2015

Associated School of Construction National Problem Statement: Sustainable Building & LEED

Brandon Jones
Montana Tech of the University of Montana

Avery Hor
Montana Tech of the University of Montana

Avery Smith
Montana Tech of the University of Montana

Joshua Klocke
Montana Tech of the University of Montana

Cody Wickham
Montana Tech of the University of Montana

See next page for additional authors

Authors
Brandon Jones, Avery Hor, Avery Smith, Joshua Klocke, Cody Wickham, and Houston Blevins

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Prepared by

Brandon Jones

Avery Hor

Avery Smith

Joshua Klocke

Kody Wickham

Houston Blevins

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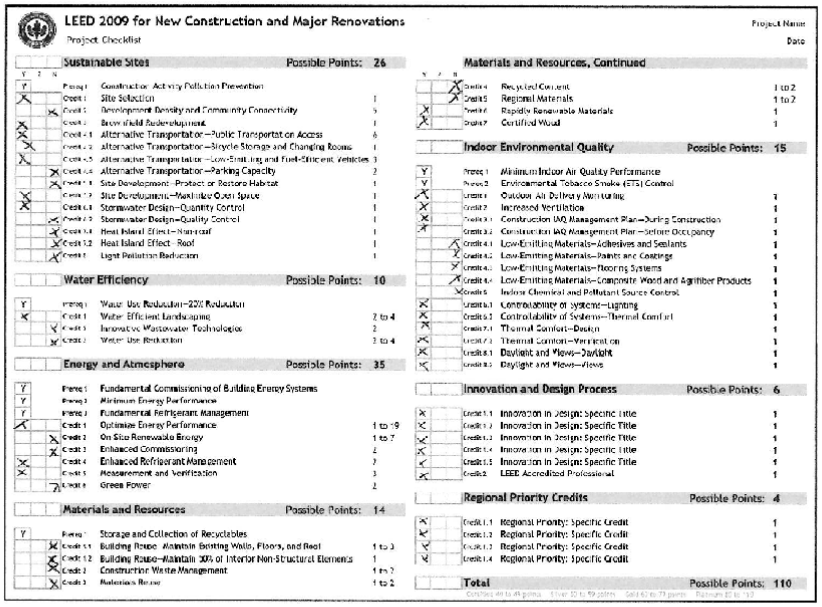
Problem Statement 1:

Part 1: Overall Project Review



LEED 2009 for New Construction and Major Renovations
Project Checklist

Project Name
Date

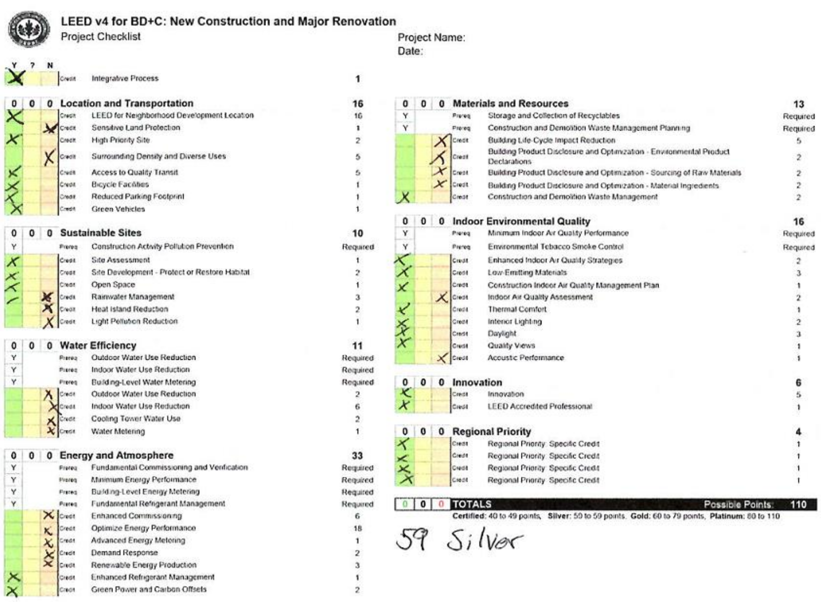
Y	?	N		Sustainable Sites	Possible Points: 26
Y			Prereq 1	Construction Activity Pollution Prevention	
X			Credit 1	Site Selection	1
		X	Credit 2	Development Density and Community Connectivity	5
X			Credit 3	Brownfield Redevelopment	1
X			Credit 4.1	Alternative Transportation—Public Transportation Access	6
X			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
X			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
		X	Credit 4.4	Alternative Transportation—Parking Capacity	2
		X	Credit 5.1	Site Development—Protect or Restore Habitat	1
X			Credit 5.2	Site Development—Maximize Open Space	1
X			Credit 6.1	Stormwater Design—Quantity Control	1
		X	Credit 6.2	Stormwater Design—Quality Control	1
		X	Credit 7.1	Heat Island Effect—Non-roof	1
		X	Credit 7.2	Heat Island Effect—Roof	1
		X	Credit 8	Light Pollution Reduction	1
				Water Efficiency	**Possible Points: 10**
Y			Prereq 1	Water Use Reduction—20% Reduction	
X			Credit 1	Water Efficient Landscaping	2 to 4
		X	Credit 2	Innovative Wastewater Technologies	2
		X	Credit 3	Water Use Reduction	2 to 4
				Energy and Atmosphere	**Possible Points: 35**
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
X			Credit 1	Optimize Energy Performance	1 to 19
		X	Credit 2	On-Site Renewable Energy	1 to 7
		X	Credit 3	Enhanced Commissioning	2
X			Credit 4	Enhanced Refrigerant Management	2
X			Credit 5	Measurement and Verification	3
		X	Credit 6	Green Power	2
				Materials and Resources	**Possible Points: 14**
Y			Prereq 1	Storage and Collection of Recyclables	
		X	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
		X	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
		X	Credit 2	Construction Waste Management	1 to 2
		X	Credit 3	Materials Reuse	1 to 2

Y	?	N		Materials and Resources, Continued	
		X	Credit 4	Recycled Content	1 to 2
		X	Credit 5	Regional Materials	1 to 2
X			Credit 6	Rapidly Renewable Materials	1
X			Credit 7	Certified Wood	1
				Indoor Environmental Quality	**Possible Points: 15**
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
X			Credit 1	Outdoor Air Delivery Monitoring	1
X			Credit 2	Increased Ventilation	1
X			Credit 3.1	Construction IAQ Management Plan—During Construction	1
X			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
		X	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
		X	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
		X	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
		X	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
		X	Credit 5	Indoor Chemical and Pollutant Source Control	1
X			Credit 6.1	Controllability of Systems—Lighting	1
X			Credit 6.2	Controllability of Systems—Thermal Comfort	1
X			Credit 7.1	Thermal Comfort—Design	1
X			Credit 7.2	Thermal Comfort—Verification	1
X			Credit 8.1	Daylight and Views—Daylight	1
X			Credit 8.2	Daylight and Views—Views	1
				Innovation and Design Process	**Possible Points: 6**
X			Credit 1.1	Innovation in Design: Specific Title	1
X			Credit 1.2	Innovation in Design: Specific Title	1
X			Credit 1.3	Innovation in Design: Specific Title	1
X			Credit 1.4	Innovation in Design: Specific Title	1
X			Credit 1.5	Innovation in Design: Specific Title	1
X			Credit 2	LEED Accredited Professional	1
				Regional Priority Credits	**Possible Points: 4**
X			Credit 1.1	Regional Priority: Specific Credit	1
X			Credit 1.2	Regional Priority: Specific Credit	1
X			Credit 1.3	Regional Priority: Specific Credit	1
X			Credit 1.4	Regional Priority: Specific Credit	1
				Total	**Possible Points: 110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

57 pts Silver

Figure 1 LEEDS Version 3



LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Project Name:
Date:

Y	?	N			
X			Credit	Integrative Process	1
0	0	0		**Location and Transportation**	**16**
X			Credit	LEED for Neighborhood Development Location	16
		X	Credit	Sensitive Land Protection	1
X			Credit	High Priority Site	2
		X	Credit	Surrounding Density and Diverse Uses	5
X			Credit	Access to Quality Transit	5
X			Credit	Bicycle Facilities	1
X			Credit	Reduced Parking Footprint	1
X			Credit	Green Vehicles	1
0	0	0		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
X			Credit	Site Assessment	1
X			Credit	Site Development - Protect or Restore Habitat	2
X			Credit	Open Space	1
		X	Credit	Rainwater Management	3
		X	Credit	Heat Island Reduction	2
		X	Credit	Light Pollution Reduction	1
0	0	0		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
		X	Credit	Outdoor Water Use Reduction	2
		X	Credit	Indoor Water Use Reduction	6
		X	Credit	Cooling Tower Water Use	2
		X	Credit	Water Metering	1
0	0	0		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
		X	Credit	Enhanced Commissioning	6
		X	Credit	Optimize Energy Performance	18
		X	Credit	Advanced Energy Metering	1
		X	Credit	Demand Response	2
		X	Credit	Renewable Energy Production	3
X			Credit	Enhanced Refrigerant Management	1
X			Credit	Green Power and Carbon Offsets	2

Y	?	N			
0	0	0		**Materials and Resources**	**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
		X	Credit	Building Life-Cycle Impact Reduction	5
		X	Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
		X	Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
		X	Credit	Building Product Disclosure and Optimization - Material Ingredients	2
X			Credit	Construction and Demolition Waste Management	2
0	0	0		**Indoor Environmental Quality**	**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
X			Credit	Enhanced Indoor Air Quality Strategies	2
X			Credit	Low-Emitting Materials	3
X			Credit	Construction Indoor Air Quality Management Plan	1
		X	Credit	Indoor Air Quality Assessment	2
X			Credit	Thermal Comfort	1
X			Credit	Interior Lighting	2
X			Credit	Daylight	3
X			Credit	Quality Views	1
		X	Credit	Acoustic Performance	1
0	0	0		**Innovation**	**6**
X			Credit	Innovation	5
X			Credit	LEED Accredited Professional	1
0	0	0		**Regional Priority**	**4**
X			Credit	Regional Priority: Specific Credit	1
X			Credit	Regional Priority: Specific Credit	1
X			Credit	Regional Priority: Specific Credit	1
X			Credit	Regional Priority: Specific Credit	1
0	0	0		**TOTALS**	**Possible Points: 110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

59 Silver

Figure 2 LEEDS Version 4

Part 2: Materials Category

With regards to LEED Version 4, it differs in many different ways to Version 3.

Version 3

Storage and Collection of Recyclables

The first credit graded by both systems is a prerequisite to the rest of the Materials category. This credit's prime concern is properly classifying and disposing of waste. It's important to classify the waste types. This takes the type of facility being studied under close observation. Depending on the type of facility, storage of that particular kind of waste will command different sizes of spacing. This credit differs from version 3 to version 4 with which materials require dedicated storage. These materials include: mercury-containing lamps, batteries, and e-waste. Teams must choose 2 of those 3 to commit specific storage. Documentation of Version 4 require: (1) verification of recycled material types, (2) narrative describing recycling storage and collection areas, (3) floor plans indicating recycling storage and collection areas, (4) and methodology and results of waste stream study.

Building Reuse (1 to 4 pts)

Version 3's next credit is worth 1 to 4 points depending on how favorably it is scored. This credit is labeled 'Building Reuse' and is broken down into two parts. They are labeled Credit 1.1 and Credit 1.2. This credit's purpose I to preserve cultural resources, reduce waste and any environmental impacts. High scores are associated with reusing older buildings, this can maintain a link with future and past neighborhoods. This can be calculated in a percentage by the formula: (Percentage Existing Elements = Area (sf) of All Retained Interior Nonstructural Elements/ Total Area (sf) of Interior Nonstructural Elements x 100.) This value must be greater than or equal to 50% in order to earn points.

Construction Waste Management (1 to 2 pts)

Construction Waste Management is related to conserving space in landfills and reusing materials whenever possible. Projects often are separated on site or are sent to an off-site sorting facility. Calculations are derived on the amount of waste that is diverted from the landfill compared with the total amount of waste that was generated on-site. This ratio is often organized by a graph. Documentation includes keeping summary log of all construction waste generated, these are further separated by type and quantity. Documentation should also include plans for diversion goals and protocols.

Materials Reuse (1 to 2 pts)

Reusing salvaged materials extends the life of materials and reduces overall costs. In order to qualify for this category, materials must not be serving their original function and have been reassigned to a new function. If money is saved then use the recycled materials. Percentage of reused materials is equal to (cost of reused material/ total materials cost x 100.) This is documented by being tabulated in a log and compared to the new price of materials.

Recycled Content (1 to 2 pts)

This credit is implemented by establishing goals for recycled content during the design phase and including them in the project specifications. Materials are reused by reworking, regrinding, or scrapping material. It is documented by (1) recording costs, percentage postconsumer content, percentage pre consumer content, manufacturer's names and products names. (2) Collecting manufacturer's letters or cut sheets to document the products' content. (3) Maintaining a list of actual materials costs, excluding equipment and labor.

Regional Materials (1 to 2 pts)

Using regional materials reduces pollution from transportation activities, it conserves fossil fuels and other finite resources. This can sometime require careful research of available local resources. This is documented by: (1) Compiling a list of products that were purchased or found locally. (2) Recording manufacturer's names, distances between the project and manufacturer, and distances between the project and extraction site. (3) Retaining cut sheets that document materials that were originated within a 500-mile radius of the project site. (4) Maintain a list of material costs, excluding labor and equipment.

Rapidly Renewable Materials (1 pt)

Rapidly renewable resources tend to have faster payback because they can be harvested more quickly. Goals for the use of these materials should be implemented early on in the design process. Proper documentation includes: (1) Compiling a list of rapidly renewable product purchases. (2) Record materials costs, manufacturer's names, percentage of each product that is renewable (by weight). (3) Retain cut sheets to document rapidly renewable criteria. (4) Maintain a list of actual materials costs, excluding labor and equipment.

Certified Wood (1 pt)

Using certified wood can cut back on irresponsible forest practices. Research should be conducted to find wood species that are most readily available from well managed forests. Documentation includes: (1) Track certified wood purchases and retain associated COC documentation. (2) Collect copies of vendor invoices for each certified wood product. (3) Maintain a list that identifies the percentage of certified wood in each purchase.

Version 4

Construction and Demolition Waste Management Planning

Version 4's next credit is a prerequisite and is labeled 'Construction and Demolition Waste Management Planning.' This credit's purpose is to reduce the amount of construction waste that end up at landfills. Alternatives include reusing, recovering, and recycling available materials. The first steps to achieve this credit are identifying at least 5 materials that can be diverted from the landfill. The second step is to look at any on-site and off-site possibilities of waste collection and sorting. Consider re-sale, on-site reuse, or donation as options. Also consider incineration or sending materials to a sorting facility. Documentation for version 4 should include (1) Construction waste management plan. (2) Total construction waste.

Building Life-Cycle Impact Reduction (5 pts)

To obtain this credit the project must demonstrate reduced environmental effects during initial project decision-making, they should do this by reducing material use through life-cycle assessment, or reusing existing buildings. Proper documentation and calculations have 5 options, depending on the type of project. These documentations can possibly include: (1) Documentation of historic designation status. (2) Narrative describing demolition. (3) Documentation of how additions and alterations meet local review board requirements. (4) Narrative describing abandoned or blighted status. (5) Reused elements table and calculations. (6) Description of LCA assumptions, scope, and analysis process for baseline building and proposed building. (7) Life-cycle impact summary showing outputs of proposed building with percentage change from baseline building for all impact indicators.

Building Product Disclosure and Optimization – Environmental Product Declarations (2 pts)

This credit encourages materials that have desirable life-cycle and environmental impacts. There was no credit for this optimization in version 3. Required documentation requires: (1) MR building product disclosure and optimization calculator or equivalent tracking tool. (2) EPD and LCA reports or compliant summary documents for 100% of products contributing toward credit. (3) Documentation of compliance with USGBC-approved program.

Building Product Disclosure and Optimization – Sourcing of Raw Materials (2 pts)

Sourcing of raw materials encourages the extrication or acquiring of materials in a responsible manner. The 500 mile requirement in version 3 has been decreased to 100 miles. Also, materials that were reused on-site are no longer required to be repurposed. This is documented by: (1) MR building product disclosure and optimization calculator or equivalent tracking tool. (2) Corporate sustainability reports for 100% of products contributing toward credit. (3) Documentation of product claims for credit requirements.

Building Product Disclosure and Optimization – Material Ingredients (2 pts)

This credit's purpose is to reward teams for using materials with the smallest amount of harmful substances as possible. Material ingredients was not a version 3 credit. Documentation includes: (1) MR building product disclosure and optimization calculator or equivalent tracking tool. (2) Documentation of chemical inventory through Health Product Declaration, Cradle to Cradle certification labels, manufacturers' lists of ingredients with Green Screen assessment reports for confidential ingredients, or USGBC-approved programs. (3) Verification of ingredient optimization through Cradle to Cradle certification labels, manufacturers' lists of ingredients with Green Screen Benchmark or LT scores listed for all ingredients, or manufacturers' declaration. (4) Documentation of supply chain optimization.

Construction and Demolition Waste Management (2 pts)

Waste management's purpose is to recover, or recycle all available materials. Changes from version 3 include: (1) a compliance option has been added for total project waste reduction per gross floor area. (2) More than one material stream diverted to waste in order to earn credit. (3) ADC has been excluded from calculations. (4) If meeting European Union requirements, waste-to-energy may count as a diversion method. Proper documentation includes: (1) MR Construction and Demolition Waste Management calculator or equivalent tool, tracking total and diverted waste amounts and material streams. (2) Documentation of recycling rates for commingled facilities. (3) Justification narrative for use of waste-to-energy strategy. (4) Documentation of waste-to-energy facilities adhering to relevant EN standards. (5) Total waste per area.

Part 3: Recommendation of Rating System

Montana Tech recommends that the LEED version 4 is used when assessing this project. Due to the above comparison of the two versions, we believe that this would be the more suitable version. Our rationalizations are based on the fact that this is a new construction and that more points could be earned using version 4. Version 4 seems to be the more flexible resource, and the reference manual is much easier to follow. After our evaluation, this project earned 59 points, being LEED silver level.

Problem Statement 2: Life Cycle Sustainability Analysis- Lighting

Part 1

A complete analysis of a ten year life cycle was conducted based on two options for lighting at the Colorado-4th Street light rail station. The first step to this process is to calculate the annual energy usage of each option. In order to do this, the watt usage for each specific fixture was determined by the fixture dimensions and lengths. Based on the provided lighting cut sheets, the following watt usages were determined for both the X-6A thru X-6C fixtures as well as the alternative LED fixtures.

Table 1: Watt Usage of X-Series fixtures vs. LED Alternatives

Fixtures	Watt Usage	Alternative fixtures	Watt Usage
X-6A	25 W	LED alternative	17.7 W
X-6B	32 W	LED alternative	23.63 W
X-6C	40 W	LED alternative	29.5 W

In order to calculate the number of fixtures required for the station lighting, drawings A-S7-101 and A-S7-301 were referenced to find the length required of each fixture. The numbers of lengths required were calculated using the following equation:

$$Lengths = 36.667ft\left(\frac{12\ inches}{1\ ft}\right)\left(\frac{1\ fixture}{38\ inches}\right)$$

Once the required number of each figure is reached, finding the product of the number of fixtures, watt usage per day, and days in a year reaches the following comparable results between the X series fixtures and their LED alternatives.

Table 2: Kilowatt hour usage per year for both lighting options.

Fixtures	Watt Usage (kWh/yr.)	Alternative fixtures	Watt Usage (kWh/yr.)
X-6A	2622.6	LED alternative	1856.8
X-6B	18742.8	LED alternative	13840.4
X-6C	3496.8	LED alternative	2578.9

Based on the results, the LED alternative fixtures are much more efficient compared to the counterpart fixtures.

Part 2

Three competing subcontractors submit costs for each option of lighting which included; supply and installation costs of fixture types X-6A thru X-6C and their alternative LED fixtures, replacement costs per fixture, overhead, profit, construction fees, design fees and warranty life times. A total present day worth was calculated for each company's bid on the specific fixtures and the alternative fixtures, which can be found in appendix 1. Once the overall cost is calculated the complete life-cycle analysis over a ten year cycle can be calculated using the following equations

$$LC = FC + FC\left(\frac{P}{A}, i, n\right)$$

With LC being the life-cycle, FC being the first cost or the annual cost, and (P/Amin) being a constant found in a compound interest factor table for the assumed interest rate. P/A is the present value given an annual value, I is the assumed interest rate of 9%, and n is the life cycle of ten years. Filling in the values for each variable, the following is calculated for each option bid.

$$LC = \$40{,}699.14 + \$40{,}699.14(5.9952)$$

Each compound interest rate constant is different based on the warranty of each bid. With each bid, each fixture will receive maintenance once annually; however maintenance fees are incurred once the warranty has expired. Based on calculations for each bid, the following costs and life-cycle values were reached.

Table 3: Annual Costs and Life-Cycle Analysis

Bidding Company	Foy Group	McKinstry	Cochran
Specified Fixtures			
Annual Cost	$40,699.14	$36,918.75	$45,175.03
Life-Cycle	$284,698.62	$222,730.82	$335,094.82
Alternative			
Annual Cost	$56,269.36	$49,395.00	$63,301.44
Life-Cycle	$393,615.21	$298,000.04	$469,551.09

Based on these results, the best subcontractor for this job can be selected.

Part 3

The right contractor for this job is chosen for a number of reasons. Cost is the largest component; however, another important component is the warranty lifetime. Best on these criteria, the best subcontractor for this project would be awarded to McKinstry. With the lowest life cycle costs as well as a three year warranty, this bid stands out as the most productive for the sustainability this effort is trying to achieve.

Part 4

With the newest technology available, efficiency is absolutely achievable and there are many incentives and credits that make the switch worth the effort. One example is rebates available for each kilowatt hour of energy saved. For the advanced technology of the LED alternative fixtures, each kilowatt hour saved can rebate up to $0.20/kWh. Other financial benefits are available for sustainable projects such as assistance in financing, and tax deductions and credits.

Part 5

Based on the total cost analysis and the life-cycle analysis combined, the best fixture choice is the LED alternative fixtures installed through McKinstry. This option is the most feasible because of both the kilowatt usage that is sustained as well as the savings in energy and money will make a huge difference throughout the lifetime of these fixtures.

Problem Statement #3: Concrete Carbon Footprint

The intent of problem number 3 was to analyze the carbon footprint caused by the concrete used in the construction of the 4th Street Station as a part of phase two of the Exposition Line that will eventually travel from Culver City to Santa Monica. In addition to the sourcing of the ready mix concrete materials and transportation of the ready mix concrete the carbon footprint caused by the commuting concrete pour crew was analyzed.

The first step into the analysis was to determine the volume of concrete that would be used in the construction of the 4th Street Station. This was done by breaking down each individual portion of the station that required concrete and adding the quantities together. A visual of this concrete take off can be seen in the table below.

Table 4: Concrete Takeoff

Item	Strength (psi)	Volume (CY)
Platform Footings		
East	4000	92.920
West	4000	92.920
Platform Walls		
East	4000	70.780
West	4000	70.780
Sidewalk Footings		
East	4000	5.440
West	4000	5.440
Sidewalk Walls		
East	4000	10.080
Walls	4000	10.080
SOG/Mat Footings		
East	4000	14.290
West	4000	11.690
TC & C		
TC & C Footings	4000	20.150
TC & C Walls	4000	27.000
TOC Building		
Mat Foundation	4000	74.000
Building Walls	4000	17.340
Cistern		
Footing	4000	1.284
Walls	4000	27.444
SOG	4000	13.370
Top Slab	4000	13.370
Sub Total		578.378
7% Extra		40.486
Total		618.864

The table above shows the answer to part 1 question 1 and states that the required quantity of concrete for the 4th Street Station is 618.864 cubic yards of 4000 psi concrete with a maximum aggregate size of one inch.

The second question under part 2 required a total price for all the concrete to be used on the 4th Street Station. There was information for 3 suppliers and the least expensive supplier was to be chosen. Tables XX through xx in appendices XX illustrate the cost breakdowns for the three given suppliers, White Castle Concrete, Slip Diamond Ready Mix, and City Park Concrete. White Castle would cost $49,976.67 to go with, Slip Diamond would cost $51,995.73 to use, and City Park Concrete carries a cost of $43,234.26. This makes City Park Concrete the least expensive supplier to use.

In part 3 question number 3 the team was asked to analyze the carbon footprint each supplier causes when sourcing the materials needed to create the ready mix concrete as well as when delivering the concrete to the site. By using the following equation it was possible to determine the carbon footprint, in tons, each supplier caused.

$$Carbon\ Footprint = (\#\ trips)(distance\ travelled)(2)\left(\frac{1}{mileage}\right)(constant)$$

Where:

$$Carbon\ Footprint = CO2\ produced\ (tons)$$

$$Constant = \frac{carbon\ produced\ (tons)}{fuel\ consumed\ (gallons)}$$

$$Distance\ Travelled = miles$$

A constant of 0.0119 $ton/gallon$ was used for diesel burning trucks and an average mileage of 3.5 miles per gallon was used. These values were taken from the EPA website. It should be noted that for City Park Concrete the West L.A. batch plant was chosen since it was closest to the construction site. It should also be noted that the fly ash for Slip Diamond Ready Mix were sourced from Joseph City Arizona since the estimate said SRMG/JoCity. The results from this calculation seen White Castle Concrete have the lowest footprint at 10.37 tons followed by City Park Concrete at 16.6 tons and finally Slip Diamond ready mix at 53.25 tons.

After calculating each company's carbon footprint a cost of $40/ton was assessed to each supplier and again the total cost of all the concrete was calculated. The resulting figures show that White Castle Concrete had to pay an extra $4414.61 bringing their total cost up to $45,025.72. Slip Diamond Ready Mix added $2,130.06 to their total cost bringing the total to $51,935.78 and finial City Park Concrete added $646.59 to their cost making their final cost $43,234.25. This again makes City Park Concrete the least expensive supplier to use.

An illustration of the previous calculations can be seen in the following table.

Table 5: Supplier Cost Including Carbon Footprint

White Castle			
Material	**Quantity (Trucks)**	**Distance (Miles)**	**Carbon Footprint (Ton)**
Cement	8	0	0.00
Fly Ash	2	48	0.61
Fine Aggregate	15	21	2.01
Course Aggregate	22	21	2.95
Ready Mix Concrete	68	11	4.78
Total			10.37
Previous Cost			$44,976.67
Carbon Cost			$414.61
Total Cost			$45,391.28
Slip Diamond			
Cement	8	35	1.79
Fly Ash	2	514	6.57
Fine Aggregate	15	96	9.21
Course Aggregate	22	96	13.50
Ready Mix Concrete	68	51	22.18
Total			53.25
Previous Cost			$51,995.73
Carbon Cost			$2,130.06
Total Cost			$54,125.79
City Park			
Cement	8	48	2.46
Fly Ash	2	48	0.61
Fine Aggregate	15	48	4.60
Course Aggregate	22	48	6.75
Ready Mix Concrete	68	4	1.74
Total			16.16
Previous Cost			$43,234.26
Carbon Cost			$646.50
Total Cost			$43,880.76

Part 2 of problem statement three had the team analyze the carbon footprint differences between using local or out of town labor. The labor crew for the project consisted 7 workers responsible for doing 11 concrete placements each taking 1-day. 3 of the workers reside in Riverside, which is 90 miles away. 2 more workers reside in Los Angeles and are 16 miles from site while the final two workers are 93 miles away in Oceanside. The same equation that was used for the suppliers was used for the workers with the only difference being that it was assumed their vehicles get a mileage of 20 miles per gallon and the constant used was 0.00982 tons of carbon/gallon of gas. For question 1 of part 2 it was determined that each worker driving their own vehicle accounted for 2.3111 tons being produced. The second question asked what the reduction carbon footprint would be if each worker was sourced locally and lived 15 miles from the construction site. The calculations for this concluded that sourcing the labor locally would result in a footprint of 0.567 tons of carbon, which is a reduction of 1.744 tons. Finally the third part of the question suggested that the commuting workers carpooling. The total carbon footprint if only one vehicle from Riverside and Oceanside were on the road was 1.053 tons. This is a reduction of 1.254 tons of carbon. The following table shows the above results for carbon footprint left by each situation.

Table 6: Labor Carbon Footprint

Part 1		
# Vehicles	Distance	Carbon Footprint
2	16	0.173
3	70	1.134
2	93	1.005
Total		2.312
Part 2		
7	15	0.567
Total		0.567
Difference		1.745
Part 3		
2	16	0.173
1	70	0.378
1	93	0.502
Total		1.053
Difference		1.258

It can be seen above that either sourcing labor locally or getting travelling workers to carpool will significantly reduce the C02 produced.

After analyzing problem number 3 a couple conclusions can be made. First off from the group's analysis the White Castle Concrete Company was the least expensive supplier to use when the carbon footprint was not included as well as when it was included. Secondly it can be concluded that sourcing labor locally or getting workers to carpool to and from work significantly reduces the carbon footprint left.

Problem Statement 4: Water Collection and Usage

The Project Team intends to capture rainwater from the platform, track, and plaza areas and store it in a cistern to be used to irrigate the landscaping areas at the 4th St. Station.

Part 1: Irrigation Consumption

1. Estimated total water usage by month for the fourth street station based on the station landscaping.
   a. *Assumptions:*
      i. The Landscape Coefficient Method/Landscape Evapotranspiration (ET_L) Formula was used to estimate irrigation needs for the landscaped areas: $ET_L = K_L * ET_o$
      ii. A landscape/plant coefficient (K_L) of 0.5 was assumed for all landscaped areas.
      iii. The daily reference evapotranspiration (ET_o) rates for Santa Monica, CA can be found in Table 1 and were used for estimating irrigation requirements for each month.
      iv. The value of ET_L is *not* the total water applied to the landscape, as the efficiency of the irrigation system needs to be factored in to calculations in order to obtain the Total Water Applied (***T.W.A***.).
      v. Irrigation system efficiency (***I.E.***) was assumed to be much lower (50%) during the first year after construction because "New Planting" significantly decreases efficiency due to undeveloped root balls and ground cover at this stage of growth.
      vi. The combination of bubbler/drip systems and overhead spray systems increases the efficiency of the system during the 1st year of irrigation while root balls and ground cover are spreading out and establishing themselves.
      vii. An ***I.E.*** of 80% was assumed for any period after the first year of irrigation. At this stage, the root balls have established themselves into the adjacent soils and plant/ground cover has increased to help capture more of the irrigation water. Losses due to runoff, wind, evaporation, and percolation are accounted for here.
      viii. The formula used for estimating Total Water Applied (inches) is: $T.W.A. = ET_L / I.E.$ The values on a per month basis for year 1 and any years after year 1 can be found in Table 2.
      ix. An assumed value of 0.62 gallons per square-foot-inch was used to convert inches of water to gallons of water applied per month. The landscaped area was estimated at **7,933 ft^2**; this value was then multiplied by the conversion factor listed above as well as the inches of ***T.W.A.*** for that month in order to estimate number of

gallons required. The total water usage, or T.W.A., values for year 1 and also any years post year 1 can be found in Table 2.

Part 2: Rain Water Collection

1. In order to reduce potable water usage, the project would like to collect rain water from the 4th St. station site and reuse it for irrigating the landscaped areas.
    a. Average monthly precipitation values for the Santa Monica, CA area were obtained from *www.usclimatedata.com/climate.php?location=usca1024* and have been tabulated in Table 3.
    b. The necessary cistern size in order to not require any supplemental water at any point during the year was estimated to be approximately **23,000 gallons.** This was based on the irrigation requirements for the driest month of the year (July) during the first year after the landscape has been planted in place. The required ***T.W.A.*** in July of year 1 was estimated to be approximately *22,871 gallons*, and values for the rest of year 1 and any years thereafter may be found in Table 2.
    c. Dimensions of interior of cistern were designed so that it could facilitate approximately **23,850 gallons**. These dimensions are 19' wide by 19' long by 8.83' deep.
    d. After year 1, the capacity of the tank will be able to facilitate an extra water storage of approximately 9,550 gallons during the driest month of the year (see Tables 2 & 3). This could leave room for water to accumulate without overflow during high intensity large storm events and create extra storage for extremely low precipitation months. This extra storage also leaves room for possible future additional landscape irrigation or other possible future gray-water applications/uses.

Part 3: Cistern

1. The only area available for cistern storage is under the area labeled "bike module-C" at the north end of the station. Maximum excavation depth is 12 ft. below the plaza precast pavers and the concrete tank requires 1 foot thick walls and 1 foot thick horizontal slabs. Plaza precast pavers are assumed to be a minimum of 2 inches thick with an underlying 4" layer of sand sitting atop the roof of the cistern. The cistern is 10.83 feet tall (outside dimension) and sits atop 8" tall footings. These dimensions meet the maximum excavation depth specification of 12 feet.
    a. The max possible capacity of cistern that can be contained underneath Bike Module "C" was estimated to be approximately ***56,670 gallons*** based upon required dimensions.

b. Based on this very large capacity, ***no*** supplemental water would be required as long as future monthly precipitation values meet or exceed the tabulated averages for the area. The largest monthly need for irrigation occurs during year 1 in July at approximately 22,871 gallons, and the largest amount of average monthly precipitation that falls on the platform, track, and plaza areas contributing to cistern storage occurs in February of each year at approximately 64,858 gallons.

The estimated values above and the large cistern area boundaries seem to accommodate irrigation needs easily with plenty of room for flooding from high intensity rain events and will be able to handle extra capacity for possible future landscaping additions or alternative grey-water usage. Tabulated data for values listed above exists in the tables below:

Table 1

Landscape Evapotranspiration per Month Calculations											
K_L =	0.5	*(Landscape Coefficient)*				***Irrigation System Efficiency (yr. 1) =***			0.5	***(after yr. 1) =***	0.8
Daily Reference Evapotranspiration Rate (ET_0) for Santa Monica (inches/day)											
January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
0.03	0.05	0.08	0.11	0.13	0.15	0.15	0.13	0.11	0.08	0.04	0.02
Monthly Reference Evapotranspiration Rate (ET_0) for Santa Monica (inches/Month)											
0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62
Landscape Evapotranspiration (ET_L) per Month (inches/month)											
0.47	0.70	1.24	1.65	2.02	2.25	2.33	2.02	1.65	1.24	0.60	0.31

Table 2

Total Water Applied (T.W.A.) per Month Calculations											
T.W.A. per Month During Year 1 (inches)											
0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62
T.W.A. per Month After Year 1 (inches)											
0.58	0.88	1.55	2.06	2.52	2.81	2.91	2.52	2.06	1.55	0.75	0.39
T.W.A. per Month During Year 1 (gallons) *(0.62 gallons/square-foot-inch)											
4,574	6,886	12,198	16,231	19,821	22,133	22,871	19,821	16,231	12,198	5,902	3,049
T.W.A. per Month After Year 1 (gallons) *(0.62 gallons/square-foot-inch)											
2,859	4,304	7,624	10,144	12,388	13,833	14,294	12,388	10,144	7,624	3,689	1,906

Table 3

Average Monthly Precipitation for Santa Monica, California (inches)											
January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
3.07	3.31	2.56	0.51	0.24	0.04	0	0.12	0.16	0.35	1.02	1.85
Average Monthly Precipitation falling on Platform, Track, & Plaza Areas (gallons)											
60,155	64,858	50,162	9,993	4,703	784	0	2,351	3,135	6,858	19,986	36,250

Problem Statement 5: On-Site Renewable Energy

Part 1: Solar Panel Design

For this part, we are required to find out the quantity of panels required for each option. The amount of total output energy is being offset to 8%. The proposed design energy demand for the TOS booth is 22382.59 kWh/yr. and 30385.61 kWh/yr. for C/S building. Using the formula below, we were able to calculate the energy output for each panel.

$$E = A * r * H * PR$$

E = energy
A = total solar panel area
r = solar panel yield
H = annual average solar radiation
PR = performance ratio

The energy output for Sunmodule Plus SW 275 Mono model is 458.90 kWh/yr., 166.87 kWh/yr. for Grape Solar GS-Start-100W model, and 575.71 kWh/yr. for Sunpower X21-345 model. Using the calculated data, we were able to find out the amount of panels required for both the TOS booth and C/S building. The summary of the data and results can be seen in the tables below.

	Sunmodule Plus SW 275 Mono	**Grape Solar GS-Start-100W**	**Sunpower X21-245**
Max Power (Wp)	275	100	345
Tolerance	±2%	0%, +6%	0%, +5%
Min. Power Output	269.5	100	345
Max. Power Output	280.5	106	365.25
Total Solar Panel Area	1.514	0.5856	1.399
Solar Panel Yield (%)	0.182	0.171	0.247
Annual Average Solar	2224.975	2224.975	2224.975
Performance Ratio	0.75	0.75	0.75
Energy Output	458.901	166.873	575.712

	Sunmodule Plus SW 275 Mono	**Grape Solar GS-Start-100W**	**Sunpower X21-245**
TOS Booth Roof			
Proposed Design Energy	22382.59	22382.59	22382.59
Amount of Panels	49	134	39
Total Cost	$21,948.45	$20,119.41	$18,078.31

	Sunmodule Plus SW 275 Mono	Grape Solar GS-Start-100W	Sunpower X21-245
C/S Building Roof			
Proposed Design Energy Demand (kWh/yr.)	30385.61	30385.61	30385.61
Amount of Panels Required	66	182	53
Total Cost	$29,796.23	$27,313.21	$14,542.31

	TOS Booth	C/S Building
Assumed Electric Price per kWh	$0.223	$0.223
Total Electric Price for Energy Demand per Year	$4,991.32	$6,775.99

	Sunmodule Plus SW 275 Mono	Grape Solar GS-Start-100W	Sunpower X21-245
Amount of Years to Pay Back (TOS Booth)	4.40	4.03	3.62
Amount of Years to Pay Back (C/S Building)	4.40	4.03	3.62

According to my calculated data, the Sunpower X21-345 models would provide the best value to the customers. The reason is because the total cost is the cheapest among the 3 different models and it would only take approximately 3 and a half year to pay back the cost and start saving on electric bill. Also, the energy output and efficiency for this model is the highest compare to the other two. The higher the energy output as well as the efficiency will result in more money saving in the long run.

For the next part, we are required to determine the optimal orientation for the solar panels. Los Angeles is located in the Northern Hemisphere, and in order to produce the maximum amount of power to help save on electric bill, the best direction for the solar panels to face is true south as the sun will be at the highest during the day at this direction.

The angle of magnetic declination depends on both location and time. By using Google Map, we manage to obtain the coordinate of Los Angeles which is 34.05º N, 118.25º W. Assuming the time and date to be 05/02/2015 and using the magnetic declination calculator provided by National Geophysical Data Center, the true angle the solar panels need to face to optimize the energy return would be approximately positive 12.24º E ± 0.33º.

The best dates to tilt the solar panels would be when the equinox occurs, during this time the sun will be directly above the equator. Equinox occurs twice in a year which is during the month March and September. Using the calendar on timeanddate.com, we can see\that the March equinox in Los Angeles will occur on March 20th and the September equinox will occur on September 23rd. The optimum panel angle for each period has been calculated using formulas as shown below as well as verified using solar angle calculator. The optimum panel angle for March would be 11º ± 3º and 31º ± 3º for September.

$$Latitude * 0.93 - 21^{o} = Optinum\ Panel\ Angle\ for\ March$$

$$Latitude * 0.98 - 2.3^{o} = Optinum\ Panel\ Angle\ for\ September$$

Part 2: Additional Renewable Energy

For this part, we were given an open 4 acre site to try and achieve a Net Zero Energy for the design build project. This site consisted of no contamination issues, ground coverage, and no existing structures. We assumed light would not be affected by surrounding buildings and placed the panels on the current ground conditions. The use of the current ground, reduced costs and also our carbon foot print on the project. The grid connection from Magnum Energy was selected for the inverter. For maintenance after the 5 year warranty period, we assumed panels would need to be cleaned three times a year and an additional $150 inspection fee was added to each cleaning. The interest rate for the entire project was assumed to be 9%.

The product chosen to meet this Net Zero Energy was the Sunmodule plus SW 275 Mono model. This product was chosen since it was cheaper than some products, but didn’t lose its production of energy. The product comes with a valuable warranty and maintenance up to 5 years. The Sunmodule comes with its own setup and can be set in place in the parcel without any excavation. Calculations for cost estimate and ten year cost analysis are in the Table 1 below.

Table 7: Alternate Energy Calculations

Area		
4 acres	16187.4m^2	
Sunmodule		Area
1.001	1.675	1.676675
Units	cost/unit	Total
9654	450	4344509.222
Grid Tie-In		
Inverter	$2,159	
50m cable	$45	$2,204
Maintenance	Units	cost*3/yr
15/unit	9654	434430
150/ inspection	1	450
	Total	434880
Cost analysis		
P/F		F/P yr. 5
0.4224		1.5386
Present Worth=	payments	M&O
PW=	$ 6,182,764.89	$ 669,106.37
PW=	**$ 6,851,871.26**	
Payback Period		
Energy Produced	Price/ kW	
458.901 kW/yr*unit	$.223/kW	
Total years	6.9	
	7 years	

Part 3: Alternative Renewable Energy Sources

In this part, we were instructed to evaluate the alternative renewable energy sources for viability onsite. Several alternatives were given which included biofuel-based electrical systems, geothermal energy systems, hydroelectric power systems, and micro wind turbines.

First hydroelectric power systems were evaluated, in our research we discovered that aqueducts were already in place. The current aqueducts are inefficient for what the building would require and tapping into the stream would only lower current hydroelectric plant's efficiency. Next, biofuel-based electrical systems were researched, data showed that a vast amount if green plants or waste would have to be dried and then burn. This burn only added more greenhouse gases to the atmosphere. Both the hydroelectric power and biofuel-based electrical were rejected for being inefficient for requirements of this project. Next, geothermal energy systems were researched results concluded that Los Angeles doesn't have good geothermal energy. However, there is a proposal from Nevada for geothermal energy; this proposal would contract Los Angeles to buy energy for $99/Mw ($0.099/ kWh). This contract would be a great deal for the city of Los Angeles.

And lastly, the micro wind turbines would be the cheapest renewable energy source. It doesn't cost much to install and the process of installing a wind turbines would not have any side effects to the environment. Not only those micro wind turbines are highly efficient and low cost, it is also suitable for urban environment such as Los Angeles due to their easy installation. Both the geothermal and the micro wind turbines would work for alternative renewable energy resources; however, micro wind turbines would be the best choice for this location.

Bonus Question

The estimated riders of the Expo 1 & 2 project in 2030 from Downtown LA to 4th Street Santa Monica Station would be 64,000 daily riders according to the expo line website. Using Google Map, we were able to estimate the distance from Downtown LA to 4th Street Santa Monica to be approximately 15.2miles and that would be 30.4 miles both ways. Assuming that all of riders would have driven both ways every day, and it would consume one gallons of gasoline every 20miles. By doing some calculation as shown below, approximately 97,280 gallons of gasoline would have been saved if all these riders would have taken the Expo Line.

$$30.4\ miles * \frac{1\ gallon}{20\ miles} * 64{,}000 = \ 97{,}280\ gallons$$

Below is a list of some ideas that could possibly increase the ridership.

1. Installing Wi-Fi on the Expo Line so that riders would have access to the internet while waiting for the light rail to reach their destination.
2. Introduce new routes and increase stations.
3. Lowering the fares.
4. Introducing apps to riders to check for schedules for easy planning of their trip.

rete									
	Quantity (CY)	7% Extra	Total Ordered	Strength (psi)	Unit Price	# Trucks	Environmental Fee	Overtime	Total
	185.84	13.0088	199	4000	63	23	575	228.46	13340.5
	141.56	9.9092	151	4000	63	17	425	0	9938
	74	5.18	79	4000	63	9	225	0	5202
	27.444	1.92108	29	4000	63	4	100	0	1927
	25.98	1.8186	28	4000	63	4	100	0	1864
ab	13.37	0.9359	14	4000	63	2	50	0	932
	13.37	0.9359	14	4000	63	2	50	0	932
alk Ftg	12.164	0.85148	13	4000	63	2	50	0	869
	27	1.89	29	4000	63	4	100	0	1927
	17.34	1.2138	19	4000	63	3	75	0	1272
	20.16	1.4112	22	4000	63	3	75	0	1461
			597			70	1750	228.46	39664.5
								0.09	3569.8
									43234.3

White Castle

Pour Tast	Quantity (CY)	7% Extra (CY)	Total Ordered (CY)	Strength (psi)	Unit Price	# Trucks	Short Load	Disposal	0vertime	Fuel Surcharge	Total
Platform ftgs.	185.840	13.009	199.00	4000	$64.00	23	$80.00	$0.00	$620.00	$460.00	$13,896.00
Platform Walls	141.560	9.909	151.00	4000	$64.00	17	$0.00	$125.00	$0.00	$340.00	$10,129.00
TOS Mat Fdn	74.000	5.180	79.00	4000	$64.00	9	$80.00	$0.00	$0.00	$180.00	$5,316.00
Cistern Walls	27.444	1.921	29.00	4000	$64.00	4	$80.00	$0.00	$0.00	$80.00	$2,016.00
SOG/Mat ftgs	25.980	1.819	28.00	4000	$64.00	4	$0.00	$125.00	$0.00	$80.00	$1,997.00
Cistern Bottom Slab	13.370	0.936	14.00	4000	$64.00	2	$80.00	$0.00	$0.00	$40.00	$1,016.00
Cistern Top Slab	13.370	0.936	14.00	4000	$64.00	2	$80.00	$0.00	$0.00	$40.00	$1,016.00
Cistern ftg/Sidewalk Ftg	12.164	0.851	13.00	4000	$64.00	2	$60.00	$0.00	$0.00	$40.00	$932.00
TC & C Walls	27.000	1.890	29.00	4000	$64.00	4	$0.00	$125.00	$0.00	$80.00	$2,061.00
TOS Wall	17.340	1.214	19.00	4000	$64.00	3	$80.00	$0.00	$0.00	$60.00	$1,356.00
Sidewalk Wall	20.160	1.411	22.00	4000	$64.00	3	$60.00	$0.00	$0.00	$60.00	$1,528.00
Sub Total			597.00			73	$600.00	$375.00	$620.00	$1,460.00	$41,263.00
Sales Tax										9%	$3,713.67
Total											$44,976.67

Slip Diamond

Pour	Quantity (CY)	7% Extra (CY)	Total Ordered (CY)	Strength (psi)	Unit Price	# Trucks	Short Load	Environmental Fee	Overtime	Fuel Surcharge	Total
Platform ftgs.	185.840	13.009	199.00	4000	$72.50	23	$0.00	$460.00	$495.00	$460.00	$15,842.50
Platform Walls	141.560	9.909	151.00	4000	$72.50	17	$100.00	$340.00	$165.00	$340.00	$11,892.50
TOS Mat Fdn	74.000	5.180	79.00	4000	$72.50	9	$45.00	$180.00	$0.00	$180.00	$6,132.50
Cistern Walls	27.444	1.921	29.00	4000	$72.50	4	$100.00	$80.00	$0.00	$80.00	$2,362.50
SOG/Mat ftgs	25.980	1.819	28.00	4000	$72.50	4	$100.00	$80.00	$0.00	$80.00	$2,290.00
Cistern Bottom Slab	13.370	0.936	14.00	4000	$72.50	2	$60.00	$40.00	$0.00	$40.00	$1,155.00
Cistern Top Slab	13.370	0.936	14.00	4000	$72.50	2	$60.00	$40.00	$0.00	$40.00	$1,155.00
Cistern ftg/Sidewalk Ftg	12.164	0.851	13.00	4000	$72.50	2	$75.00	$40.00	$0.00	$40.00	$1,097.50
TC & C Walls	27.000	1.890	29.00	4000	$72.50	4	$100.00	$80.00	$0.00	$80.00	$2,362.50
TOS Wall	17.340	1.214	19.00	4000	$72.50	3	$100.00	$60.00	$0.00	$60.00	$1,597.50
Sidewalk Wall	20.160	1.411	22.00	4000	$72.50	3	$100.00	$60.00	$0.00	$60.00	$1,815.00
Sub Total			597.00			73	$840.00	$1,460.00	$660.00	$1,460.00	$47,702.50
Sales Tax										9%	$4,293.23
Total											$51,995.73