential Savings: $34,081.70/yr.

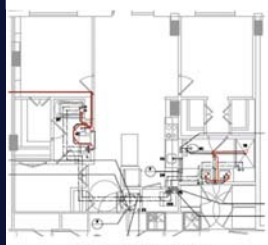
| | Rate per 1,000 Gal. | Gal./Month | Gal./Year | Monthly Savings | Yearly Savings |
|---|---|---|---|---|---|
| Water Supply | $ 3.98 | 225,229.33 | 2,702,752 | $ 896.41 | $ 10,756.9 |
| Sewage | $ 8.63 | | | $ 1,943.75 | $ 23,324.7 |
| Total Savings | | | | $ 2,840.16 | $ 34,081.7 |

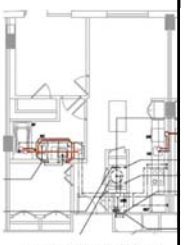


Credit: Google

## Grey Water Recapture System

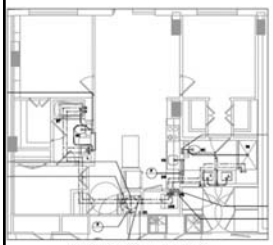
- Separates Waste Water from Grey Water
- Delivers Toilet, Shower and Faucet Water
- Filtration and Storage Tank

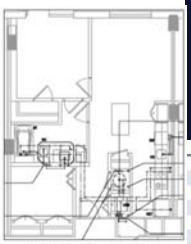


Typical 2 Bathroom Unit


Typical 1 Bathroom Unit

47




Typical 2 Bathroom Unit


Typical 1 Bathroom Unit

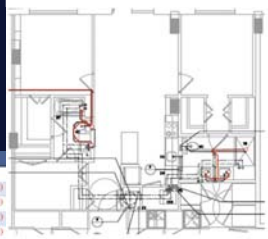
## System Comparison

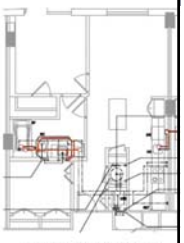
$1,497,577.41 Cost Increase

| | Total Cost |
|---|---|
| Original Mechanical System | $ 3,625,247.85 |
| New Mechanical System | $ 5,122,825.26 |

44 Year Payback Period

| | Costs | Utility Savings | |
|---|---|---|---|
| Initial Cost | ($ 1,497,577.41) | | |
| Year 1 | | $ 34,081.70 | ($ 1,464,695.72) |
| Year 10 | | $ 34,081.70 | ($ 1,224,923.81) |
| Year 20 | | $ 34,081.70 | ($ 815,943.41) |
| Year 30 | | $ 34,081.70 | ($ 475,126.41) |
| Year 40 | | $ 34,081.70 | ($ 202,472.81) |
| Year 44 | | $ 34,081.70 | $ 2,017.39 |
| Year 50 | | $ 34,081.70 | $ 206,507.59 |


Typical 2 Bathroom Unit


Typical 1 Bathroom Unit

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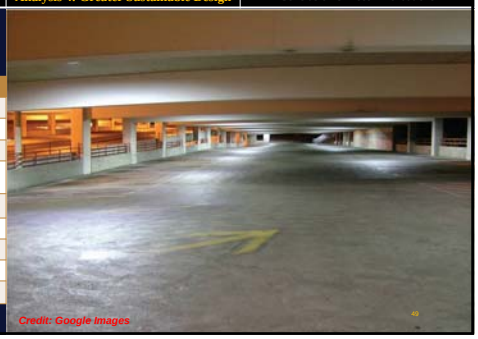
Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
| Grey Water Recapture | 1 | $1,497,577.41 | $34,081.70/yr. Utility Savings |
| **Upgrade Core Lighting** | **1** | **Negligible** | **$5,112/yr. Utility Savings** |
| Reduce Garage Lighting Power Density | - | Negligible | $14,912/yr. Utility Savings |
| Add Garage Occupancy Sensors | 1 | Negligible | $5,022/yr. Utility Savings |
| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| CO Monitoring | 1 | $10,000 | Life Safety |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |


Credit: Google Images

Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations

Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
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| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
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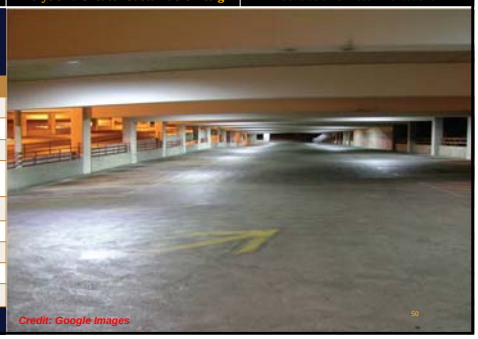
Credit: Google Images

Credit: LEED

## Obtainable Credits

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| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |


Credit: Google Images

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Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | **Analysis 4: Greater Sustainable Design** | Conclusion & Recommendations

Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
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| Add Garage Occupancy Sensors | 1 | Negligible | $5,022/yr. Utility Savings |
| **Tennant Sub-Metering** | **1** | **Negligible** | **Better Utility Monitoring** |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| CO Monitoring | 1 | $10,000 | Life Safety |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |


Credit: Google Images

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Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
| Grey Water Recapture | 1 | $1,497,577.41 | $34,081.70/yr. Utility Savings |
| Upgrade Core Lighting | 1 | Negligible | $5,112/yr. Utility Savings |
| Reduce Garage Lighting Power Density | - | Negligible | $14,912/yr. Utility Savings |
| Add Garage Occupancy Sensors | 1 | Negligible | $5,022/yr. Utility Savings |
| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| **Green Power** | **1** | **$127.60/mnth** | **Sustainable Power Supply** |
| CO Monitoring | 1 | $10,000 | Life Safety |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |


Credit: Dominion






Credit: LEED

## Obtainable Credits

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|---|---|---|---|
| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
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| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| **CO Monitoring** | **1** | **$10,000** | **Life Safety** |
| Thermal Comfort Survey | 1 | Negligible | Occupant Satisfaction |


Credit: Google Images

Credit: LEED

## Obtainable Credits

| Strategy | Pts. | Cost | Additional Benefit |
|---|---|---|---|
| Storm Water Collection | 4 | $200,000 | 70,000+ gal Harvested |
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| Tennant Sub-Metering | 1 | Negligible | Better Utility Monitoring |
| Green Power | 1 | $127.60/mnth | Sustainable Power Supply |
| CO Monitoring | 1 | $10,000 | Life Safety |
| **Thermal Comfort Survey** | **1** | **Negligible** | **Occupant Satisfaction** |

- Verifies Location in Building
- Temperature Comfort
- Air Quality Comfort

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Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | **Analysis 4: Greater Sustainable Design** | Conclusion & Recommendations

Credit: LEED

## LEED Gold

| | Old Score | New Score | Possible Points |
|---|---|---|---|
| Sustainable Sites | 9 | 11 | 14 |
| Water Efficiency | 1 | 3 | 5 |
| Energy & Atmosphere | 1 | 5 | 17 |
| Materials & Resources | 4 | 4 | 13 |
| Indoor Environmental Quality | 8 | 10 | 15 |
| Innovation & Design | 5 | 5 | 5 |
| Total | 28 | 39 | 69 |

**LEED Re-Evaluation**

Credit: LEED

56

Credit: LEED

## Conclusion & Recommendation

### Recommended!

- Storm Water Collection
- Upgrade Core Lighting
- Reduce Garage Power Distribution
- Tennant Sub-Metering
- Dominion Virginia Green Power
- Carbon Monoxide Monitoring
- Thermal Comfort Survey

### Not Recommended!

- Grey Water Recapture System









## Conclusion & Recommendation

- Analysis 1 – Mobile Technology Integration
  - 3 Week Payback Period
  - $210,912.00 Cost Savings
  - Valuable Knowledge

Recommended!

- Analysis 2 – Bathroom Modularization
  - 55 Day Schedule Acceleration
  - Minimal Cost Increase
  - Site Congestion Cleared

Recommended!

- Analysis 3 – Façade Prefabrication
  - 47 Week Schedule Acceleration
  - $830,000 Cost Increase
  - Structural Unsuitability

Not Recommended!

- Analysis 4 – Greater Sustainable Design
  - LEED Gold Rating
  - No Grey Water Recapture

Recommended!



## Conclusion & Recommendation

- Analysis 1 – Mobile Technology Integration
  - 3 Week Payback Period
  - $210,912.00 Cost Savings
  - Valuable Knowledge

✓ Recommended!

- Analysis 2 – Bathroom Modularization
  - 55 Day Schedule Acceleration
  - Minimal Cost Increase
  - Site Congestion Cleared

✓ Recommended!

- Analysis 3 – Façade Prefabrication
  - 47 Week Schedule Acceleration
  - $830,000 Cost Increase
  - Structural Unsuitability

✗ Not Recommended!

- Analysis 4 – Greater Sustainable Design
  - LEED Gold Rating
  - No Grey Water Recapture

✓ Recommended!

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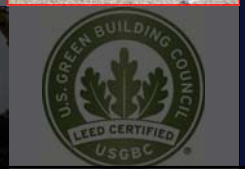
Project Introduction | Analysis 1: Mobile Technology Integration | Analysis 2: Bathroom Modularization | Analysis 3: Façade Prefabrication | Analysis 4: Greater Sustainable Design | Conclusion & Recommendations


## Conclusion & Recommendation

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  - 3 Week Payback Period
  - $210,912.00 Cost Savings
  - Valuable Knowledge

✓ Recommended!

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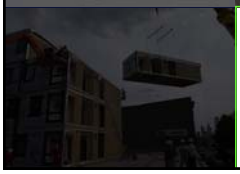
✗ Not Recommended!

- Analysis 4 – Greater Sustainable Design
  - LEED Gold Rating
  - No Grey Water Recapture

✓ Recommended!

60


## Conclusion & Recommendation

- Analysis 1 – Mobile Technology Integration
  - 3 Week Payback Period
  - $210,912.00 Cost Savings
  - Valuable Knowledge

✓ Recommended!

- Analysis 2 – Bathroom Modularization
  - 55 Day Schedule Acceleration
  - Minimal Cost Increase
  - Site Congestion Cleared

✓ Recommended!

- Analysis 3 – Façade Prefabrication
  - 47 Week Schedule Acceleration
  - $830,000 Cost Increase
  - Structural Unsuitability

✗ Not Recommended!

- Analysis 4 – Greater Sustainable Design
  - LEED Gold Rating
  - No Grey Water Recapture

✓ Recommended!

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## Thank You

## Questions?

### Acknowledgments

Donohoe Construction Company
*Ryanc Sullivan, Project Engineer*
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SK&A Engineers

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Friends & Family

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