Design of a Sustainable Parking Lot

Spring 2013 Design Proposal Report

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Prepared for:

Oklahoma Department of Environmental Quality

Table of Contents

Problem Statement

Urban Sustainability Solutions' will implement low-impact development design techniques in order to retrofit an existing parking lot half-owned by the Oklahoma Department of Environmental Quality and OCU Law School. Our goal is to provide a cost-competitive, low-maintenance, and aesthetically pleasing design that returns the site's hydrologic functionality to a near-predevelopment state.

Mission Statement

Urban Sustainability Solutions strives to provide environmentally compliant, low-impact development designs for a sustainable future. Our designs use innovative techniques that save money and resources. Urban Sustainability Solutions strives to retrofit existing sites, provide sustainable design and installation at undeveloped sites, and promote the growth of green technologies in the central United States.

Statement of Work

Purpose:

Traditional approaches to stormwater management are being replaced with an eco-friendly approach whose goal is to return hydrologic functionality of developed areas to pre-development states through the use of low-impact development techniques. EPA intends to propose a rule to strengthen the national stormwater program by June 10, 2013 and complete a final action by December 10, 2014. EPA has already announced that the national rulemaking is considering the following key rulemaking actions:

- Develop performance standards from newly developed and redeveloped sites to better address stormwater management as projects are built;
- Explore options for expanding the protections of the municipal separate sewer systems (MS4) program;
- Evaluate options for establishing and implementing a municipal program to reduce discharges from existing development;
- Evaluate establishing a single set of minimum measure requirements for regulated MS4s. However, industrial requirements may only apply to regulated MS4s serving populations of 100,000 or more;
- Explore options for establishing specific requirements for transportation facilities; and
- Evaluating additional provisions specific to the Chesapeake Bay watershed.

One performance standard that currently exists in several states, and that is anticipated by ODEQ to be a requirement of the rule to be proposed by EPA, is to be able to process stormwater from a 95^{th} percentile storm in order to maintain a predevelopment hydrologic regime at newly developed or redeveloped sites. The rule may also call for the use of numeric water quality effluent limits in some cases, or the use of surrogates for numeric water quality limits, such as flow rate and percent impervious cover for developed areas. The new rule will likely encourage the use of a combination of best management practices such as sustainability, green infrastructure, and low-impact development as the most acceptable method in order to meet the new performance standards and requirements. In anticipation of an intensive federal stormwater rule, ODEQ would like to redesign their headquarters building parking lot in order to promote new LID techniques and to become a role model in stormwater management for other agencies and companies.

Organization of Tasks

USS performed the following tasks in order to complete the project:

Background Research and Literature Review on:

- Stormwater management
- Low-Impact Development techniques
- LID products currently on the market
- Example LID projects
- Xeric landscape design

Surveying

- Survey of parking lot
- Use survey data to create topographic maps
- Determine slope of key areas of parking lot

Concept Generation

- Perform hydrologic model analysis for each proposed design concept
    - Interpret results generated
- Create list of techniques/systems to be used in Proposed Design Concept No. 2
- Develop specific dimensions and decide construction materials of retention grate for Proposed Design Concept No. 1
- Create list of drought tolerant plants to be used in xeric landscape
- Create list of LID techniques to be displayed in xeriscape for educational purposes
- Create images of each design concept in order to pitch to ODEQ in the fall

Experiments & Testing

- Design and construct a platform in order to test partition concept
    - Interpret results of this experiment
- Delegate an experiment to freshman team to test effect of freeze/thaw on pervious concrete strength
    - Interpret results of this experiment
- Hydrologic modeling program - IDEAL
    - Interpret results of model and produce graphs to help future design

Storyboard/Poster

- Coordinate with Landscape Architecture student to create images of design and landscape
- Write captions for each image describing the key features of Proposed Design Concept No. 2
- Use images and captions to create a storyboard poster

Administrative

- Meet every other Friday with Dr. Vogel
- Meet regularly with team and/or communicate via email & text
- Design Proposal Report
    - Problem statement
    - Statement of work, WBS, & tasks list
    - Technical analysis/market research/patent search
    - ODEQ requirements
    - Engineering specifications
    - Generation and selection of design concepts
    - Selected design concepts
    - Experiments/Testing
    - Results and discussion of experiments/testing
    - Potential impacts
    - Project schedule (Gantt chart)
    - Budget
- Oral Presentation
    - PowerPoint presentation
- Develop a basic website
    - Move team folder to appropriate location
        - Each team member must place their files in this folder
        - Convert files to .pdf
        - Organize files & folders
    - Coordinate with Craig Trimble to ensure files can load
- Submit project notebooks

Work Breakdown Structure for Fall/Spring Semester

1. "Green" Parking Lot	**100**

1. "Green" Parking Lot	
1.1. Background Research	**15**
1.2. Administrative Tasks	**35**
1.3. Concept Generation	**40**
1.4. Project Management	**10**
	100

1. "Green" Parking Lot	
1.1. Background Research	
1.1.1. Stormwater management	**1**
1.1.2. Low-Impact Development techniques	**5**
1.1.3. LID products currently on the market	**2**
1.1.4. Example LID projects	**7**
1.2. Administrative Tasks	
1.2.1. Design Proposal Report	**20**
1.2.2. Oral Presentation	**10**
1.2.3. Basic Website	**3**
1.2.4. Project Notebook	**2**
1.3. Concept Generation	
1.3.1. Brainstorming	**6**
1.3.2. Surveying	**6**
1.3.3. Pervious Concrete Testing	**4**
1.3.4. Hydrologic Modeling	**12**
1.3.5. 3-D Visual Modeling	**12**
1.4. Project Management	
1.4.1. Meetings	**2**
1.4.2. Site Visits	**2**
1.4.3. Regular Communication	**1**
1.4.4. Peer-reviewing assignments	**5**
	100

Required Resources for Completion of Tasks

The resources needed for the completion of the above tasks are organized below:

1. "Green" Parking Lot

1.1. Background Research

Resources Required: *Team Labor*

- 1.1.1. Stormwater management
- 1.1.2. Low-Impact development techniques
- 1.1.3. LID products currently on the market
- 1.1.4. Example LID projects
- 1.1.5. Xeric landscape design
- 1.1.6. Partition design

1.2. Administrative Tasks

Resources Required: *Team Labor*

- 1.2.1. Design proposal report
- 1.2.2. Oral presentation
- 1.2.3. Basic website
- 1.2.4. Project notebook

1.3. Concept Generation

Resources Required: *Team Labor, Kayla Copeland, Haley Malle, Surveying Equipment, Pervious Concrete, IDEAL software, Sketchup software, Photoshop software, AutoCAD software, Fuel*

- 1.3.1. Brainstorming
- 1.3.2. Surveying
- 1.3.3. Pervious concrete testing
- 1.3.4. Partition design testing
- 1.3.5. Hydrologic modeling
- 1.3.6. Storyboard/Poster
- 1.3.7. 3-D visual modeling

1.4. Project Management

Resources Required: *Dr. Vogel, Dr. Weckler, Kelly Dixon, Kayla Copeland*

- 1.4.1. Meetings
- 1.4.2. Site visits
- 1.4.3. Regular communication
- 1.4.4. Peer-reviewing assignments

Deliverables

Urban Sustainability Solutions has provided ODEQ with the following work-product:

- Project report
- Two design concepts
- Results from hydrologic modeling software analysis and physical experiments & testing
- Storyboard poster with hand-drawn images outlining the different aspects of the parking lot design
- Resources for future developers wanting similar results with partitions for varying slopes and storms

Monitoring Deliverables

The storyboard posters can be displayed in the lobby of the ODEQ headquarters building. Public response to the design concepts can be monitored by ODEQ staff.

Technical Analysis

Research & Literature Review:

Although our team helped develop a new low-impact development (LID) solution, the project was best completed by integrating several existing products and methods. The team analyzed, researched, and investigated technical literature and patents which provided insight into whether the existing products and methods suited our design needs, or if additional inventions/methods were to be developed.

The following items were identified:

- Similar items or solutions to the problem
- Technical specifications for existing products or methods (evaluations of strengths and weaknesses)
- Durability, reliability, maintenance costs, maintenance requirements, etc.
- Characteristics that are technically possible excluded in existing products
- Safety issues that must be addressed.
- Relevant patents

Our research focused on LID design strategies that would significantly minimize pollutant transport, soil erosion, and flooding caused by stormwater runoff. These strategies created a multi-functional design aimed to return the hydrologic functionality of developed areas to a near-predevelopment state, remove pollutants from the retained stormwater, and create a low-maintenance and aesthetically-pleasing natural landscape. The table on the following page outlines traditional parking lot materials, existing LID concepts, and descriptions of their associated strengths and weaknesses.

Material/Concept	Strengths	Weaknesses
Efficient Parking Lot Design	- Greatly reduces impervious area - Provides the extra room needed for LID design	- This may require convincing governing bodies to changes city code. - Reduced number of parking stalls
Asphalt	- Smooth finish provides limits noise and allow for easy snow removal - Lower initial cost - Recyclable	- Heat adsorbing properties - Not suitable for heavy loads - Moderate upkeep - High maintenance costs - Impervious
Concrete	- Heavy load-bearing - Reflective properties - Long-lasting - Low maintenance costs compared to asphalt	- Moderate upkeep - Impervious - Higher initial cost
Pervious Paving	- Different options/looks (concrete, pavers, reinforced grass, reinforced gravel) - Reduces pollutant transport - Reduces stormwater erosion - Recharges groundwater	- Reflective properties - High maintenance costs - Moderate upkeep - Higher initial cost - Unsmooth surface makes for more difficult snow removal
Adding Tree Canopy	- Intercepts/slows, absorbs, and filters stormwater - Helps reduce urban heat-island effect - Known to remove air pollutants such as ozone, nitrogen oxides, sulfur dioxide, and ammonia - Mature trees can increase property values	- Roots can damage building foundations and parking lots
Vegetated Swales/Planters	- Require less infrastructure (piping) - Simple to construct - Low initial cost - Low maintenance cost - Low upkeep - Improves water quality	- Requires long, continuous spaces - Not as aesthetically-pleasing
Weirs/Check Dams	- Can be adjustable to control amount of water to be retained - Useful when slopes are 4% or greater - Slows runoff on sloped gradient and replaces piping - Inexpensive to build	- Upkeep similar to that of traditional landscaping - Requires appropriate topography - Grading must be sufficient to allow water to enter
Green Gutters	- Slows and filters stormwater - Inexpensive to build	- Offer little or no water retention - Require a long footprint to effectively slow and filter stormwater
Bioretention Cells/Rain Gardens	- Inexpensive to build - Can provide the greatest stormwater flow - Can improve water quality/remove pollutants - Offer versatility in shape. - Aesthetically-pleasing	- Upkeep similar to that of traditional landscaping - Can be difficult to find large spaces for rain gardens in ultra-urban or retrofit conditions.
Rain Barrels/Cisterns	- Can retain large amounts of water - Retained water can be used for landscaping or grey-water	- Typically used for in rooftop collection applications - Unless gravity fed, a pump would be required and can be costly

Technically possible characteristics excluded in existing products:

Limiting factors exist in all design applications; often the reason is something other than technical feasibility. Spatial area, city/county code, cost, and topography are often limiting factors in LID design. Examples deemed non-usable due to limited amount of space include: detention ponds, fountains, solar panel roofs, and geothermal energy. Three other examples will be described in further detail.

One design idea that has not yet been implemented is the exchange of electricity for local commerce between local businesses and consumers. This is a great idea for shopping centers and malls to lure potential clientele. This idea is not used because electric vehicles are not commonly used. In addition, the prime locations for charging stations are most commonly handicap reserved spaces. These spaces are most practical due to their proximity to the building. Although this idea has flaws, it might be used in the not-so-distant future.

Porous pavement can be found in locations across the country. However, a mix with large pore spaces relative to what is commonly used that allows significantly more infiltration is possible. However, the design is not used because the large pore spaces cause a trip hazard to pedestrians with wearing high heels or those that use canes.

The prospect of xeriscaping, a landscaping method that employs drought-resistant plants in an effort to conserve resources, especially water, is most commonly excluded in landscaping design. However, LID systems usually incorporate this particular landscaping method. The concept is based on resource conservation. The use of drought-resistance plants native to a particular site's geographic area can often result in a less than ideal scene. However, if properly researched and designed xeriscaping can result in a both aesthetically-pleasing and natural looking landscape that requires less resources and upkeep.

Safety issues:

Safety should always be a top priority and consideration during any design process, even a parking lot retrofit design. The following safety issues have been identified:

<u>Safety</u>

- Utility line identification prior to specific design and construction
- Slip hazards if lot freezes over
- Appropriate lighting
- Designated pedestrian walkways

<u>Safety and Legal</u>

- Consideration of the American Disability Act
- Consideration of City/County Parking Lot Code

Relevant Patents:

Patent searches using the keywords “low impact development”, “pervious concrete”, and “environmentally friendly parking lots” were conducted, yielding the following:

US 8113740 B2 - Issue Date: February 14, 2012. Issued to: Oldcastle Precast, Inc.
Method and apparatus for capturing, storing, and distributing stormwater. This method reinforced the design idea for capturing the stormwater in the sub base. It also proves that a negative run off system is possible.

US 6277274 B1 - Issue Date: August 21, 2001. Issued to: Coffman, Larry.
Method and apparatus for treating storm water runoff. This method will reduce chemical pollutants and sediment from water in a bioretention cell. We can utilize this technology in the bioretention cells that we will use to prevent any possible pollutants getting into either the groundwater or in the Oklahoma River if our storage system overflows.

US 7967979 B2- Issue Date: June 28, 2011. Issued to: The Ohio State University.
Bi-phasic bioretention systems. This is a very effective method for reducing organic pollutants (Methane and Alcohols). It optimizes the water’s time in the bioretention cell by being bi-phasic and using anaerobic and aerobic sequences. We could utilize this technology in our bioretention cells to reduce the pollutants from cars.

US 4225357- Issue Date: September 30, 1980. Issued to: Hodson, Harry.
Method of producing and distributing a pervious concrete product. This will be used because we plan to use pervious concrete in our designs. This is only an example of method of production but not necessarily the one we will utilize.

Pub No.: US 2011/0230598 A1- Issue Date: December 3, 2009. Issued to: Wacker Chemie Ag.
Pervious concrete composition. This patent shows one mixture of pervious concrete that we might be able to use. This might not be the best mixture for strength and economics for us. It is just an example of a previously used mixture and additive.

US 2011/0011930 A1- Issue Date: March 21, 2010. Issued to: Starr, Gary and Bao Tran.
Parking meter with EV recharging capability. This technology is a little far-fetched. The only thing that could possibly be gained from this is the solar recharging. We could use this for lighting in the parking lot or even a message board, if ODEQ wanted.

Investigation & Testing Analysis

Methods and Materials for Data Collection

- *Survey of Parking Lot*
  - Items for surveying of the parking lot were survey equipment from the BAE lab as well as a BAE truck. These required no cost. This information allowed for the development of a topographical map of the parking lot and helped determine the varying slope.
- *Determining Location of Lines in Parking Lot*
  - OKIE One-Call System. This will require no cost.
- *Hydrologic Modeling Software Analysis*
  - This analysis determined estimated runoff from the parking lot at its predeveloped state (rangeland), existing state (impervious surface), and proposed state (pervious concrete/partition design) as well as required partitions for zero runoff in varying slopes and rainfall events. A beta version of the IDEAL modeling software was provided at no cost by Dr. Vogel.
- *Freeze/Thaw Strength Testing on Pervious Concrete*
  - This project was delegated to the freshman BAE 1012 team. The materials required were blocks of pervious concrete, water, a freezer, and the Civil Engineering Department's concrete crusher. All of these materials were provided at no cost.
- *Scale Model Platform to Test Partition Design*
  - The team tested the innovative partition design by building a platform that housed a scale model of a partition and the pervious layers used in the pervious concrete design. The machinists in the BAE lab helped the team design the platform and construct the platform. The materials required for the platform were Plexiglas, steel, black paint, casters, and a small hydraulic jack. The cost of materials and labor associated with the platform was approximately $XXXX We need a number
- *Storyboard/Poster for Proposed Design Concept No. 2*
  - The team hired a landscape architecture student to create professional images that describe the key aspects of our design. Captions describing each image were provided by the team a storyboard poster was created. The cost of this work was $675.00

Development of Engineering Specifications

ODEQ Requirements:

ODEQ has established the following as key requirements to be met:

- Process stormwater from a 95th percentile storm in a manner that will maintain a predevelopment hydrologic regime.
    - This can be accomplished by using various LID techniques (bioretention cells, pervious concrete, pervious pavers, ect…)
- Retain the current number of parking spaces (83), and increase this number if possible.
    - Codes for the dimensions of parking lot and stalls must be followed in addition to American Disability Act rules and regulations for handicapped stalls.
- Decrease "heat-island effect" caused by dark asphalt
    - An attempt to decrease this effect can be accomplished by planting trees in the parking lot area. In addition, the lighter color and geometric characteristics found in the aggregate of pervious concrete should reflect much more light than the dark-colored and smooth asphalt currently in place.
- Create a xeric landscape featuring native plants that:
    - Creatively features low-impact development techniques in order to provide public education and outreach on LID and stormwater management.
    - Is aesthetically pleasing and can be a popular tourist attraction.
    - Attracts and provides habitat for birds, butterflies, and other animals.
- Aims to set a precedent in LID design for the State of Oklahoma.

Generation & Selection of Design Concepts

In order to maximize creativity and innovation in our design concepts, each team member brainstormed designs during the first few weeks of the fall semester. The team then combined various ideas from this process in order to develop two designs; an economic design concept (Proposed Design Concept No. 1) and large-budget design concept (Proposed Design Concept No. 2).

At the end of the fall semester, Urban Sustainability Solutions presented ODEQ with each design. After thoroughly critiquing each design, ODEQ requested that we proceed with both designs. However, ODEQ requested that we primarily focus our time and resources on Proposed Design Concept No. 2, since Proposed Design Concept No. 1 was fundamental in nature and relatively easy to design.

Selected Design Concepts

Proposed Design Concept No.1

Of the two proposed design concepts, this design will require the least overall cost, but will be an effective tool to manage stormwater runoff from the parking lot. This design assumes the OCU Law School will not want their half of the parking lot to be included in the retrofit. The design shall include:

Best Management Practice grate

In this design, an angled grate will be installed slightly in front of the ODEQ property line. The grate will extend from the curb of the ODEQ building to the curb of the landscaped area. The grate will be located on grade to allow runoff to be effectively captured and processed at a high level. Underneath the grate, a pre-engineered concrete lined tank with no bottom will be put in place to keep the collected stormwater runoff onsite. Once the stormwater enters the pre-engineered tank, it will be filtered out and then able to infiltrate into the soil or be transported by means of evaporation. This is all done to fulfill ODEQ's requirement of processing stormwater runoff from a 95th percentile storm.

Tank Design

In order to determine the various dimensions of the tank, three simplifying assumptions were made:

- Infiltration/evaporation rates are negligible
- Complete capture of the runoff, meaning no bypass flow over the grate
- The tank will be in the shape of a basic rectangle

Once these assumptions were made, the team decided that the tank would be designed to retain stormwater from a 25-year, 24-hour storm. Based on the appropriate intensity-frequency-duration (IDF) curves for Central Oklahoma the depth of rainfall for this storm was 6.4 inches. The team than came up with an equation that determined the depth required to collect the runoff:

$$Depth\ of\ Tank = \frac{A * B}{C}$$

Where:

- A = Area of parking lot (ft^2)
- B = Depth of Rainfall (ft)
- C = Area of Continuous grate (ft^2)

The length and width of the grate will be 137 feet and 5 feet respectively. The depth required of the tank will be 14 feet deep. Of this 14 foot depth, 2 feet will be used for #57 Grade Limestone which will be placed at the bottom. The remaining depth will consist of void space. A ½ inch diameter PVC pipe will be installed and placed 6 inches above the #57 Grade Limestone. The pipe will be put in place to essentially keep the collected runoff from freezing.

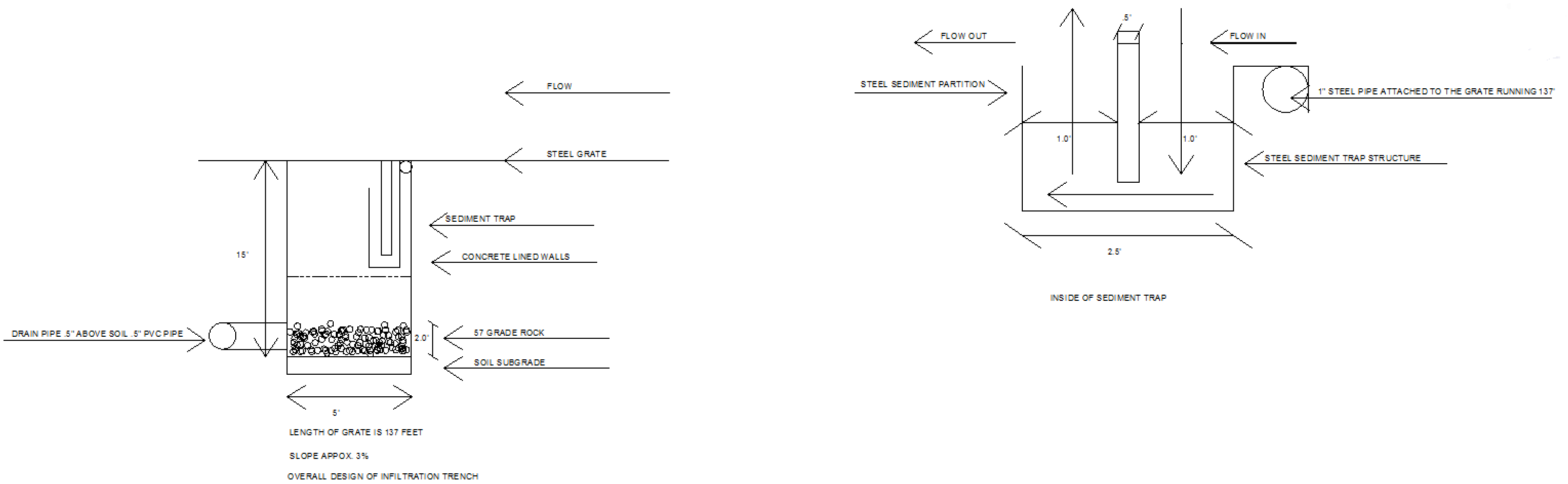

Figure 1. Schematic showing the sediment trap

Filtration

As shown in Figure 1, a sediment trap will be installed to allow stormwater to flow underneath a barrier while trapping unwanted sediment that might otherwise cause harm to the environment. The structure will hook over a 1 inch steel bar underneath the grate, attached by welds or bolts running the length of the grate. The steel partition will run the length of the parking lot and will attach with bolts to the concrete trench lining. After the sediment settles at the bottom, the water is allowed to flow out underneath the partition relatively free of sediment and pour into the trench below. Sediment traps are a relatively inexpensive way to filter stormwater. In addition, sediment traps require minimal maintenance which implies that the sediment trap does not have to be cleaned out after every rainfall event. When it does need to be cleaned out, the depth is short enough that a person can lift the grate up and shovel the sediment out of the bottom and relocate it to a dumpsite.

Proposed Design Concept No. 2

This design assumes the OCU Law School will want their half of the parking lot to be included in the retrofit. This proposed design concept includes the following:

Pervious Concrete & Partition Design

Pervious concrete will be installed in order to fulfill ODEQ's requirement of processing stormwater runoff from a 95th percentile storm. The impervious concrete existing in the loading area will be retained in order to prevent damage which would have been caused to the pervious concrete if it were installed in the truck loading area. This effort will also limit construction costs. In addition, rather than applying paint to the surface, parking stalls will be defined by lines of light colored brick.

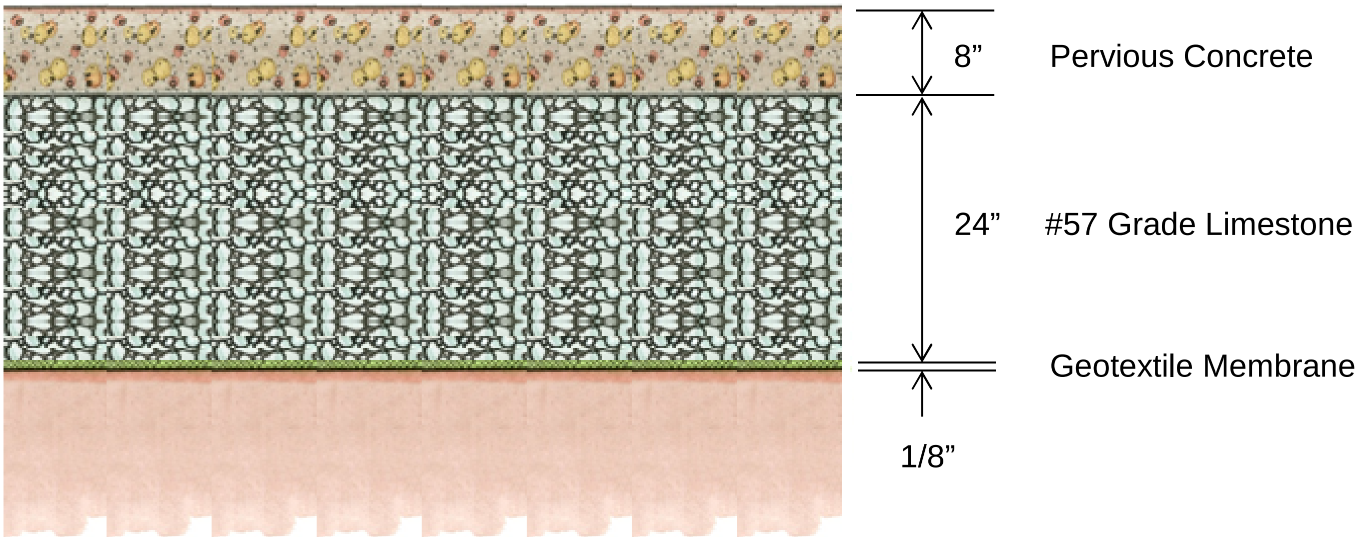

Figure 2: Pervious Concrete Design

This particular pervious concrete design, as seen in Figure 1 above and Figure 2 below, calls for an 8-inch pervious concrete layer, a 24-inch storage layer comprised of #57 grade limestone, a geotextile membrane, and 1-foot wide, 22-inch high concrete partitions placed 50-feet apart across the length of the parking lot . The 8-inch pervious concrete layer provides the strength needed in a parking lot design and the 24-inch storage layer provides the volume required to retain water from a 25-year, 24-hour storm, which is approximately 7 inches. The innovative partitions decrease the likelihood of having runoff by creating a ponding effect which aids in water infiltration by preventing the flow of retained stormwater down the gradient of the parking lot. The function of the geotextile membrane is to allow water to infiltrate into the soil, but to prevent soil subgrade material from ascending into and potentially clogging the storage layer.

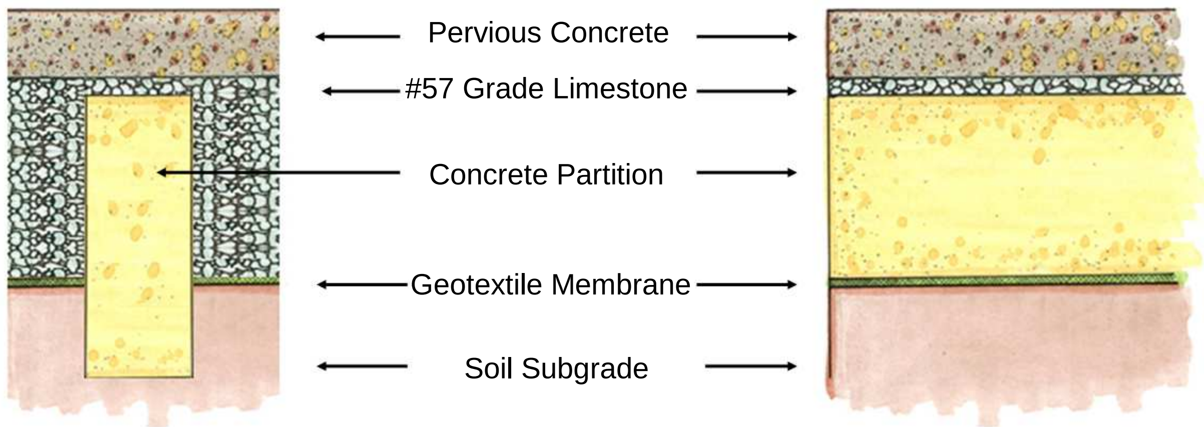

Figure 3: Partition Design

Regrade

A regrade of the OCU Law School portion of the parking lot to 2% will play a large role in managing stormwater runoff. This will eliminate the west exit, but will create an opportunity for a creative landscape at the bottom end of the sloped parking lot. The location of this landscaped area can be seen in Figure 3 below.

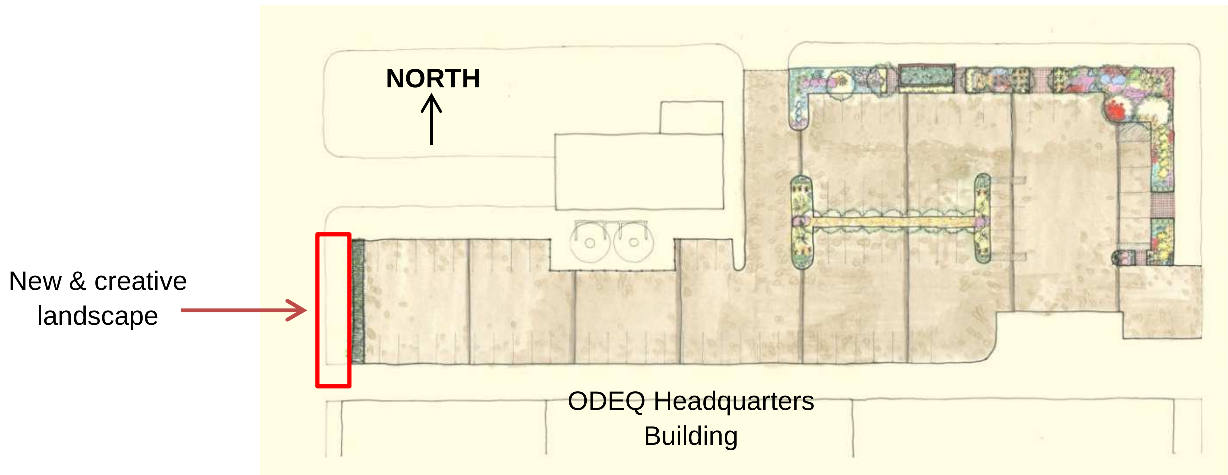

Figure 4: Plan View of Parking Lot & Landscape

Xeriscape and Bus Stop Green Roof

An ordinary landscaped area will be transformed into a xeric landscape comprised of drought-tolerant plants native to Oklahoma, creating much-desired improvement in aesthetics and increase in wildlife and insect habitat. An example of this transformation can be seen on the next page in Figure 4.

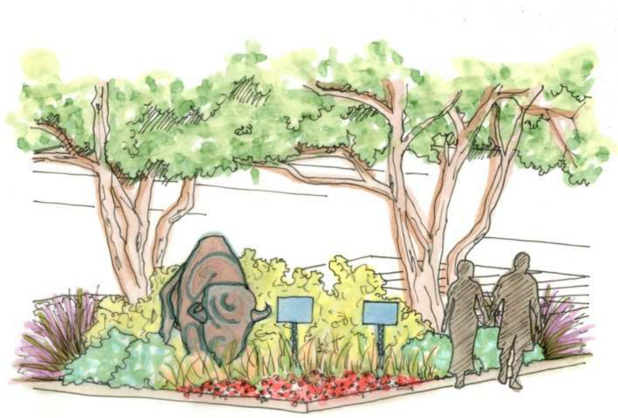

Figure 5: Northeast Corner of Parking Lot

In order to take advantage of an opportunity for public outreach & education on stormwater management, low-impact development techniques will be creatively featured within the landscape and their functions will be described on strategically placed signs. In addition, signs will also describe items such as the historical importance and role native grasses had on the once near-extinct American Bison, local economic impact Switchgrass may have in the near-future, and the purpose some of the selected plants have in the landscape and the reason they were selected. An example of this can be seen in Figure 4 above.

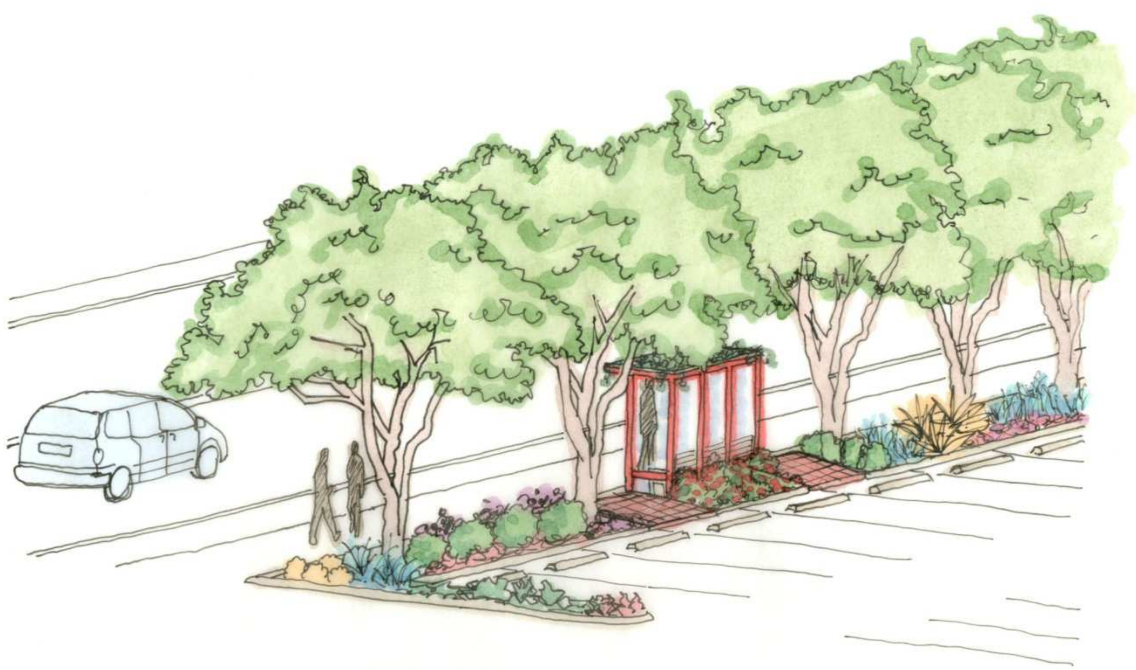

Figure 6: Bus Stop Green Roof

The northwest section of the landscaped area will feature plants that require slightly more water than those featured in the northeast section. This will aide in creating a more diverse landscape. In addition, a bus stop will be added that has a green roof. The bus stop will also be surrounded by pervious paver walkways. The roof will be constructed of layers typically found in green roofs and the main plants will be of the genus Sedum (leaf succulents). The green roof and pavers will both be functional tools for public education and outreach. An example can be found in Figure 5 above.

Any existing trees will be retained in an effort to provide shade to a portion of the parking lot. In addition, the existing medians may be replanted with drought-tolerant plants and native trees in order to provide shade to the middle portion of the parking lot. The goal will be to create a natural-looking xeric landscape that includes various forms of low-impact development techniques and has display signs that will provide education and outreach to the public on stormwater management.

IDEAL Modeling

Background

Ideal software was created by NAME to model many different hydrologic events with various different parameters (i.e. type of concrete, soil type, slope of area, length of area, urban or other setting, under drains, bioretention cells, etc.) for the state of South Carolina. With minor adjustments, this software is able to model the parking lot in question in the pre-developed, current, and designed states to determine runoff. The adjustments required are finding a storm in South Carolina with a comparable rainfall intensity to the storms that were of interest to this challenge as well as finding soil that is comparable in composition as found in the area in question.

Results

IDEAL Modeling Results		
Condition	Total Runoff Volume (ac-ft)	Peak Runoff Flow (cfs)
Pre-developed	0.1319	0.07812
Existing	0.425	0.6013

Table 1. Modeling results for the parking lot

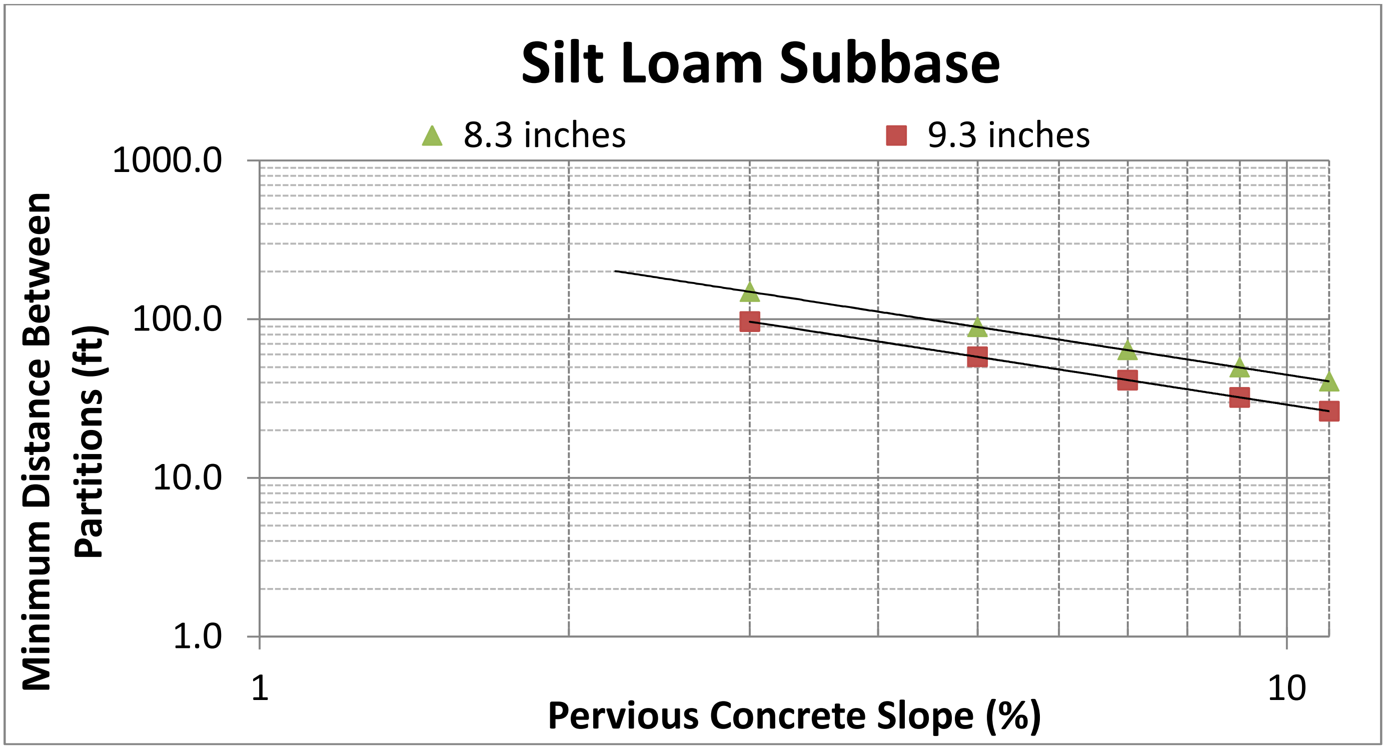

Figure 7. Nomograph showing the minimum distance between partitions for zero runoff for different slope levels and rainfall events for silt loam subbase.

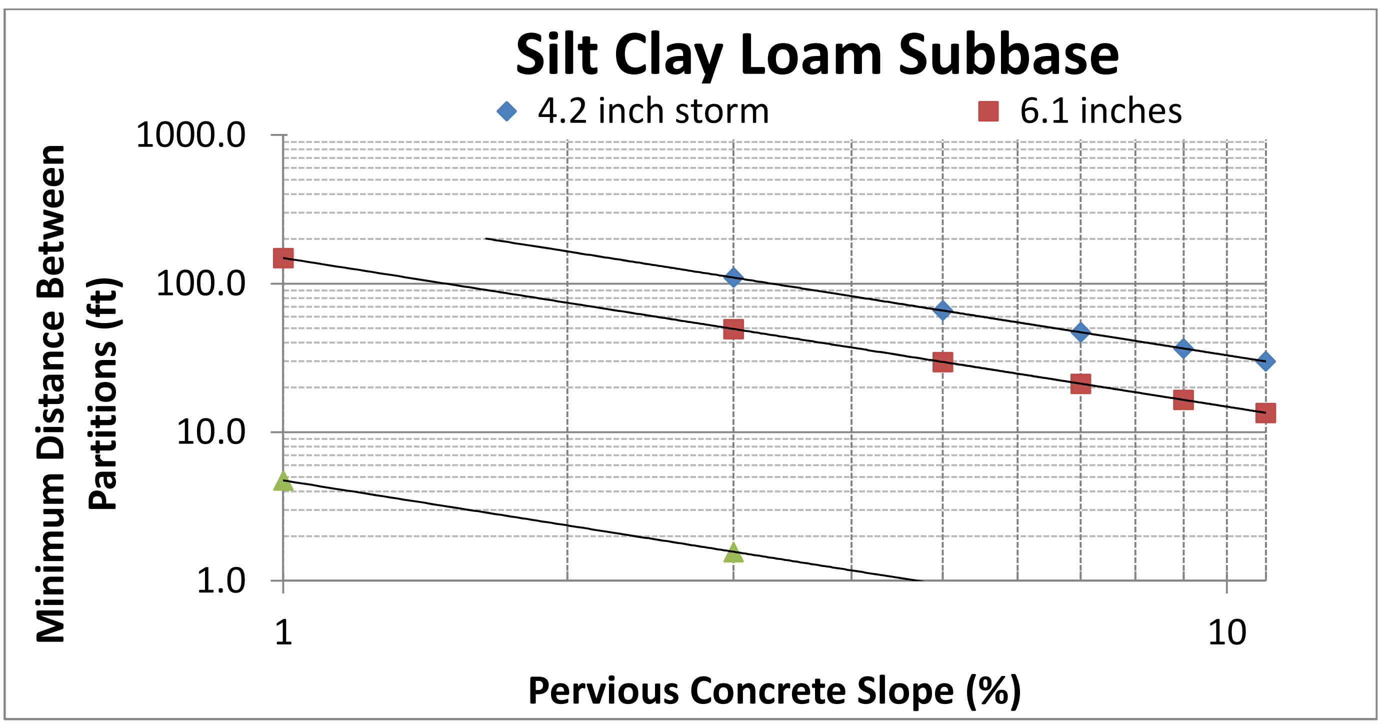

Figure 8. Nomograph showing the minimum distance between partitions for zero runoff for different slope levels and rainfall events for silt clay loam subbase.

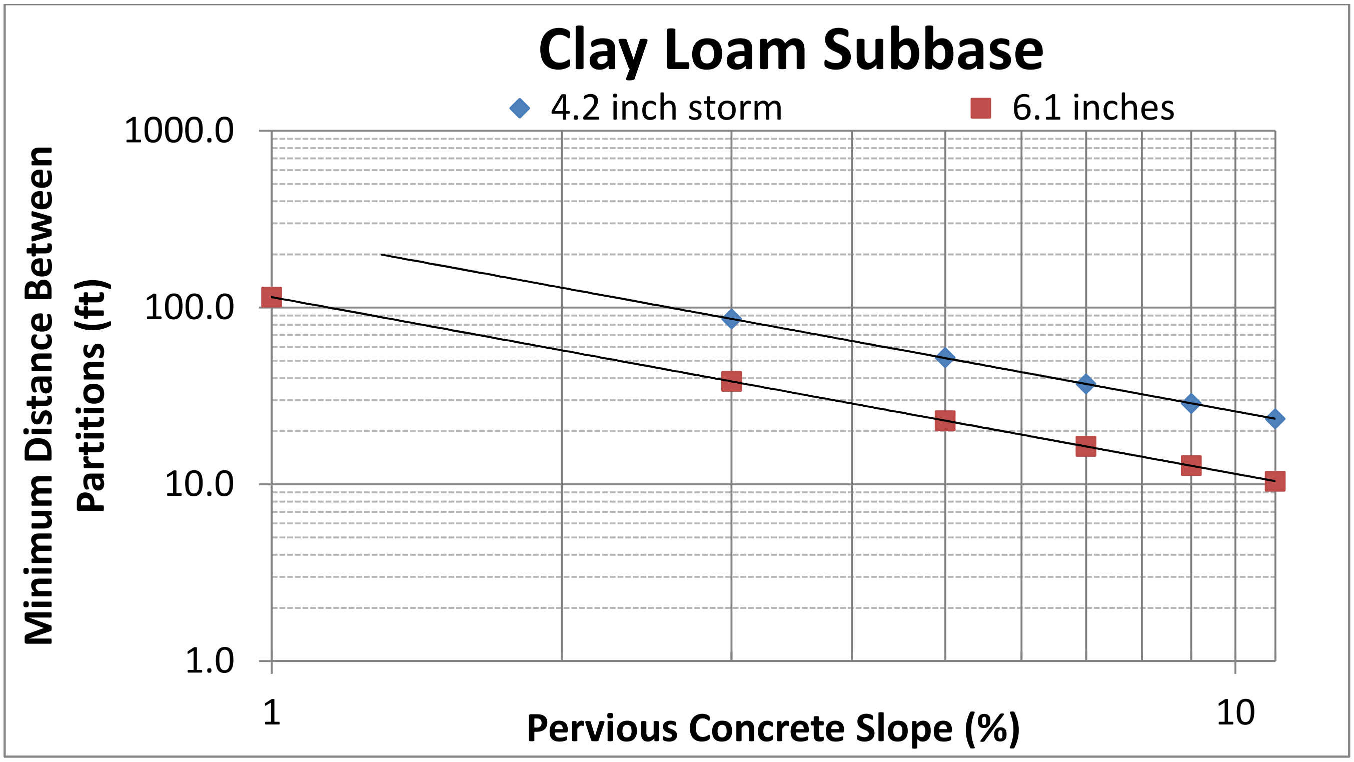

Figure 9. Nomograph showing the minimum distance between partitions for zero runoff for different slope levels and rainfall events for clay loam subbase

Discussion

The initial modeling was undertaken in order to have a grasp on the current runoff and what the site experience in runoff before it was developed. The goal of the first concept design is to return the parking lot to at least pre-developed runoff amount. After this modeling, we had a tangible number to chase in that design. The nomographs show design standards based on soils and storms so that other engineers are able to design their sites to have minimal or zero runoff. To use the nomographs, a designer must know the slope of their site, the subbase composition, and have a required storm. With this information, a designer will be able to follow the trendline and determine the distance between the partitions to achieve zero runoff. From this data, the team has not only proven that zero runoff is possible in our setting, it is also possible for various slopes.

Experiments & Testing

As previously mentioned, Urban Sustainability Solutions used a hydrologic modeling program to analyze the hydrologic functionality of each proposed design concept. One of team's goals was to use the analysis obtained from the hydrologic modeling software in conjunction with physical experiments in order to meet ODEQ's stormwater processing requirements. Urban Sustainability Solutions designed and built a platform which would replicate the layers used in a pervious concrete design. The platform was built with the purpose of testing the innovative partitions discussed in Proposed Design Concept No. 2. The platform would have the ability to adjust slope and calculate volume of runoff at an outlet. We must note due to time and budget constraints, Urban Sustainability Solutions was not able to perform any meaningful experiments on Proposed Design Concept No.1. However, engineering calculations were done to validate that all ODEQ requirements were met.

Proposed Design Concept No. 2 – Partition design:

In order to determine the various dimensions of the partition design, the team made the general assumption that the shape of the subbase was that of basic parallelogram. Geometric formulas used determining for the area of a parallelogram was included in an equation developed to determine the distance required between the partitions:

$$\textit{Retention Capacity Efficiency} = \frac{\left(0.4 * \left((H * D) - \left(Slope * D^2\right)\right)\right)}{((H * D) * 0.4)} * 100$$

Where:

- D = Distance between Partitions (ft)
- H = Partition Height (ft)
- Slope = Surface Slope (decimal)

During initial calculations, the team decided that the partitions would have the capacity to retain water at 75% efficiency. The required water retention volume was determined by analyzing appropriate intensity-frequency-duration (IDF) curves for Central Oklahoma for the following rainfall data amounts:

10-year, 24-hour storm	25-year, 24-hour storm	50-year, 24-hour storm
5.65 in.	7 in.	8 in.

The heights of the partitions were calculated to be 22-inches due to the length of the subbase and the water retention volume required. The team used the following parameters in order to determine the partition spacing of 50 feet for Proposed Design Concept No. 2:

Retention Capacity Efficiency	75%
Distance between Partitions	*50 ft.*
Partition Height	22 in.
Surface Slope	1% after regrading

Proposed Design Concept No. 2 has been designed to have the ability to process stormwater from a 50-year, 24-hour storm.

Proposed Design Concept No. 2 - Scale model platform design:

Dimensions

Before the team designed the scale model platform, the effects similitude would have on any conducted experiment needed to be addressed. A model is said to have similitude with the real world application if it shares three types of similitude. These types of similitude are:

- Geometric similitude
- Kinematic similitude
- Dynamic similitude

With the intention of getting the scale model to behave as similar to the actual parking lot as possible, Urban Sustainability Solutions attempted to satisfy each type of similitude. By way of geometric similitude and proof of concept, the team decided to use the following dimensions for the platform: a rectangular 1ft by 6ft rectangle with a depth of 1 foot. A 0.015 scale factor was used to determine the depth in order to make the model portable. A model that would have more closely accounted for all three types of similitude mentioned above might have yielded more accurate results, but time did not allot for this. However, since the primary concern in proposal Design No.2 was to greatly reduce and possibly eliminate runoff with the partition design, solely focusing on geometric similitude was suitable.

Wall thickness and weight

After determining the platform dimensions, the team considered using different materials for its construction. The most important requirements were:

- Strength to support the weight of materials housed in platform
- Allow for direct sight into the platform
- A function that would simulate different slopes

With the assistance of the Biosystems lab, a platform design that met all of the requirements above was created and built. The sides of the scale model platform and the bottom consists of plexi-glass, and the legs and base are supported by steel tubing. Also, included in the design are steel braces that provide the additional support required to negate pressure the soil and rock material exerts on the Plexiglas.

Slope Considerations

A small hydraulic jack was placed on one side of the platform in order to meet the requirement of simulating different slopes. The jack can provide a range of 1% - 5.3% in slope adjustments. If necessary, much higher slopes can be attained by making additional modifications to the entire platform.

Drainage Considerations

In order to measure and calculate runoff from the platform, the team placed a 1 inch diameter hole on one side of the model and another 1 inch hole at the bottom of the model. The hole on the side was strategically placed near the top so that a hose could be connected, the runoff could flow by gravity through the hose into a basin that was setup with a pressure transducer. The hole at the bottom was placed to allow water that had infiltrated through the different layers to effectively drain out.

Proposed Design No. 2 – Experimental design

Materials

• Scale Model Platform	• Tamp
• 1 bucket of Limestone	• Clinometer (For Quick Slope measurement)
• 7 buckets of Soil – Silt loam, Clay	• Partitions
• 4 buckets of Gravel	• Rainfall simulator
• Filter Fabric • braces (For scale model) *Note Buckets are 5 gallons	• Data logger

Methods

1. Sieve through all buckets of soil and gravel
2. Cut out 2 pieces of filter fabric (one square inch) to cover up the drainage hole and hole that leads to sensor.
3. Place half an inch of limestone on the bottom of the scale model platform. Be sure that the limestone is relatively uniform, and that the filter fabric is securely over the bottom hole.
4. Cover the limestone with 2 inches of silt loam clay. Make sure that the 2 inch layer is as uniform as possible. (Try not to disturb the limestone layer).
5. Use the tamp to compact the 2 inch layer of soil
6. Confirm that the soil layer is 2 inches all the way around the scale model platform. This can be done using a ruler.
7. Add Another 1 inch layer of soil on top of the tamped layer.
8. Place the partitions 6 inches apart on top of existing soil layer. Help may be needed to hold partitions securely in place.
9. With the partitions in place, add one inch of soil to the uncompact layer of soil.
10. With partitions in place, tamp the soil until layer is uniform. At this point, there should be 4 inches of soil.
11. Add another 2 inches of soil, and tamp the layer. Be sure that partitions are secure and not disturbed by tamping.
12. Place the 2x6 pieces of filter fabric in between the partitions, and on top of the 6 inches of soil.
13. Place braces uniformly across the top of the scale model.

14. Place 4 inches of gravel on top of the filter fabric. Make sure that the gravel is 4 inches throughout the scale model platform
15. Use hand- jack to jack the scale model platform to a slope of 5.7%. Use the clinometer to determine this 5.7% slope.
16. Place 3 rain gauges throughout the scale model platform.
17. Plug hose into the hole on side, this is to allows runoff to be tabulated using data logger.
18. Once the sensor and rain gauges are in place, turn the rainfall simulator on in order to simulate a certain storm event.
19. Record rain gauge reading every ten minutes for 1 hour and 30 minutes.
20. Allow rainfall simulator to run for at least 24 hours.
21. After the allotted time, turn off rainfall simulator and retrieve data.

Measurements and Calculations

Measurements and Calculations

In order to accurately quantify how much runoff the scale model platform yielded vs. amount of rainfall, the team needed to compensate for barometric pressure fluctuations within our platform. In addition, the team also needed to have general knowledge of the NRCS runoff Equation. This general knowledge enabled the team to compare our observed data to the data obtained from the NRCS runoff equation. To obtain the relationship between rainfall and runoff the team needed to essentially perform 4 steps:

1. Manually perform barometric compensation by subtracting barometric pressure readings (obtained from Oklahoma Mesonet) from the readings obtained from the level logger.
2. Convert the depth that we calculated in Step # 1 to a volume
3. Convert the volume from step # 2 to the depth of our scale model platform
4. Plot the observed data to the calculated data and compare results

The equation listed below is referred to as the NRCS curve number equation. It was used to help calculate runoff.

$$Q = \frac{(P - Ia)^2}{P - Ia + S}$$

Where,

- Q = Runoff (in.)
- P = Rainfall (In.)
- S = Potential maximum retention after runoff begins (in.)
- I_a = initial abstraction

Proposed Design No. 2 – Results and Discussions

Currently Undergoing Trials

Potential Impacts

Urban Sustainability Solutions' sustainable parking lot design will have the following impacts:

Environmental:

- A significant reduction of stormwater runoff and possible reduction of associated pollutants
- Increase in wildlife and insect habitat

Societal:

- Increase in amount of parking spaces
- Increase in area tourism
- Improvement of landscape aesthetics
- Encouragement of further low-impact development in downtown OKC
- Public education & outreach

Global:

Low-impact development is commonly implemented throughout the coastal regions of the U.S. and throughout various parts of Europe. However, this design has the potential to be a followed example for developing urban areas worldwide.

Project Schedule

Figure 5: Timeline of the proposed project schedule

Task Name	Duration	Start	Finish
"Green" Parking Lot	**205 days**	**Mon 8/27/12**	**Fri 6/7/13**
General Conditions	**1 day**	**Mon 8/27/12**	**Mon 8/27/12**
Meet with client and establish parameters	1 day	Mon 8/27/12	Mon 8/27/12
Background Research and Literature Review	**28 days**	**Tue 8/28/12**	**Thu 10/4/12**
Stormwater management	7 days	Tue 8/28/12	Wed 9/5/12
Low Impact Development Techniques	7 days	Thu 9/6/12	Fri 9/14/12
LID products currently on the market	7 days	Mon 9/17/12	Tue 9/25/12
Example LID projects	7 days	Wed 9/26/12	Thu 10/4/12
Site Work	**3 days**	**Fri 10/5/12**	**Tue 10/9/12**
Surveying	**3 days**	**Fri 10/5/12**	**Tue 10/9/12**
Survey first part of parking lot	1 day	Fri 10/5/12	Fri 10/5/12

Survey second half of parking lot	1 day	Mon 10/8/12	Mon 10/8/12
Identify current landscape features	1 day	Tue 10/9/12	Tue 10/9/12
Administrative	**174 days?**	**Tue 8/28/12**	**Fri 4/26/13**
First Semester Tasks	**63 days**	**Tue 8/28/12**	**Thu 11/22/12**
Design proposal Report	7 days	Tue 8/28/12	Wed 9/5/12
Write a problem statement	7 days	Thu 9/6/12	Fri 9/14/12
Write a statement of work, WBS, and task list	7 days	Mon 9/17/12	Tue 9/25/12
Write a technical analysis	7 days	Wed 9/26/12	Thu 10/4/12
Define customer requirements	7 days	Fri 10/5/12	Mon 10/15/12
Develop engineering specifications	7 days	Tue 10/16/12	Wed 10/24/12
Propose a communications plan	7 days	Thu 10/25/12	Fri 11/2/12
Propose a business plan	7 days	Mon 11/5/12	Tue 11/13/12
Generate three design Concepts	7 days	Wed 11/14/12	Thu 11/22/12
Develop a project schedule	7 days	Fri 11/2/12	Mon 11/12/12
Create a budget	1 day	Tue 11/13/12	Tue 11/13/12
Second Semester Tasks	**111 days?**	**Fri 11/23/12**	**Fri 4/26/13**
Presentation	**32 days**	**Fri 11/23/12**	**Mon 1/7/13**
Create a PowerPoint presentation	30 days	Fri 11/23/12	Thu 1/3/13
Oral Presentation	2 days	Fri 1/4/13	Mon 1/7/13
Poster	**111 days?**	**Fri 11/23/12**	**Fri 4/26/13**
Acquire poster	1 day?	Fri 11/23/12	Fri 11/23/12
Poster Design	102 days?	Thu 12/6/12	Fri 4/26/13
Develop a website	**5 days?**	**Fri 11/23/12**	**Thu 11/29/12**
Move team folder to appropriate location	1 day?	Fri 11/23/12	Fri 11/23/12
Make individual files for each team member	1 day?	Mon 11/26/12	Mon 11/26/12
Convert files to pdf	1 day?	Tue 11/27/12	Tue 11/27/12
Organize files and folders	1 day?	Wed 11/28/12	Wed 11/28/12
Coordinate with Craige Trumble to ensure files can load	1 day?	Thu 11/29/12	Thu 11/29/12
Submit project folders	1 day?	Fri 11/30/12	Fri 11/30/12
Concept Generalization	**151 days?**	**Fri 11/9/12**	**Fri 6/7/13**
First Semester Tasks	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Brainstorming	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Meet every other Friday with Dr. Vogel	30 days	Fri 11/23/12	Thu 1/3/13
Meet regularly with team	30 days	Fri 11/23/12	Thu 1/3/13
Technical Aspect	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Run a hydrologic model for each design concept	7 days	Fri 11/23/12	Mon 12/3/12
Create a 3- D visual model for each design concept	30 days	Fri 11/23/12	Thu 1/3/13
Second Semester Tasks	**30 days**	**Mon 4/29/13**	**Fri 6/7/13**
Brainstorming	**30 days**	**Mon 4/29/13**	**Fri 6/7/13**
Meet every other Friday with Dr. Vogel	30 days	Mon 4/29/13	Fri 6/7/13
Meet regularly with team	15 days	Mon 4/29/13	Fri 5/17/13
Create a list of drought tolerant plants to be used for xeric landscape	7 days	Mon 4/29/13	Tue 5/7/13
Create a list of LID techniques to	7 days	Wed 5/8/13	Thu 5/16/13

be displayed in xeric landscape			
Technical Aspect	**7 days**	**Mon 4/29/13**	**Tue 5/7/13**
Re-Run a hydrologic model for each design concept	7 days	Mon 4/29/13	Tue 5/7/13
Re-Create a 3- D visual model for each design concept	7 days	Mon 4/29/13	Tue 5/7/13
Modeling	**116 days?**	**Fri 11/9/12**	**Fri 4/19/13**
IDEAL Model No Budget	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Econ.	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Current	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Predev.	116 days?	Fri 11/9/12	Fri 4/19/13
Pervious Pavement Software	116 days?	Fri 11/9/12	Fri 4/19/13
Partition Model	26 days?	Fri 11/9/12	Fri 12/14/12

Proposed Budget

The budget for this project will be very small because the team will not be building anything except the demonstration models. Even then, the pervious concrete is the only demonstration exhibit that will need to be built, the others are conceptual. Therefore, the budget listed below is the budget for if ODEQ was to actually build the parking lot; here is the cost/benefit analysis.

According to the city of Oklahoma City's website, a retail store is charged $2.55 per 1000 gallons of water (the city of Oklahoma City, 2012).

The cost of establishing a permeable concrete is at $10 per square foot and the amount of water runoff saved per square feet 18.2 gallons of water annually (assuming at least a 10 inch annual rainfall).

The cost of establishing bioretention cells is at $27.86 per square foot and the amount of water saved per square feet 132.14 gallons of water annually (assuming at least a 10 inch annual rainfall).

Placing a monetary value on environmental benefits is difficult to estimate. The estimated benefits are associated with mitigation of climatic change, purification of air by the trees and flowers planted, improved aesthetics, and control of soil erosion and water pollution.

Item	Supplier	Quantity	Unit Price	Total
Posters	Biosytems Dept.	2	$60.00	**$120.00**
Pervious Concrete	Biosytems Dept.	1	Free	**Free**
Rubber tube for water flow	Lowe's Hardware	1	$24.95	**$24.95**
Building materials for model of partition design	Lowe's/Biosystems Dept.	-	-	**$500**
			Total	**$644.95**

Table 2:Proposed Budget for Prototype

Table 3: Actual Budget for Prototype

Item	Supplier	Quantity	Unit Price	Total
Posters	Biosytems Dept.	2	$60.00	**$120.00**
Pea Gravel	Lowe's Hardware	12	$3.00	**$36.00**
Soil – Silt loam, Clay	Biosytems Dept.	Free	Free	**-**
1 foot of PVC Pipe	Lowe's Hardware	1	$2.00	**$2.00**
Building materials for scale model	Biosystems Dept.	-	-	**$200**
Labor – Associated with building model.	Biosytems Dept.	-	-	**$300**
Landscape architecture student - Kayla	Landscape Architecture Dept.	-	-	**$675**
Transportation – using OSU vehicle: includes gas	Biosytems Dept.	Free	Free	**-**
			Total	**$958.00**

Table 3: Actual Budget for Prototype

Works Cited

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LID Retrofit of a Sloped, Impervious Parking Lot:

Urban Sustainability Solutions

Spring 2013 Presentation

Oklahoma City, OK | April 22, 2013

Sponsor: ODEQ

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY
...for a clean, attractive, prosperous Oklahoma

Instructor: **Dr. Paul Weckler**
Associate Professor

Team Advisor: **Dr. Jason Vogel**
Assistant Professor

Senior Design II
BAE 4023

OKLAHOMA STATE UNIVERSITY

LID Retrofit of a Sloped, Impervious Parking Lot:

Urban Sustainability Solutions: Team Members

Kylea Boyd – Team Leader	Biosystems Engineering – Bioprocessing & Biotechnology
Kristi Harkrider	Biosystems Engineering – Environmental & Natural Resources
Lucky Airehrour	Biosystems Engineering – Environmental & Natural Resources
Landon Johnston	Biosystems Engineering – Environmental & Natural Resources

LID Retrofit of a Sloped, Impervious Parking Lot:

Presentation Contents

Scope of Project
- Problem Statement
- Purpose
- LID Background
- Site Description

Design Specifications
- List of ODEQ Requirements

Selected Design Concepts
- Retention Grate
- Pervious Concrete & Partitions
- Xeriscape

Experiments & Testing
- Partition Design

Hydrologic Modeling
- Runoff Volumes & Flow Rates
- Nomographs

Design Quality
- Meeting ODEQ Design Specs.

Budget
- Senior Design Project Budget
- Estimated Cost to Implement Design

LID Retrofit of a Sloped, Impervious Parking Lot:

Scope of Project: Problem Statement

Urban Sustainability Solutions' will implement low-impact development techniques in a design that will retrofit an existing Oklahoma Department of Environmental Quality headquarters parking lot. Our goal is to provide a cost-competitive, low-maintenance, and aesthetically pleasing design that returns the site's hydrologic functionality to a near-predevelopment state.

LID Retrofit of a Sloped, Impervious Parking Lot:

Federal Stormwater Rule Proposal

- EPA intends to propose a new stormwater rule
- Proposal by June 10, 2013
- Final action by December 10, 2014
- The new rule will likely encourage the use of green infrastructure and low-impact development as the acceptable management methods

LID Retrofit of a Sloped, Impervious Parking Lot:

Scope of Project: LID Background

LID → Low-impact Development

Predevelopment Runoff = Development Runoff

<u>In our case:</u>

Runoff from rangeland = Runoff from parking lot

Examples include:

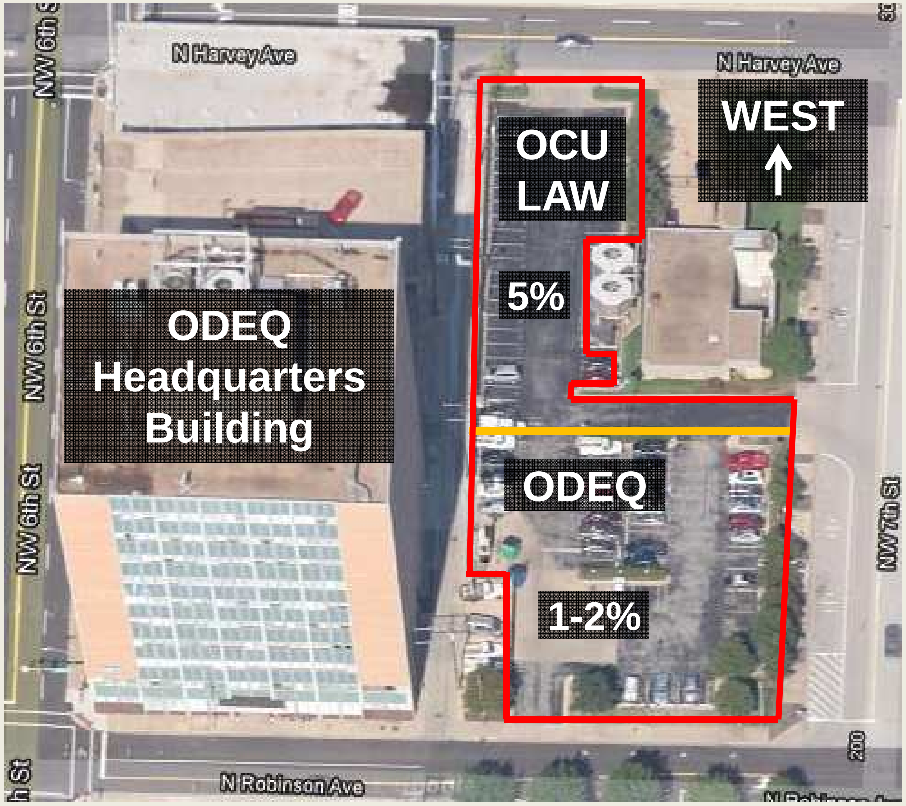
- Bioretention Cells, Rain Gardens
- Rainwater harvesting for non-potable use
- Green Roofs
- Pervious Pavement

LID Retrofit of a Sloped, Impervious Parking Lot:

Scope of Project: Site Description

ODEQ Headquarters Parking Lot

Downtown Oklahoma City, Oklahoma



- Up to 5% slope
- 0.70 acres of impervious area
  - Asphalt
  - Concrete loading area
- Split-ownership
  - ODEQ owns East
  - OCU Law owns West
- 83 parking spaces
- Ordinary landscaping

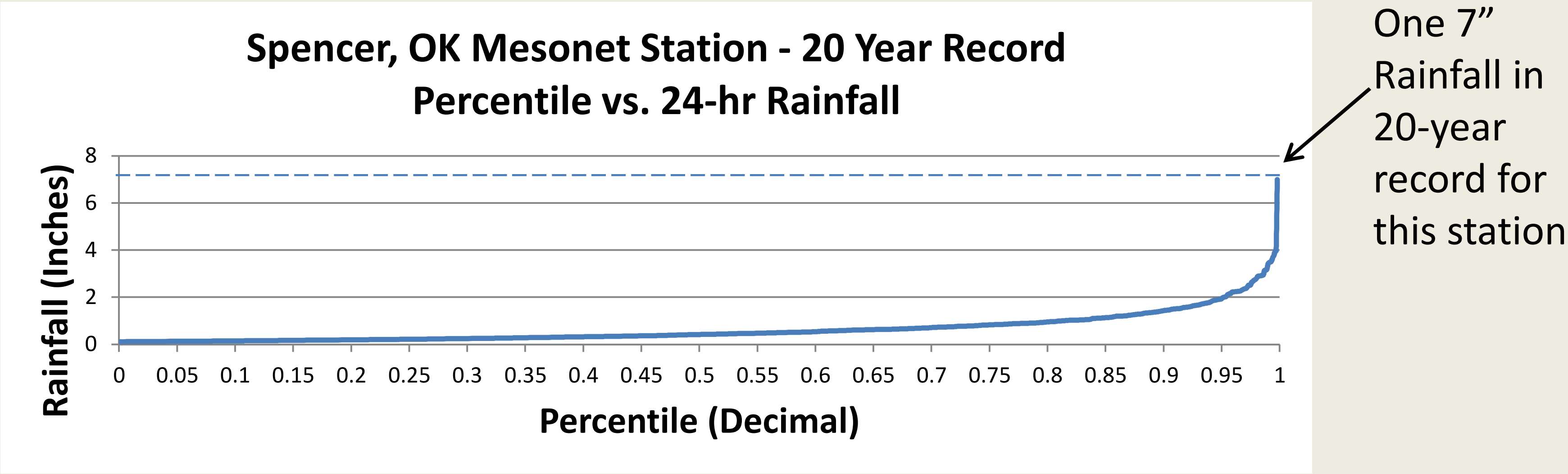
LID Retrofit of a Sloped, Impervious Parking Lot:

Design Specifications: ODEQ Requirements

- Process stormwater from a 95th percentile 24-hr storm in a manner that will maintain a predevelopment state of hydrologic functionality.
- Retain the current number of parking spaces (83), and increase this number if possible.
- Retain the impervious concrete area for truck loading
- Create a xeric landscape featuring native plants.
- Aims to set a precedent in LID design for the State of Oklahoma.

LID Retrofit of a Sloped, Impervious Parking Lot:

What is a 95th Percentile 24-hr Storm



Rainfall event where 95 percent are less than and 5 percent are greater than

- 95th Percentile 24-hr Storm = **1.92”**
- 25-year 24-hour storm = **7”** (USGS IDF Curve)

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts

Retention Grate:

- Low-budget alternative

Pervious Concrete & Partitions:

- Non-limiting initial cost alternative

Xeriscape:

- Implemented in both design alternatives

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Retention Grate

Function:

- Manage a 24-hr, 25-yr storm (7 inch/day)
- Filter sediment
- Allow water to infiltrate into soil

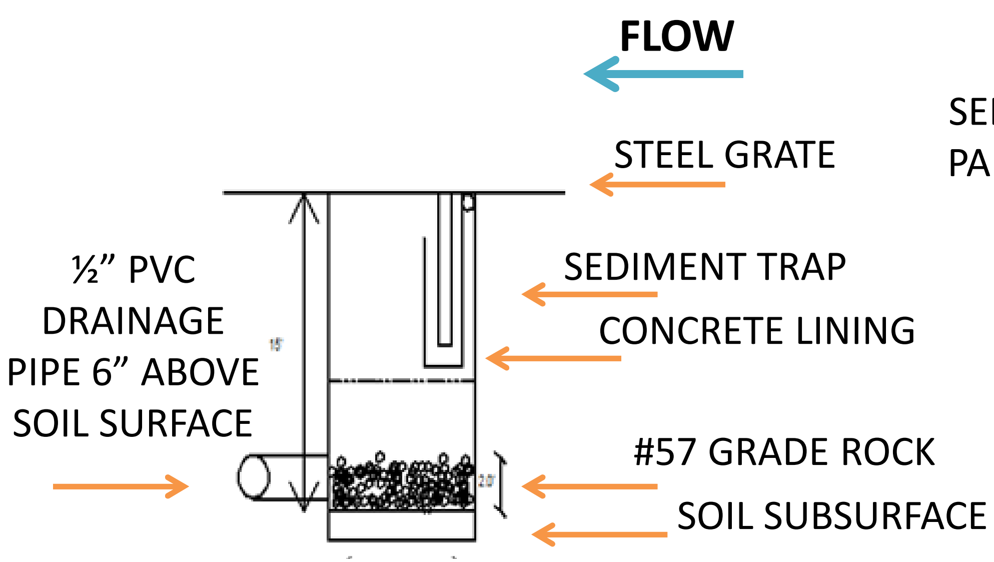
Materials:

- Concrete
- #57 Grade Rock
- Cast Iron Grates
- Steel Sediment Trap
- PVC Pipe

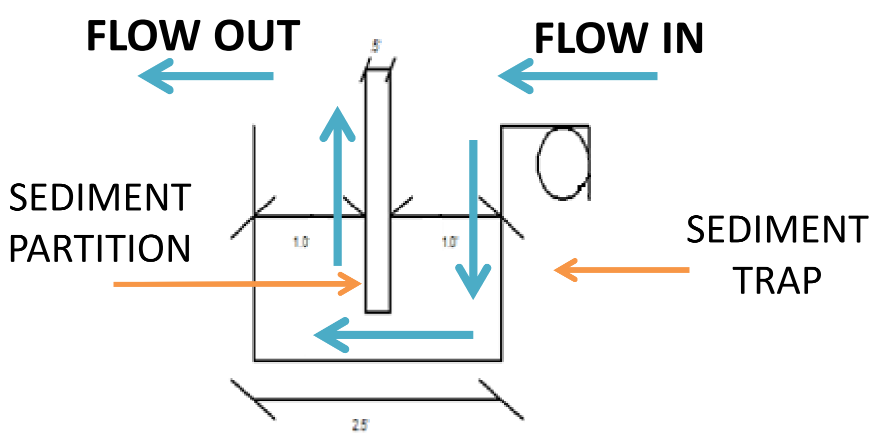
LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Retention Grate

<u>Retention Grate Design:</u>



INFILTRATION TRENCH



INSIDE OF SEDIMENT TRAP

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Pervious Concrete & Partitions

Function:

- Capture stormwater
- Negate effects of slope
- Retain stormwater
- Prevent stormwater runoff
- Allow water to infiltrate into soil

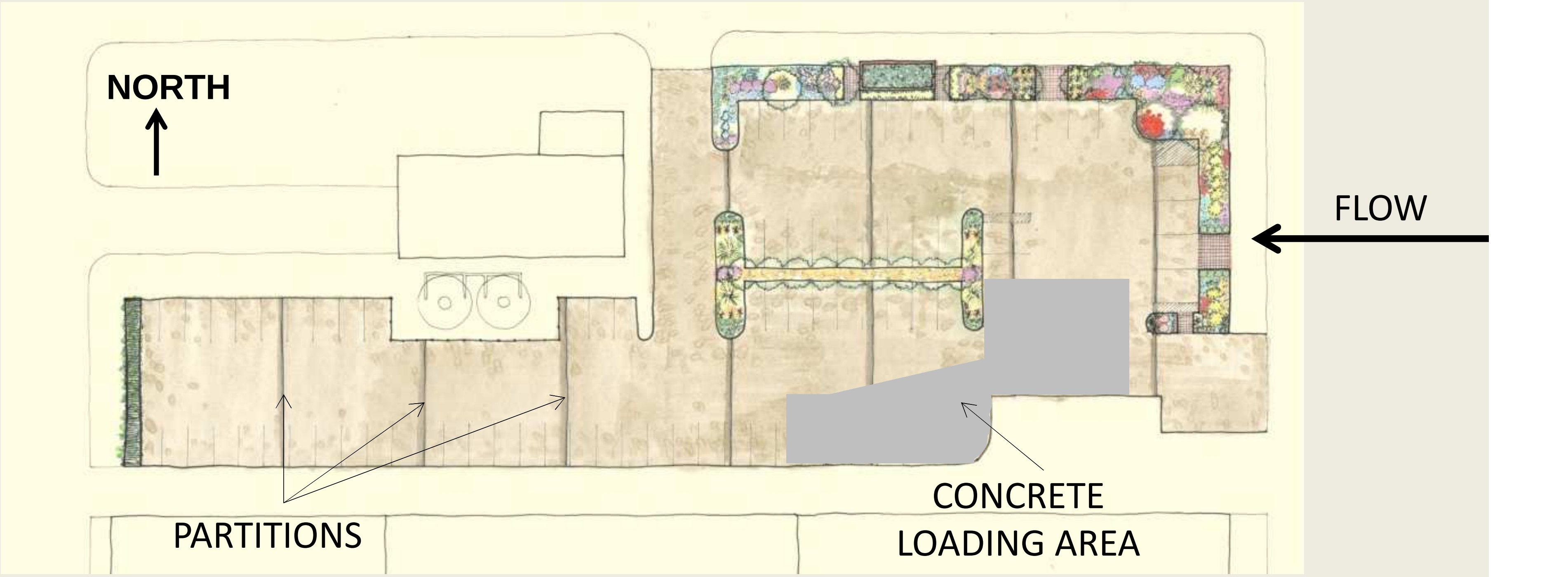
Materials:

- Pervious Concrete
- #57 Grade Rock
- Impervious Concrete Partitions
- Geotextile Membrane

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Pervious Concrete & Partitions

Plan View of Parking Lot & Landscape:

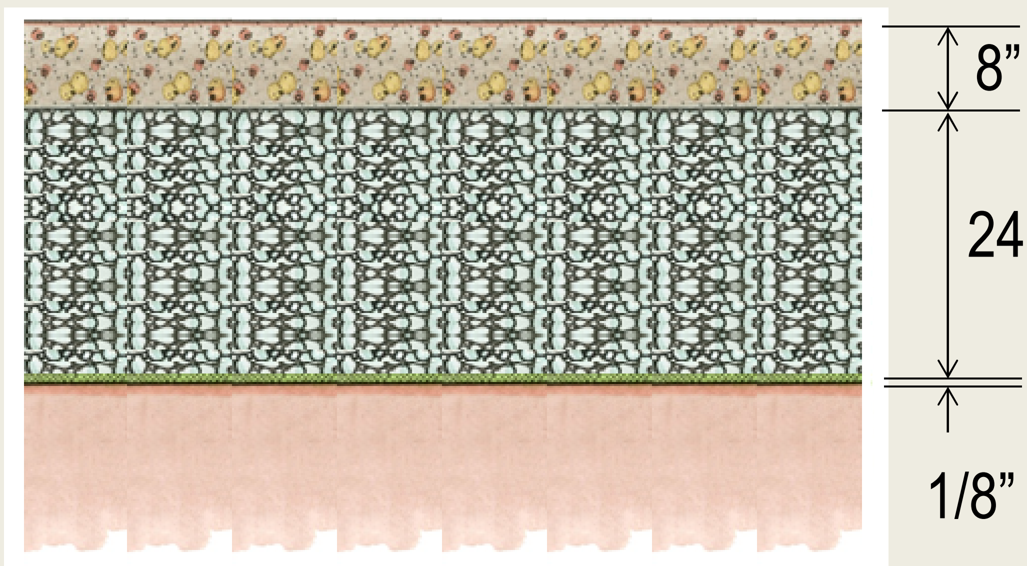


ODEQ Headquarters Building

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Pervious Concrete & Partitions

<u>Pervious Concrete Design:</u>



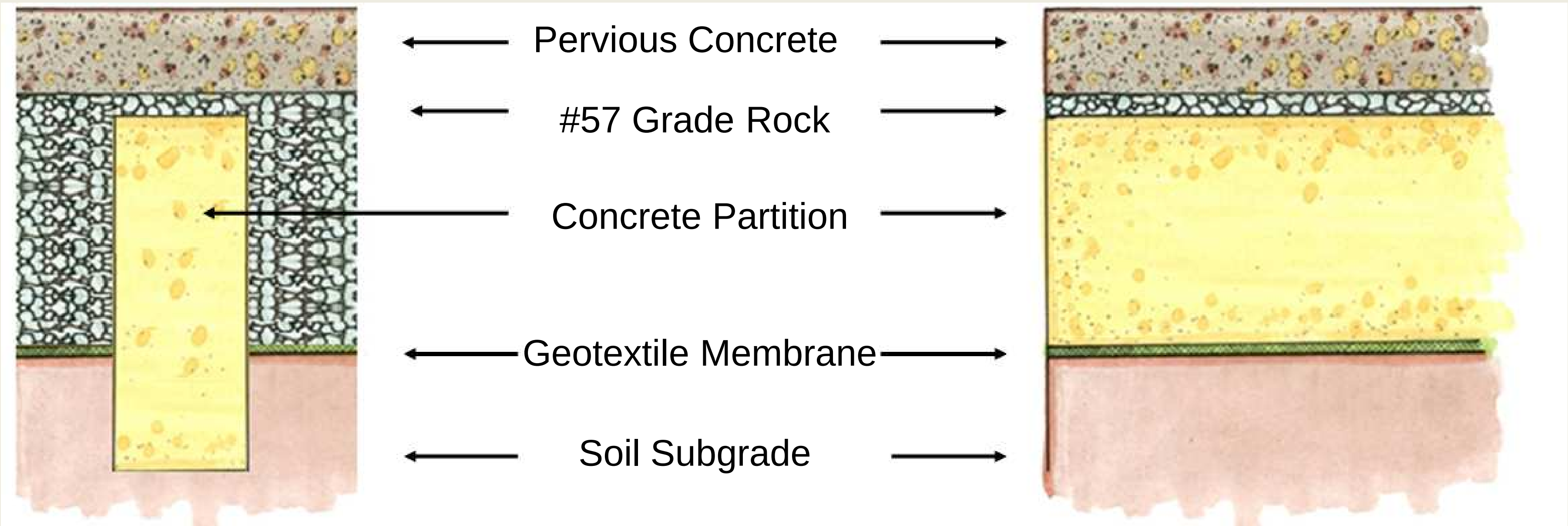
LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Pervious Concrete & Partitions

Partition Design:

Side View

Front View

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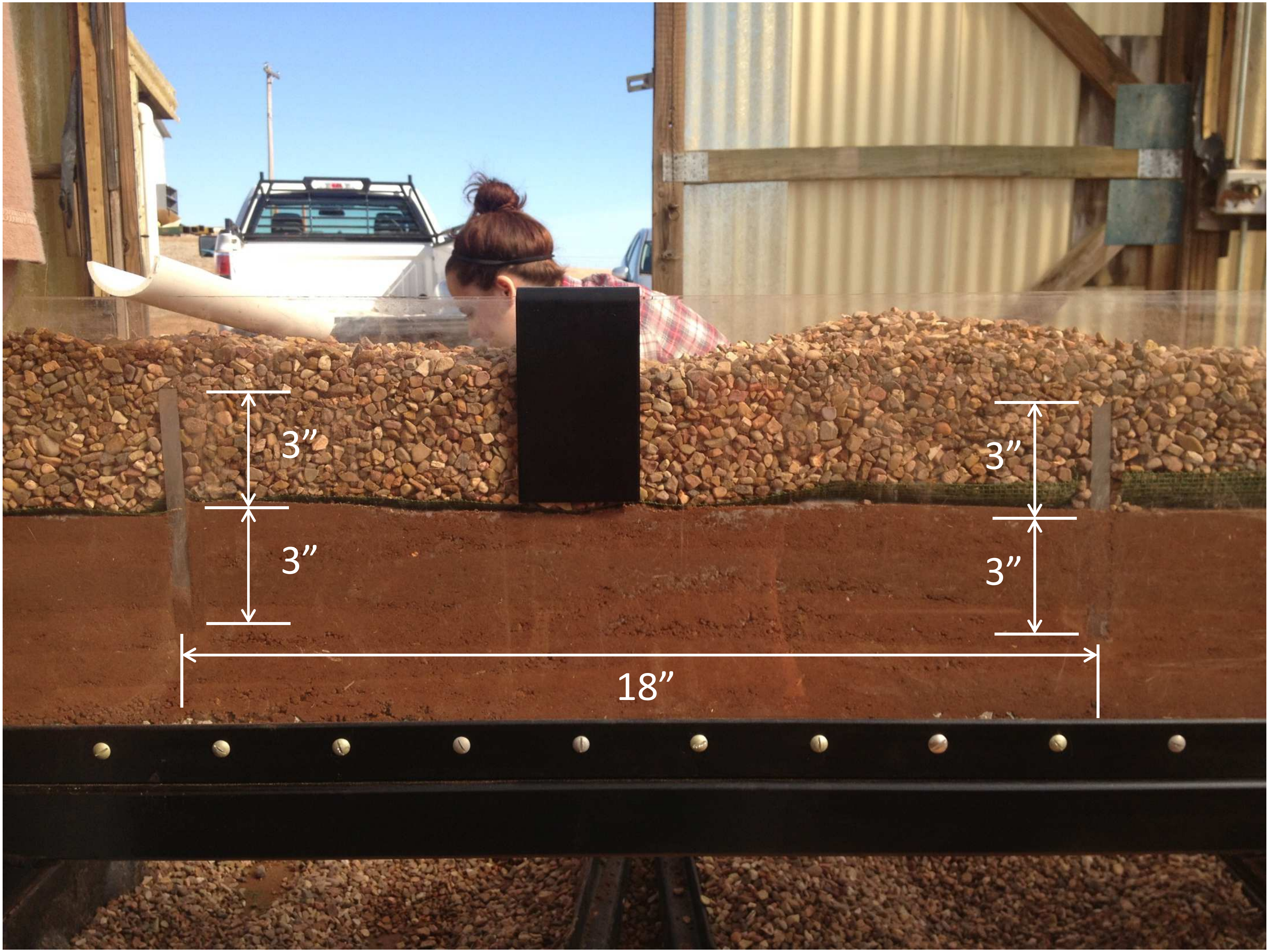
1 ft
6 ft


3”
3”
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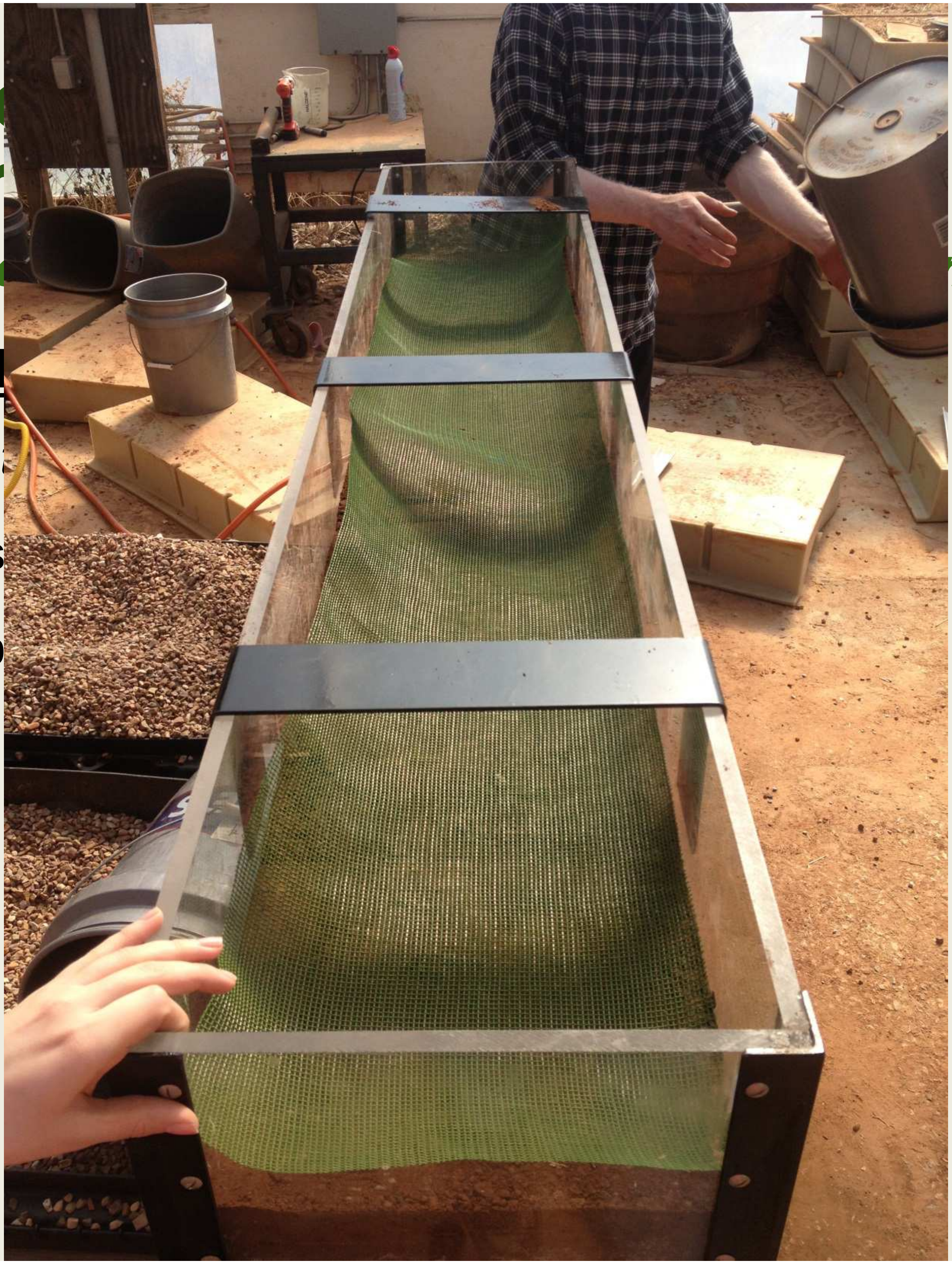

<u>Scale-model I</u>

Soil Representa

- Silt loam clos
- Textile memb

LID Retrofit of a Sloped, Impervious Parking Lot:

Experiments & Testing: Partition Design

Scale-model Partition Experiment:

Concrete Representation

- Not included in the experiment due to established ability to drain through conrete

LID R
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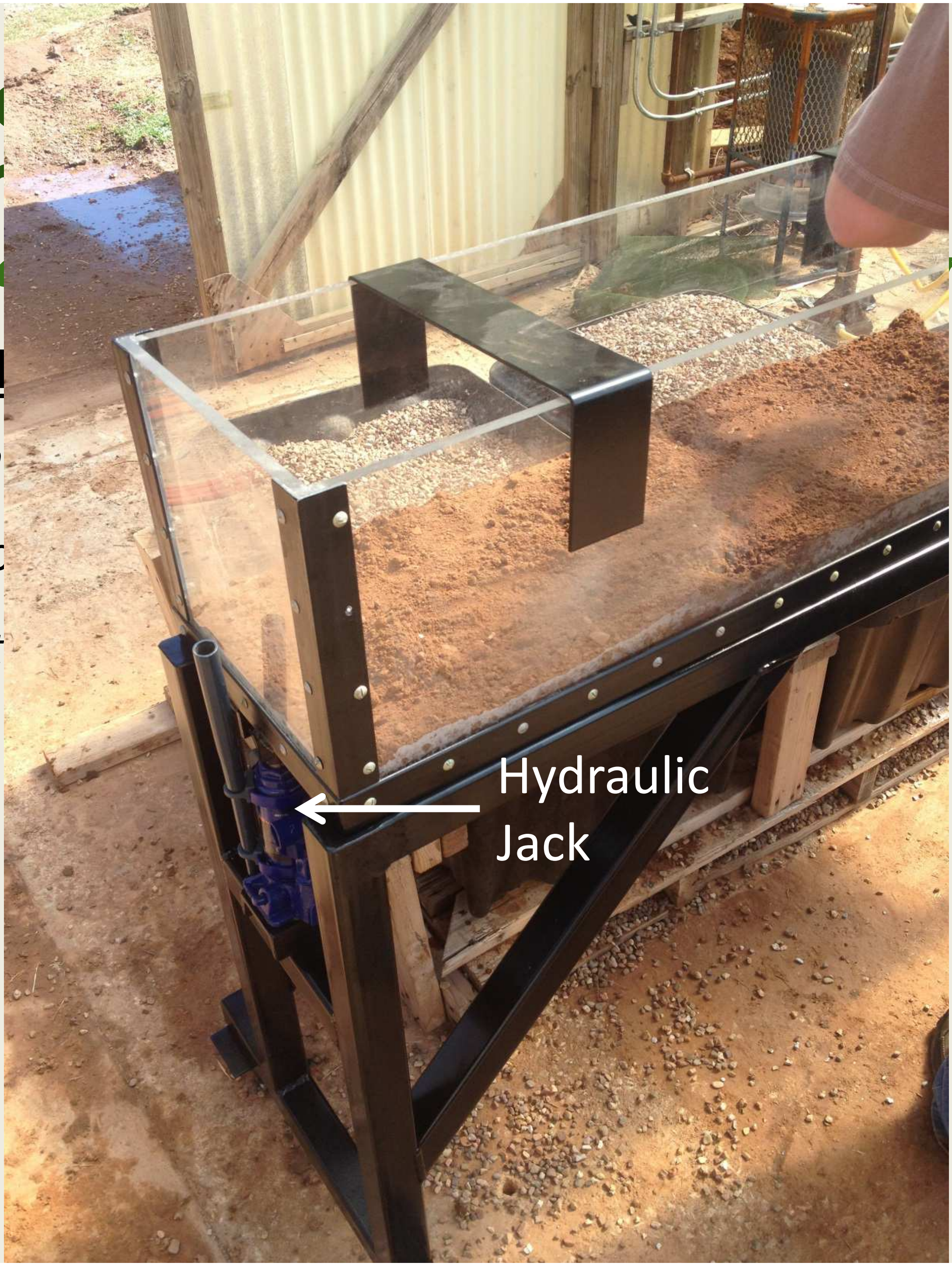
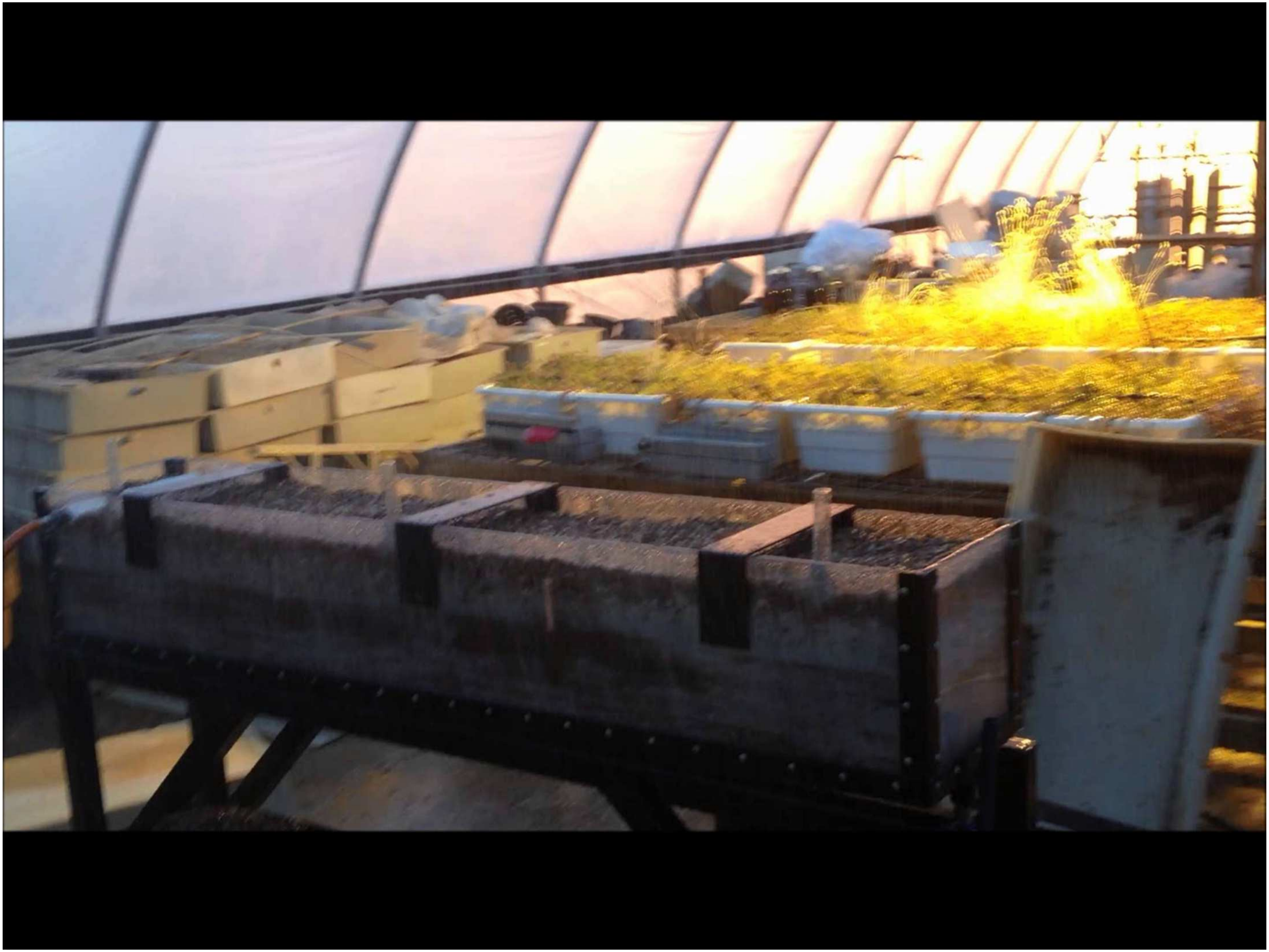
Scale-model I

Slope Represen

- *Hydraulic Ja*
- *Provides up t*

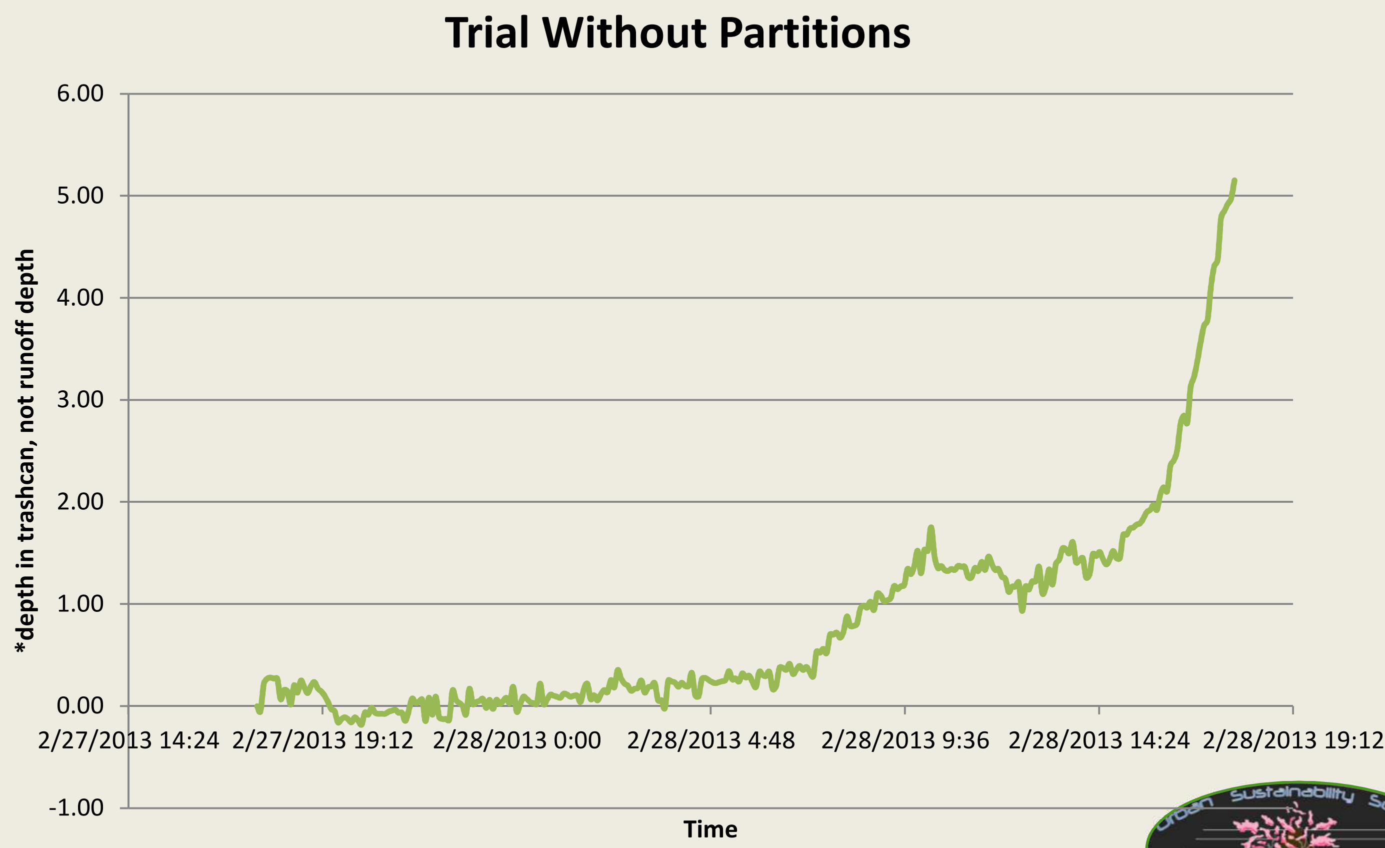




LID Retrofit of a Sloped, Impervious Parking Lot:

Experiments & Testing: Partition Design

Scale-model Platform Results:



LID Retrofit of a Sloped, Impervious Parking Lot:

Experiments & Testing: Partition Design

Scale-model Platform Results:

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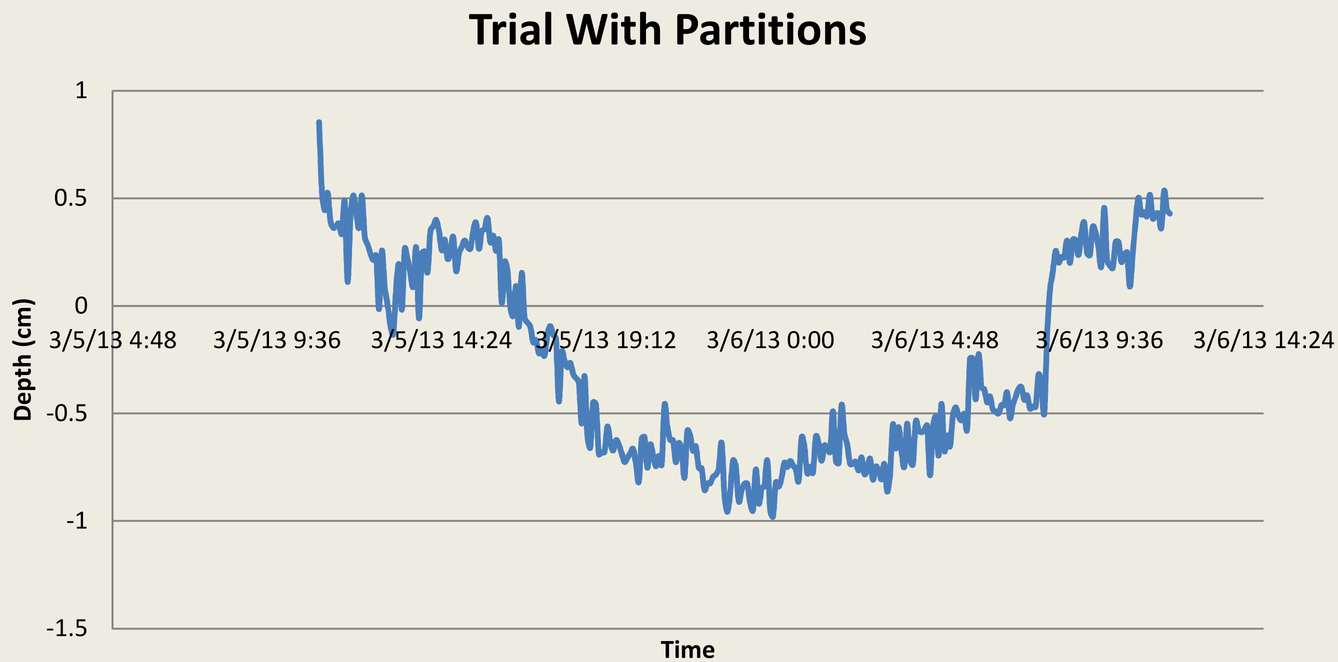


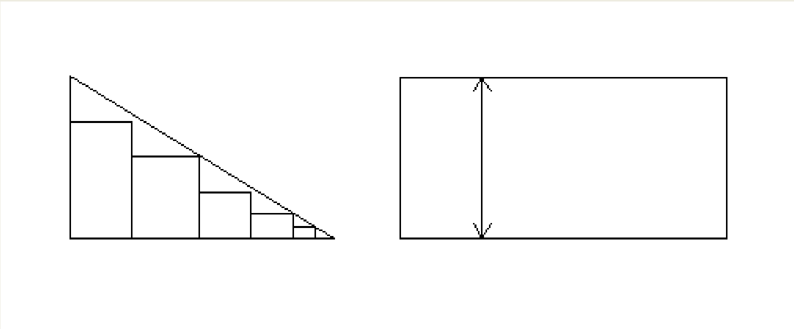
LID Retrofit of a Sloped, Impervious Parking Lot:

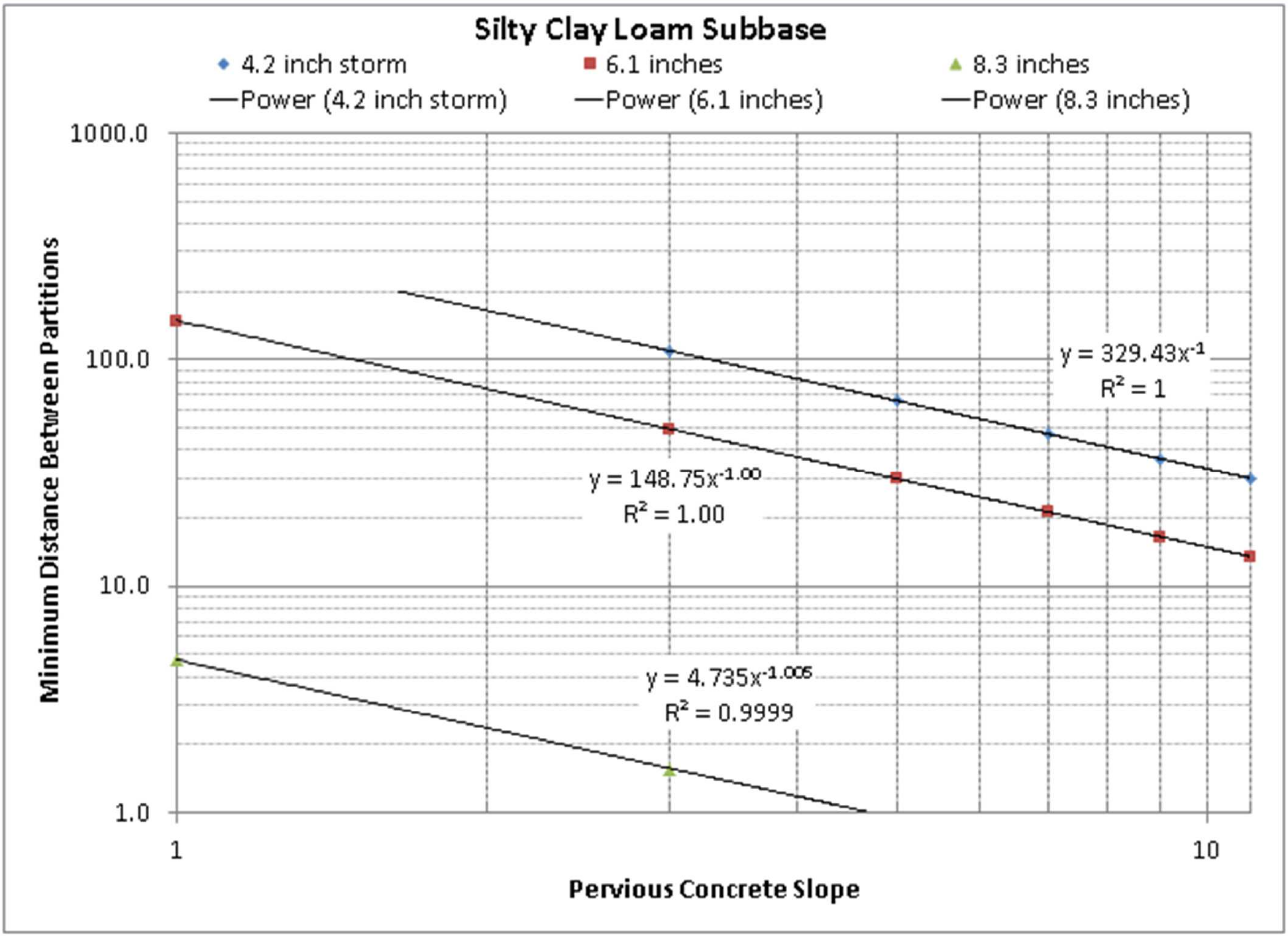
Hydrologic Modeling: IDEAL Inputs

- Subbase as a parrallelogram

$$Retention\ Capacity\ Efficiency = \frac{\left(0.4 * \left((H * D) - \left(Slope * D^2\right)\right)\right)}{((H * D) * 0.4)} * 100$$

- Create equivalent thickness for 0.001% slope
- Entered into IDEAL to gather runoff=0



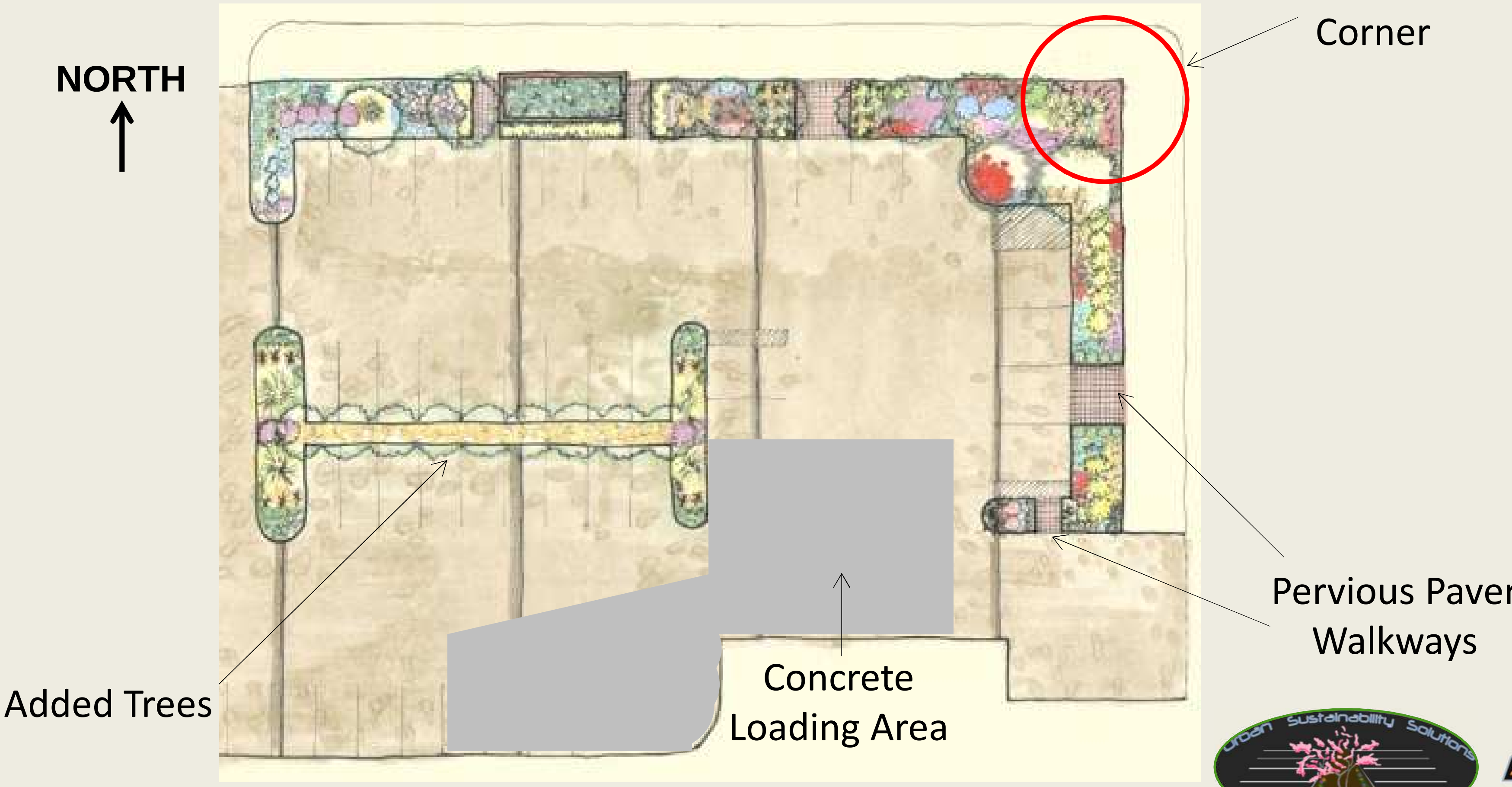


Silty Clay Loam Subbase
4.2 inch storm
6.1 inches
8.3 inches
Power (4.2 inch storm)
Power (6.1 inches)
Power (8.3 inches)
1000.0
100.0
10.0
1.0
1
10
Minimum Distance Between Partitions
Pervious Concrete Slope
y = 329.43x-1
R² = 1
y = 148.75x-1.00
R² = 1.00
y = 4.735x-1.006
R² = 0.9999

LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Xeriscape

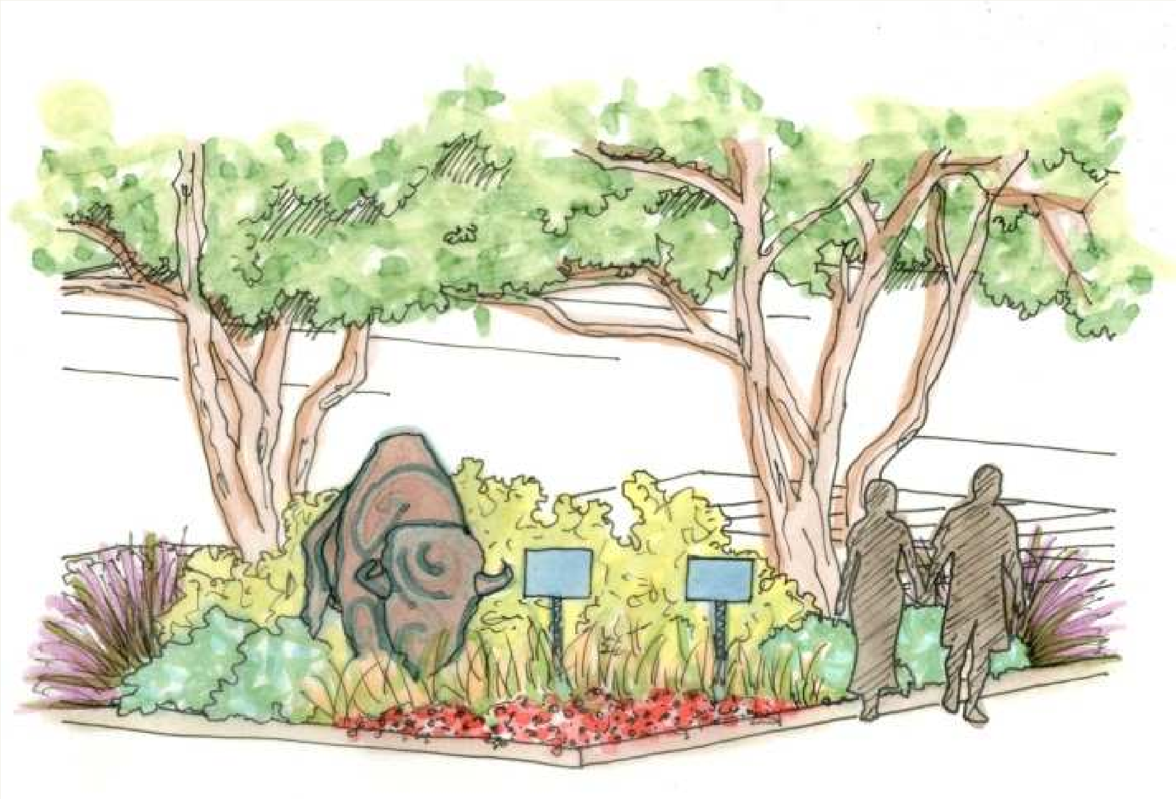
Plan View of Parking Lot & Landscape:



LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Xeriscape

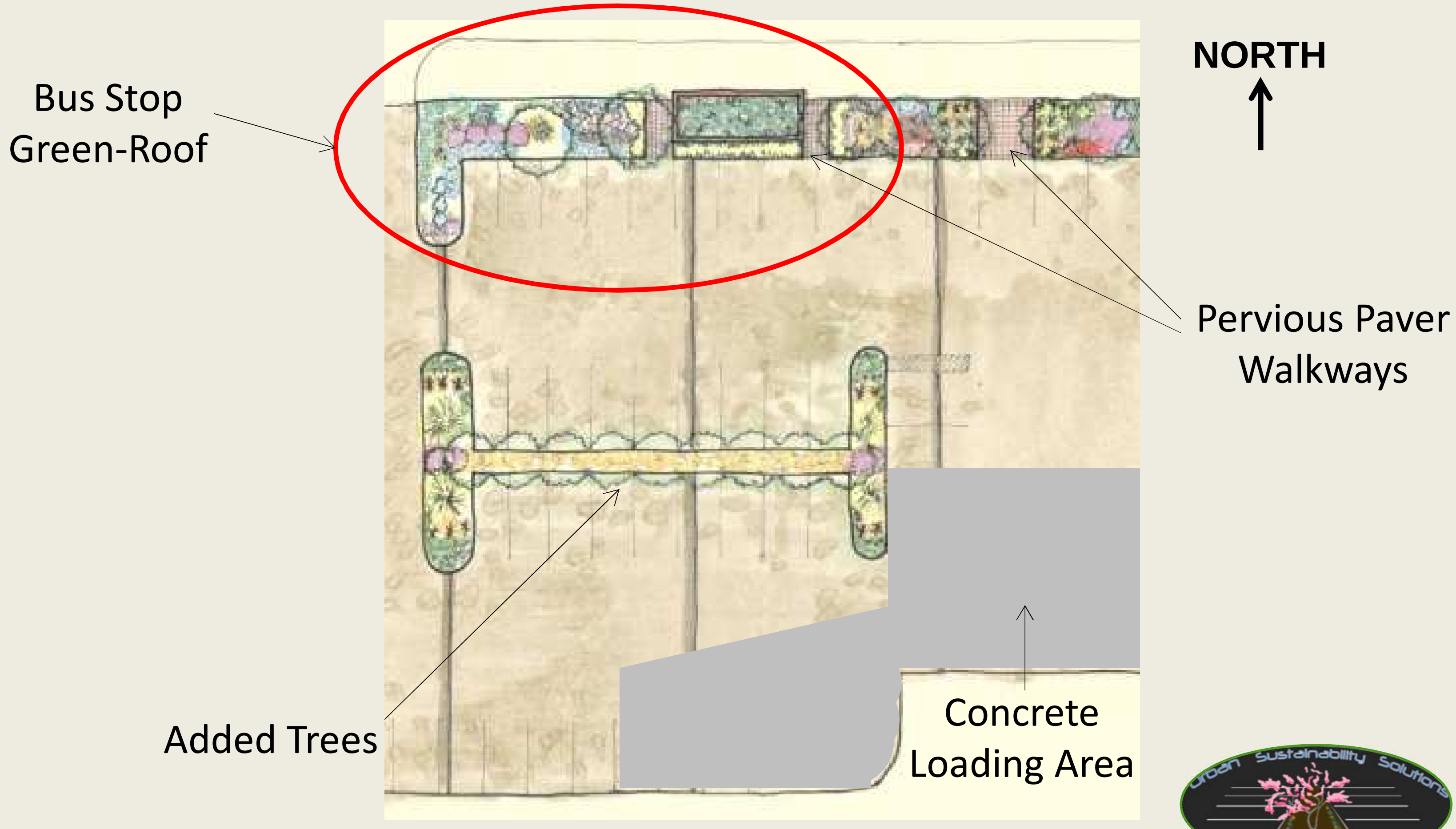
<u>Northeast Corner of Parking Lot:</u>



LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Xeriscape

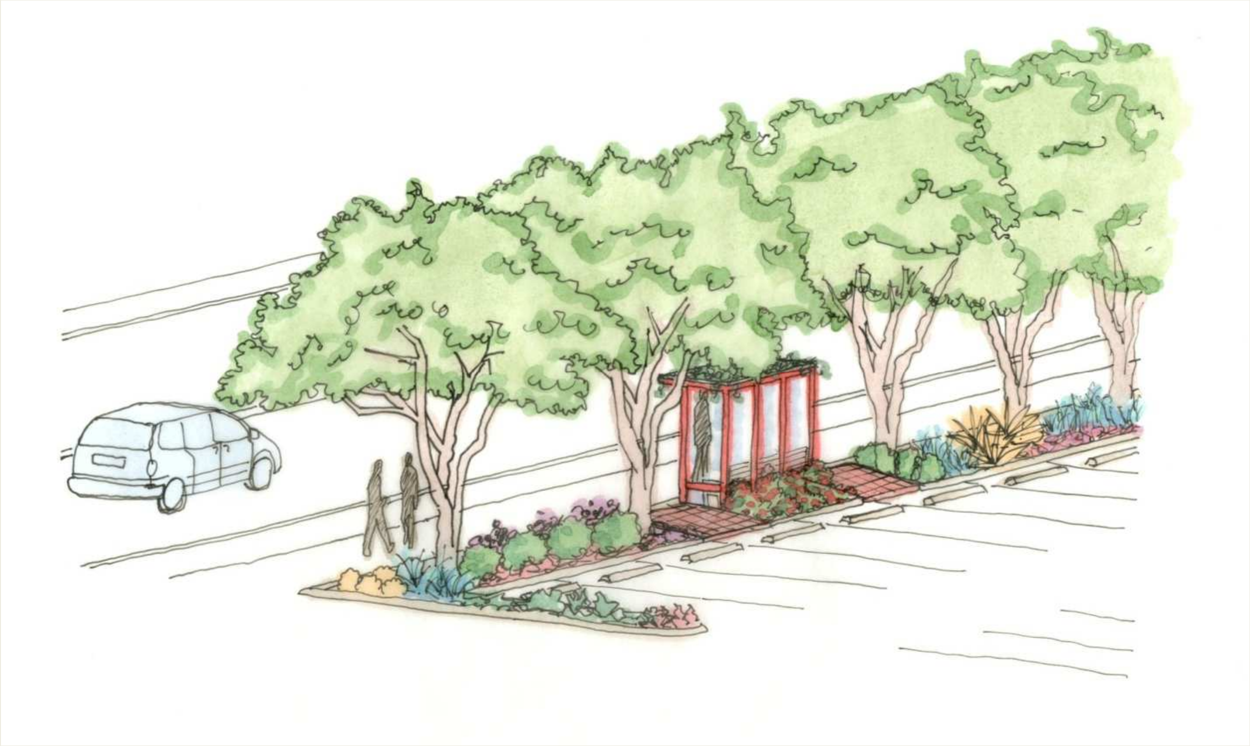
Plan View of Parking Lot & Landscape:



LID Retrofit of a Sloped, Impervious Parking Lot:

Selected Design Concepts: Xeriscape

Bus Stop Green-Roof:



LID Retrofit of a Sloped, Impervious Parking Lot:

Budget: Estimated Cost to Implement Impervious Concrete

Impervious Concrete Parking Lot Costs			
Title	**Area (ft^2)**	**Cost ($\$/ft^2$)**	**Total**
West End Impervious	13357.64	$ 6.00	$ 80,145.81
East End Impervious	16922.00	$ 6.00	$ 101,532.00
TOTAL			**$ 182,886.81**

Prices quoted from Canterra Concrete and Homewyse (include labor)

LID Retrofit of a Sloped, Impervious Parking Lot:

Budget: Estimated Cost to Implement Pervious Concrete & Partition Design

Pervious Concrete Parking Lot Costs			
Title	**Area**	**Cost**	**Total**
West End Pervious Concrete	13357.64 ft^2	\$11.00/ft^2	\$146,933.99
East End Pervious Concrete	16922 ft^2	\$11.00/ft^2	\$186,142.00
East End Excavation (all costs included)	1733 ft^3	\$98.46/ft^3	\$23,773.76
West End #57 Grade Rock	989 tons	\$15/ton	\$14,921.80
East End #57 Grade Rock	1253.48 tons	\$15/ton	\$ 18,802.20
	# Bricks/Plants		
Bricks	2418	\$ 0.50/brick	\$1,209.00
Plants	200	\$ 6.50/plant	\$1,300.00
TOTAL			**\$ 393,042.75**

Prices quoted from Canterra Concrete and Homewyse (include labor)

LID Retrofit of a Sloped, Impervious Parking Lot:

Design Quality: Meeting ODEQ Requirements

- Process stormwater from a 95th percentile storm in a manner that will maintain a predevelopment state of hydrologic functionality.

Implementation of either of the two proposed designs.

- Retain the current number of parking spaces (83), and increase this number if possible.

Remove medians and replace with extra spaces. Reevaluate how the current layout meets ADA standards.

- Create a xeric landscape featuring native plants.

Creatively feature LID techniques in order to provide public education and outreach on LID and stormwater management. Is aesthetically pleasing and can be a popular tourist attraction. Attracts and provides habitat for birds, butterflies, and other animals.

LID Retrofit of a Sloped, Impervious Parking Lot:

Budget: Senior Design Proposed Project Budget

Actual Project Budget

Budget from ODEQ	
Item	Amount
Posters	$ 120.00
Pea Gravel	$ 36.00
PVC Pipe	$ 2.00
Buiding Materials for model	$ 130.60
Shop Charges	$ 100.00
Landscape Architecture Student	$ 675.00
Total from ODEQ	$ 1,063.60

In Kind Budget

Salaries and Wages

Title	Price
Student Intern	$20/hour
Grad Student	$30/hour
Senior Faculty	$125/hour

Person	Hours	Total
Design Team	300	$6,000.00
Dr. Jason Vogel	40	$5,000.00
Halley Malle	15	$450.00

Equipment			
Item	Price	Unit	Amount
Surveying Equipment	$200/day	2	$400.00
Greenhouse Use	$30/day	14	$420.00

Total	$12,270.00

LID Retrofit of a Sloped, Impervious Parking Lot:

Special Thanks and Acknowledgements to:

- Oklahoma Department of Environmental Quality
- Dr. Jason Vogel
- Wayne Kiner and the BAE shop
- Dr. Paul Weckler
- Haley Malle
- Kayla Copeland
- BAE 1012 Freshmen Students

Design of a Sustainable Parking Lot

Fall 2012 Design Proposal Report

By:

Kristi Harkrider
Kylea Boyd
Landon Johnston
Lucky Airehrour

Prepared for:

Oklahoma Department of Environmental Quality

Table of Contents

Problem Statement

Urban Sustainability Solutions' will implement low-impact development techniques in a design that will retrofit an existing Oklahoma Department of Environmental Quality headquarters parking lot. Our goal is to provide a cost-competitive, low-maintenance, and aesthetically pleasing design that returns the site's hydrologic functionality to a near-predevelopment state. A functional design model of the parking lot demonstrating LID techniques will be built for display in the lobby of the ODEQ headquarters office that will set a precedent for future low impact development in Oklahoma.

Mission Statement

Urban Sustainability Solutions strives to provide environmentally compliant, low-impact development designs for a sustainable future. Our designs use innovative technologies that save money and resources. From non-profit to Fortune 500 companies, Urban Sustainability Solutions strives to retrofit existing sites or provide sustainable design and installation at undeveloped sites that promote the growth of green technologies in the central United States.

Statement of Work

Purpose:

Traditional approaches to stormwater management are being replaced with an eco-friendly approach whose goal is to return hydrologic functionality of developed areas to pre-development states through the use of low-impact development techniques. Laws requiring newly developed areas to process stormwater from a 95th percentile storm in order to maintain a predevelopment hydrologic regime currently exist in several states and will soon be proposed by the EPA. Although nonexistent in Oklahoma, the Oklahoma Department of Environmental Quality anticipates the approval of such a law at the federal level in the near future. In anticipation of a more intensive federal stormwater law, ODEQ would like to redesign their headquarters building parking lot in order to meet future stormwater management requirements set by the EPA.

Organization of Tasks

USS will perform the following tasks in order to accomplish the objectives listed above:

Background Research and Literature Review on:

- Stormwater management
- Low-Impact Development techniques
- LID products currently on the market
- Example LID projects

Surveying

- Survey parking lot in two trips
- Use survey data to create topographic maps

- Determine slope of key areas of parking lot

Administrative

- Design Proposal Report
    - Write problem statement
    - Write statement of work, WBS, & tasks list
    - Write technical analysis/market research/patent search
    - Define customer requirements
    - Develop engineering specifications
    - Propose a media/communications plan
    - Propose a business plan/financial analysis
    - Generate 3 design concepts
    - Develop a project schedule (Gantt chart)
    - Create/Propose a budget
- Oral Presentation
    - Create a PowerPoint presentation
    - Create posters
- Develop a basic website
    - Move team folder to appropriate location
        - Each team member must place their files in this folder
        - Convert files to .pdf
        - Organize files & folders
    - Coordinate with Craig Trimble to ensure files can load
- Submit project notebooks

Concept Generation

- Meet every other Friday with Dr. Vogel
- Meet regularly with team and/or communicate via email & text
- Run a hydrologic model for each design concept
    - Identify important figures generated by model
- Create list of techniques/systems to be used in Design 3
- Create list of drought tolerant plants to be used in xeric landscape
- Create list of LID techniques to be displayed in xeric landscaped area for educational purposes
- Create a 3-D visual model for each design concept

Work Breakdown Structure

1. "Green" Parking Lot	**100**

1. "Green" Parking Lot	
1.1. Background Research	**15**
1.2. Administrative Tasks	**35**
1.3. Concept Generation	**40**
1.4. Project Management	**10**
	100

1. "Green" Parking Lot	
1.1. Background Research	
1.1.1. Stormwater management	**1**
1.1.2. Low-Impact Development techniques	**5**
1.1.3. LID products currently on the market	**2**
1.1.4. Example LID projects	**7**
1.2. Administrative Tasks	
1.2.1. Design Proposal Report	**20**
1.2.2. Oral Presentation	**10**
1.2.3. Basic Website	**3**
1.2.4. Project Notebook	**2**
1.3. Concept Generation	
1.3.1. Brainstorming	**6**
1.3.2. Surveying	**6**
1.3.3. Pervious Concrete Testing	**4**
1.3.4. Hydrologic Modeling	**12**
1.3.5. 3-D Visual Modeling	**12**
1.4. Project Management	
1.4.1. Meetings	**2**
1.4.2. Site Visits	**2**
1.4.3. Regular Communication	**1**
1.4.4. Peer-reviewing assignments	**5**
	100

Required Resources for Completion of Tasks

The resources needed for the completion of the above tasks are organized below:

1. "Green" Parking Lot

1.1. Background Research

Resources Required: *Team Labor*

1.1.1. Stormwater management
1.1.2. Low-Impact Development techniques
1.1.3. LID products currently on the market
1.1.4. Example LID projects

1.2. Administrative Tasks

Resources Required: *Team Labor*

1.2.1. Design Proposal Report
1.2.2. Oral Presentation
1.2.3. Basic Website
1.2.4. Project Notebook

1.3. Concept Generation

Resources Required: *Team Labor, Surveying Equipment, Pervious Concrete, IDEAL software, Sketchup software, Photoshop software, AutoCAD software, Fuel*

1.3.1. Brainstorming
1.3.2. Surveying
1.3.3. Pervious Concrete Testing
1.3.4. Hydrologic Modeling
1.3.5. 3-D Visual Modeling

1.4. Project Management

Resources Required: *Dr. Vogel, Dr. Weckler, Kelly Dixon*

1.4.1. Meetings
1.4.2. Site Visits
1.4.3. Regular Communication
1.4.4. Peer-reviewing assignments

Deliverables

Urban Sustainability Solutions will develop three design concepts to be reviewed by ODEQ at the end of the fall semester. A hydrologic modeling program will be used to provide insight to the hydrologic functionality of each design. In addition, a 3-D visual modeling program will be created for each design concept. One or more posters can be created by using the 3-D renderings in conjunction with the hydrological models. This will increase ODEQ's ability to make suggestions and select a combination of techniques they would like to see included in a final design.

Monitoring Deliverables

The posters to be created by the end of the fall semester can be displayed in the lobby of the ODEQ headquarters building. Public response to the design concepts can be monitored by ODEQ staff.

Parameters for Quality

Meeting the objectives listed will be the factor that determines the quality of design concepts created by USS:

- Process stormwater from a 95^{th} percentile storm in a manner that will maintain a predevelopment hydrologic regime.
- Retain the current number of parking spaces (83), and increase this number if possible.
- Create a xeric landscape that:
    - Creatively features low-impact development techniques in order to educate the public on LID and stormwater management.
    - Is aesthetically pleasing and can be a popular tourist attraction.
    - Attracts and provides habitat for birds, butterflies, and other animals.
- Synergistically combine proven techniques with new technologies in order to maximize innovation in the design.
- Aims to set a precedent in LID design for the State of Oklahoma.

Technical Analysis

Research & Literature Review:

Although our team may invent new low-impact development (LID) solutions, we will best complete the project by integrating several products and methods that already exist. The team has analyzed, researched, and investigated technical literature and patents which will provide insight into whether existing products and methods will suit our design needs, or if new inventions/methods will be required in addition.

We will identify the following:

- Similar items or solutions to the problem
- Technical specifications for existing products or methods (evaluations of strengths and weaknesses)
- Durability, reliability, maintenance costs, maintenance requirements, ect.
- Characteristics that are technically possible excluded in existing products
- Safety issues that must be addressed.
- Relevant patents

Our research focuses on LID design strategies that significantly minimize pollutant transport, soil erosion, and flooding caused by stormwater runoff. These strategies create a multi-functional design aimed to return the hydrologic functionality of developed areas to a near-predevelopment state, remove pollutants from the retained stormwater, and create a low-maintenance and aesthetically-pleasing natural landscape. The table on the following page outlines traditional parking lot materials, existing LID concepts, and descriptions of their associated strengths and weaknesses.

Material/Concept	Strengths	Weaknesses
Efficient Parking Lot Design	- Greatly reduces impervious area - Provides the extra room needed for LID design	- This may require convincing governing bodies to changes city code. - Reduced number of parking stalls
Asphalt	- Smooth finish provides limits noise and allow for easy snow removal - Lower initial cost - Recyclable	- Heat adsorbing properties - Not suitable for heavy loads - Moderate upkeep - High maintenance costs - Impervious
Concrete	- Heavy load-bearing - Reflective properties - Long-lasting - Low maintenance costs compared to asphalt	- Moderate upkeep - Impervious - Higher initial cost
Pervious Paving	- Different options/looks (concrete, pavers, reinforced grass, reinforced gravel) - Reduces pollutant transport - Reduces stormwater erosion - Recharges groundwater	- Reflective properties - High maintenance costs - Moderate upkeep - Higher initial cost - Unsmooth surface makes for more difficult snow removal
Adding Tree Canopy	- Intercepts/slows, absorbs, and filters stormwater - Helps reduce urban heat-island effect - Known to remove air pollutants such as ozone, nitrogen oxides, sulfur dioxide, and ammonia - Mature trees can increase property values	- Roots can damage building foundations and parking lots
Vegetated Swales/Planters	- Require less infrastructure (piping) - Simple to construct - Low initial cost - Low maintenance cost - Low upkeep - Improves water quality	- Requires long, continuous spaces - Not as aesthetically-pleasing
Weirs/Check Dams	- Can be adjustable to control amount of water to be retained - Useful when slopes are 4% or greater - Slows runoff on sloped gradient and replaces piping - Inexpensive to build	- Upkeep similar to that of traditional landscaping - Requires appropriate topography - Grading must be sufficient to allow water to enter
Green Gutters	- Slows and filters stormwater - Inexpensive to build	- Offer little or no water retention - Require a long footprint to effectively slow and filter stormwater
Bioretention Cells/Rain Gardens	- Inexpensive to build - Can provide the greatest stormwater flow - Can improve water quality/remove pollutants - Offer versatility in shape. - Aesthetically-pleasing	- Upkeep similar to that of traditional landscaping - Can be difficult to find large spaces for rain gardens in ultra-urban or retrofit conditions.
Rain Barrels/Cisterns	- Can retain large amounts of water - Retained water can be used for landscaping or grey-water	- Typically used for in rooftop collection applications - Unless gravity fed, a pump would be required and can be costly

Technically possible characteristics excluded in existing products:

Limiting factors exist in all design applications; often the reason is something other than technical feasibility. Spatial area, city/county code, cost, and topography are often limiting factors in LID design. Examples deemed non-usable due to limited amount of space include: detention ponds, fountains, solar panel roofs, and geothermal energy. Three other examples will be described in further detail.

One design idea that has not yet been implemented is the exchange of electricity for local commerce between local businesses and consumers. This is a great idea for shopping centers and malls to lure potential clientele. This idea is not used because electric vehicles are not commonly used. In addition, the prime locations for charging stations are most commonly handicap reserved spaces. These spaces are most practical due to their proximity to the building. Although this idea has flaws, it might be used in the not-so-distant future.

Porous pavement can be found in locations across the country. However, a mix with large pore spaces relative to what is commonly used that allows significantly more infiltration is possible. However, the design is not used because the large pore spaces cause a trip hazard to pedestrians with wearing high heels or those that use canes.

The prospect of xeriscaping, a landscaping method that employs drought-resistant plants in an effort to conserve resources, especially water, is most commonly excluded in landscaping design. However, LID systems usually incorporate this particular landscaping method. The concept is based on resource conservation. The use of drought-resistance plants native to a particular site's geographic area can often result in a lackluster scene. However, if properly researched and designed xeriscaping can result in a both aesthetically-pleasing and natural looking landscape that requires less resources and upkeep.

Safety issues:

Safety should always be a top priority and consideration during any design process, even a parking lot retrofit design. The following safety issues have been identified:

<u>Safety</u>

- Utility line identification prior to specific design and construction
- Slip hazards if lot freezes over
- Appropriate lighting
- Designated pedestrian walkways

<u>Safety and Legal</u>

- Consideration of the American Disability Act
- Consideration of City/County Parking Lot Code

Relevant Patents:

Patent searches using the keywords “low impact development”, “pervious concrete”, and “environmentally friendly parking lots” was conducted, yielding the following:

US 8113740 B2 - Issue Date: February 14, 2012
Method and apparatus for capturing, storing, and distributing stormwater. This method reinforced the design idea for capturing the stormwater in the sub base. It also proves that a negative run off system is possible.
http://www.google.com/patents/US8113740?pg=PA18&dq=low+impact+development&hl=en&sa=X&ei=5PFuUPmIOIjO2wX6qoCgCA&sqi=2&pjf=1&ved=0CEcQ6AEwCA#v=onepage&q=low%20impact%20development&f=false

US 6277274 B1 - Issue Date: August 21, 2001
Method and apparatus for treating storm water runoff. This method will reduce chemical pollutants and sediment from water in a bioretention cell. We can utilize this technology in the bioretention cells that we will use to prevent any possible pollutants getting into either the groundwater or in the Oklahoma River if our storage system overflows.
http://www.google.com/patents/US6277274?pg=PA1&dq=low+impact+development&hl=en&sa=X&ei=5PFuUPmIOIjO2wX6qoCgCA&sqi=2&pjf=1&ved=0CDIQ6AEwAQ#v=onepage&q=low%20impact%20development&f=false

US 7967979 B2- Issue Date: June 28, 2011
Bi-phasic bioretention systems. This is a very effective method for reducing organic pollutants (Methane and Alcohols). It optimizes the water’s time in the bioretention cell by being bi-phasic and using anaerobic and aerobic sequences. We could utilize this technology in our bioretention cells to reduce the pollutants from cars.
http://www.google.com/patents/US7967979?pg=PA2&dq=low+impact+development&hl=en&sa=X&ei=5PFuUPmIOIjO2wX6qoCgCA&sqi=2&pjf=1&ved=0CEoQ6AEwCQ#v=onepage&q=low%20impact%20development&f=false

US 4225357- Issue Date: September 30, 1980
Method of producing and distributing a pervious concrete product. This will be used because we plan to use pervious concrete in our designs. This is only an example of method of production but not necessarily the one we will utilize.
http://www.google.com/patents?id=iwY5AAAAEBAJ&printsec=abstract&zoom=4#v=onepage&q&f=false

Pub No.: US 2011/0230598 A1- Issue Date: December 3, 2009
Pervious concrete composition. This patent shows one mixture of pervious concrete that we might be able to use. This might not be the best mixture for strength and economics for us. It is just an example of a previously used mixture and additive.
http://www.google.com/patents/US20110230598?pg=PA2&dq=pervious+concrete&hl=en&sa=X&ei=RfZuUPCxFsfq2AWiloDwBA&ved=0CEEQ6AEwBQ#v=onepage&q=pervious%20concrete&f=false

US 2011/0011930 A1- Issue Date: March 21, 2010
Parking meter with EV recharging capability. This technology is a little far-fetched. The only thing that could possibly be gained from this is the solar recharging. We could use this for lighting in the parking lot or even a message board, if ODEQ wanted.
http://www.google.com/patents/US20110011930?pg=PA8&dq=environmentally+friendly+parking+lots&hl=en&sa=X&ei=IvduUJH0KIqQ2QX3vIGoCg&ved=0CD4Q6AEwBA#v=onepage&q=environmentally%20friendly%20parking%20lots&f=false

Investigation & Testing Analysis

Methods and Materials for Data Collection

- *Surveying of Parking Lot*
    - Items that the team required for the surveying of the parking lot were surveying equipment from the BAE lab as well as a BAE truck. The software required to display the surveying data is ArcGIS. These require no cost. This information will allow us to have a topographical map of the parking lot.
- *Determining Location of Lines in Parking Lot*
    - The only thing required is a call to OKIE. This requires no cost.
- *Hydraulic Modeling of Runoff*
    - This modeling will provide information of the runoff of the pre-developed parking lot and allow us to more easily retrofit our design. There is software for this that Dr. Jason Vogel has so there will be no cost.
- *Free/Thaw Strength Testing on Pervious Concrete*
    - This data will be able to show how the pervious concrete will act over time in a constantly changing climate like Oklahoma's. This project has been given to the members of the BAE 1012 team. The materials required will be blocks of pervious concrete, water, a freezer, and the Civil Engineering Department's concrete crusher. There will be no cost.
- *Additives and Mixes for Strength in Pervious Concrete*
    - This information will enable us to determine the best mixture and additive for the parking lot based on cost analysis and strength. Because a member of the team is working on different mixtures of pervious concrete in a separate research, there will be no cost to the team. The equipment required will be the concrete as well as the Civil Engineering Department's concrete crusher.
- *Water Quality Sampling of Runoff*
    - This information can be collected during the beginning of a new rainstorm. It will provide information for a baseline of pollutants that are currently being emptied into the Oklahoma River. We will be able to provide solid numbers for the benefit of our design. The equipment required will be water sampling equipment and

possibly sending off to a company to break down the components. This will depend on which option is more economically feasible.

- *Small Scale Model to Test Sub-Base Design*
    - The team has come up with a design to hold the storm water in the sub base that has never been used before so this design will need to be tested in small scale to ensure that theory is correct. The equipment required will be BAE lab tools and other currently unknown equipment. Because we have not yet determined a way to test this, we cannot estimate a cost.
- *Visual Models of Parking Lot Designs*
    - This will allow us to show how each parking lot that we design could be laid out if it were built. This will help the ODEQ visualize our design. This will require some type of Landscape design software. We are no sure of the cost associated with the acquirement of this software.
- *Build LID Technique for Demonstration*
    - This will allow us to have a physical model to show some of the LID techniques that we can or do include in the designs of the parking lot. The equipment required will be BAE lab tools and other currently unknown building materials. We do not currently know the cost associated with the building of the techniques.

Potential Impacts

Urban Sustainability Solutions' sustainable parking lot design will have the following impacts:

Environmental:

- A significant reduction of stormwater runoff and associated pollutants
- A significant reduction in "heat-island effect"
- Increase in habitat for animals such as birds and butterflies

Societal:

- Increase in amount of parking spaces
- Increase in area tourism
- Improvement of landscape aesthetics
- Encouragement of further low-impact development in downtown OKC

Global:

Low-impact development is commonly implemented throughout the coastal regions of the U.S. and throughout various parts of Europe. However, this design has the potential to be a followed example for developing urban areas worldwide.

Development of Engineering Specifications

ODEQ Requirements:

ODEQ has established the following as key requirements to be met:

- Process stormwater from a 95th percentile storm in a manner that will maintain a predevelopment hydrologic regime.
    - This can be accomplished by using various LID techniques (bioretention cells, pervious concrete, pervious pavers, ect…)
- Retain the current number of parking spaces (83), and increase this number if possible.
    - Codes for the dimensions of parking lot and stalls must be followed in addition to American Disability Act rules and regulations for handicapped stalls.
- Decrease "heat-island effect" caused by dark asphalt
    - This can be accomplished by planting trees in the parking lot area. In addition, the lighter color of pervious concrete will reflect the light and reduce the heat.
- Create a xeric landscape featuring native plants that:
    - Creatively features low-impact development techniques in order to provide public education and outreach on LID and stormwater management.
    - Is aesthetically pleasing and can be a popular tourist attraction.
    - Attracts and provides habitat for birds, butterflies, and other animals.
- Aims to set a precedent in LID design for the State of Oklahoma.

Generation of Design Concepts

In order to maximize creativity and innovation in our design, each team member brainstormed potential designs. The team then combined various ideas from this process in order to create preliminary economic and no-limit budget designs.

All three of the designs listed below will modify/improve the existing xeric landscape and incorporate examples of LID techniques for educational purposes.

<u>Designs 1&2:</u>

The first design concept will feature a technique fundamental in nature that will effectively manage stormwater for the area of the parking lot actually owned by ODEQ. The value gained from this design will only be in the form of a drastic reduction stormwater runoff and its negative environmental impact. The second design is slightly more invasive than the first, as it will call for the replacement of existing asphalt with pervious concrete for the area of the parking lot owned by ODEQ, in addition to the technique included in the first design concept.

<u>Design 3:</u>

The third design will assume a co-sponsored project between OCU Law School and ODEQ is a possibility. This design will be the most creative, innovative, and effective of the three design concepts. This design concept will include a combination of techniques and systems:

- Pervious Concrete
  - Partitioning of sub-base material in the most sloped area of the parking lot
  - Regrading of the most sloped area so that stormwater not able to infiltrate into the soil beneath the parking lot can exit down a landscaped wall into a bioretention cell/rain garden at the low end of the lot.
- Bioretention Cells
  - Can replace medians that currently exist in the lot if necessary
- Sustainable Irrigation System
  - Cistern/Solar pump system with microprocessor and soil-moisture sensor

A hydrologic modeling program will be used to provide insight to the hydrologic functionality of each design. In addition, a 3-D visual modeling program will be created for each design concept. One or more posters can be created by using the 3-D renderings in conjunction with the hydrological models. This will increase ODEQ’s ability to make suggestions and select a combination of techniques they would like to see included in a final design.

Selection of Design Concept

The final design concept has yet to be selected. A selection of concepts will be presented to ODEQ at the end of the fall semester. The effectiveness and innovativeness increases with each design concept, as does the costs involved. ODEQ will select a design concept to move forward with into the spring semester.

Selected Design Concepts

Basic economic design

This design will require the least overall cost, yet will be an effective tool for managing the stormwater runoff. This design assumes the OCU Law School will not want their half of the parking lot to be included in the retrofit. The design shall include

1. Best Management Practice grate

   ODEQ shall install a grate along the length of OCU Law School's and ODEQ's parking lot property boundary. The grate shall be 3 feet wide with slits 2 feet apart so that cars may drive over. Underneath the grate will be a layer of 57 grade stone and a layer of sand whose combined depth will be approximately 10 feet. This "pit" will act similarly to a bioretention cell; the rock & sand layers will act as a filter and the rock layer will act as a storage zone, allowing the stored water to slowly infiltrate into the soil subgrade. To maintain the grate, a manhole shall be placed near the grate for access to the cavity for cleaning and capture of foreign objects.

2. Xeriscape

   ODEQ shall plant aesthetically pleasing plants which are both native and drought tolerant within the existing L-shaped landscaped area. Name plates will be provided for all plants used in the landscape. In addition, descriptions of and/or information about plants of particular importance to Oklahoma's history and/or future will be provided. I.e. the importance of bufflo grass to the buffalo herds that used to thrive and roam throughout the area or the potential switchgrass has to be a key crop in the energy industry. Any existing trees will be retained in an effort to provide shade to a portion of the parking lot. In addition, the existing medians may be replanted with xeriscape plants and native trees to provide shade to the middle portion of the parking lot. The specific plants to be used in the landscape will be selected in the spring semester and will require ODEQ's approval. Educational demonstrations and examples of low-impact development will also be incorporated into this xeric landscape. The goal is to create a natural-looking xeric landscape with various forms of low-impact development tools and techniques that will provide education and outreach to the public on stormwater management.

Increased economic design

This design also assumes the OCU Law School will not want their half of the parking lot to be included in the retrofit. The educational xeric landscape will still be used as part of this design, but will also include:

1. Permeable Concrete or Pavers

   ODEQ shall install either permeable concrete or pavers. Rather than applying paint to the surface, parking stalls will be defined by lines of light colored brick. The concrete existing in the loading area will be retained. This will limit construction costs and will eliminate the possibility of structural integrity issues of the permeable concrete from application of heavy loads.

2. A design is being explored to minimize the effects of slope on runoff. The team is currently exploring patent rights for the intellectual property.

Pie in the sky 1

This design assumes the OCU Law School will want their half of the parking lot to be included in the retrofit and assume installation costs will not be much of a factor. This design concept includes all of the tools and techniques mentioned in the previous design concept and will also include:

1. Regrade

   A regrade of the OCU Law School portion of the parking lot that will match the slope of ODEQ's portion is a large addition in this design concept. This will eliminate the west exit, but will create an opportunity for a creative landscape at the bottom end of the sloped parking lot. A portion of the asphalt area could be retained which will provide a "floor" for a large cistern. A solar power pump could pump captured water from the cistern, up to the educational xeric landscape for irrigation.

2. Bus stop Rain Garden

   ODEQ shall install a bus stop near the landscape demonstration section where visitors can sit and while they wait for the bus, view the demonstrations. The bus stop will itself be a demonstration with the rain garden that will be placed on top of the structure to collect rainwater.

Modeling

The figures below demonstrate the hydrologic modeling performed for the pervious concrete planned to be utilized in the design concepts. Figure 1 shows the parameters entered to produce the results shown in Figure 2. The results show that the design concept for the pervious concrete is a successful item at reducing runoff and slowing the peak runoff.

Figure 1: Parameters entered for pervious concrete design

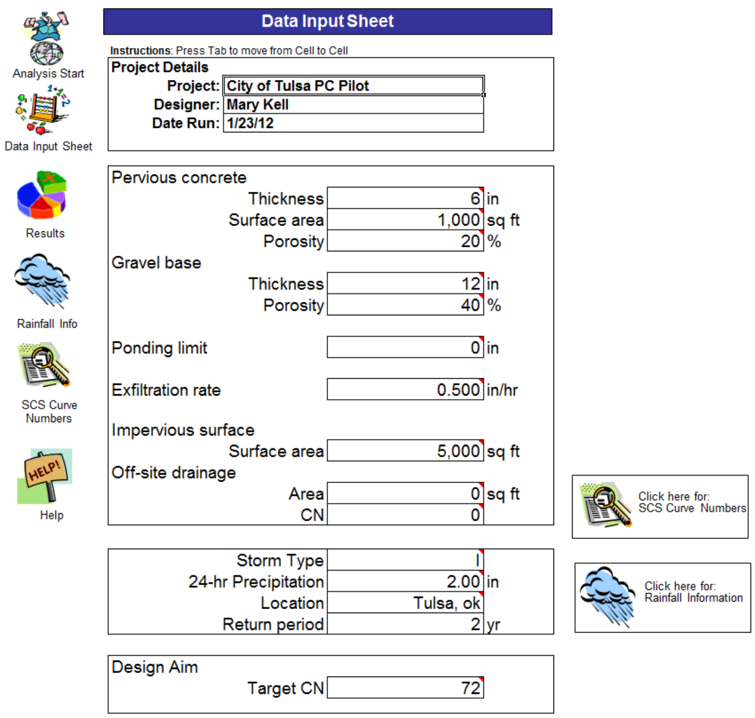
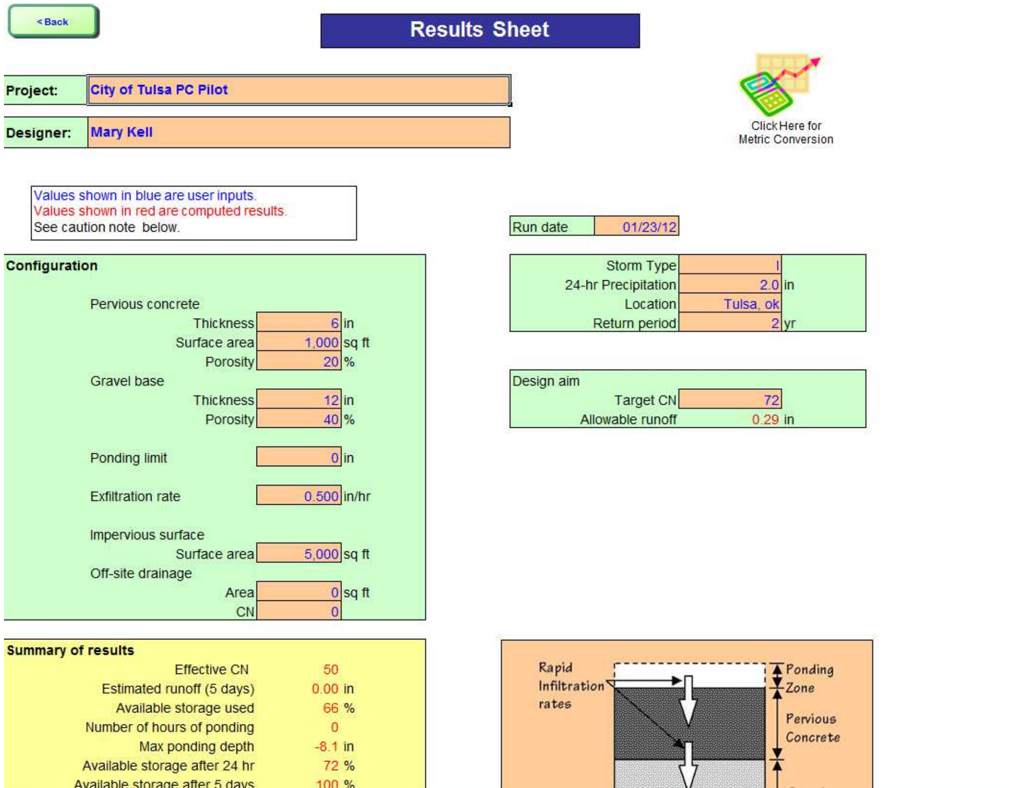


Figure 2: Hydrologic modeling results for pervious concrete design



< Back

Results Sheet

Project:	City of Tulsa PC Pilot
Designer:	Mary Kell

Click Here for Metric Conversion

Values shown in blue are user inputs.
Values shown in red are computed results.
See caution note below.

Run date 01/23/12

Configuration

Pervious concrete		
Thickness	6	in
Surface area	1,000	sq ft
Porosity	20	%
Gravel base		
Thickness	12	in
Porosity	40	%
Ponding limit	0	in
Exfiltration rate	0.500	in/hr
Impervious surface		
Surface area	5,000	sq ft
Off-site drainage		
Area	0	sq ft
CN	0	

Storm Type	I	
24-hr Precipitation	2.0	in
Location	Tulsa, ok	
Return period	2	yr

Design aim		
Target CN	72	
Allowable runoff	0.29	in

Summary of results

Effective CN	50	
Estimated runoff (5 days)	0.00	in
Available storage used	66	%
Number of hours of ponding	0	
Max ponding depth	-8.1	in
Available storage after 24 hr	72	%
Available storage after 5 days	100	%

Figure 2

Figure 3: Pervious concrete design

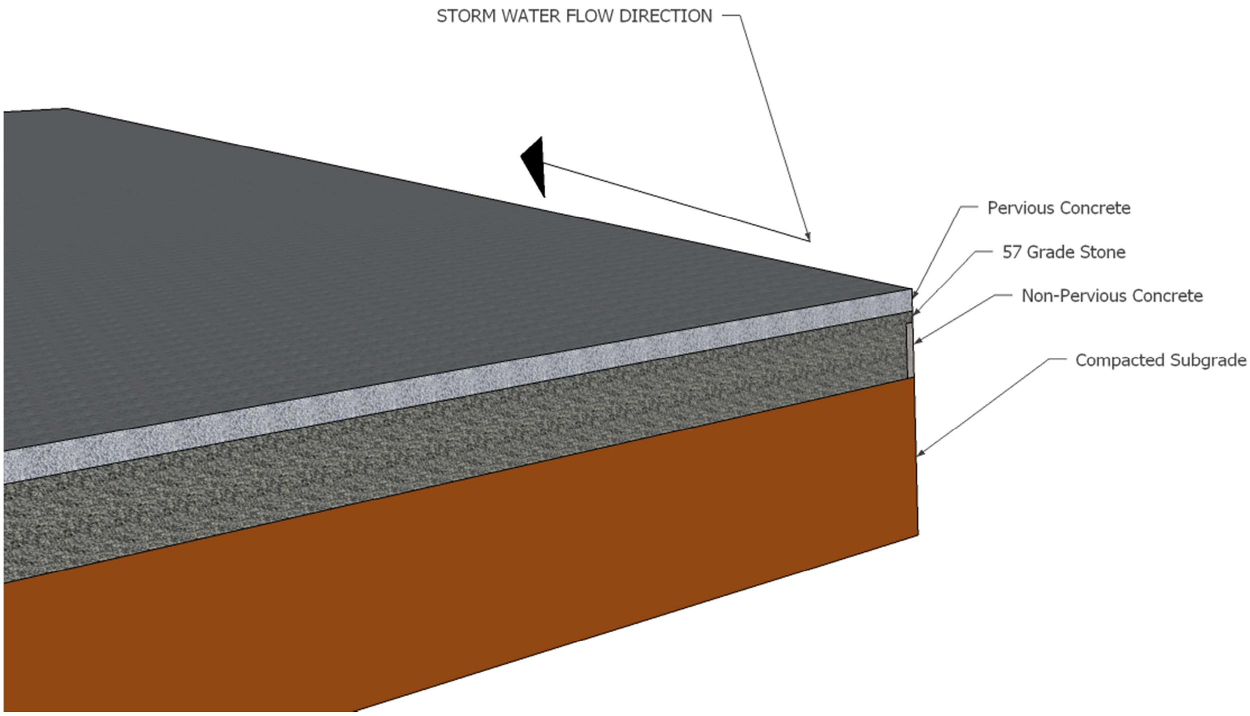
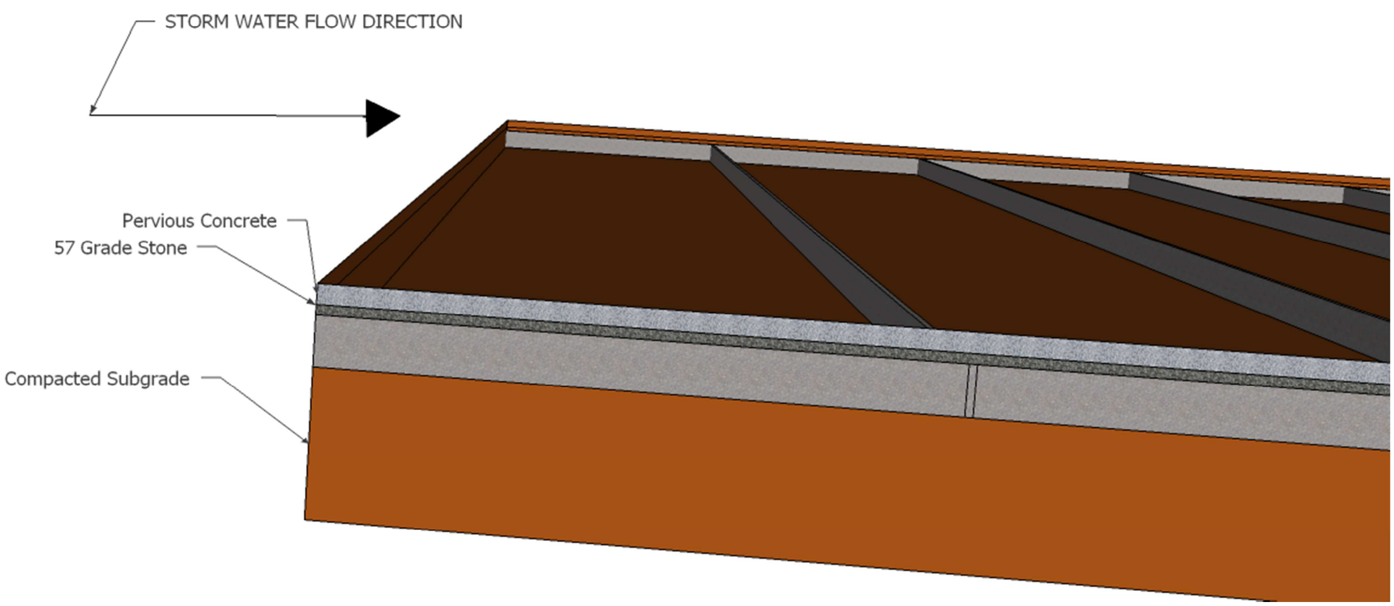


Figure 3: Partition Design



The report below comes from a program called IDEAL which models runoff in a water shed for different green technologies and your given parameters. In this way, the report shows how effective putting in pervious concrete and a bioretention cell is at reducing runoff which is the ultimate goal of the project. This first report is for the pre developed site which was before there was construction present. The next report demonstrates the exisiting runoff conditions at the ODEQ parking lot. USS' goal is to achieve the runoff from the pre developed stage or better. This modeling will have to be done by hand as the partitions are a new technology not used in the IDEAL model. This program just gives USS a starting point and a goal.

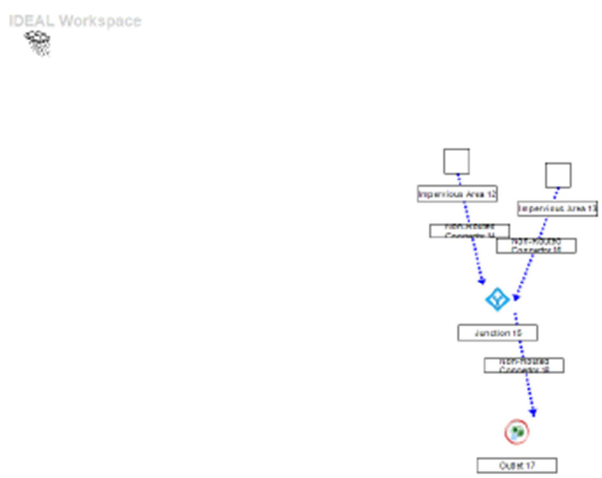
Figure 4: IDEAL Modeling Software Report

IDEAL Report

(IDEAL Greenville 2.3.7.0)

Name	
Description	
Analyst Name	kyleamb
Date	11/13/2012, 4:51 PM
Comments	

Model Image



Storm		
Inputs		
Parameter	**Value**	**Units**
Location	Northern Greenville, SC	-
Region		-
Storm Type	II	-
Return Period	10	yrs
Precipitation	6.1	in.
Duration	24	hrs
Season	Growing	-
Antecedent Moisture Condition	Average	-

Impervious Area 13	
Name	Impervious Area 13

Hydrology Inputs		
Parameter	**Value**	**Units**
Area	0.27	acres
Curve Number	98	-
Peak Rate Factor	550	-
Time of Concentration	4.33	hrs
Sediment Inputs		
Parameter	**Value**	**Units**
Even Mean Concentration	117	mg/L
Power function Coefficient	1	-
Nutrient Inputs		
Parameter	**Value**	**Units**
EMC Nitrogen	1.97	mg/l
EMC Nitrogen Particulate fraction	0.43	-
EMC Phosphorous	0.15	mg/l
EMC Phosphorous Particulate fraction	0.43	-
Isotherm Rate - Nitrogen	32	micro g/g/mg/l
Isotherm Max - Nitrogen	925	micro g/g
Isotherm Rate - Phosphorous	190	micro g/g/mg/l
Isotherm Max - Phosphorous	925	micro g/g
Bacteria Inputs		
Parameter	**Value**	**Units**
EMC Bacteria	13600	cfu/100 ml
Decay Coefficient - Bacteria	0.8	-
Growth Coefficient - Bacteria	0.4	-
Radiation Induced Decay Coefficient - Bacteria	0.55	-
Isotherm Rate - Bacteria	132	cfu/g/mg/l
Isotherm Max - Bacteria	7.9E+10	cfu/g
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.1316	ac-ft
Peak Runoff Flow	0.3121	cfs
Total Sediment Yield	41.88	lb/s
Total Sediment Yield (Clay)	10.89	lb/s
Total Sediment Yield (Silt)	23.04	lb/s
Total Sediment Yield (Sand)	7.958	lb/s
Total Sediment Yield (Small Agg.)	0	lb/s
Total Sediment Yield (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	216.3	mg/l
Total Nitrogen Yield	0.7052	lb/s
Total Nitrogen Yield (Particulate)	0.3033	lb/s
Total Nitrogen Yield (Sorbed)	0.0005537	lb/s
Total Nitrogen Yield (Dissolved)	0.4014	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.641	mg/l
Total Phosphorus Yield	0.0537	lb/s
Total Phosphorus Yield (Particulate)	0.02309	lb/s
Total Phosphorus Yield (Sorbed)	0.0002485	lb/s
Total Phosphorus Yield (Dissolved)	0.03036	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2773	mg/l
Total Bacteria Yield	2.208E+10	cfu
Total Bacteria Yield (Sorbed To Clay)	8.766E+07	cfu
Total Bacteria Yield (Sorbed To Silt)	1.854E+08	cfu
Total Bacteria Yield (Planktonic)	2.18E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.513E+04	cfu/100 ml

Non-Routed Connector 16		
Name	Non-Routed Connector 16	
Description	Please enter a brief description	
Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.1316	ac-ft
Peak Runoff Flow	0.3121	cfs

Total Sediment Discharged	41.88	lb/s
Total Sediment Discharged (Clay)	10.89	lb/s
Total Sediment Discharged (Silt)	23.04	lb/s
Total Sediment Discharged (Sand)	7.958	lb/s
Total Sediment Discharged (Small Agg.)	0	lb/s
Total Sediment Discharged (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	216.3	mg/l
Total Nitrogen Discharged	0.7052	lb/s
Total Nitrogen Discharged (Particulate)	0.3033	lb/s
Total Nitrogen Discharged (Sorbed)	0.0005537	lb/s
Total Nitrogen Discharged (Dissolved)	0.4014	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.641	mg/l
Total Phosphorus Discharged	0.0537	lb/s
Total Phosphorus Discharged (Particulate)	0.02309	lb/s
Total Phosphorus Discharged (Sorbed)	0.0002485	lb/s
Total Phosphorus Discharged (Dissolved)	0.03036	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2773	mg/l
Total Bacteria Discharged	2.208E+10	cfu
Total Bacteria Discharged (Sorbed To Clay)	8.766E+07	cfu
Total Bacteria Discharged (Sorbed To Silt)	1.854E+08	cfu
Total Bacteria Discharged (Planktonic)	2.18E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.513E+04	cfu/100 ml

Impervious Area 12		
Name	Impervious Area 12	
Description	Please enter a brief description.	
Hydrology Inputs		
Parameter	**Value**	**Units**
Area	0.602	acres
Curve Number	98	-
Peak Rate Factor	300	-
Time of Concentration	6.5	hrs
Sediment Inputs		
Parameter	**Value**	**Units**
Even Mean Concentration	117	mg/L
Power function Coefficient	1	-
Nutrient Inputs		
Parameter	**Value**	**Units**
EMC Nitrogen	1.97	mg/l
EMC Nitrogen Particulate fraction	0.43	-
EMC Phosphorous	0.15	mg/l
EMC Phosphorous Particulate fraction	0.43	-
Isotherm Rate - Nitrogen	32	micro g/g/mg/l
Isotherm Max - Nitrogen	925	micro g/g
Isotherm Rate - Phosphorous	190	micro g/g/mg/l
Isotherm Max - Phosphorous	925	micro g/g
Bacteria Inputs		
Parameter	**Value**	**Units**
EMC Bacteria	13600	cfu/100 ml
Decay Coefficient - Bacteria	0.8	-
Growth Coefficient - Bacteria	0.4	-
Radiation Induced Decay Coefficient - Bacteria	0.55	-
Isotherm Rate - Bacteria	132	cfu/g/mg/l
Isotherm Max - Bacteria	7.9E+10	cfu/g
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.2934	ac-ft
Peak Runoff Flow	0.3161	cfs
Total Sediment Yield	93.34	lb/s
Total Sediment Yield (Clay)	24.27	lb/s
Total Sediment Yield (Silt)	51.34	lb/s
Total Sediment Yield (Sand)	17.73	lb/s
Total Sediment Yield (Small Agg.)	0	lb/s
Total Sediment Yield (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	179.5	mg/l

Total Nitrogen Yield	1.572	lb/s
Total Nitrogen Yield (Particulate)	0.6758	lb/s
Total Nitrogen Yield (Sorbed)	0.00106	lb/s
Total Nitrogen Yield (Dissolved)	0.8947	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.023	mg/l
Total Phosphorus Yield	0.1197	lb/s
Total Phosphorus Yield (Particulate)	0.05146	lb/s
Total Phosphorus Yield (Sorbed)	0.0004761	lb/s
Total Phosphorus Yield (Dissolved)	0.06773	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2302	mg/l
Total Bacteria Yield	4.919E+10	cfu
Total Bacteria Yield (Sorbed To Clay)	1.953E+08	cfu
Total Bacteria Yield (Sorbed To Silt)	4.132E+08	cfu
Total Bacteria Yield (Planktonic)	4.858E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.086E+04	cfu/100 ml

Non-Routed Connector 14		
Name	Non-Routed Connector 14	
Description	Please enter a brief description	
Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.2934	ac-ft
Peak Runoff Flow	0.3161	cfs
Total Sediment Discharged	93.34	lb/s
Total Sediment Discharged (Clay)	24.27	lb/s
Total Sediment Discharged (Silt)	51.34	lb/s
Total Sediment Discharged (Sand)	17.73	lb/s
Total Sediment Discharged (Small Agg.)	0	lb/s
Total Sediment Discharged (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	179.5	mg/l
Total Nitrogen Discharged	1.572	lb/s
Total Nitrogen Discharged (Particulate)	0.6758	lb/s
Total Nitrogen Discharged (Sorbed)	0.00106	lb/s
Total Nitrogen Discharged (Dissolved)	0.8947	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.023	mg/l
Total Phosphorus Discharged	0.1197	lb/s
Total Phosphorus Discharged (Particulate)	0.05146	lb/s
Total Phosphorus Discharged (Sorbed)	0.0004761	lb/s
Total Phosphorus Discharged (Dissolved)	0.06773	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2302	mg/l
Total Bacteria Discharged	4.919E+10	cfu
Total Bacteria Discharged (Sorbed To Clay)	1.953E+08	cfu
Total Bacteria Discharged (Sorbed To Silt)	4.132E+08	cfu
Total Bacteria Discharged (Planktonic)	4.858E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.086E+04	cfu/100 ml

Junction 15		
Name	Junction 15	
Description	Please enter a brief description.	
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.425	ac-ft
Peak Runoff Flow	0.6013	cfs
Total Sediment Discharged	135.2	lb/s
Total Sediment Discharged (Clay)	35.16	lb/s
Total Sediment Discharged (Silt)	74.37	lb/s
Total Sediment Discharged (Sand)	25.69	lb/s
Total Sediment Discharged (Small Agg.)	0	lb/s

Total Sediment Discharged (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	190.7	mg/l
Total Nitrogen Discharged	2.277	lb/s
Total Nitrogen Discharged (Particulate)	0.979	lb/s
Total Nitrogen Discharged (Sorbed)	0.001613	lb/s
Total Nitrogen Discharged (Dissolved)	1.296	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.212	mg/l
Total Phosphorus Discharged	0.1734	lb/s
Total Phosphorus Discharged (Particulate)	0.07455	lb/s
Total Phosphorus Discharged (Sorbed)	0.0007245	lb/s
Total Phosphorus Discharged (Dissolved)	0.09809	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2445	mg/l
Total Bacteria Discharged	7.127E+10	cfu
Total Bacteria Discharged (Sorbed To Clay)	2.83E+08	cfu
Total Bacteria Discharged (Sorbed To Silt)	5.986E+08	cfu
Total Bacteria Discharged (Planktonic)	7.039E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.216E+04	cfu/100 ml

Non-Routed Connector 18		
Name	Non-Routed Connector 18	
Description	Please enter a brief description	
Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.425	ac-ft
Peak Runoff Flow	0.6013	cfs
Total Sediment Discharged	135.2	lb/s
Total Sediment Discharged (Clay)	35.16	lb/s
Total Sediment Discharged (Silt)	74.37	lb/s
Total Sediment Discharged (Sand)	25.69	lb/s
Total Sediment Discharged (Small Agg.)	0	lb/s
Total Sediment Discharged (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	190.7	mg/l
Total Nitrogen Discharged	2.277	lb/s
Total Nitrogen Discharged (Particulate)	0.979	lb/s
Total Nitrogen Discharged (Sorbed)	0.001613	lb/s
Total Nitrogen Discharged (Dissolved)	1.296	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.212	mg/l
Total Phosphorus Discharged	0.1734	lb/s
Total Phosphorus Discharged (Particulate)	0.07455	lb/s
Total Phosphorus Discharged (Sorbed)	0.0007245	lb/s
Total Phosphorus Discharged (Dissolved)	0.09809	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2445	mg/l
Total Bacteria Discharged	7.127E+10	cfu
Total Bacteria Discharged (Sorbed To Clay)	2.83E+08	cfu
Total Bacteria Discharged (Sorbed To Silt)	5.986E+08	cfu
Total Bacteria Discharged (Planktonic)	7.039E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.216E+04	cfu/100 ml

Outlet 17		
Name	Outlet 17	
Description	Please enter a brief description.	
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.425	ac-ft
Peak Runoff Flow	0.6013	cfs
Total Sediment Discharged	135.2	lb/s
Total Sediment Discharged (Clay)	35.16	lb/s

Total Sediment Discharged (Silt)	74.37	lb/s
Total Sediment Discharged (Sand)	25.69	lb/s
Total Sediment Discharged (Small Agg.)	0	lb/s
Total Sediment Discharged (Large Agg.)	0	lb/s
Sediment Concentration	117	mg/l
Peak Sediment Concentration	190.7	mg/l
Total Nitrogen Discharged	2.277	lb/s
Total Nitrogen Discharged (Particulate)	0.979	lb/s
Total Nitrogen Discharged (Sorbed)	0.001613	lb/s
Total Nitrogen Discharged (Dissolved)	1.296	lb/s
Nitrogen Concentration	1.97	mg/l
Peak Nitrogen Concentration	3.212	mg/l
Total Phosphorus Discharged	0.1734	lb/s
Total Phosphorus Discharged (Particulate)	0.07455	lb/s
Total Phosphorus Discharged (Sorbed)	0.0007245	lb/s
Total Phosphorus Discharged (Dissolved)	0.09809	lb/s
Phosphorus Concentration	0.15	mg/l
Peak Phosphorus Concentration	0.2445	mg/l
Total Bacteria Discharged	7.127E+10	cfu
Total Bacteria Discharged (Sorbed To Clay)	2.83E+08	cfu
Total Bacteria Discharged (Sorbed To Silt)	5.986E+08	cfu
Total Bacteria Discharged (Planktonic)	7.039E+10	cfu
Bacteria Concentration	1.359E+04	cfu/100 ml
Peak Bacteria Concentration	2.216E+04	cfu/100 ml

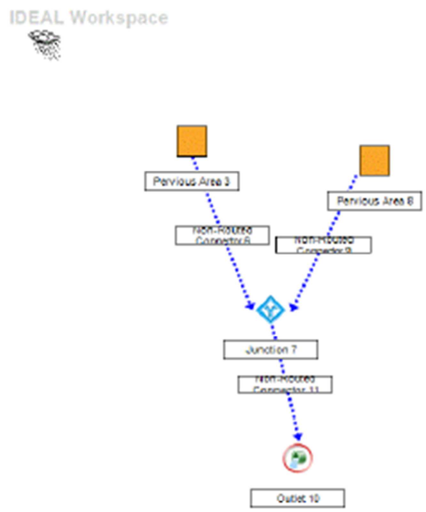
Watershed Results		
Treatment Train 1		
Parameter	**Value**	**Units**
Objects in Tree	Outlet 17, Impervious Area 12, Impervious Area 13	-
Overall Trapping Efficiency of Sediment	0	%

IDEAL Report

(IDEAL Greenville 2.3.7.0)

Name	
Description	
Analyst Name	kyleamb
Date	11/13/2012, 4:51 PM
Comments	

Model Image



Storm		
Inputs		
Parameter	**Value**	**Units**
Location	Northern Greenville, SC	-
Region		-
Storm Type	II	-
Return Period	10	yrs
Precipitation	6.1	in.
Duration	24	hrs
Season	Growing	-
Antecedent Moisture Condition	Average	-

Pervious Area 8	
Name	Pervious Area 8

Hydrology Inputs		
Parameter	**Value**	**Units**
Area	0.27	acres
Soil Series	ASHE	-
Depth Range		-
Curve Number	58	-
Peak Rate Factor	180	-
Time of Concentration	7.58	hrs
Sediment Inputs		
Parameter	**Value**	**Units**
Length	200	ft
Slope	0.048	ft/ft
Soil Erodibility	0.24	-
Cover & Practice Factor	0.001	-
Tendency to Rill	Medium	-
Power Function Coefficient	1	-
Clay Percent	13.5	%
Silt Percent	34	%
Sand Percent	52.5	%
Nutrient Inputs		
Parameter	**Value**	**Units**
EMC Nitrogen	0.97	mg/l
EMC Nitrogen Particulate fraction	0.43	-
EMC Phosphorous	0.2	mg/l
EMC Phosphorous Particulate fraction	0.43	-
Isotherm Rate - Nitrogen	61.75	micro g/g/mg/l
Isotherm Max - Nitrogen	1734.4	micro g/g
Isotherm Rate - Phosphorous	4.95	micro g/g/mg/l
Isotherm Max - Phosphorous	4690.7	micro g/g
Bacteria Inputs		
Parameter	**Value**	**Units**
EMC Bacteria	1000	cfu/100 ml
Decay Coefficient - Bacteria	0.8	-
Growth Coefficient - Bacteria	0.4	-
Radiation Induced Decay Coefficient - Bacteria	0.55	-
Isotherm Rate - Bacteria	132	cfu/g/mg/l
Isotherm Max - Bacteria	7.9E+10	cfu/g
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.04092	ac-ft
Peak Runoff Flow	0.02627	cfs
Total Sediment Yield	0.8099	lb/s
Total Sediment Yield (Clay)	0.02843	lb/s
Total Sediment Yield (Silt)	0.07856	lb/s
Total Sediment Yield (Sand)	0.2059	lb/s
Total Sediment Yield (Small Agg.)	0.1968	lb/s
Total Sediment Yield (Large Agg.)	0.3002	lb/s
Sediment Concentration	7.278	mg/l
Peak Sediment Concentration	9.403	mg/l
Total Nitrogen Yield	0.1079	lb/s
Total Nitrogen Yield (Particulate)	0.04642	lb/s
Total Nitrogen Yield (Sorbed)	1.063E-06	lb/s
Total Nitrogen Yield (Dissolved)	0.06153	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.253	mg/l
Total Phosphorus Yield	0.02226	lb/s
Total Phosphorus Yield (Particulate)	0.00957	lb/s
Total Phosphorus Yield (Sorbed)	1.757E-08	lb/s
Total Phosphorus Yield (Dissolved)	0.01269	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2584	mg/l
Total Bacteria Yield	5.046E+08	cfu
Total Bacteria Yield (Sorbed To Clay)	6.551E+04	cfu
Total Bacteria Yield (Sorbed To Silt)	4.707E+04	cfu
Total Bacteria Yield (Planktonic)	5.045E+08	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1291	cfu/100 ml

Non-Routed Connector 9

Name	Non-Routed Connector 9	
Description	Please enter a brief description	
Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.04092	ac-ft
Peak Runoff Flow	0.02627	cfs
Total Sediment Discharged	0.8099	lb/s
Total Sediment Discharged (Clay)	0.02843	lb/s
Total Sediment Discharged (Silt)	0.07856	lb/s
Total Sediment Discharged (Sand)	0.2059	lb/s
Total Sediment Discharged (Small Agg.)	0.1968	lb/s
Total Sediment Discharged (Large Agg.)	0.3002	lb/s
Sediment Concentration	7.278	mg/l
Peak Sediment Concentration	9.403	mg/l
Total Nitrogen Discharged	0.1079	lb/s
Total Nitrogen Discharged (Particulate)	0.04642	lb/s
Total Nitrogen Discharged (Sorbed)	1.063E-06	lb/s
Total Nitrogen Discharged (Dissolved)	0.06153	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.253	mg/l
Total Phosphorus Discharged	0.02226	lb/s
Total Phosphorus Discharged (Particulate)	0.00957	lb/s
Total Phosphorus Discharged (Sorbed)	1.757E-08	lb/s
Total Phosphorus Discharged (Dissolved)	0.01269	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2584	mg/l
Total Bacteria Discharged	5.046E+08	cfu
Total Bacteria Discharged (Sorbed To Clay)	6.551E+04	cfu
Total Bacteria Discharged (Sorbed To Silt)	4.707E+04	cfu
Total Bacteria Discharged (Planktonic)	5.045E+08	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1291	cfu/100 ml

Pervious Area 3		
Name	Pervious Area 3	
Description	Please enter a brief description.	
Hydrology Inputs		
Parameter	**Value**	**Units**
Area	0.602	acres
Soil Series	ASHE	-
Depth Range		-
Curve Number	58	-
Peak Rate Factor	180	-
Time of Concentration	11.28	hrs
Sediment Inputs		
Parameter	**Value**	**Units**
Length	450	ft
Slope	0.0559	ft/ft
Soil Erodibility	0.24	-
Cover & Practice Factor	0.001	-
Tendency to Rill	Medium	-
Power Function Coefficient	1	-
Clay Percent	13.5	%
Silt Percent	34	%
Sand Percent	52.5	%
Nutrient Inputs		
Parameter	**Value**	**Units**
EMC Nitrogen	0.97	mg/l
EMC Nitrogen Particulate fraction	0.43	-
EMC Phosphorous	0.2	mg/l
EMC Phosphorous Particulate fraction	0.43	-
Isotherm Rate - Nitrogen	61.75	micro g/g/mg/l
Isotherm Max - Nitrogen	1734.4	micro g/g
Isotherm Rate - Phosphorous	4.95	micro g/g/mg/l
Isotherm Max - Phosphorous	4690.7	micro g/g
Bacteria Inputs		
Parameter	**Value**	**Units**

EMC Bacteria	1000	cfu/100 ml
Decay Coefficient - Bacteria	0.8	-
Growth Coefficient - Bacteria	0.4	-
Radiation Induced Decay Coefficient - Bacteria	0.55	-
Isotherm Rate - Bacteria	132	cfu/g/mg/l
Isotherm Max - Bacteria	7.9E+10	cfu/g
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.09101	ac-ft
Peak Runoff Flow	0.05301	cfs
Total Sediment Yield	3.134	lb/s
Total Sediment Yield (Clay)	0.11	lb/s
Total Sediment Yield (Silt)	0.304	lb/s
Total Sediment Yield (Sand)	0.7968	lb/s
Total Sediment Yield (Small Agg.)	0.7616	lb/s
Total Sediment Yield (Large Agg.)	1.162	lb/s
Sediment Concentration	12.66	mg/l
Peak Sediment Concentration	15.83	mg/l
Total Nitrogen Yield	0.2401	lb/s
Total Nitrogen Yield (Particulate)	0.1032	lb/s
Total Nitrogen Yield (Sorbed)	4.052E-06	lb/s
Total Nitrogen Yield (Dissolved)	0.1368	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.213	mg/l
Total Phosphorus Yield	0.0495	lb/s
Total Phosphorus Yield (Particulate)	0.02128	lb/s
Total Phosphorus Yield (Sorbed)	6.698E-08	lb/s
Total Phosphorus Yield (Dissolved)	0.02821	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2501	mg/l
Total Bacteria Yield	1.122E+09	cfu
Total Bacteria Yield (Sorbed To Clay)	2.535E+05	cfu
Total Bacteria Yield (Sorbed To Silt)	1.821E+05	cfu
Total Bacteria Yield (Planktonic)	1.122E+09	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1250	cfu/100 ml

Non-Routed Connector 6

Name	Non-Routed Connector 6
Description	Please enter a brief description

Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.09101	ac-ft
Peak Runoff Flow	0.05301	cfs
Total Sediment Discharged	3.134	lb/s
Total Sediment Discharged (Clay)	0.11	lb/s
Total Sediment Discharged (Silt)	0.304	lb/s
Total Sediment Discharged (Sand)	0.7968	lb/s
Total Sediment Discharged (Small Agg.)	0.7616	lb/s
Total Sediment Discharged (Large Agg.)	1.162	lb/s
Sediment Concentration	12.66	mg/l
Peak Sediment Concentration	15.83	mg/l
Total Nitrogen Discharged	0.2401	lb/s
Total Nitrogen Discharged (Particulate)	0.1032	lb/s
Total Nitrogen Discharged (Sorbed)	4.052E-06	lb/s
Total Nitrogen Discharged (Dissolved)	0.1368	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.213	mg/l
Total Phosphorus Discharged	0.0495	lb/s
Total Phosphorus Discharged (Particulate)	0.02128	lb/s
Total Phosphorus Discharged (Sorbed)	6.698E-08	lb/s
Total Phosphorus Discharged (Dissolved)	0.02821	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2501	mg/l
Total Bacteria Discharged	1.122E+09	cfu
Total Bacteria Discharged (Sorbed To Clay)	2.535E+05	cfu
Total Bacteria Discharged (Sorbed To Silt)	1.821E+05	cfu

Total Bacteria Discharged (Planktonic)	1.122E+09	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1250	cfu/100 ml

Junction 7		
Name	Junction 7	
Description	Please enter a brief description.	
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.1319	ac-ft
Peak Runoff Flow	0.07812	cfs
Total Sediment Discharged	3.944	lb/s
Total Sediment Discharged (Clay)	0.1384	lb/s
Total Sediment Discharged (Silt)	0.3826	lb/s
Total Sediment Discharged (Sand)	1.003	lb/s
Total Sediment Discharged (Small Agg.)	0.9584	lb/s
Total Sediment Discharged (Large Agg.)	1.462	lb/s
Sediment Concentration	10.99	mg/l
Peak Sediment Concentration	13.61	mg/l
Total Nitrogen Discharged	0.348	lb/s
Total Nitrogen Discharged (Particulate)	0.1496	lb/s
Total Nitrogen Discharged (Sorbed)	5.115E-06	lb/s
Total Nitrogen Discharged (Dissolved)	0.1984	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.208	mg/l
Total Phosphorus Discharged	0.07175	lb/s
Total Phosphorus Discharged (Particulate)	0.03085	lb/s
Total Phosphorus Discharged (Sorbed)	8.454E-08	lb/s
Total Phosphorus Discharged (Dissolved)	0.0409	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2491	mg/l
Total Bacteria Discharged	1.627E+09	cfu
Total Bacteria Discharged (Sorbed To Clay)	3.19E+05	cfu
Total Bacteria Discharged (Sorbed To Silt)	2.292E+05	cfu
Total Bacteria Discharged (Planktonic)	1.626E+09	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1245	cfu/100 ml

Non-Routed Connector 11		
Name	Non-Routed Connector 11	
Description	Please enter a brief description	
Inputs		
Parameter	**Value**	**Units**
Flow Type	Concentrated	-
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.1319	ac-ft
Peak Runoff Flow	0.07812	cfs
Total Sediment Discharged	3.944	lb/s
Total Sediment Discharged (Clay)	0.1384	lb/s
Total Sediment Discharged (Silt)	0.3826	lb/s
Total Sediment Discharged (Sand)	1.003	lb/s
Total Sediment Discharged (Small Agg.)	0.9584	lb/s
Total Sediment Discharged (Large Agg.)	1.462	lb/s
Sediment Concentration	10.99	mg/l
Peak Sediment Concentration	13.61	mg/l
Total Nitrogen Discharged	0.348	lb/s
Total Nitrogen Discharged (Particulate)	0.1496	lb/s
Total Nitrogen Discharged (Sorbed)	5.115E-06	lb/s
Total Nitrogen Discharged (Dissolved)	0.1984	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.208	mg/l
Total Phosphorus Discharged	0.07175	lb/s
Total Phosphorus Discharged (Particulate)	0.03085	lb/s
Total Phosphorus Discharged (Sorbed)	8.454E-08	lb/s
Total Phosphorus Discharged (Dissolved)	0.0409	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2491	mg/l

Total Bacteria Discharged	1.627E+09	cfu
Total Bacteria Discharged (Sorbed To Clay)	3.19E+05	cfu
Total Bacteria Discharged (Sorbed To Silt)	2.292E+05	cfu
Total Bacteria Discharged (Planktonic)	1.626E+09	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1245	cfu/100 ml

Outlet 10		
Name	Outlet 10	
Description	Please enter a brief description.	
Single Event Results		
Parameter	**Value**	**Units**
Total Runoff Volume	0.1319	ac-ft
Peak Runoff Flow	0.07812	cfs
Total Sediment Discharged	3.944	lb/s
Total Sediment Discharged (Clay)	0.1384	lb/s
Total Sediment Discharged (Silt)	0.3826	lb/s
Total Sediment Discharged (Sand)	1.003	lb/s
Total Sediment Discharged (Small Agg.)	0.9584	lb/s
Total Sediment Discharged (Large Agg.)	1.462	lb/s
Sediment Concentration	10.99	mg/l
Peak Sediment Concentration	13.61	mg/l
Total Nitrogen Discharged	0.348	lb/s
Total Nitrogen Discharged (Particulate)	0.1496	lb/s
Total Nitrogen Discharged (Sorbed)	5.115E-06	lb/s
Total Nitrogen Discharged (Dissolved)	0.1984	lb/s
Nitrogen Concentration	0.97	mg/l
Peak Nitrogen Concentration	1.208	mg/l
Total Phosphorus Discharged	0.07175	lb/s
Total Phosphorus Discharged (Particulate)	0.03085	lb/s
Total Phosphorus Discharged (Sorbed)	8.454E-08	lb/s
Total Phosphorus Discharged (Dissolved)	0.0409	lb/s
Phosphorus Concentration	0.2	mg/l
Peak Phosphorus Concentration	0.2491	mg/l
Total Bacteria Discharged	1.627E+09	cfu
Total Bacteria Discharged (Sorbed To Clay)	3.19E+05	cfu
Total Bacteria Discharged (Sorbed To Silt)	2.292E+05	cfu
Total Bacteria Discharged (Planktonic)	1.626E+09	cfu
Bacteria Concentration	999.6	cfu/100 ml
Peak Bacteria Concentration	1245	cfu/100 ml

Watershed Results		
Treatment Train 1		
Parameter	**Value**	**Units**
Objects in Tree	Outlet 10, Pervious Area 3, Pervious Area 8	-
Overall Trapping Efficiency of Sediment	0	%

End of report for existing conditions of the parking lot.

Project Schedule

Figure 5: Timeline of the proposed project schedule

Task Name	Duration	Start	Finish
"Green" Parking Lot	**205 days**	**Mon 8/27/12**	**Fri 6/7/13**
General Conditions	**1 day**	**Mon 8/27/12**	**Mon 8/27/12**
Meet with client and establish parameters	1 day	Mon 8/27/12	Mon 8/27/12
Background Research and Literature Review	**28 days**	**Tue 8/28/12**	**Thu 10/4/12**
Stormwater management	7 days	Tue 8/28/12	Wed 9/5/12
Low Impact Development Techniques	7 days	Thu 9/6/12	Fri 9/14/12
LID products currently on the market	7 days	Mon 9/17/12	Tue 9/25/12
Example LID projects	7 days	Wed 9/26/12	Thu 10/4/12
Site Work	**3 days**	**Fri 10/5/12**	**Tue 10/9/12**
Surveying	**3 days**	**Fri 10/5/12**	**Tue 10/9/12**
Survey first part of parking lot	1 day	Fri 10/5/12	Fri 10/5/12
Survey second half of parking lot	1 day	Mon 10/8/12	Mon 10/8/12
Identify current landscape features	1 day	Tue 10/9/12	Tue 10/9/12
Administrative	**174 days?**	**Tue 8/28/12**	**Fri 4/26/13**
First Semester Tasks	**63 days**	**Tue 8/28/12**	**Thu 11/22/12**
Design proposal Report	7 days	Tue 8/28/12	Wed 9/5/12
Write a problem statement	7 days	Thu 9/6/12	Fri 9/14/12
Write a statement of work, WBS, and task list	7 days	Mon 9/17/12	Tue 9/25/12
Write a technical anaylsis	7 days	Wed 9/26/12	Thu 10/4/12
Define customer requirments	7 days	Fri 10/5/12	Mon 10/15/12
Develop engineering specifications	7 days	Tue 10/16/12	Wed 10/24/12
Propose a communications plan	7 days	Thu 10/25/12	Fri 11/2/12
Propse a business plan	7 days	Mon 11/5/12	Tue 11/13/12
Generate three design Concepts	7 days	Wed 11/14/12	Thu 11/22/12
Develop a project schedule	7 days	Fri 11/2/12	Mon 11/12/12
Create a budget	1 day	Tue 11/13/12	Tue 11/13/12
Second Semester Tasks	**111 days?**	**Fri 11/23/12**	**Fri 4/26/13**
Presentation	**32 days**	**Fri 11/23/12**	**Mon 1/7/13**
Create a PowerPoint presentation	30 days	Fri 11/23/12	Thu 1/3/13
Oral Presentation	2 days	Fri 1/4/13	Mon 1/7/13
Poster	**111 days?**	**Fri 11/23/12**	**Fri 4/26/13**
Aquire poster	1 day?	Fri 11/23/12	Fri 11/23/12
Poster Design	102 days?	Thu 12/6/12	Fri 4/26/13
Develop a website	**5 days?**	**Fri 11/23/12**	**Thu 11/29/12**
Move team folder to appropriate location	1 day?	Fri 11/23/12	Fri 11/23/12
Make individual files for each team member	1 day?	Mon 11/26/12	Mon 11/26/12
Convert files to pdf	1 day?	Tue 11/27/12	Tue 11/27/12
Organize files and folders	1 day?	Wed 11/28/12	Wed 11/28/12
Coordinate with Craige Trumble to ensure files can load	1 day?	Thu 11/29/12	Thu 11/29/12
Submit project folders	1 day?	Fri 11/30/12	Fri 11/30/12
Concept Generalization	**151 days?**	**Fri 11/9/12**	**Fri 6/7/13**
First Semester Tasks	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Brainstorming	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Meet every other Friday with Dr. Vogel	30 days	Fri 11/23/12	Thu 1/3/13
Meet regularly with team	30 days	Fri 11/23/12	Thu 1/3/13

Technical Aspect	**30 days**	**Fri 11/23/12**	**Thu 1/3/13**
Run a hydrologic model for each design concept	7 days	Fri 11/23/12	Mon 12/3/12
Create a 3- D visual model for each design concept	30 days	Fri 11/23/12	Thu 1/3/13
Second Semester Tasks	**30 days**	**Mon 4/29/13**	**Fri 6/7/13**
Brainstorming	**30 days**	**Mon 4/29/13**	**Fri 6/7/13**
Meet every other Friday with Dr. Vogel	30 days	Mon 4/29/13	Fri 6/7/13
Meet regularly with team	15 days	Mon 4/29/13	Fri 5/17/13
Create a list of drought tolerant plants to be used for xeric landscape	7 days	Mon 4/29/13	Tue 5/7/13
Create a list of LID techniques to be displayed in xeric landscape	7 days	Wed 5/8/13	Thu 5/16/13
Technical Aspect	**7 days**	**Mon 4/29/13**	**Tue 5/7/13**
Re-Run a hydrologic model for each design concept	7 days	Mon 4/29/13	Tue 5/7/13
Re-Create a 3- D visual model for each design concept	7 days	Mon 4/29/13	Tue 5/7/13
Modeling	**116 days?**	**Fri 11/9/12**	**Fri 4/19/13**
IDEAL Model No Budget	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Econ.	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Current	116 days?	Fri 11/9/12	Fri 4/19/13
IDEAL Model Predev.	116 days?	Fri 11/9/12	Fri 4/19/13
Pervious Pavement Software	116 days?	Fri 11/9/12	Fri 4/19/13
Partition Model	26 days?	Fri 11/9/12	Fri 12/14/12

Proposed Budget

The budget for this project will be very small because the team will not be building anything except the demonstration models. Even then, the pervious concrete is the only demonstration exhibit that will need to be built, the others are conceptual. Therefore, the budget listed below is the budget for if ODEQ was to actually build the parking lot, here is the cost/benefit analysis.

According to the city of Oklahoma City's website, a retail store is charged $2.55 per 1000 gallons of water (the city of Oklahoma City, 2012).

The cost of establishing a permeable concrete is at $10 per square foot and the amount of water runoff saved per square feet 18.2 gallons of water annually (assuming at least a 10 inch annual rainfall).

The cost of establishing bioretention cells is at $27.86 per square foot and the amount of water saved per square feet 132.14 gallons of water annually (assuming at least a 10 inch annual rainfall).

Placing a monetary value on environmental benefits is difficult to estimate. The estimated benefits are associated with mitigation of climatic change, purification of air by the trees and flowers planted, improved aesthetics, and control of soil erosion and water pollution.

Table 1: Proposed Budget for Prototype

Item	Supplier	Quantity	Unit Price	Total
Posters	Biosytems Dept	2	$60.00	**$120.00**
Pervious Concrete	Biosytems Dept	1	Free	**Free**
Rubber tube for water flow	Lowe's Hardware	1	$24.95	**$24.95**
Building materials for model of partition design	Lowe’s/Biosystems Dept.	-	-	**$500**
			Total	**$644.95**

Works Cited

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ODEQ Green Parking Lot

Urban Sustainability Solutions

Fall 2012 Presentation

Stillwater, OK | December 11, 2012

Sponsor: Oklahoma Dept. of Environmental Quality

DEQ Oklahoma Department of Environmental Quality ...for a clean, attractive, prosperous Oklahoma

Senior Design I
BAE 4012

Instructor: **Dr. Paul Weckler**
Associate Professor

Faculty Mentor: **Dr. Jason Vogel**
Assistant Professor

Oklahoma State University

ODEQ Green Parking Lot

Urban Sustainability Solutions: Team Members

Kylea Boyd – Team Leader — Biosystems Engineering – Bioprocessing & Biotechnology Option

Kristi Harkrider — Biosystems Engineering – Environmental & Natural Resources Option

Lucky Airehrour — Biosystems Engineering – Environmental & Natural Resources Option

Landon Johnston — Biosystems Engineering – Environmental & Natural Resources Option

ODEQ Green Parking Lot

Presentation Contents

Scope of Project
- Site Description
- Problem Statement
- Purpose

Technical Analysis
- Research & Literature Review
- Safety
- Investigation & Testing

Statement of Work
- Organization of Tasks & Required Resources
- Work Breakdown Structure
- Deliverables
- Monitoring Deliverables
- Parameters for Quality

Engineering Specifications
- ODEQ Requirements
- Generation of Design Concepts
- Selected Design Concepts
  - *Basic Economic Design*
    - 3-D Visualization Model
    - Hydrologic Model
  - *Increased Economic Design*
    - 3-D Visualization Model
    - Hydrologic Model
- ADA Design Standards & Co. Zoning Reg

Spring Semester
- Partition Design Concept
  - Mathematic/Hydrologic Calculations for Partition Design
  - Construct a scale-model to prove design theory
- Small-scale model of parking lot design

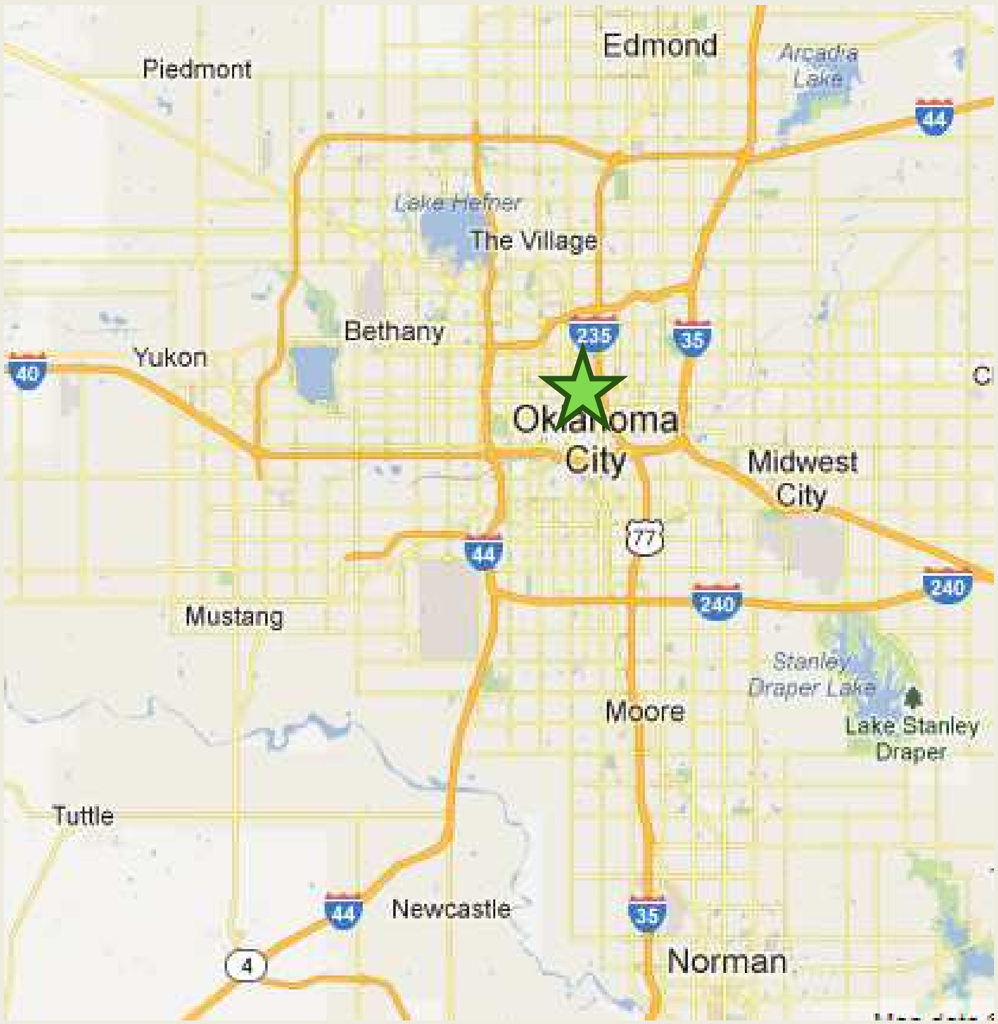
Proposed Budget

ODEQ Green Parking Lot

Scope of Project: Site Description

ODEQ Headquarters

Downtown Oklahoma City, Oklahoma



ODEQ Green Parking Lot

Scope of Project: Site Description

ODEQ Headquarters

Downtown Oklahoma City, Oklahoma

ODEQ Green Parking Lot

Scope of Project: Site Description

ODEQ Headquarters

Downtown Oklahoma City, Oklahoma

ODEQ Green Parking Lot

Scope of Project: Problem Statement

Urban Sustainability Solutions' will implement low-impact development techniques in a design that will retrofit an existing Oklahoma Department of Environmental Quality headquarters parking lot. Our goal is to provide a cost-competitive, low-maintenance, and aesthetically pleasing design that returns the site's hydrologic functionality to a near-predevelopment state. A functional design model of the parking lot demonstrating LID techniques will be built for display in the lobby of the ODEQ headquarters office that will set a precedent for future low impact development in Oklahoma.

Purpose:

- EPA Rule Proposal: 95th percentile storm retention
- Educate public
- Encourage LID design

ODEQ Green Parking Lot

Technical Analysis: Research & Literature Review

<u>We will identify the following</u>:

- Similar items or solutions to the problem
- Technical specifications for existing products or methods
- Durability, reliability, maintenance costs, maintenance requirements, etc
- Safety issues
- Relevant patents

ODEQ Green Parking Lot

Technical Analysis: Conventional Materials

Asphalt	**Impervious Concrete**
	

Strengths for both:

- Smooth surface
- Readily available and cheap material

Weaknesses for both:

- Absorbs heat
- Impervious

ODEQ Green Parking Lot

Technical Analysis: Pervious Concrete

Pervious Concrete

Strengths:

- Different options/looks
- Reduces pollutant transport
- Reduces storm water erosion
- Recharges groundwater

Weaknesses:

- Higher initial cost compared to conventional materials
- Not a smooth surface when compared to conventional materials

ODEQ Green Parking Lot

Technical Analysis: LID Solutions

Vegetated Swales/Planters

- Require less infrastructure (piping)
- Simple to construct
- Low initial cost
- Low maintenance cost
- Improves water quality

Added Tree Canopy

- Intercepts/slows, absorbs, and filters storm water
- Helps reduce urban heat-island effect
- Known to remove air pollutants such as ozone, nitrogen oxides, sulfur dioxide, and ammonia

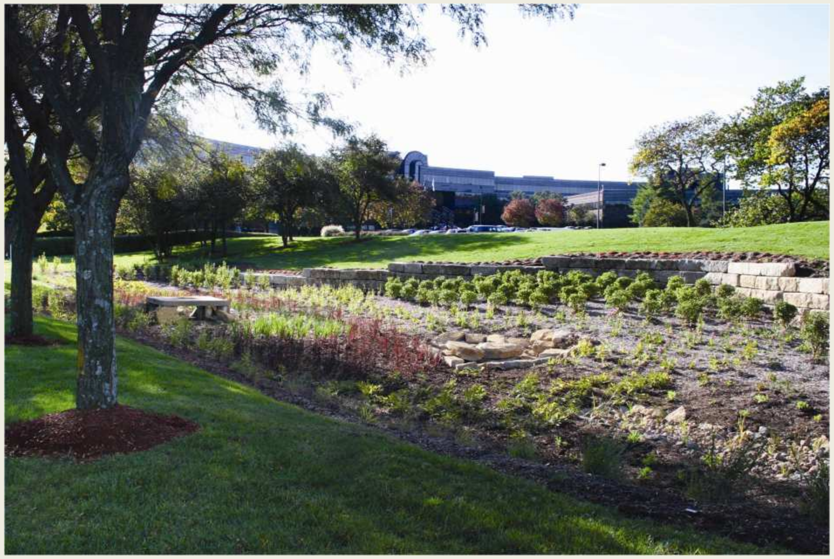
Urban Sustainability Solutions

OKLAHOMA STATE UNIVERSITY

ODEQ Green Parking Lot

Technical Analysis: LID Solutions

Bioretention Cells & Rain Gardens



- Inexpensive to build
- Requires large area
- Can retain largest storm water volume
- Can improve water quality/remove pollutants

Rain Barrels & Cisterns

- Can retain large amounts of water
- Retained water can be used for irrigation or grey-water

ODEQ Green Parking Lot

Technical Analysis: Safety Issues

<u>Safety</u>

- Utility line identification prior to specific design and construction
- Slip hazards if lot freezes over
- Appropriate lighting
- Designated pedestrian walkways

<u>Safety and Legal</u>

- Consideration of the American Disability Act
- Consideration of City/County Parking Lot Code

ODEQ Green Parking Lot

Technical Analysis: Relevant Patents

- **US 8113740 B2-** Method and apparatus for capturing, storing, and distributing storm water
- **US 7967979 B2-** Effective method for reducing organic pollutants
- **US 4225357-** Method of producing and distributing a pervious concrete product
- **US 2011/0230598 A1-**Pervious concrete composition

ODEQ Green Parking Lot

Technical Analysis: Investigation & Testing

Data Collection/Experiment

- Freshman Design Team: Freeze/thaw experiment
- Parking lot survey to determine slope of the parking lot

ODEQ Green Parking Lot

Technical Analysis: Investigation & Testing

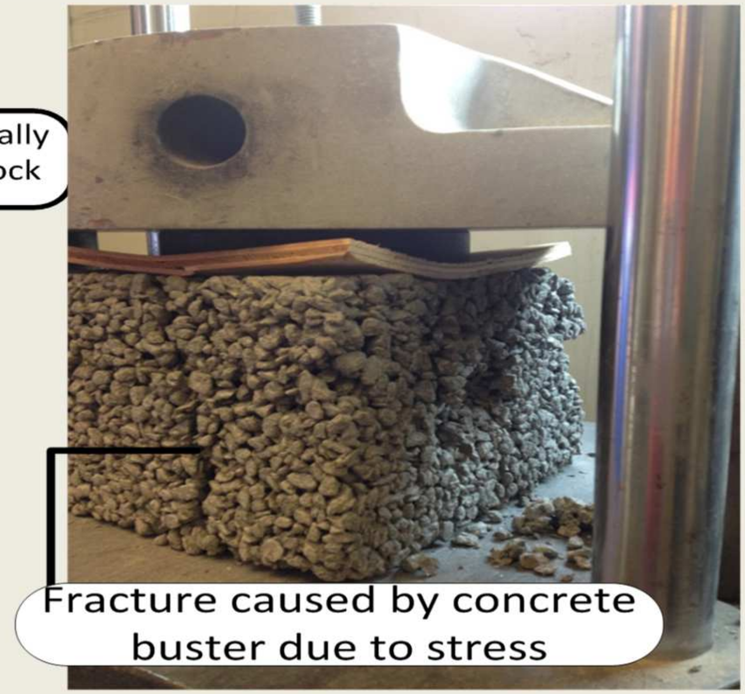


Figure 1 (Left): This shows block number 4, which had gone under 14 freeze thaw cycles, being tested by the concrete crusher

Figure 2 (Right):This shows block 6, which had undergone 35 freeze thaw cycles, being tested by the concrete buster. The image highlights a stress fracture on one side

ODEQ Green Parking Lot

Technical Analysis: Investigation & Testing

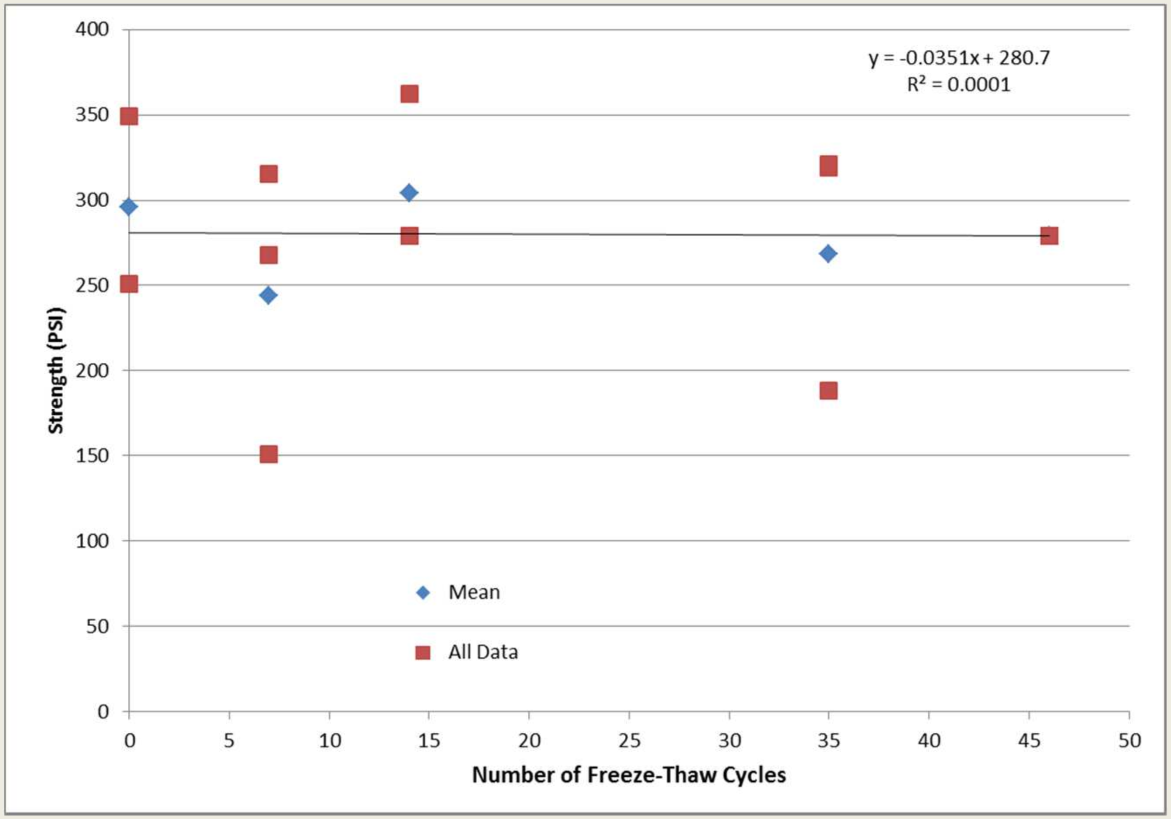


Figure 1: After normalizing the density of the blocks this graph was created to show the projected lastingness of the pervious blocks

ODEQ Green Parking Lot

Technical Analysis: Investigation & Testing

ODEQ Green Parking Lot

Statement of Work: Organization of Tasks & Required Resources

"Green" Parking Lot

Background Research

- Resources Required: Team Labor
  1. Storm water management
  2. Low-Impact Development techniques
  3. LID products currently on the market
  4. Example LID projects

Administrative Tasks

- Resources Required: Team Labor
  1. Design Proposal Report
  2. Oral Presentation
  3. Basic Website
  4. Project Notebook

Concept Generation

- Resources Required: Team Labor, Surveying Equipment, Pervious Concrete, IDEAL software, Sketchup software, Shaderlight software, AutoCAD software, Fuel
  1. Brainstorming
  2. Surveying
  3. Pervious Concrete Testing
  4. Hydrologic Modeling
  5. 3-D Visual Modeling

Project Management

- Resources Required: Dr. Vogel, Dr. Weckler, Kelly Dixon
  1. Meetings
  2. Site Visits
  3. Regular Communication
  4. Peer-reviewing assignments

ODEQ Green Parking Lot

Statement of Work: Deliverables

Design Concepts

- Basic Economic Design
- Increased Economic Design

Models

- 3-D CAD Drawings
- Hydrologic Models

ODEQ Green Parking Lot

Statement of Work: ODEQ Requirements

Meet the Following Objectives:

- Process storm water from a 95th percentile storm in a manner that will maintain a predevelopment hydrologic regime
- Retain or increase the number of parking spaces (83 current)
- Decrease “heat island” affect
- Create a xeric landscape that:
  - Creatively feature LID techniques in order to educate the public on LID and storm water management
  - Is aesthetically pleasing and can be a popular tourist attraction
  - Attracts and provides habitat for birds, butterflies, and other animals
- Aims to set a precedent in LID design

ODEQ Green Parking Lot

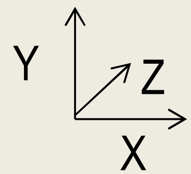
Engineering Specifications: Engineering Calculations

Preliminary Engineering Calculations

- Dimensions:
  - Measured dimensions of parking lot & landscape
  - Aerial layout of existing parking lot drawn using AutoCAD
- Subgrade soil type:
  - Sandy Loam - U.S. Web Soil Survey
- Slope:
  - Calculated slope using parking lot survey data
  - Calculated slope using other method
  - Slope to be used as a parameter in hydrologic model
- Storm water runoff peak flows and volumes:
  - Predevelopment
  - Existing Parking Lot
- Estimate of materials required:
  - Calculated surface areas & volumes

ODEQ Green Parking Lot

Engineering Specifications: Parking Lot Survey

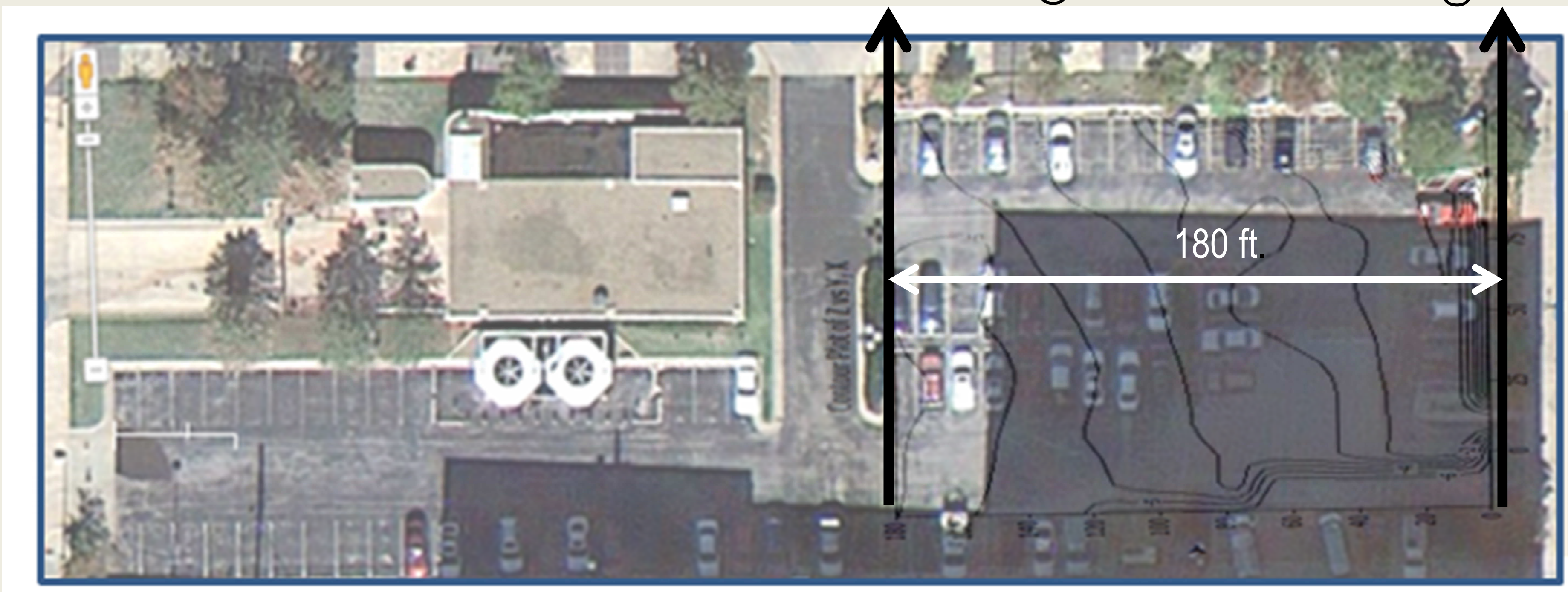


<u>ODEQ-Owned (East-End)</u>

<u>Parking Lot Survey Slope Calculation</u>

Z = - 6 ft. w.r.t. Benchmark @ X = 180 ft.

Benchmark
Z = 0 ft. @ X = 0 ft.



$$\text{Slope} = \frac{Rise}{Run} = \frac{Z}{X} \rightarrow \text{Slope} = \frac{Rise}{Run} = \frac{6\ ft.}{180\ ft.} = \boxed{3.33\%}$$

<u>Software Used:</u>

Minitab 16 Statistical Software

ODEQ Green Parking Lot

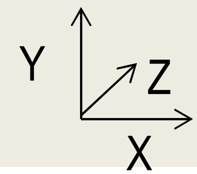
Engineering Specifications: Parking Lot Survey

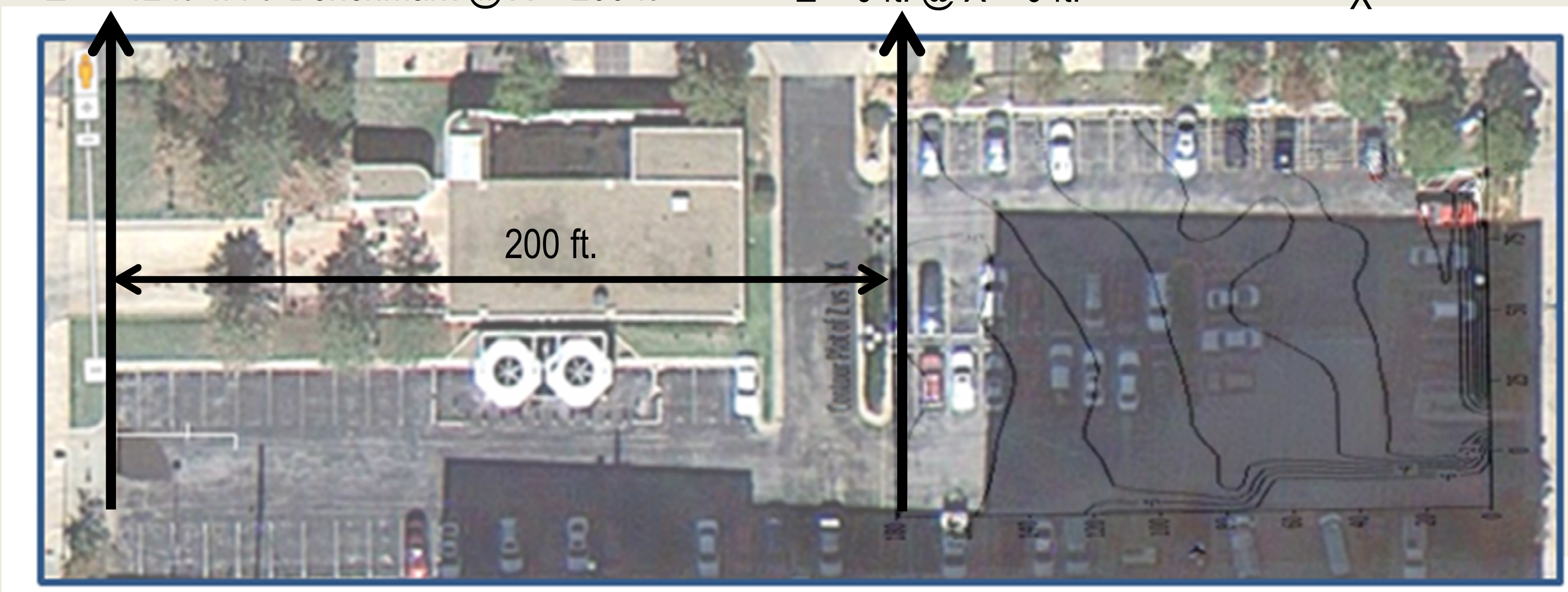
<u>OCU Law School-Owned (West-End)</u>

<u>Parking Lot Survey Slope Calculation</u>

Z = - 12 ft. w.r.t. Benchmark @ X = 200 ft.

Benchmark
Z = 0 ft. @ X = 0 ft.





$$\text{Slope} = \frac{Rise}{Run} = \frac{Z}{X} \rightarrow \text{Slope} = \frac{Rise}{Run} = \frac{12\ ft.}{200\ ft.} = \boxed{6.00\%}$$

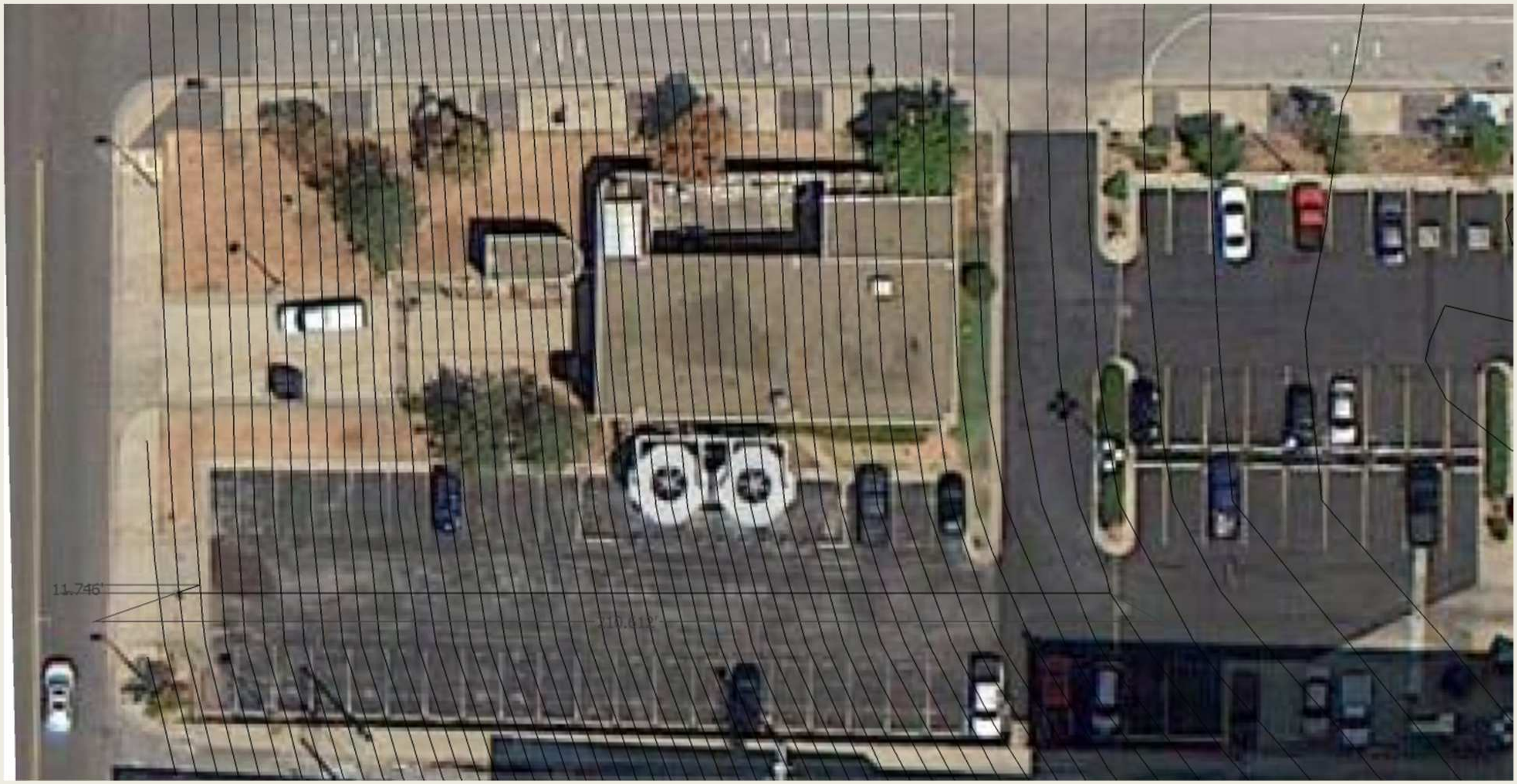
<u>Software Used:</u>

Minitab 16 Statistical Software

ODEQ Green Parking Lot

Engineering Specifications: Creating Topo Map

Contour map created by intersecting planes with 3D topo



Software Used:

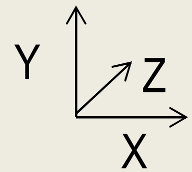
Sketchup 8 integrated with Google Earth

ODEQ Green Parking Lot

Engineering Specifications: Slope w/Google Earth

OCU Law School-Owned (West-End)

Parking Lot Slope Calculation



- Verified slope calculated from parking lot survey
- Used measurement tool to calculate slope

Slope $= \frac{Rise}{Run} = \frac{Z}{X}$ ➔ Slope $= \frac{Rise}{Run} = \frac{11.746\ ft.}{210.612\ ft.} = \boxed{\mathbf{5.58\%}}$

Software Used:

Sketchup 8 integrated with Google Earth

ODEQ Green Parking Lot

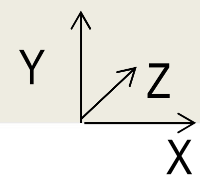
Engineering Specifications: Angle w/Google Earth

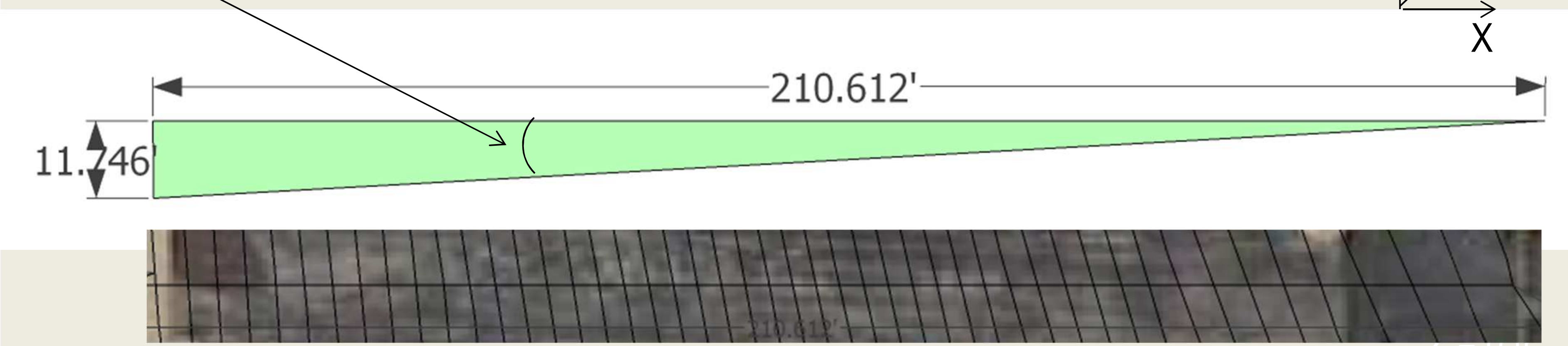
OCU Law School-Owned (West-End)

Parking Lot Angle Calculation

- Calculated angle of parking lot to be used in Sketchup 3D model:

Angle $= \tan^{-1}(\frac{opp}{adj})$ ➔ Angle $= \tan^{-1}(\frac{opp}{adj}) = \tan^{-1}\left(\frac{11.746\ ft.}{210.612\ ft.}\right) =$ **3.19°**



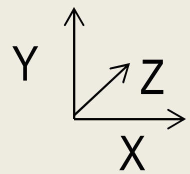


Software Used:

Sketchup 8 integrated with Google Earth

ODEQ Green Parking Lot

Engineering Specifications: Slope w/Google Earth

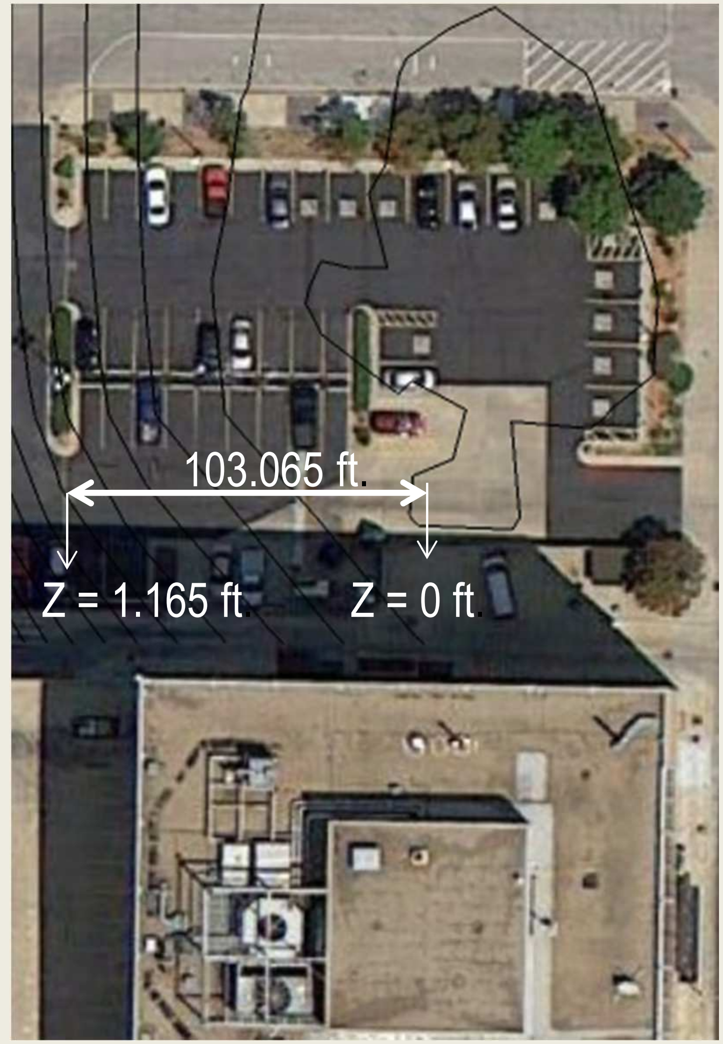


ODEQ-Owned (East-End)

Parking Lot Slope Calculation

- Verified slope calculated from parking lot survey
- Created contour map by intersecting planes with 3D topo
- Used measurement tool to calculate slope

$$\text{Slope} = \frac{Rise}{Run} = \frac{Z}{X} \Rightarrow \text{Slope} = \frac{Rise}{Run} = \frac{1.165\ ft.}{103.065\ ft.} = \boxed{\mathbf{1.11\%}}$$



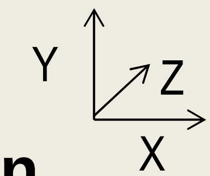
Software Used:

Sketchup 8 integrated with Google Earth

ODEQ Green Parking Lot

Engineering Specifications: Angle w/Google Earth

ODEQ-Owned (East End)



Parking Lot Angle Calculation

- Calculated angle of parking lot to be used in Sketchup 3D model:

Angle $= \tan^{-1}(\frac{opp}{adj})$ ➔ Angle $= \tan^{-1}(\frac{opp}{adj}) = \tan^{-1}\left(\frac{1.165\ ft.}{103.065\ ft.}\right) =$ **.647°**

Software Used:
Sketchup 8 integrated with Google Earth

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Basic Economic

Assumes OCU Law School will not allow use of their side of the parking lot

Retention Grate

- Details on next slide

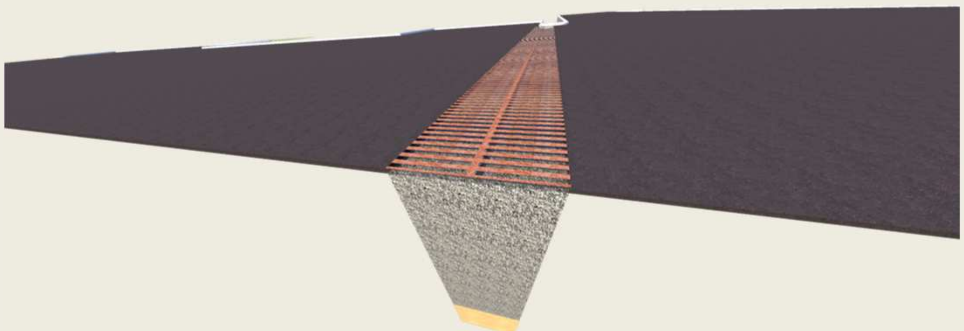
Xeriscape

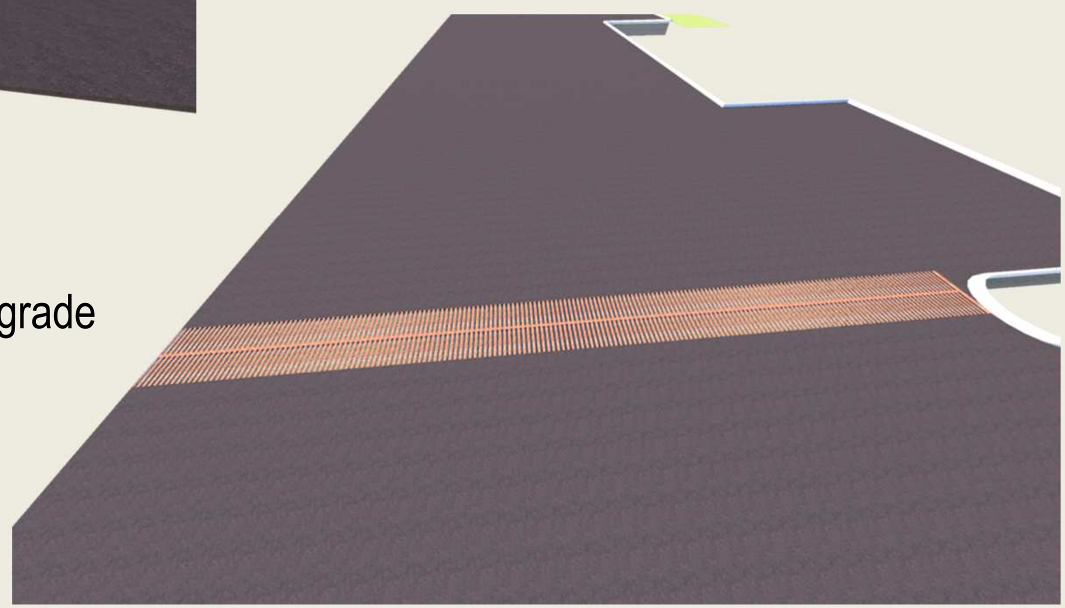
- Native and drought tolerant plants
- Natural-look
- Name plates with information about plants of particular importance to Oklahoma's history and/or future will be provided
- Incorporate educational demonstrations of LID within the landscape

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Basic Economic
3-D CAD Drawing

Retention Grate





- 3 feet wide
- Underneath the grate will be a layer of #57 grade gravel and a layer of sand
- Has same functionality as bioretention cell
- Approximately 10 feet in depth

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

Pervious Concrete or Pavers

- Design tool chosen to retain, filter, and allow storm water infiltration

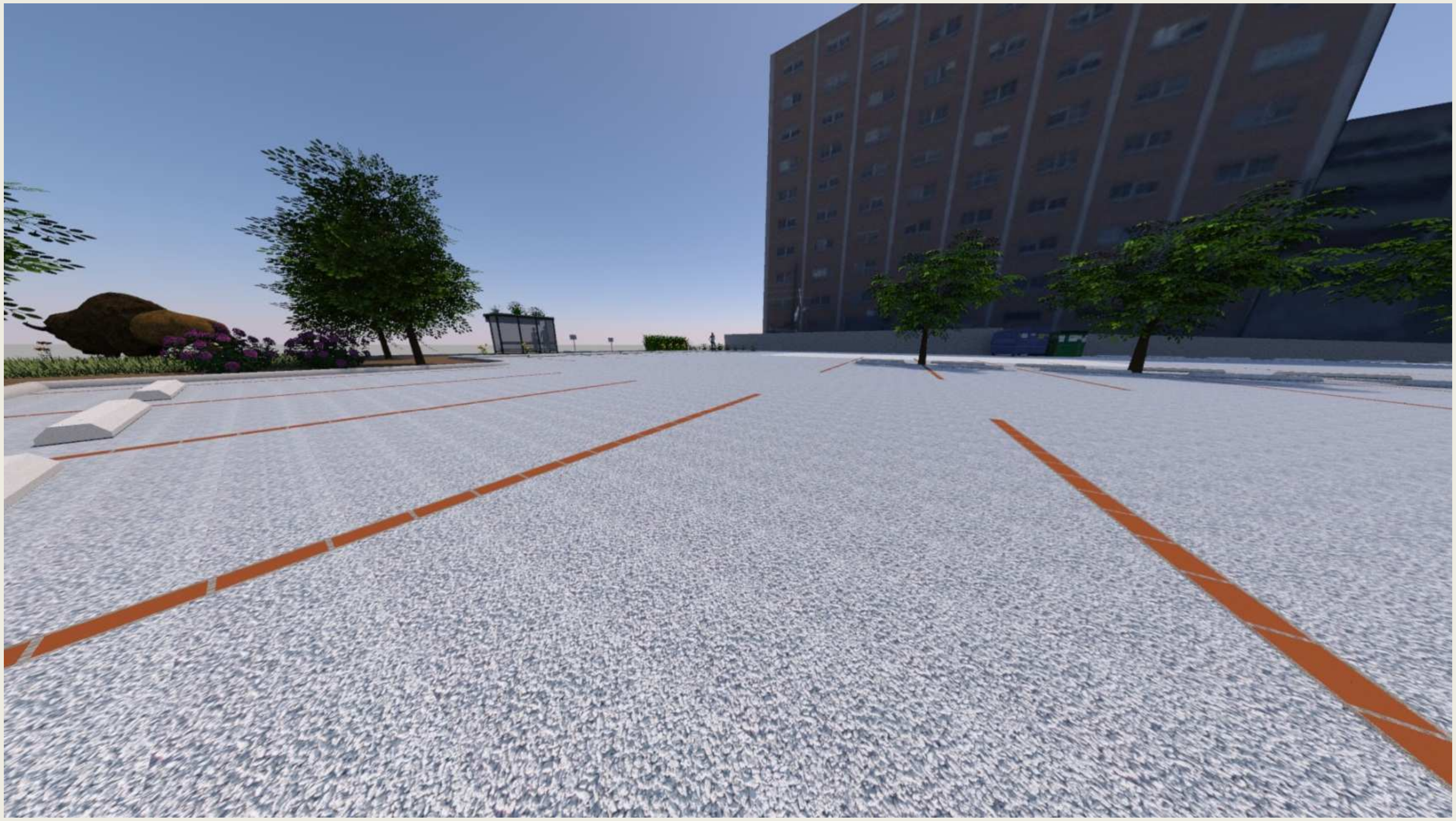
Subsurface Partitions

- Design concept developed to negate the effects of the slope

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

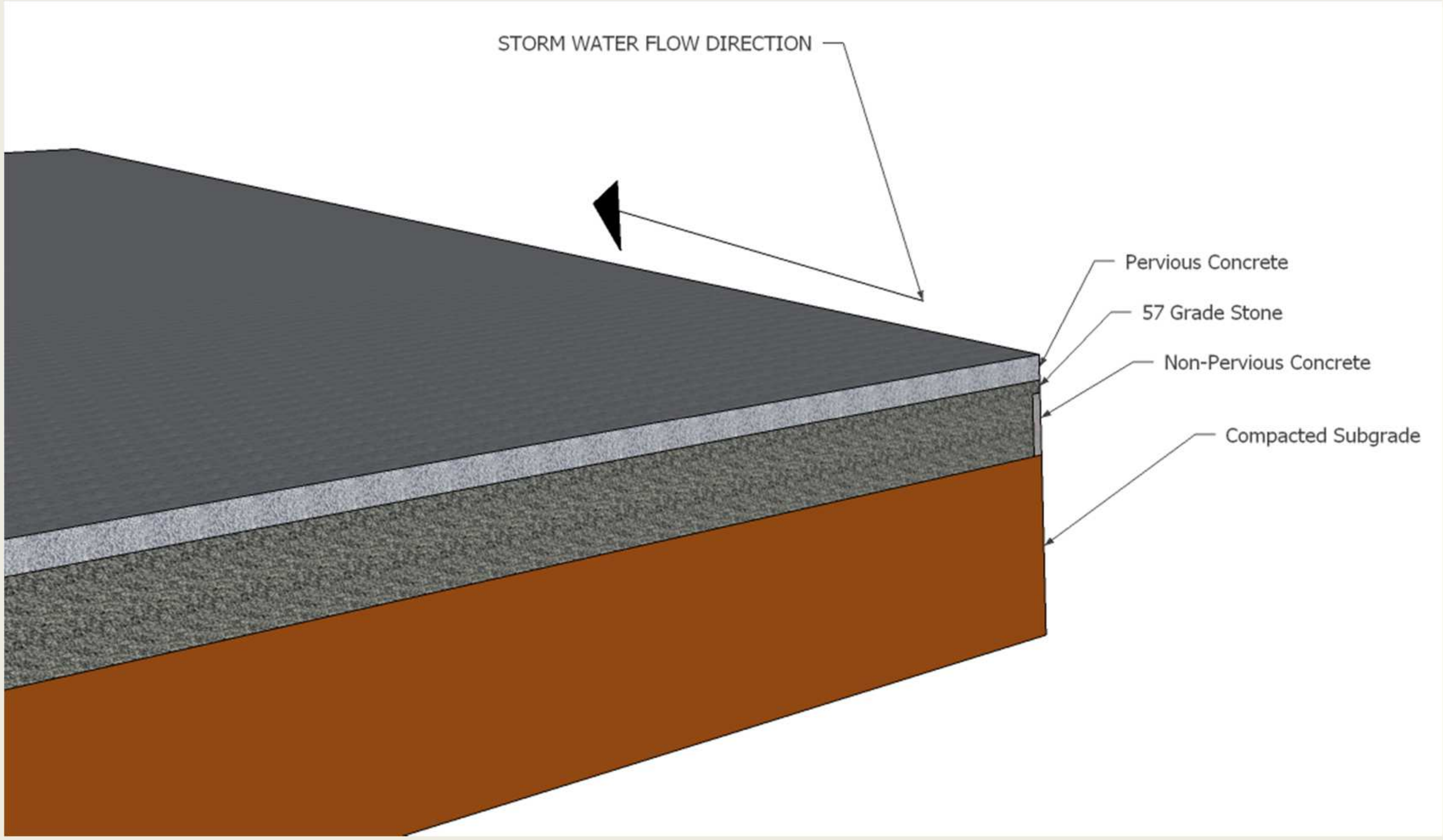
Pervious Concrete



ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

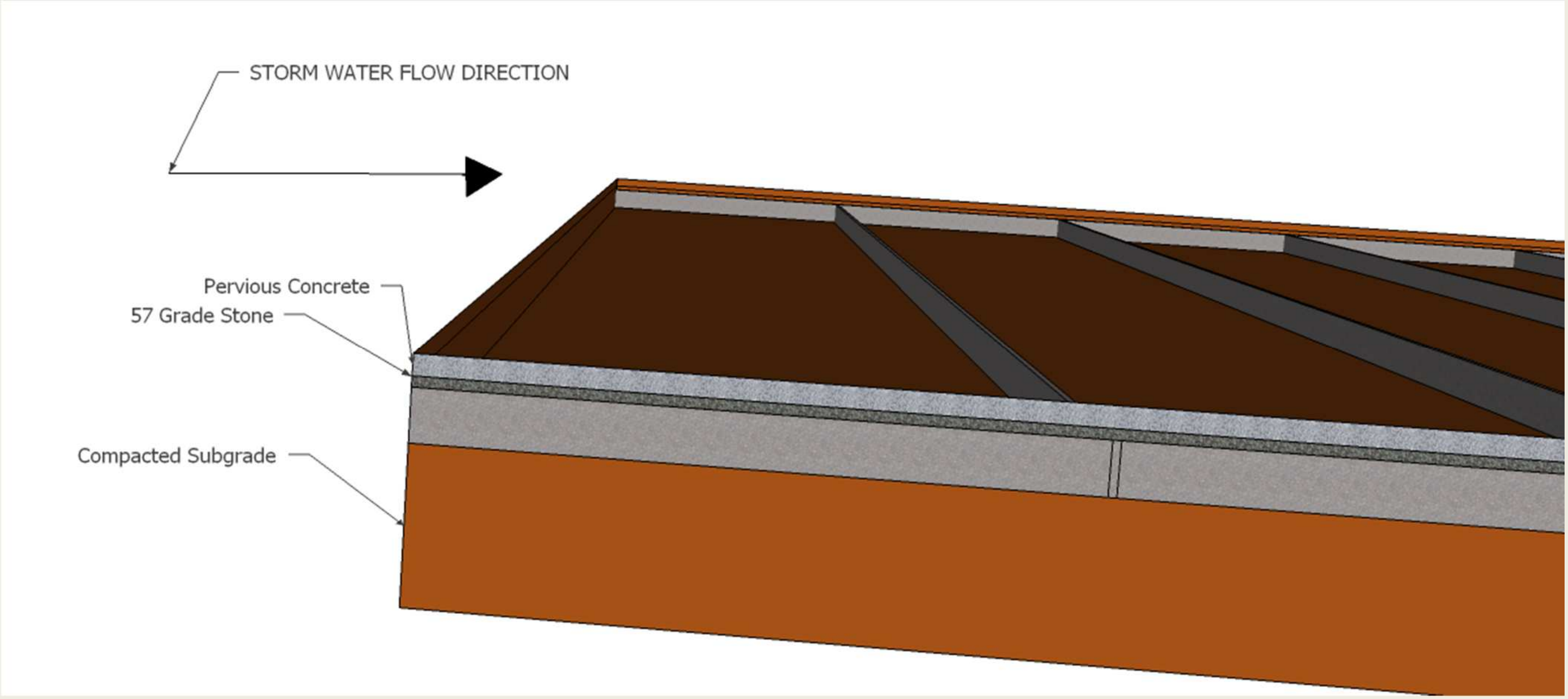
<u>**Subsurface Partition Design Concept**</u>



ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

<u>**Subsurface Partition Design Concept**</u>



ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

Improved Xeriscape

- As previously described

Bus Stop with Green Roof

- Installation of a bus stop with green roof near landscaped area

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Basic Economic
3-D CAD Drawing

Improved Xeriscape

ODEQ Green Parking Lot

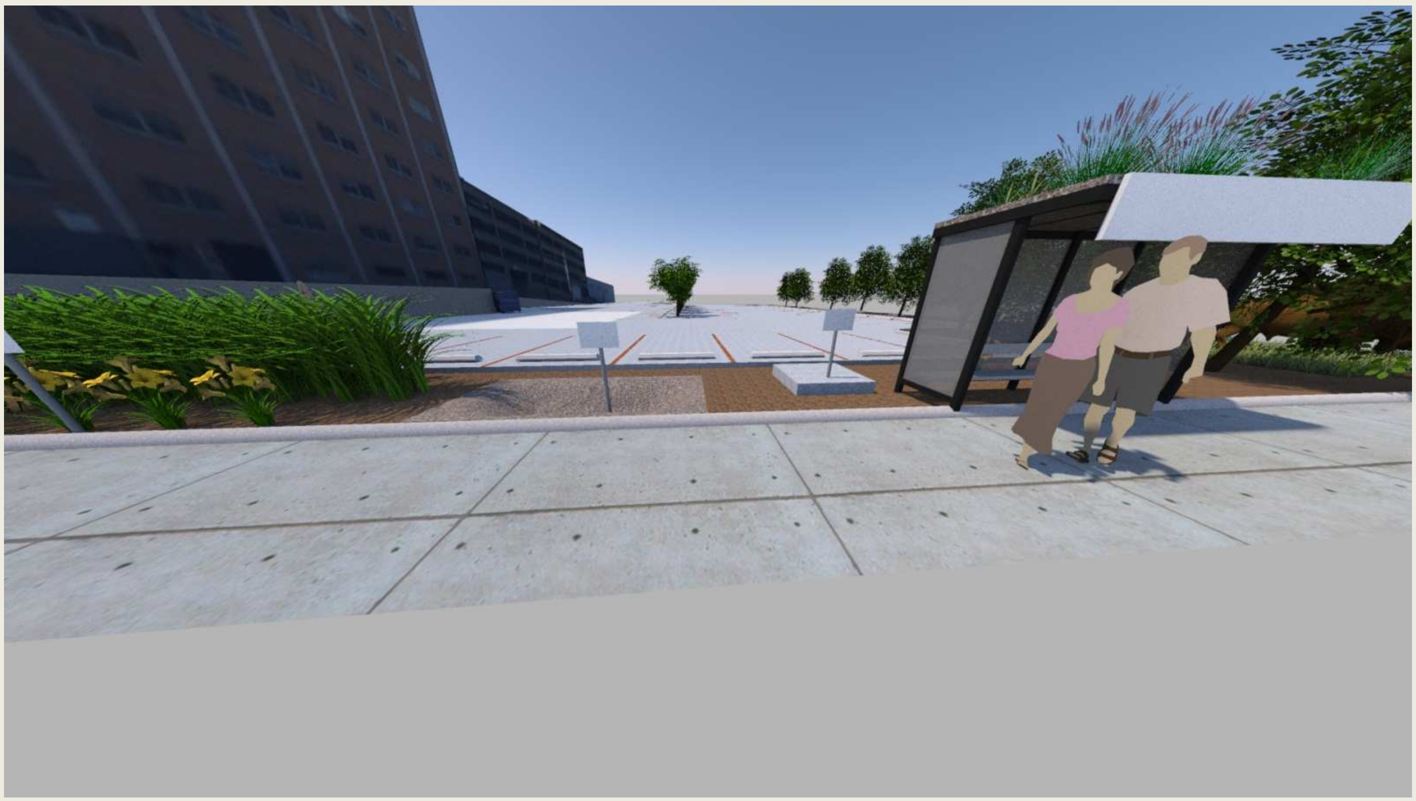
Engineering Specifications:
Selected Design Concepts – Increased Economic

Bus Stop Rain Garden/ Green Roof

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Basic Economic
3-D CAD Drawing

Improved Xeriscape/Green Roof Bus Stop



ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

West-End Regrade

- Regrade west-end to slope of east-end

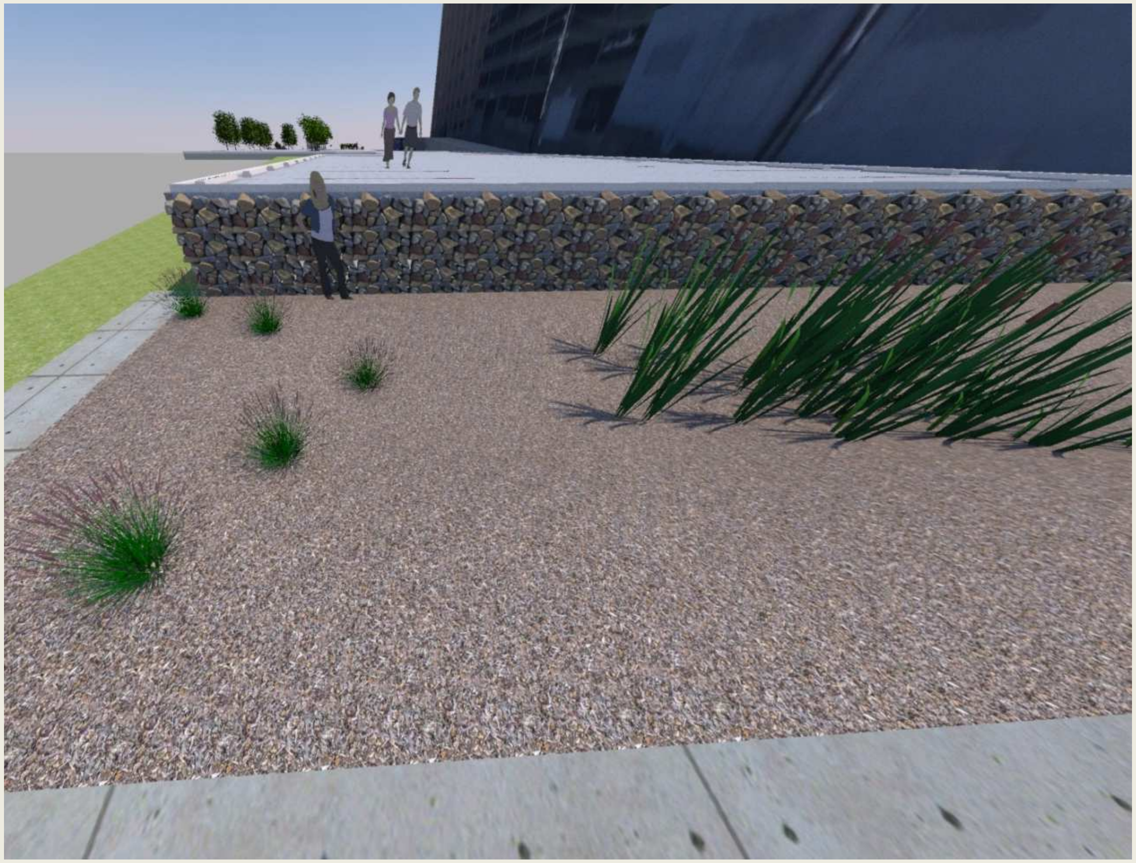
Irrigation System

- Install a cistern that will collect storm water
- Install solar powered irrigation system
  - Must determine if this is cost-effective

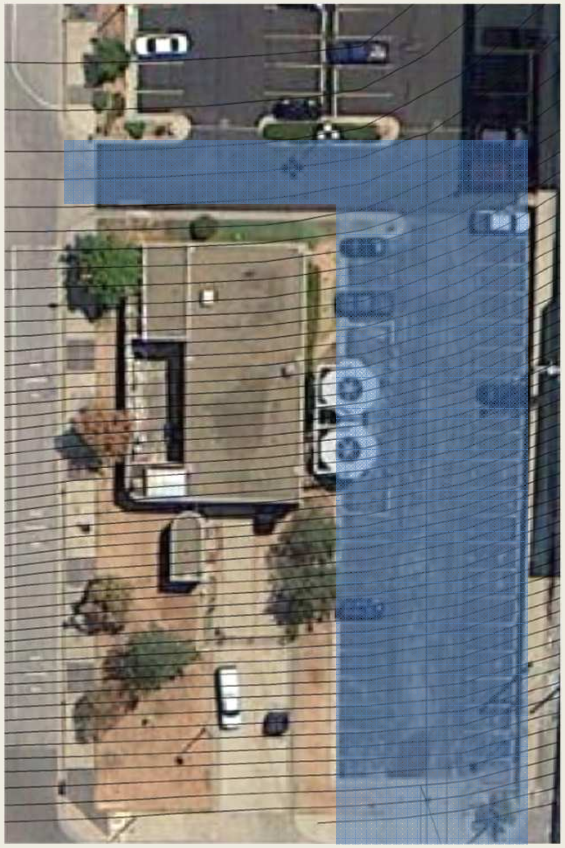
ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

<u>West-End slope regrade</u>



Area in blue to be regraded



ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts – Increased Economic

West-End Wall

http://www.theatlantic.com/national/archive/2011/06/how-to-turn-a-parking-lot-into-an-ideal-green-community/239973/
http://www.seattle.gov/util/groups/public/documents/webcontent/spu01_006146.pdf

ODEQ Green Parking Lot

Engineering Specifications: Zoning Regulations

Oklahoma County Zoning Regulations

- Existing parking lot is compliant
- Design concept will be compliant

A	B	C	D	E	F
90 degree	8'6"	18.0	8.5	24.0	60.0
	9'0"	18.0	9.5	24.0	60.0

A. Stall Angle

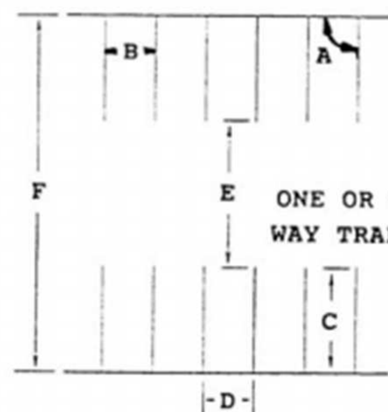
B. Stall Width

C. Vehicle Projection for 18' Stall Length

D. Curb Length Per Car

E. Aisle Width

F. Wall to Wall Width for Double Aisle



ODEQ Green Parking Lot

Engineering Specifications: ADA Design Standards

ADA Handicap Parking Design Standards

- Existing Parking Lot is compliant
- Design concept will be compliant

TABLE 4. REQUIRED HANDICAP PARKING SPACES

Total Required Parking Spaces	*Number of Parking Spaces Handicap Accessible
up to 25	1
26-50	2
51-75	3
76-100	4
101-150	5
151-200	6
201-300	7
301-400	8
401-500	9
501-1,000	2% of total
over 1,000	20 plus one space for each 100 total spaces over 1,000

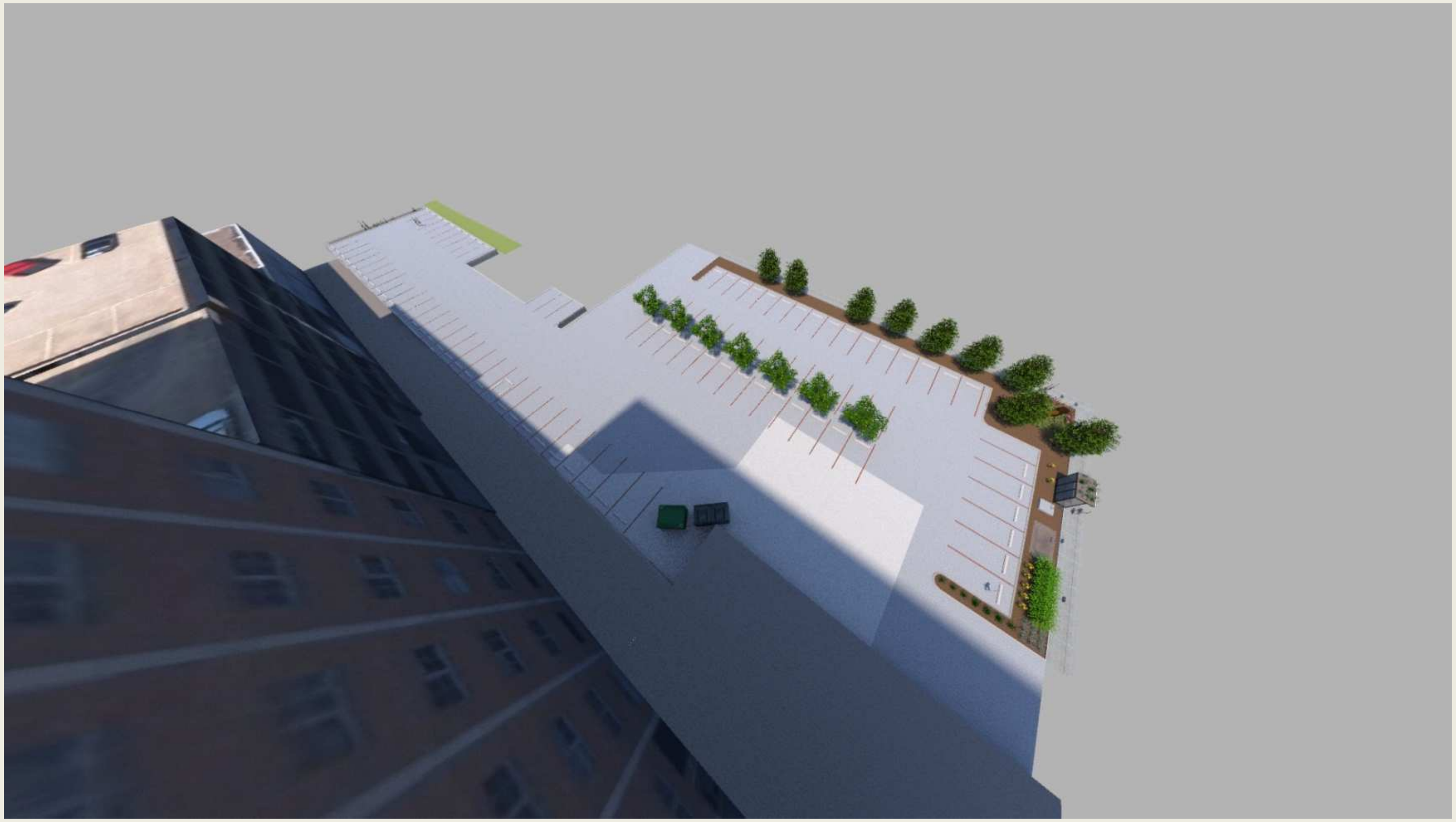
*in all cases, the minimum as required by ADA shall be provided.

At least one parking space must be van-accessible, and for every 6 (six) accessible parking spaces, there must be one van-accessible space.

ODEQ Green Parking Lot

Engineering Specifications: Selected Design Concepts – Increased Economic

Aerial View



ODEQ Green Parking Lot

Proposed Budget

Pervious Concrete Parking Lot Costs			
Title	**Area (ft²)**	**Cost ($/ft²)**	**Total**
West End Pervious Concrete	13357.64	$ 11.00	$ 146,933.99
East End Pervious Concrete	16922.00	$ 11.00	$ 186,142.00
West End #57 Grade Limestone	13357.64	TBD	TBD
East End #57 Grade Limestone	16922.00	TBD	TBD
Title	**# Bricks**	**Cost ($/brick)**	**Total**
Bricks	2418.00	$ 0.50/brick	$ 1,209.00
			$ 334,284.99

Impervious Concrete Parking Lot Costs			
Title	**Area (ft²)**	**Cost ($/ft²)**	**Total**
West End Impervious	13357.64	$ 6.00	$ 80,145.81
East End Impervious	16922.00	$ 6.00	$ 101,532.00
			$ 182,886.81

Price quoted from Canterra Concrete

ODEQ Green Parking Lot

Engineering Specifications:
Selected Design Concepts –Hydrologic Model

Results of IDEAL modeling:

- Predeveloped
  - Total Runoff Volume: .1319 ac-ft
  - Peak Runoff Flow: .07812 cfs
- Existing conditions
  - Total Runoff Volume: .425 ac-ft
  - Peak Runoff Flow: .6013 cfs
- Initial Modeling
  - All models show equal or less runoff compared to predeveloped JLS6

Slide 47

JLS6 Do you have the numbers to back-up this claim? We should have the values for the pervious concrete and for the retention grate.
Johnston, Landon Scott, 12/9/2012

ODEQ Green Parking Lot

Spring Semester

Partition Design Concept:

- Mathematic/Hydrologic Calculations for Partition Design
- Construct a scale-model to prove design theory

Small-scale Models of LID Techniques:

- Replicates hydrologic functionality of design
- Tests water quality

Posters:

- Basic economic design
- Increased economic design

ODEQ Green Parking Lot
Spring Semester

<u>Milestones:</u>

January

- Begin making prototype for underground design
- Begin calculating runoff with the underground design

Feb-March

- Have plants selected
- Have designs drawn up to 80% in Sketchup and AutoCAD
- Have the demonstration model for underground design completed and the bioretention cell profile completed up to 80%

April

- Have all the demonstrations built
- The poster drawings are printed and finished
- Begin working on administrative tasks for the final presentation

May

- Everything complete

ODEQ Green Parking Lot

Proposed Budget

Senior Design Project Cost Estimation

Model Construction Experiments/Testing				
Item	Supplier	Quantity	Unit Price	Total
Posters	Biosytems Dept	2	$60.00	$120.00
Pervious Concrete	Biosytems Dept	1	Free	Free
Building materials for model of partition design	Lowe's/Biosystems Dept.	-	-	$500
			Total	$644.95

ODEQ Green Parking Lot

Questions & Discussion