Stormwater Management at the
University of North Carolina at Chapel Hill’s
Outdoor Education Center

The report and recommendations were assembled by Collin Carroll, Emeraghi David, Blais Hickey, Madi Rivers, Elizabeth Sebastian, and Parris Smallwood

ENST Capstone Class (Fall 2012)

This paper represents work done by a UNC-Chapel Hill undergraduate student team. It is not a formal report of the Institute for the Environment, nor is it the work of UNC-Chapel Hill faculty.
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Executive Summary

Campus Rainwater Group: Stormwater Management Practices at UNC-Chapel Hill’s Outdoor Education Center

Introduction and background
For this capstone course, we were challenged to work as a team to improve stormwater management infrastructure currently in place on the University of North Carolina at Chapel Hill campus. Due to limited time, resources, and subject expertise, our group decided to select a small, feasible section of campus to focus on. Before choosing a specific site, however, it was important to consider the nature of stormwater management. Stormwater is the product of precipitation once it hits the ground.

Generally, this term refers to water that both infiltrates the ground and runs off any given surface. Sometimes stormwater is absorbed quickly into the ground, while other times it migrates for miles, picking up debris, harboring bacteria, and eroding surfaces on its way to primary rivers, lakes, and oceans. The best practices for managing stormwater ("best management practices" or "BMPs") seek to address the unique problems associated with stormwater flow, including, but not limited to, flooding, nutrient levels, and erosion.

Given the constraints on time and resources, the group decided to focus on low impact development options for stormwater management. This type of development emphasizes natural filtering and redirection of stormwater through the implementation of small surface modifications. Upon deciding to focus on low impact development, the group was easily able to select a site on the UNC campus to critique. The site the group decided to evaluate and propose changes to is the Outdoor Education Center.

The Outdoor Education Center (OEC) is a twenty-acre green space located on the outskirts of UNC-Chapel Hill’s campus. The OEC provides several recreational opportunities for not only UNC students and staff, but also for the Chapel Hill and Carrboro community at large. Among the recreational activities the OEC hosts are: tennis, sand volleyball, disc golf, and ropes courses.

Because of the OEC’s involvement with UNC and local schools, it provides the opportunity to not only serve as a recreational facility, but also a source of environmental education. Also, because the OEC consists of almost all green space as opposed to impermeable surfaces, it allows for a wider, and cheaper, range of best management practices to be explored. Many of the BMPs that could be implemented at this site have relatively low construction and maintenance costs, yet would be able to effectively mitigate erosion and nutrient loading, which are the two primary problems at the site.
Methods
To determine which BMPs would best address the major issues at the site and be most cost effective for the site, an initial site assessment was conducted. During this initial assessment, the major problems at the OEC were assessed, key areas were determined, and the stormwater flow route was determined. After the initial site assessment and much discussion, the group decided to narrow its focus even more to specific sites within the OEC. The areas the group decided to focus on are: the entryway, the parking lot, the hillside, and the pond.

Next, group members suggested landscape features for each specific site based on the nature of the problems of that site and how stormwater might be best controlled over that area. The team broke into pairs, and each pair was assigned a specific site to critique. After viewing the physical layout of each site, each pair discussed what features could be implemented at their site. Upon drafting a list of options, the pairs researched each of the proposed BMPs.

In addition to researching general information about the proposed features, a cost-benefit analysis was performed for each feature. This research included determination of placement of the BMP, approximate estimation of the cost of installation and maintenance, the amount of nitrogen and phosphorous that might be removed from the passing water, and potential ecological impacts that the BMP might have on the site. Based on the research mentioned above, specific recommendations were prepared. These recommendations include a list of which combination of BMPs is most likely to best treat the stormwater, and address other major concerns at the OEC.

Findings
Based on the initial site assessment, two primary problems were observed: erosion and nutrient loading. Both of these problems are so major due to the current stormwater management practices, or lack thereof. The majority of erosion at the OEC is on the side hill. Major stripping of soil and the formation of gullies has occurred along the hillside. There is very little vegetation around the edges of the parking lot and along the hillside to slow the flow of water, thus allowing a greater degree of erosion to occur.

Additionally, because there is very little vegetation around the parking lot and on the hillside, runoff from the parking lot is not treated until the water reaches a large retention pond. This prevents many of the nutrients, sediments, and organic materials from being filtered out of the stormwater before reaching the pond.

Recommendations
Recommendations were based on both cost and the amount of nutrient removal for the BMPs provided. The Tar-Pamlico Piedmont Worksheet, a program that determines yearly nitrogen and phosphorous removal amounts based on user inputs (BMP type, BMP size, watershed area), was used to calculate the per pound nitrogen and phosphorus load reductions. A GIS program was used to determine the size of each of the landscape features and the approximate size of the watershed (based on gradient maps, as well as flow patterns).

For the entryway, the recommendation is to replace the concrete gutter leading to the site.
with grass and other vegetation. Exchanging impervious surface for a porous surface will drastically increase nutrient removal and infiltration. In addition, the vegetation and rocks in the swale will slow stormwater, and thus reduce the rate of erosion at the outflow sites. This will also decrease the amount of sediment that eventually ends up in the pond, and thus improve the stormwater quality.

For the parking lot area, the recommendation is to construct a rain garden along the southern border of the parking lot and to place a bioretention island in the parking lot. Placing a bioretention island near the top of the hill will result in greater infiltration, lessening the volume and momentum of the stormwater that flows downhill. The island will also help alleviate the flooding that occurs in the OEC parking lot due to its turtle-top slope and downhill gradient. To complement the island, a rain garden should be added along the southern border of the lot, near the drains, to serve as a buffer. The rain gardens will function similarly to the bioretention island, filtering nutrients and capturing excess water to slow the path of erosion that rainwater has cut into the OEC landscape. Both of these features will absorb nutrients and slow the outflow of stormwater.

For the hillside area, the recommendation is to expand and improve the series of terraces going down the hillside and to place a series of small, interconnected retention ponds at the bottom on the hill. Expanding and updating the terracing will not only further the erosion control of the hillside, but also help slow and direct stormwater flow through the site. A small series of interconnected retention ponds would be better than a larger pond or wetland because smaller ponds are less likely to become vector breeding grounds. They also have much shorter residence time than wetlands and larger ponds, yet have similar rates of nutrient removal. These BMPs will help control erosion on the hillside and reduce the burden on the larger pond by retaining, filtering, and treating stormwater that passes through the hillside area.

For the pond, the recommendation is to increase the size of the pond by adding a fore bay area, increasing the depth of the pond, and expanding the perimeter of the pond. Because a large pond already exists, funds can be directed at improving its functionality as a habitat and as a remover of nutrients and sediments. Expanding the perimeter slightly, planting new wetland vegetation, and deepening small areas within the pond can significantly improve the quality of water flowing out of the OEC and into Jordan Lake. Updating these features will improve nutrient removal by providing additional filtration vegetation and allowing a greater volume of water to be stored and filtered.

Figure A displays the costs for each proposed BMP and the percentage or nutrient removal each feature would remove. Figure B displays the pounds of nitrogen and phosphorous removed each year for each specific site based the proposed BMPs. Figure C displays an aerial map with the locations and relative sizes of these proposed recommendations. This map should function as a comprehensive guide to improving stormwater management at the OEC.
<table>
<thead>
<tr>
<th>BMP (section)</th>
<th>Initial Construction Cost</th>
<th>Maintenance Cost (per year)</th>
<th>Nitrogen Removal</th>
<th>Phosphorus Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention Islands</td>
<td>$90,000</td>
<td>$3,000-$4,000</td>
<td>49%</td>
<td>65%</td>
</tr>
<tr>
<td>Rain Gardens</td>
<td>$5,000</td>
<td>$1,000</td>
<td>40%</td>
<td>65%</td>
</tr>
<tr>
<td>Terracing</td>
<td>$45,000-$72,000</td>
<td>$2,000</td>
<td>57.5%</td>
<td>65%</td>
</tr>
<tr>
<td>Retention Ponds</td>
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<td>$2,000</td>
<td>31%</td>
<td>61%</td>
</tr>
<tr>
<td>Wetland Pond</td>
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<td>$3,000</td>
<td>28%</td>
<td>46%</td>
</tr>
<tr>
<td>Swales</td>
<td>$30,000</td>
<td>$2,400</td>
<td>56%</td>
<td>24%</td>
</tr>
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</table>

Figure A: Initial cost and maintenance cost for each BMP, and amounts of nutrients reduction

<table>
<thead>
<tr>
<th>Site</th>
<th>Nitrogen Removal (lb/year)</th>
<th>Phosphorus Removal (lb/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Lot</td>
<td>6.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Hillside</td>
<td>8.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Pond</td>
<td>74.1</td>
<td>23.7</td>
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<tr>
<td>Entryway</td>
<td>2.2</td>
<td>0.2</td>
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</tbody>
</table>

Figure B: Nitrogen and phosphorus removal for each site based on the proposed BMPs

Figure C: Aerial map of location and relative size of recommended BMPs. Details in full report
As students in a Capstone class, we were challenged to work together to improve the infrastructure currently in place to manage stormwater on the University of North Carolina at Chapel Hill campus. It was evident from the start that six students could not overhaul the entire stormwater management plan for such a large geographic area, so it was necessary to select a smaller, more feasible area on which to focus.

Before choosing specific sites, it was important to think about the true nature of stormwater management. Stormwater is the product of precipitation once it hits the ground. Generally, this term refers to water that both infiltrates the ground and runs off any given surface. Sometimes stormwater is absorbed quickly into the ground, while other times it migrates for miles, picking up debris, harboring bacteria, and eroding surfaces on its way to primary rivers, lakes, and oceans. The best practices for managing stormwater (“best management practices” or “BMPs”) should address the unique problems associated with stormwater flow including (but not limited to) flooding, nutrient levels, and erosion.

While subterranean pipes, culverts, and manmade sewer systems comprise much of the human attempt to control stormwater runoff, these features typically require high levels of development such as excavation or trenching. Given the constraints on time and resources, this report primarily focuses on the low impact development options for stormwater management. This type of development emphasizes natural filtering and redirection of stormwater through the implementation of small surface modifications.

Selecting the sites for this report was relatively straightforward given the preconditions of limited time, limited resources, and an emphasis on limited impact development. Time was a
limiting factor because the Capstone course, [for which this report was compiled] was only one semester long. The lack of access to a lab, chemicals, money, and individuals with specific knowledge about how nutrients and pollutants might be measured constrained our analysis to theoretical models instead of empirically based answers. For this reason, candidates for analysis needed to be compact in geographic scale and local. Additionally, since low impact development stormwater management practices are most useful in areas where high impact development would cause major disruption in land use, the best site candidates would be those with high foot traffic and prominent public visibility.

The group selected the Outdoor Education Center as the general site due to its proximity to main campus, its continuity (not spread out/piecewise), and its high foot traffic (due to its frisbee golf course, tennis courts, and running trails). The site presents the opportunity to manage a 67-acre watershed through the implementation of low impact best management practices across a few specific sub-sites: the entry road, the parking lot, the hillside, and pond.

Additionally, we chose to focus on nutrient reduction and erosion control in our management plan for the OEC. Nutrient reduction is important due to the fact that the water from the OEC drains to Jordan Lake, which has specific rules limiting the amount of nutrients in incoming waters. Additionally, the Jordan Lake nutrient credit system means that reductions in nutrients at one location can be used to offset poor nutrient removal at a different location. The OEC which is predominately pervious surface (94.6%), presents a great opportunity for the university to offset its on-campus nutrient levels. Erosion control was the other major area of focus because it has had a clear impact on the land, vegetation, and stormwater quality.

This report is broken down into five major sections. The first section is an initial site assessment that details the problems associated with specific features at the OEC. The second
section explores potential BMPs that could be effectively implemented at the sites. The third section analyzes the efficacy, cost, and potential drawbacks of each of the suggested manage practices. The fourth section is our suggestions about which of the proposed changes to the landscape will give the greatest benefit for nutrient removal and erosion control.
1. INITIAL SITE ASSESSMENT

Figure 1. Diagram of the entire site, with outlines around the sites of interest. Green outlines the road, red the parking lot, blue the hillside, and yellow the retention pond.

Figure 1 is a map of the Outdoor Education Center. It is the site which we chose to develop a management plan for. The map demarcates in different colors (see legend), the different sub-sites that were determined to have the most significant problems associated with stormwater control. These sites represent the most eroded areas, those that poorly filter stormwater, and those with the greatest potential to improve downstream stormwater quality.
1.1 Parking Lot

The first site focuses on the combined parking lot and hill at the summit of the OEC. The parking lot has direct access to the disc golf course, the tennis courts, and the clubhouse. Its capacity is around one hundred cars, and it has two storm drains in its immediate vicinity (pictured in Figure 2).

![Image showing the location of the two storm drains which drain the parking lot and side road. The drain to the right will hence forth be referred to as Drain A, and the one on the right as Drain B.](image)

The parking lot is a single slab of impervious asphalt with dimensions 123 by 233 feet. Surface cracks indicate significant weathering and contraction and expansion of the lot surface. A six to eight inch curb surrounds the perimeter of the parking lot and separates it from the adjacent vegetation. During periods of high rainfall, the rain courses onto the lot and down towards the Drain A. Within the lot itself, a slight ridge creates two local, small-scale catchments. Drain A is the major outflow for the parking lot, collecting approximately 75% of
the parking lot runoff. Based on the erosion patterns next to the drain (show in figure 3), it probably overflows on a regular basis even during brief heavy rain events.

Figure 3. Erosion that has occurred next to Drain A, the low end storm drain. This has likely been caused by high volumes of stormwater overflowing the drain and curb. Additionally, note the poor soil quality next to the drain.

Sparse vegetation, mostly young pines and minimal undergrowth, flanks the side of the rectangular lot adjacent to the entry road. This pattern occurs fairly uniformly around the rest of the parking lot, although the other three sides sport even poorer soil quality – semi-impervious hard clay – punctuated by portions of soil under-layers and roots (see figure 3). In at least two cases, water pathways have formed along man-made footpaths, leading to the exposed bedrock and roots. It appears that no more than four to five species of vegetation prevail in the immediate vicinity, mostly pine, oak, and patchy grass. An open green space dominates the high side of the lot covered in nothing but planted and maintained grass. As shown below in Figure 5, five plastic
bins, two large dumpsters and two plastic “port-a-potties” sit in the low-end corner of the lot where flooding often occurs. They are not elevated above the surface.

Figure 4. Drain A is surrounded by five plastic bins, two dumpsters and two port-a-potties.

The two storm drains and the ridge that bisects the lot longitudinally comprise the existing stormwater management features of the lot (see Figure 5). While the curb may also influence stormwater runoff, it does not appear to be either an intentional or functionally prudent mechanism for management.
The parking lot has a few conspicuous issues: the uneven drainage of the lot, the erosion caused by the lot’s overflow onto the eroding hill, and the poor ability of the surrounding environment to slow or filter runoff in contiguous areas. Less obvious issues include the questionable necessity of the curb, the runoff of oil from the asphalt, and the placement of the solid and human waste receptacles near the main storm drain at the low end of the lot.
1.2 Hillside

![Hillside Image]

Figure 6. Erosion and root exposure are major problems on the hillside.

The hill site begins at the far end of the parking lot near the storm drains and waste receptacles, slopes steeply downwards through one disc golf hole, and ends at a large retention pond. A low area on the hill creates a trail that concentrates rainwater onto a single path, shown in Figure 6. The parking lot forms the peak of the hill, so its excess stormwater drains directly onto the slope during heavy rains. Figure 7 depicts the gradient of the slope coming down from the parking lot.
Figure 7. Topographic contour map of the hillside. Colors closer to red represent smaller slopes, contours closer to green represent steeper slopes

A building of bathrooms stands down the hill near the edge of the parking lot, and a small pathway leads to the low-lying tennis courts to the right of the hill. Most of the surrounding areas are covered in grass that the maintenance staff preserves, but little natural vegetation thrives in the area.
As visible in the figure above (Figure 8), the OEC staff has augmented the top of the hill with a thick layer of mulch, which has somewhat alleviated the erosion problem. However, the strong flow of stormwater caused by the hill’s extreme elevation has washed most of the topsoil away below this area. This leaves a surface of impervious soil, exposed roots and bedrock. Moss grows on much of the bedrock because of its repeated exposure to water and perpetual dampness. Virtually no undergrowth exists. Only established hardwood trees, moss and English Ivy manage to survive. As an invasive species, however, the presence of English Ivy most likely degrades the OEC’s natural ecosystem. Decomposing trees litter the hill and impede the flow of water. The gulch at the bottom of the slope appears to be poorly drained and constantly wet, as much of the water collects here during a storm.

A few attempts at stormwater management already exist at the OEC. Most notably, a pipe at the top of the hill empties water from the parking lot storm drains. This water flows extremely
quickly and has contributed significantly to the erosion on the hill. Areas of strongest flow from the pipe have carved a gulley into the hill. Additionally, using old logs to terrace the hill three to four feet across for every three feet down has been relatively successful. Areas further down the hill remain eroded due to the flow of water during heavy rains.

Figure 9. Root exposure and soil erosion are depicted as well as frisbee golf hole.

Significant soil erosion appears to be the major issue at the site, seen in Figure 9. Water, not foot traffic, causes the erosion, as evident upon examination of the uniform patterns of erosion around areas of visible water outflows. Large volumes of runoff rush down the slope and sweep soil and uprooted vegetation downhill. The large volume likely results from the impervious parking lot and the similarly eroded surrounding areas. The concentration of this high volume of water within the pipe and consequent expulsion down the hill is the primary cause of erosion. Additionally, the lack of undergrowth prevents natural removal of nutrients before the water
enters the pond. The disc golf course on the hill requires a special consideration of this site; any changes made must minimize interference with the Frisbee golf course.

1.3 **Pond**

The pond, seen in Figure 10, sits at the lowest point of the Outdoor Education Center, located just past the bottom of the hill described in the section above. It is approximately 1000 m$^3$ in volume. A small grassy area surrounds most of the pond, and a pathway runs parallel to the south side. Water from the surrounding 67 acre watershed collects here, including the stormwater from the OEC. An outflow from the pond flows into a nearby stream, which drains to Jordan Lake.

The wetland vegetation consists predominantly of low-lying grasses. Bundles of English Ivy, ferns, small trees, and low bushes and pines surround the perimeter of the pond, though many roots exposed by erosion. While the water remains notably stagnant, there have been signs and reports of wildlife, including bass and other aquatic animals residing in the pond. A
significant amount of greenish-yellow organic matter, including leaves from the surrounding trees, covers the water surface.

A spring begins near the initial entrance to the pond by the paved hill and flows along its edge, although a parcel of land separates it from the pond. The pond’s water level fluctuates depending on the weather conditions, from extremely high during rainy weeks to very low during droughts. The surrounding soil consists mainly of impervious clay and course gravel, seen in Figure 11.

![Figure 11. Rocky trench along paved hill towards pond](image)

Multiple issues currently plague the pond, including the overflow of the pond after a large influx of water coming from the other areas of the OEC. There is an issue with pollution of the pond, mainly oil and gasoline runoff from the parking lot, as well as high levels of nutrients in the water. Water running into the pond does not adequate nutrient filtration due to the lack of vegetation and the high velocity with which the water travels towards the pond.
1.4 Entrance to the Outdoor Education Center

The sole entrance road to the OEC branches off of Country Club Road, depicted in Figure 12. A forest on the right side separates the OEC road from the residential Laurel Hill Road. As one enters, a small field stretches to the right, approximately 50 feet across and 200 feet long. Most of this land has been mowed, except for the center, which grows freely and includes various types of tall grasses, saplings, and small bushes. This patch plays a significant role in slowing stormwater flow and removing nutrients. The field transitions into thick woods, and a short but steep hill separates this thick mixture of trees, English Ivy, and other shrubs from the road above. Bushes periodically line the right side of the road for the first 100 feet. After this, a two to three foot border of grass and impervious dirt line the remainder of the road’s right side. On the opposite side, a short hill covered in pine straw, grass, and small pine trees slopes down to a gutter and the road. The culvert at the end crosses beneath the road and releases water down
the slope on the right side into the thick woods. A clubhouse and tennis courts sit at the bottom of a hill at the end of the initial long, straight section of road, and the sloped OEC parking lot is located to the left.

Currently, the two wide, shallow gutters run along the sides of the road, collecting runoff and releasing it into the woods. The gutters, however, are not deep enough to successfully transport all the runoff from the road into the woods, and they do not filter the water. A significant amount of water sloshes over the edges of the gutters, stripping the ground of its grass and exposing the semi-impervious clay soil. Little has been done to slow the water flow and remove nutrients at the OEC entrance.
2. POTENTIAL BEST MANAGEMENT PRACTICES (BMPs)

Each site presents unique opportunities and challenges, as is evident from the initial site assessments. This section narrows down the endless opportunities for stormwater improvement to a handful of realistically implementable best management practices. Since each site is so different regarding its use as well as geologically, the section reviews specific management practices that would best serve each particular site. The following does not aim to lay out the details of affordability and implementation of each best management practice but rather narrow the scope of possible options for consideration in the final recommendation.

2.1 Parking Lot

Although the initial site visit to the parking lot at the Outdoor Education Center was not on a rainy day, subsequent observations confirmed that the impervious pavement combined with high sheet flow volume across the surface often leads to low-end flooding near the primary storm drain. This issue is, by far, the most pressing regarding stormwater management. It appears that excessive flow rates and physical blockage from dead leaves and some sediment runoff cause the flooding. Therefore, these issues should be first in mind when developing a stormwater management plan for the lot.

2.1(a) Bioretention Islands

Unsurprisingly, the imperviousness of the pavement affects the high flow rate of rainwater across the parking lot. The asphalt parking lot is non-porous and seems to lack any underflow buffer. The diversion of three fourths of the parking to the primary drain exacerbates
the problem of a lack of underflow buffer. Correcting this ridge surface design could reduce the volume of water leading to the drain, but it would still divert the rest of the water down toward the sidehill and retention pond sites.

![Image](image.jpg)

Figure 13. Example of bioretention cells similar to those that could be implemented in the parking lot.

Instead, bioretention islands, as shown in Figure 13, should be considered as a possible solution in the parking lot. These subtle depressions in the primary surface capture a portion of the first half inch of rain from each storm. Not only do they slow the flow of rainwater and allow for subtle stream redirection, but they also provide a natural cell through which to filter out nutrients and pathogens (“Stormwater Management”, 2008).

Bioretention islands are also one of the most feasible best management practices because it can be implemented relatively simply in the parking lot. Since the parking lot is not “new” construction, excavated sediment runoff should not cause the drains to clog. In addition, patrons could still use most of the parking lot during the bioretention construction process. Bioretention islands typically cover only 5%-10% of the surface (Perrin, 2009), accounting for the loss of less than ten parking spaces. Proper space redesign and management could allow for the installation
of bioretention islands without losing any parking spaces. Figure 14 is one potential redesign option that adds two spaces (yellow) to offset the loss of two spaces (red) during bioretention island (green) construction.

Figure 14. Diagram of the potential new layout of the parking lot. The large square indicates the location of the proposed rain garden. The smaller green rectangles indicate the location of the proposed rain gardens.
Finally, bioretention islands usually work when the island is between 5-10% of the watershed. While redesigning the parking lot, this consideration was met.

Bioretention islands are also aesthetically pleasing. The OEC provides a natural escape from the overdeveloped world that is main campus, so it seems only fitting that even the paved areas of the expanse should incorporate as much vegetation as possible. Although grass-covered bioretention islands would be the most economic, planting regional trees like oaks and dogwoods could add to the beauty of the OEC. Because roots can damage pavement, the trees chosen should be those with root structures that are noninvasive and would not cause buckling of the pavement. Additionally, increased foliage has the potential to accelerate parking lot flooding, so proper maintenance of the parking lot would be crucial for the success of this BMP.

Overall, bioretention islands offer a medium-cost investment that could significantly improve sheet flow rates, nutrient and pathogen filtering, and natural beauty. Because bioretention cells are designed to slow down high velocity flow by using vegetation, in a similar manner to a riparian buffer system: it acts as a vegetated area which is more difficult for the water to traverse when compared to smooth impervious surface. Nutrient and pathogen removal are also accomplished plants in the bioretention cell. For these reasons, it is a great option for stormwater management at the OEC.

2.1(b) Water Quality Inlets

While water quality inlets (Figure 15) do nothing to reduce stormwater flow rates or volumes, they are considered a structural best management practice that can filter out detritus, trash, and debris from entering the main stormwater streams.
The periphery of the parking lot is covered mostly by clayish soil with some pines and a few leaf-bearing trees. The presence of small paper bits, plastic pen caps, and drinking straws on the overflowed side of the curb near the lot’s primary drain, combined with leaves from the aforementioned trees, create physical blockages in the drain.

Typically constructed of erosion-resistant metal, water quality inlets are “boxes” that can be embedded in the ground or incorporated into existing stormwater drainage pipes to filter out macro-pollution (University of North Carolina, 2004). Although they do not inherently add to the “natural” beauty of the lot, they would certainly decrease flooding prevalence and visible pollution on-site, and their installation is a simple and feasible solution.

Considering the range of alternatives, water quality inlets are relatively unobtrusive to install. Crews can install multiple boxes in just one day without inconveniencing anyone at the OEC. In fact, deciding where to place the inlets (in the parking surface or along the outside of the curbed perimeter) presents the most significant problem.
Should the first trial installations prove beneficial, future water quality inlets could be easily added. Given the low cost for materials and installation of these boxes, even multiple units would be a prudent investment in stormwater management. At the same time, the relatively high cost of maintenance (sediment vacuuming and debris removal) that must occur two to four times each year may prohibit more installation (“Water Quality Inlet”, 2003).

Nevertheless, water quality present a serious option for stormwater management at the OEC. Through their physical removal of sediment and debris, they ensure a cleaner look to the property and help to prevent stormwater drain blockage during heavy rains. This would reduce flooding of the low-end corner of the parking lot and could reduce erosive overflow down through the hillside site that leads to the retention pond.

2.1(c) Permeable Pavement with Infiltration Beds

Permeable pavement used in conjunction with infiltration beds can decrease the amount of runoff from the parking lot. The lot creates a high volume of runoff at the OEC due to its elevation and how poorly it allows infiltration of stormwater to the underlying soil.

The Environmental Protection Agency recommends permeable pavement as a best management practice for managing runoff on a local level. The pavement, comprising aggregate particles combined with a paste, leaves a series of interconnected voids that easily drain water. Once the water filters through this layer, it moves into a gravel storage layer and then either infiltrates the soil, gets carried away by an outflow pipe, or builds up until the storage is full and seeps back out of the top layer, resulting in runoff.

Permeable pavement would reduce the overall quantity of surface runoff flowing onto the OEC campus from its parking lot. Using it to replace the impervious parking lot could increase
rainwater infiltration up to a rate of 3.67 cubic feet of water per square foot or surface area, independent of underlying soils (Stormwater Management Plan, 2004). Not only would this reduce the amount of runoff, but, by increasing the residence time of water within the lot, it would also result in more nutrient filtering and groundwater recharge.

While this pavement would significantly improve stormwater management at the OEC, the implementation of such a large project remains daunting. The project costs much more than other best management practices, with the total approximate cost running $8.00/square foot of parking lot. The parking lot will also be partially or wholly unusable during installation. Construction would have to begin over the summer to minimize the inconvenience to OEC patrons, most of whom visit the center during the school year.

Successful implementation also depends on the soil type under the current parking lot.

Sandy soils are generally preferred because they facilitate infiltration more than the clayey soils (pictured in Figure 16) typical of North Carolina’s piedmont region. Permeable pavement has not been implemented on most of UNC’s campus due to this very issue. The soil type at the OEC must be a certain composition before permeable pavement is installed to ensure that it will
absorb enough water to make it cost effective. Still, the potential benefits of improved infiltration and nutrient reduction may justify the cost of implementing permeable pavement in the site’s parking lot.

2.1(d) Rain Gardens

Figure 17. Placing a rain garden in the parking lot, as shown above, can slow water flow and remove nutrients and sediments.

Rain gardens are typically some of the shallowest types of bioretention basins. Constructed to hold large quantities of water, these basins also facilitate settling of large particulate matter found in the stormwater. Plants within and around the basin have access to the stormwater and can remove nutrients from it (see Figure 17). Additionally, microbes within the basin can remove nitrogen and phosphorous from runoff, the two nutrients of greatest concern in stormwater management. With proper maintenance and upkeep, the vegetation and accompanying microbes function as a living filter.
Rain gardens also help to partition outflow, slowing water and the erosion it causes. This allows more time for filtration and infiltration (two difficulties that arise from the relatively non-porous clay soil of the piedmont region), reducing the volume of rainwater and nutrients carried into major waterways. Based on a sand filter design pictured in Figure 18, an underlying pipe covered in specialized soil promotes infiltration, facilitates vegetation germination, and serves as the drainage outlet for the rain garden.

Each rain garden could absorb an estimated 2.67 cubic feet of water per square foot of surface. Finally, the lush vegetation of gardens can improve the aesthetics of the blacktop driveway and entrance.

Shallow rain garden bioretention basins placed strategically around the OEC parking lot could reduce the volume of rain that reaches the lot from the surrounding slopes, as indicated in Section 2.1 (a), Figure 14.

Implementation of these rain gardens would be fairly simple, as most of the labor and costs would go into buying and planting the new vegetation. The strong flow of rainwater could pose a problem to the initial establishment because of its tendency to sweep away the necessary
topsoil. Thus, only constant maintenance can ensure continued benefits. Such gardens would be overwhelmed by stormwater if other best management practices are not designed in conjunction with this one.

While strong flows increase erosion, rain gardens outfitted with soils and layers of subterranean beds can keep plants alive even in harsh, dry conditions. Additionally, rain gardens can capture the water that spills over the curb of the parking lot, preventing it from wreaking havoc on the sensitive topsoils of the adjacent hills.

2.2 Hillside

The most pressing issue facing the sidehill is the intense erosion caused by heavy runoff from the adjacent parking lot and strong outflow from the lot’s stormwater drain situated next to the hillside. This flow has eroded topsoil across the entire hill, exposing tree roots and rocks, and has even managed to uproot several trees. The hill is also home to two Frisbee golf holes, so the constant use by “frolfers” also contributes to the erosion problem. The erosion reduces the ability of plants to grow which, combined with the assumption that the parking lot runoff is full of pollutants and nutrients, plays a significant role in increasing the OEC pond’s nutrient loads. Potential best management practices for the hillside should slow the flow of water enough to rebuild topsoil levels and reduce the amount of nutrients that enter the pond without interfering with the Frisbee golf course.
Carving a series of trenches, or small tributaries (Figure 20), to create channels and funnel stormwater can increase the surface area over which the stormwater is distributed, slowing the flow of the stormwater. They have the ability to improve infiltration and nutrient removal, increase groundwater recharge, and decrease erosion. They remove nutrients by allowing plants to grow which then uptake these nutrients. Additionally, the increase in surface area decreases the velocity of water flow which allows the soil to adsorb some of the nutrients. These trench diversions will not only slow the flow of water, but they will also create multiple channels through which water can flow to the retention pond below ("Minnesota Urban Small Sites BMP Manual", 2011).

Infiltration trenches are fairly shallow and lined with porous stones, allowing water to seep through the porous bottom and into the subsoil. This process removes nutrients and
facilitates plant growth. The primary purpose of infiltration trenches, however, is to reduce the volume of runoff by diverting some of the water to the subsurface ("Minnesota Urban Small Sites BMP Manual", 2011). This will consequently increase the diversity of the sidehill and improve the water quality.

It is challenging to predict the success of the infiltration component of this best management practice on the hillside site since the trenches typically work best with gentle slopes (less than 15%) and permeable soils, neither of which are characteristics of the hillside. Nevertheless, this best management practice could still be used along fairly shallow gradients, such as the areas at the bottom of the side hill.

![Figure 21. Potential locations for trenching along the sidehill.](image)
As a side note, one should either place the trenches away from the main Frisbee golf paths to ensure the usability of the course, or move the hole placements to accommodate trench-digging (as depicted in Figure 21).

Removing water through trench infiltration before it enters the retention pond would help decrease the amount of flooding that occurs around the retention pond after heavy rains. Additionally, implementation of this best management practice could bring plants back to the sidehill, increasing the aesthetic appeal of the Frisbee golf course.

2.2(b) Terracing

Terracing (Figure 22) is the practice of cutting steps into a hillside to increase surface area. Historically, it has been used to facilitate farming in naturally hilly places by cutting steps into the hillside, effectively producing a uniformly structured grade across the constructed area. Terracing can also decrease the flow rate of rainwater downhill and promote infiltration, depending on underlying soil conditions. (“Gradient Terracing”, 2006) In this case, terracing
could slow the stormwater and decrease the amount of soil erosion occurring at the site ("Gradient Terracing," 2006).

Terracing was chosen as a potential stormwater management tool at this site because the steep incline of the sidehill combined with a lack of undergrowth (due to erosion) limits infiltration and does nothing to slow the flow of water. Terracing would increase the surface area of the hill and impede the flow of water, giving new undergrowth the chance to survive. These terraces could also act as the pre-treatment for a retention pond ("Gradient Terracing", 2006).

![Figure 23. Image showing falling trees that indicates that the hillside is an appropriate area for terracing.](image)

The area clearly lends itself to terracing since it already naturally incorporates the practice to some degree; fallen trees on the hill create natural terraces (seen in Figure 23). While these natural flow obstructions temporarily lessen soil erosion, they are not highly effective since
they form only two narrow steps. Better, more thought-out implementation of this terracing would provide better results.

Figure 24. Diagram indicating the potential location of the terrace steps that are approximately to scale.

To implement terracing, steps similar to the existing ones would be cut into the hillside (Figure 24). These would have to be constructed using inorganic materials, such as fiberglass beams, as organic materials would eventually degrade. A contractor would have to oversee the process, and the construction would disturb existing vegetation. The amount of disturbance obviously complicates the feasibility of the project. Additionally, newly planted vegetation could meet the fate of its predecessors and be washed away in a large rain event. The ability of the terraces to withstand heavy rainfall must be thoroughly analyzed before implementation.
Stormwater wetlands (see Figure 25), also called constructed wetlands, are similar to retention ponds except that they use wetland plants instead of the typical flora. They are among the most effective stormwater management practices for removing pollutants and detaining stormwater. Aside from these benefits, stormwater wetlands also offer aesthetic value and provide habitats for various plants and animals. This being said, stormwater wetlands have far fewer species of plants and animals than natural wetlands because they fundamentally differ from natural wetlands in that they are designed specifically for treating stormwater runoff. Designs for stormwater wetlands vary based on water levels and the area of land available. Constructing wetlands is often preferred to diverting stormwater to a natural wetland because this water can alter the hydrology of a natural wetland, seriously effecting both plants and animals ("National Pollutant Discharge Elimination System (NPDES)", 2012).
Wetlands improve overall runoff water quality and can thus benefit the OEC, where much of the runoff comes from the parking lot and contains oil and other chemicals. They could also reduce flooding of the retention pond during heavy rains, in turn increasing the usability of the field area adjacent to the retention pond. Directing some stormwater from the sidehill toward a wetland would relieve pressure on the retention pond which already collects stormwater from the rest of the OEC. Wetlands are a good option in areas with all types of soils, so this best management practice would still work well with the site’s clay soil. Finally, they require little maintenance, so they would not distract the grounds crew from its regular tasks.

Figure 26. Image indicating the site that could potential house a wetland.
Due to the slope and shape of the sidehill, most of the stormwater coming down the hill passes through a low-lying basin area at the bottom of the site (noted in Figure 26). It currently contains very little vegetation and has some larger stones gathered together. Removing the stones and expanding the basin slightly would create a suitable location for implementing a wetland. Depending on the wetland size, there may be some interference with the frisbee golf course. As long as this interference stays minimal, however, the paths between holes are flexible enough to be redirected around the wetland.

2.2(d) Retention Ponds

Retention ponds are the larger and deeper form of bioretention basins that can hold larger quantities of water. These ponds retain, filter, and treat stormwater for a particular site.

A retention pond is an attractive option for many reasons. Primarily, based on the initial assessment, the site of the proposed pond is generally wet. Its geographic location at the bottom of the slope causes this area to collect all the water that drains from the top of parking lot and hillside. Additionally, the fallen trees and collections of debris that have washed down the hillside indicate that the area does not yet have a function, aside from its proximity to the Frisbee golf course paths. One of the basic guidelines for retention cells is soil stability, and, based on its location at the bottom of the slope and its consistent marshy quality, a retention pond would be a reasonable choice for this location. Furthermore, the current pond, also a retention pond discussed in detail later, drains an astounding 67 acres. Constructing an adjacent bioretention pond could ease some of the burden of that site and serve as a forebay for the pond.
Precautions are necessary to prevent sediment clogging when constructing a bioretention pond at the base of the sidehill (shown in Figure 27). Implementing pre-treatment measures, such as the swales or trenches discussed in previous sections, can effectively prevent clogging and maintain the pond’s infiltration capacity. Regarding actual construction, a deep retention pond with significant surrounding undergrowth will remove the most pollutants and nutrients. The pond’s shape and the soil used to line the bottom will also have a large effect on the magnitude of infiltration and nutrient removal that occurs within the pond. Additionally, the retention pond must be well-maintained to prevent the formation of vector habitats (i.e. mosquito breeding grounds).

2.3 Pond and surrounding areas

The OEC pond acts as the catchment for the surrounding 67 acre subwatershed, collecting stormwater from the parking lot and surrounding vegetated areas. Based on
conversations with Sally Hoyt, we were told that the pond contains high levels of both nutrients and pollutants. The biggest concern regarding the management of the pond is the release of nutrients into Jordan Lake, part of the Haw River Watershed. Therefore, any potential best management practices for the pond site should focus on removing nutrients and sediments.

2.3(a) Shallow Backyard Wet Pond

![Shallow Backyard Wet Pond](image)

**Figure 28.** Example of well-constructed wet pond


A shallow backyard wet pond (shown in Figure 28) much like bioretention ponds, collects and treats stormwater runoff from surrounding areas. They typically vary from four to eight feet deep, and have shallow banks planted with wetland vegetation. This characteristically dense vegetation effectively controls sediments, promotes evapotranspiration and infiltration, and removes pollutants, including nitrogen. The vegetation and bacteria uptake nitrogen in the
form of ammonia and nitrate/nitrite and use it in metabolic processes, thus removing it from the water column (Perrin et. al, 2012).

Given that one retention pond already exists for the 67-acre watershed, implementation of this best management practice will be fairly simple. Instead of constructing a new pond, one could simply make sweeping improvements of the existing site. This carries an added bonus of not altering land use at the center. Additionally, wetland ponds work in all soil types, including the clayey soils at this site. The benefits offered by the pond target the central problem surrounding stormwater management of the site: removing nutrients and sediments to prevent their entrance into Jordan lake.

![Figure 29. Proposed modification to the pond.](https://example.com/figure29.png)

Modification of the existing pond to better filter nutrients would focus on altering and improving the wetland vegetation on the banks (green), creating a forebay (yellow), deepening
the pond (blue) and improving the outflow area (red). The pond works best when it intersects at least the seasonal high water table and potentially even the seasonal low water table, ensuring that water always exists in the pond. Placing a forebay at the inlet of the pond will slow water flow and remove sediments before the water enters the pond. The forebay could be the bioretention cell or wetland mentioned above. Improving the outflow area would involve more frequent maintenance to slow sediment clogging and a more defined connection between the pond and the nearby streambed that eventually carries the water to Jordan Lake. The surrounding wetland plants should be native, adaptive enough to survive both drought and floods, and not attract mosquitoes. Common examples found in North Carolina include rushes, hibiscus, woolgrass, and other weedy plants. Implementing these changes will increase the removal of sediments and pollutants and slow the flow of water (Perrin et. al, 2012).

2.3(b) Swales, Trenches, and Infiltration Devices

![Figure 30. Proposed swale and trench locations](image-url)
Swales are generally shallow dips or channels in the landscape that collect and transport water to an outflow site (see Figure 30). They are usually grass, but can also be covered in wetland vegetation. The swales can tolerate water flow up to four feet per second, with turf mats under the grass providing further stabilization for the vegetation.

Swales were chosen for this site because they improve water quality more than simple concrete gutters, and wetland swales remove even more nutrients (see Figure 31). They are also relatively inexpensive and low-maintenance, only requiring the occasional mow. Stormwater from across the OEC property flows into the pond. By channeling water through swales and trenches as opposed to gutters or flat fields, one can decrease the volume of water and nutrients entering the pond (Perrin et. al, 2012). A swale would easily replace the concrete gutter lining the entry road. This would increase the pervious surface area, removing more sediments and nutrients while still directing the water down the hill.

Figure 31. Layout and possible design of swale (Source: 2009. F.X. Browne, Inc. Web. 15 Nov 2012.)

Trenches are similar to swales but are deeper, narrower, and rock-filled. They do not slow water as effectively, but deeper trenches do improve infiltration, as water seeps through the
rock cracks and into the soil. Trenches should be on relatively flat land, but the land leading to it can have a maximum 15% grade (EPA: BMP Menu, 2012). Most of the grade at the site falls within these criteria, however certain sections have a steeper gradient. For example, a trench could not be placed at the immediate foot of the hillside, where water initially enters the retention pond site since the gradient exceeds 15%. A trench could effectively channel water alongside the paved road leading to the pond. A small trench currently exists there, but deepening it and adding more substantial rocks and vegetation would improve its effectiveness. Because the slope is significant along this hill, deepening the trench could maximize the rates of infiltration and nutrient removal and slow rates of water flow.
3. **COST BENEFIT ANALYSIS**

This section determines the dollar amount that each BMP will cost the university to implement. Because this project design focused on the need to decrease the amount of nutrients that make it downstream to Jordan Lake, the nitrogen and phosphorus removal were also considered for each BMP. This section includes the percentages of nitrogen and phosphorous, the two main nutrients regulated by the Jordan Lake rules, removed by each suggested BMP. It is worth noting that the OEC maintains its own ground staff. OEC Directors David Rogers and Dave Yeargan provided information on hourly wage rates that were used to then estimate maintenance costs for each BMP in this section.

3.1 **Parking Lot**

3.1(a) **Bioretention Islands**

Bioretention islands are one of the less construction and labor intensive options for managing stormwater in the parking lot. Per EPA (*Stormwater Guide*, 2006) studies, an effective bioretention cell should comprise about 5% of the impervious land area through which the stormwater flows. In this case, that will be easy to calculate since the parking lot and paved entrance/exit roads are the only impermeable surfaces within the immediate vicinity. The total area of the bio retention island will be approximately 11 feet by 18 feet. Given the area under scrutiny, it is reasonable to assume a construction cost of about $54,000 (*Stormwater Guide*, 2006) plus an additional $17,000 for design, contingencies, and permitting costs. These numbers do not take into account the additional excavation costs that are necessary to install islands flush with the parking surface.
Taking the EPA’s recommendation of a 5-7% upkeep cost per year, the bioretention island upkeep would be between $3,000 and $4,000 per year. This money would go toward activities such as watering plants, re-mulching voided areas, treating diseased plants, and removing litter or debris. Real costs for implementation at the UNC site would probably be closer to the low end of that estimate given that the campus already has employees who could work there (lower upfront employment costs).

Nevertheless, one must take into account that the area of the parking lot itself must be repainted so that the placement of a bioretention island does not eliminate available parking spaces. But given that the current parking grid is minimally space efficient, some slight changes such as parking spot angling could help to minimize the costs of resolving this issue.

So, overall, a conservative estimate of the 5-year cost for a bioretention island project in the Outdoor Education Center Parking Lot would be just under $90,000. In order to see whether this type of investment is prudent, one must now look at the expected benefits.

This BMP typically is most effective in removing suspended sediments, phosphorus, nitrogen, and heavy metals (“Bioretention Systems”, 2001). While the size and specific type of bioretention island constructed obviously has a variable impact on the quantification of pollutant removal, EPA data from bioretention sites in Maryland show promising results. More than 65% of runoff phosphorus was removed from drainage areas while almost half (49%) of nitrogen was removed. These results are confirmed by studies done at North Carolina State University (“Evaluation of Costs”, 2003). This primary service provided by bioretention islands is important for water quality management as high nitrogen and phosphorus levels can lead to excessive algae growth in wet areas and change the ecological make up of surrounding areas (i.e. the downstream OEC retention pond).
Finally, bioretention islands are a great option in terms of secondary benefits and aesthetic factors. The island itself would reduce the probability of flooding in the low-end gutter of the parking lot. Additionally, the construction phase of the project would only minimally affect parking lot usage. The majority of the area would still be available for visitors, and the finished product will only add to the natural beauty of the OEC itself.

3.1(b) Water Quality Inlets

Water quality inlets are a relatively simple best management practice option. Capital and installation costs for a pre-cast water quality inlet can be as low as $5,000 (“Water Quality Inlet”, 2003). This low-end inlet is probably of the type that UNC would be considering at the OEC site. For the sake of simplicity, the following lists costs on a per-inlet basis, but multiple inlets could be installed in the vicinity of the parking lot location.

An existing study lists operational/upkeep costs at about $1,000 per year for each inlet (“Water Quality Inlet”, 2003). Given that UNC already has the special pump truck required for automated sediment/separator vacuuming, this cost may be less than estimated above. Still, that would put the 5-year cost for one inlet at around $10,000, a significantly lower price than a majority of the other best management practices.

While water quality inlets are useful to separate sediments or hydrocarbons from storm water, they do little in terms of nitrogen and phosphorus removal. That means that they are most effective in locations with high concentrations of oil runoff or sedimentary deposition. Even though the parking lot does have an arguably excessive amount of surface hydrocarbons, the majority of the drainage area is actually grassy or pine-dominated. That means that the primary
service typically provided by water quality inlets may not be substantially effective at the OEC parking lot site.

Another primary service offered by water quality inlets is the removal of physical debris. Theoretically, this ecosystem service could prevent clogging of drains and, therefore, reduce flooding frequency. But, more detailed research is necessary in order to decide on the potential placements for water quality inlets, as well as to evaluate their effectiveness.

Finally, one should recognize the intangible benefits of water quality inlets as well. They require minimal labor and space for installment -- a fact that means OEC operations will be minimally affected by the implementation of water quality inlets as a best practice management. Additionally, the removal of physical debris will improve the cleanliness and the aesthetic beauty of the site.

3.1(c) Permeable Pavement

Permeable Pavement is one of the more expensive potential BMP’s for the parking lot. In addition to the sizable investment of expensive materials and labor hours required to install the pavement, there is a perpetual maintenance cost associated with the practice that must be assumed. Installation costs include both the removal of the current non-permeable pavement and the laying down of the new asphalt. The total area of the parking lot is 133 by 223 feet. One company’s estimate puts the price of asphalt removal at $4.10 per square foot ("Advanced Asphalt Recycling"). The asphalt removal cost from 2002, according to the University’s stormwater management plan, is $4.00/sq. foot (Stormwater Management Plan, 2004). The same document prices the installation of permeable pavement on an unpaved surface at $4.00/sq. foot. The total cost of permeable pavement will come to approximately $8.00/sq. foot of asphalt. In
addition, maintenance of permeable pavement costs around 3 times as much as normal asphalt (Stormwater Management Fact Sheet). The total cost of the BMP will be around $240,000 for the initial installation.

Proper maintenance of the parking lot is crucial to ensure the effectiveness of the permeable pavement. Existing University staff at the OEC can effectively control most of the maintenance tasks; these include inspecting the lot monthly for early signs of pavement clogging, preventative street sweeping of the parking lot 2-4 times/year, and mowing/weeding the lot each inspection during the high growth seasons (Hunt, 2011). At the standard assumed wage rate of $10/hour, monthly inspection will run 1-2 hours during the six cold months and 3-4 hours during the six warm months, accruing an expense of about $360/year. With the conservative assumption that one street sweeping session runs at 6 labor hours, the four sessions per year runs an annual total of $240/year. The combined total annual maintenance reaches $600, which will be a perpetual cost.

Pollutant reduction estimates for porous pavement depend on each pollutant found in the runoff. Total phosphorus falls by 65%, total Nitrogen by 82%, and heavy metals by 98% (Stormwater Management Fact Sheet).

The stormwater runoff quality increases with the introduction of a permeable pavement cover. Some styles of permeable pavement contain grasses that trap silt and sand runoff while other styles are filled with gravel and sand that can be swept away by heavier rainfalls (Hunt, 2011). The grass-infused pavements must be mowed, a cost that is considered in the total maintenance cost calculated above.

Permeable pavement provides massive benefits to erosion avoidance. The effluent piped down from the parking lot and the overflow that cascades down the hill cut swaths of eroded dirt
through the woods, so permeable pavement could contain some of this volume during periods of heavy precipitation. About 4-6 inches of North Carolina’s annual 46 inches of rainfall will be sequestered by the pavement. Simply installing permeable pavement will reduce the volume of water by a minimum of 10% (Stormwater Management Plan, 2004). This is especially critical in the parking lot, where the water collects before flowing towards the more heavily-used sections of the OEC.

3.1(d) Rain Garden

A rain garden 6 feet wide and approximately 150 feet long could be located along the curb on the south side of the parking lot. A majority of the garden would be in the southeast corner, and it would continue along the curb on the other side of the driveway. The cost of installing a rain garden is mainly accrued in the excavation process; the actual setting of the soil and plant life is far less expensive. Excavating the site costs about $9.50/cubic yard. This cost includes removing foliage, soil, and rocks. The particular sensitivity of the rain garden means new rock and sand must be imported before the new trees and grasses can be moved onto the site; this costs $.40/foot cubed. Piping and filter fabric is installed to prevent the soil from being swept away and to allow for filtration, and it will run upwards of $2/linear foot. Finally, mulch and vegetation need to be added to the site at $.20/sq. foot and $.30/sq. foot respectively. The total cost of rain garden installation: $4.65/sq. foot (Hunt and White, 2001). The total cost for the addition of a rain garden would be $10,000.

Maintaining a rain garden is time-intensive, more so than most BMP’s. The rain gardens are living BMP’s and need to be cared for as such, so the maintenance staff will be responsible
for ensuring the continued survival of a rain garden if it is installed by the OEC parking lot. The following jobs and their estimated cost in man-hours is as follows (Hunt and Lord, 2006):

<table>
<thead>
<tr>
<th>Task</th>
<th>Frequency</th>
<th>Time Needed/Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruning</td>
<td>1-2 times/year</td>
<td>2 hours</td>
</tr>
<tr>
<td>Mowing</td>
<td>2-12 times/year</td>
<td>1 hour</td>
</tr>
<tr>
<td>Mulching</td>
<td>1-2 times/year</td>
<td>6 hours</td>
</tr>
<tr>
<td>Mulch Removal</td>
<td>1 time/2-3 years</td>
<td>6 hours</td>
</tr>
<tr>
<td>Watering</td>
<td>1 time/2-3 days</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Fertilization</td>
<td>Once a year</td>
<td>4 hours</td>
</tr>
<tr>
<td>Dead Plant Removal</td>
<td>Once a year</td>
<td>4 hours</td>
</tr>
<tr>
<td>Misc. Maintenance</td>
<td>12 times/year</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

Table 1. Break down of labor rates for OEC grounds crew.

The final labor cost to the OEC will be about 100 hours/year with a one-time, four hour investment, costing a total of $1000/year.

Rain gardens are a useful BMP for reducing the nutrient load of each rainfall. Runoff is a crucial issue for this site since Jordan Lake is so sensitive to the pollutants that drain into it. A study of rain gardens in Chapel Hill measured a total nitrogen removal of 40% and a total phosphorous removal of 65% (Hunt and Lord, 2006). Rain gardens effectively reduce organics as well through the microbial processes that take part in the biotic BMP (Hunt and White, 2001).

Stormwater quality concerns both UNC and OEC staff. Since Jordan Lake receives such a large quantity of water, managing what reaches the basin is crucial. Rain gardens can help this, for the gardens can actually retain a large volume of water, equal to 1 inch of rainfall per square foot of BMP (Stormwater Management Plan, 2004). This will approximate 75 cubic feet based on the proposed size of the BMP. Additionally, the soil and plant life filters rainwater so well that the garden reduces total suspended solids by 85% (Hunt, 1999). Additionally, rain gardens
in equivalent North Carolina clay loam soil do an excellent job retaining water. Overflow only occurred at 18 of 63 equivalent sites studied (Brown et al., 2009).

Public Health is always important, for a BMP with beneficial health side effects can often offset concerns regarding its cost. The rain garden plants’ microbial processes, exposure to sunlight and sedimentation all serve to reduce soil-bound pathogens that could run off into the surrounding area or the nearby creeks that lead to the Jordan Lake watershed (Hunt and White, 2001).

Another benefit is the social context of the rain garden. The aesthetic beauty of the rain gardens should be taken into account, for a well-groomed garden would enhance the look of a parking lot that is currently circumscribed by woods (Stormwater Management Plan, 2004; Hunt, 1999).

3.2 Hillside

3.2(a) Trenches

There is little data about constructing a series of trenches without an infiltration or percolation component. Thus, the cost estimates in this analysis may be slightly off, as they are based on the costs of infiltration trenches. The typical base capital construction cost for a 100-foot long trench is about $40/foot ("Costs and Benefits of Storm Water BMPs", 2006). If a system of ten 100-foot long trenches was constructed from the top of the hill to the retention pond at the bottom of the hill, the base construction cost of the trenches would be around $40000. The typical base cost of application of an infiltration trench for a 5-Acre commercial site is about $45,000 ("Costs and Benefits of Storm Water BMPs", 2006).
In addition to the monetary costs of construction of the trenches, the installation would present some ecological costs as well. Digging a series of trenches across the hill would disturb habitats for both animals living at the OEC and plants living on the hillside. The process of digging the trenches, will likely uproot or damage roots for some plants, and any small vegetation on the hill will likely be destroyed. Damaging and destroying vegetation on the hillside will decrease the food supply of any animals that feed on these plants.

The primary service provided by trenches is soil conservation. They will serve as a means to spread the water rather than to promote its infiltration into the ground water. Thus, there will be very minimal nutrient removal from the stormwater, and implementing a series of trenches will serve primarily as a means to prevent erosion. Trenches are best used in collaboration with other BMPS because they are poor nutrient and particulate filters ("Minnesota Urban Small Sites BMP Manual", 2011). This is a feasible BMP however, because the existing retention pond would serve to remove the majority of nutrients.

Preventing soil erosion will provide several benefits to the site by increasing the quality of the soil. Improvements in soil quality will lead to higher infiltration rates, greater water-holding capacity, and higher nutrient levels, organic matter, soil biota, and soil depth (Pimentel et al, 1995). “Moderately eroded soils absorb from 10 to 300mm less water per hectare per year than un-eroded soils, or between 7 to 44% of total rainfall” (Pimentel et al, 1995). Additionally, soil erosion leads to deficiencies in nitrogen, phosphorous, potassium, calcium, and other nutrients that are essential for plant growth (Pimentel et al, 1995). The eroded topsoil often contains about three times more nutrients than the remaining soil (Pimentel et al, 1995). Stormwater washes this high-nutrient soil washes into the retention pond, causing nutrient loading in the pond. High nutrient levels in the pond can be detrimental to plants and animals living there and in waters
downstream, including Jordan Lake. A potential downside to this BMP is that it requires frequent maintenance and inspection. Because the trenches are so narrow and there are no filters to prevent sediment from coming into them, they are susceptible to frequent clogging ("Minnesota Urban Small Sites BMP Manual", 2011). Also, using trenches to spread water down a hillside does not work consistently. It is not uncommon to have to divert the flow of water and to build a place to channel the water (Hoyt, Interview, 2012). Both the clogging and diversion aspects will require frequent maintenance.

This BMP would impact the use of the site to some degree. It is possible that the Frisbee golf hole on the hillside would have to be relocated if the series of trenches could not be installed around it due to flow patterns. Also, it will be relatively difficult to access for the maintenance crew, as the hill is rather steep. This could cause difficulty and delay in some of the maintenance that would be necessary to ensure that the trenches weren’t clogging and were functioning smoothly. There is little use of the hillside beyond that of Frisbee golfers, so there will be minimal impact on the site use if the trenches can be planned around the Frisbee golf hole.

3.2(b) Terracing

Terracing could solve the issues related to soil erosion on the hillside by preventing soil stripping and root exposure. Terraces spread the stormwater across a larger area and reduce the velocity of the water flowing down the hills (City of Madison, WI). This consequently prevents large volumes of soil from being eroded and carried down the hillside during rain events. The terrace steps would essentially serve as speed bumps for the water as it traveled down the hill ("Gradient Terracing”, 2006). Small retention “pools” (similar to puddles found in a parking lot) approximately 5-8 inches deep slow the flow of water within each step.
Terrace steps should be approximately 10 feet wide by 15 feet across and constructed roughly 3 feet apart from each other. A small stream would connect adjacent steps. The installation cost of each step would be approximately equal the cost of constructing a similarly sized infiltration trench (City of Madison, WI). Each infiltration trench costs between $3,000-8,000 (EPA 2012), and the size of the site would require the construction of approximately 9 steps. Based on these costs and dimensions, the total cost of construction at the site would be between $45,000 and $72,000. Additionally, maintenance would cost approximately $2,000 per year.

In addition to erosion control, terracing would also improve the quality of the outbound water. Because it functions as an infiltration trench, those values were used to approximate nutrient loading (EPA, 2009). Terracing would remove approximately 55-60% of outbound nitrogen, and approximately 60-70% of outbound phosphorus (EPA, 2012). Additionally, terraces will add aesthetic beauty, a serious benefit considering the hillside serves as a backdrop to the Frisbee golf course, without interfering with the present site use. Further, between infiltration and the movement of water between steps, water will collect in the terraces for no longer than 24 hours, even during the heaviest rain events. Thus, mosquitoes cannot use it as a breeding ground.

Terracing also will help to increase the ecological diversity of the site. Because the steps will decrease the flow of water, more trees and undergrowth will be able to survive. The only trees present currently are those with deep roots because the storm water runoff makes it impossible for young trees to survive. Also, humus and other upper soil layers will be restored, as the upper soil layers will no longer be removed by water flowing rapidly down the hill.
This BMP should be very effective at this site. The terracing technique should solve the problems of erosion and nutrient control at the sites. It can slow the high volumes of water, consequently increasing ecological diversity and reducing nutrients from the outbound storm water.

**3.2(c) Stormwater Wetland**

Because it is rare to find data regarding the construction cost of data for wetlands, Brown and Schueler developed an equation to estimate the cost of construction a stormwater wetland. This formula is based on the assumption that it typically costs about twenty-five percent more to construct a stormwater wetland than a stormwater pond of the same size. The resulting formula is: 

\[ C = 30.6V^{0.705} \]

where \( C \) equals the “construction, design, and permitting cost”, and \( V \) equals the “wetland volume needed to control the 10-year storm (ft³)” ("National Pollutant Discharge Elimination System (NPDES)", 2012). Using this formula, the construction cost for a one acre wetland is $57,100. There would be very little environmental cost of implementation because there is not much vegetation growing in this area. Much of the area is visibly eroded, and there are some fallen trees and large rocks in the basin area. Wetland plants can replace the existing vegetation that is removed during construction.

In regards to nutrient and pollution removal, stormwater wetlands are one of the most effective BMPs. Wetlands are among the most effective practices for removing pollutants and extra nutrients and are particularly effective at removing nitrate and bacteria ("NPDES", 2012). Both the plants and animals living in wetlands are instrumental in removing pollutants and nutrients. Studies have shown that stormwater wetlands can remove over 40% of the nitrate that enters the wetland and about 80% of total suspended solids (Hunt, 1999). Additionally, it can
remove 28% of total nitrogen and 46% of phosphorus. Wetlands are more land intensive than ponds, but they are rarely deeper than one to one and a half feet. Wetlands do have an additional cost, however, that wet ponds do not: planting (Hunt, 1999). Wetlands are often very biodiverse, offering aesthetic and habitat value in addition to their nutrient removal value ("NPDES," 2012). This makes wetlands good sites for environmental education, which would increase the value of the OEC to local school groups coming to the OEC for student recreation and for environmental classes being taught at the university. Although stormwater wetlands are often less diverse than natural wetlands, it is often more beneficial to construct a wetland for stormwater management than to divert stormwater into a natural wetland. Diverting water into a natural wetland can alter the hydrology of the site, resulting in destruction of habitats and unsuitable living conditions for native plants and animals ("National Pollutant Discharge Elimination System (NPDES)", 2012).

There are many different advantages to constructing a stormwater wetland as a BMP. The first is that these wetlands have very few restrictions as to where they can be implemented and how they can function ("National Pollutant Discharge Elimination System (NPDES)", 2012). This means that they will work in almost any climate or region and can be altered at each site to meet the specific needs of that site. They can also be used on sites that have an upstream slope of up to approximately 15% ("National Pollutant Discharge Elimination System (NPDES)", 2012. While the slope of the hillside is greater than 15%, approximately 20% of wetlands do need an elevation drop so that gravity can convey the water from the inlet to the outlet. Another reason a wetland would be appropriate for this site is because the soil is primarily composed of clay. Wetlands can be constructed in almost all soil types, but the less porous the soil is, the more water it will be able to filter, store, and transport ("National Pollutant Discharge Elimination System (NPDES)", 2012).
Although the initial investment may seem a little steep, it is important to note that wetlands typically last over twenty years. Also, the maintenance for this BMP is not very high; “The annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost” ("National Pollutant Discharge Elimination System (NPDES)", 2012). The primary maintenance for a wetland includes inspecting for and removing invasive species, monitoring for sediment accumulation, repairing eroded areas, and harvesting wetland plants ("National Pollutant Discharge Elimination System (NPDES)", 2012).

For this site, the greatest disadvantage of building a stormwater wetland is the amount of land needed. Wetlands need a sufficient amount of land to drain and to make-up the fore bay area (Hunt, 1999). At this site, less than an acre could be converted into a stormwater wetland. Another disadvantage of a wetland ecosystem is that it may attract mosquitoes. Because this site is heavily used by Frisbee golfers, having large mosquito population could be a potential public health concern. However, in diverse, healthy wetland ecosystems, mosquito predators are also present, such as spiders and fish (Hunt, 1999).

Because a wetland would require so much space, it is likely that the Frisbee golf hole on the hillside would have to be relocated. Luckily, the hillside and basin area do not appear to be used for any other purpose than Frisbee golf, so constructing a wetland at this site would not have a huge effect on site use. It seems that the benefits the wetland could provide in terms of nutrient removal and educational and aesthetic value would outweigh the costs of moving the Frisbee golf hole. The educational and aesthetic value created could also apply to a larger group of people than the value of using the site for a Frisbee golf hole.
3.2(d) Retention Pond

A series of small interconnected retention ponds was suggested as a possible way to help decrease the burden on the larger pond that is discussed later in this document, as well as dealing with the swampy area that has developed at the base of the hill. These ponds would help to direct water flow down from the hillside to the larger retention pond and ultimately into Jordan Lake.

An installation of this type would cost approximately $50,000 in initial labor and capital costs and about $2,000 to maintain annually (EPA, 2012). However, this is necessary to add to the site, as the site is presently swampy and ill cared for. Additionally, because the site is part of a forested area, it would be easier for the grounds staff to maintain than an installation with plants or grass. Maintenance would be the biggest issue if this installation were chosen, as it does require semi-annual inspections (EPA, 2012). However, cleaning and intensive labor driven maintenance is suggested to occur every 5-7 years according to the EPA (EPA, 2012).

Additionally, the use of small islands would be more ideal than installing a single large feature because the site is close to the Frisbee golf course. One downside to the choice of a pond, however, is that it will add a significant amount of vector habitat (CMHC, 1996). It is important that measures are taken to prevent the breeding of mosquitoes and other vectors (EPA, 2012).

Using a retention pond at this site will change the ecology of the site entirely (EPA, 2012). It is possible that some of the trees and other plants would not survive because the conditions would change from being a damp forest floor to a series of ponds. However, the lack of biodiversity in the forest, the only real surviving trees are pines and oaks, as well as the presence of lots of English Ivy, an invasive species, suggests that this change might be beneficial in improving the diversity of the site. This installation is a good choice for the site because it also has the capacity to improve stormwater quality immensely. Not only does it have good removal
rates of nitrogen (31%) and phosphorus removal (61%), it can also remove large quantities of suspended solids (87%), metals (60-80%) and oil and grease (79%) (EPA, 2012).

3.3 **Pond (and Related Areas)**

3.3(a) *Wetland Pond*

Constructing a wetland pond on a new site generally costs around $100,000 (Hunt et. al, 2007). Improving the OEC pond, therefore, will likely cost slightly less than this estimate. Approximately 800 cubic feet will be added to the pond, both around the perimeter and by making it deeper in a few spots, bringing the ponds total volume to 1800 m$^3$. Deepening the pond will provide a larger reservoir for stormwater and aquatic animals alike. Ponds are more effective removing nutrients and sediments with two or three deep spots. Monetizing biodiversity and ecological loss during construction proves difficult, but the lives of a few bass and one snapping turtle would definitely be disturbed. Finally, planting new, indigenous wetland plants will improve nutrient removal, slow water flow, and suspend sediments. Thus, the total base cost of improving the pond will, as previously stated, approach $100,000.

The wetland pond requires yearly and semi-yearly maintenance. This includes dredging every 5-8 years, keeping the outflow clear, and removing unwanted plants such cattails which attract mosquitoes and other pests. Using a formula provided by the EPA and the pond size of 18,000 square feet, maintenance will cost an estimated 3-6% of construction costs, or a total of $3,000 per year (EPA 2006). This cost is likely high, given the fact that the grounds crews at the OEC already work to maintain the pond at a much lower price.

The improved wetland pond will increase sediment removal significantly. Indeed, vegetated land has less than 1% the erosion potential of bare soil. Wetlands remove an average
of 65% of total suspended sediment from stormwater. The pond also removes 46% of total phosphorous and 28% total nitrogen from stormwater (NPRPD, 2007), which equal benefits of $18-236 and $76-1,1600 per pound of nutrient removed, respectively (NCDENR, 2011). The improved biological diversity and increased nutrient removal are important for bettering the quality of outbound stormwater and compliance with the Jordan Lake rules.

3.3(b) Swale Along Driveway

Replacing the concrete gutter along both sides of the driveway with a grassy swale could provide numerous ecological benefits at a small cost and slow the flow of stormwater down the driveway. The construction costs include removing the concrete, digging a deeper swale, and installing planting weedy vegetation and large rocks to slow the water. Swales vegetated with sod cost an average of $18/linear foot (Malvern.org). Constructing a 1200 foot long swale will thus cost $22,000. Adding 32% for planning and sediment control and another $300 for vegetation and $700 for seventy-two hours of labor, the total base construction costs $30,000 (EPA 2006). Maintenance of sod swales costs $2/linear foot, totaling $2,400 (Malvern.org).

The swale would slow water and prevent erosion and the formation of more gullies, as well as improve infiltration. The swale would also remove sediments, phosphorus, and nitrogen at a rate of 81%, 24%, and 56%, respectively (NPRPD, 2007).

3.3(c) Trench Along Paved Hill

The paved hill leading from the parking lot to the pond currently has a small, rocky trench along the side of the road which cannot hold significant amounts of stormwater.
Constructing a bigger, deeper path would provide numerous benefits to the pond water quality and reduce erosion in the area.

Improvements to the trench include digging a deeper trench, filling it with large rocks and weedy plants, and extending it to meet the pond so that the water is more channeled and will cause less erosion. The EPA estimates base construction costs of a 3-foot deep, 4-foot wide, 100-foot long trench to be $7155 in current dollars (EPA 2006). Adding 32% for sediment and erosion control would cost $2290, and thirty-two hours of labor would add $320. This totals $9764 for initial construction. Maintenance at 15% of the total cost would be $1460 per year (EPA 2006).

The trench would slow water and prevent erosion at the bottom of the hill. The trench would provide filtration for water flowing off the road. It will improve infiltration and raise groundwater tables. Additionally, it will remove 89% of the total suspended sediments as well as 65% total phosphorous and 42% total nitrogen (NPRPD, 2007). Again, this equates to $18-236 per pound of phosphorus and $76-1,600 per pound of nitrogen (NCDENR, 2011).

3.4 Summary of Cost Benefit

The information from the previous sections has been compiled into Table 2 (below). The intent is to provide the reader with a concise summation of the cost, amount of nitrogen and phosphorus percentages that would likely be removed by each of the proposed BMPs. Section 4.4 presents the pounds/year removal of nitrogen and phosphorus.
<table>
<thead>
<tr>
<th>BMP (section)</th>
<th>Initial Construction Cost</th>
<th>Maintenance Cost (per year)</th>
<th>Percent Nitrogen Removal</th>
<th>Percent Phosphorus Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention Islands (3.1(a))</td>
<td>$90,000</td>
<td>$3,000-$4,000</td>
<td>49%</td>
<td>65%</td>
</tr>
<tr>
<td>Water Quality Inlets (3.1(b))</td>
<td>$5,000/inlet</td>
<td>$1,000</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Permeable Pavement (3.1(c))</td>
<td>$240,000</td>
<td>$600</td>
<td>82%</td>
<td>65%</td>
</tr>
<tr>
<td>Rain Gardens (3.1(d))</td>
<td>$5,000</td>
<td>$1,000</td>
<td>40%</td>
<td>65%</td>
</tr>
<tr>
<td>Trenching (3.2(a))</td>
<td>$45,000</td>
<td>$2000</td>
<td>55%</td>
<td>60%</td>
</tr>
<tr>
<td>Terracing (3.2(b))</td>
<td>$45,000-$72,000</td>
<td>$2,000</td>
<td>57.5%</td>
<td>65%</td>
</tr>
<tr>
<td>Stormwater Wetlands (3.2(c))</td>
<td>$57,000</td>
<td>$3,000</td>
<td>28%</td>
<td>46%</td>
</tr>
<tr>
<td>Retention Ponds (3.2(d))</td>
<td>$50,000</td>
<td>$2,000</td>
<td>31%</td>
<td>61%</td>
</tr>
<tr>
<td>Wetland Pond (3.3(a))</td>
<td>$100,000</td>
<td>$3,000</td>
<td>28%</td>
<td>46%</td>
</tr>
<tr>
<td>Swales (3.3(b))</td>
<td>$30,000</td>
<td>$2,400</td>
<td>56%</td>
<td>24%</td>
</tr>
</tbody>
</table>

Table 2. This table displays the initial cost and maintenance cost for each BMP, as well as the amount of nutrients reduced by each.

4. **FINAL SITE-SPECIFIC RECOMMENDATIONS**

This section narrows down the potential BMPs discussed in Section 3 and provides the final recommendations for each site. Recommendations were based on both cost and the amount of nutrient removal the BMP provided. The Tar-Pamlico Piedmont Worksheet, a program that determines yearly nitrogen and phosphorous removal amounts based on user inputs (BMP type, BMP size, watershed area), was used to calculate the per pound nitrogen and phosphorous load reductions. We used a GIS program to determine the size of each of the BMPs and the
approximate size of the watershed (based on gradient maps, as well as flow patterns). The total removal rates for the BMPs was based on the rates in Section 3 (The cost benefit analysis) These results, summarized in Table 3 below, show the potential nutrient removal if each BMP is implemented. When constructed together, these recommended BMPs can prevent a significant amount of nutrients from leaving the OEC and entering Jordan Lake. Finally, the map shown in Figure 32 displays the locations and relative sizes of all recommended BMPs.

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen Removal (lb/year)</th>
<th>Phosphorus Removal (lb/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Lot</td>
<td>6.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Hillside</td>
<td>8.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Pond</td>
<td>74.1</td>
<td>23.7</td>
</tr>
<tr>
<td>Entry Way</td>
<td>2.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 3. This compares the amount of nitrogen and phosphorous removed by each BMP per year

4.1 Parking Lot

After taking into account a careful determination of soil quality, current drainage solutions, and cost-benefit analyses, we recommend installing a bioretention island and rain gardens in the parking lot area.

The bioretention island will offer a holistic solution to the multitude of problems plaguing the parking lot. The turtletop slope of the lot contributes heavily to its problems. Water rushes from the top of the slope down both the north and south ends of the lot, sweeping pollutants and runoff into the woods and eventually into the Jordan Lake watershed. Positioning the island near the top of the hill will force water to infiltrate the soil before gaining momentum
downhill. This will alleviate the flooding for which the OEC parking lot is known, and it also greets visitors to the OEC with a great example how the University promotes environmental sustainability.

The island cannot absorb all the rain that lands on the parking lot. To complement it, a rain garden should also be added along the southern border of the lot, near the drains, to serve as a buffer. Two drainage grates anchor the south side of the parking lot, yet they are often useless, becoming flooded during rainstorms and not trapping the rainwater that spills over the concrete lip of the lot. The rain gardens will act similarly to the bioretention island, filtering nutrients and capturing excess water to slow the path of erosion that rainwater has cut into the OEC landscape.

Both of these BMPs are ideal for the parking lot. Permeable pavement and water quality inlets may not need constant upkeep like the gardens and island do, but they are expensive to install and are not suitable solutions to the problems of the parking lot. The other BMPs reduce runoff, capture and hold sediment, and recycle organic pollutants. Installing both bioretention islands and rain gardens in the OEC parking lot will do a great service to the soil, the watershed, and the site as a whole.

4.2 Hillside

The proposed combination of BMPs for the hillside based on the cost-benefit analysis, as well as consultation with Sally Hoyt, is expanding and improving the hillside terracing in conjunction with a series of small, interconnected retention ponds. This combination of BMPs is optimal for this space. It will ensure access to the frisbee golf holes and will not hinder movement between the holes, thus allowing visitors to continue to use the site in the same manner that they currently do.
The current presence of terracing on the hillside suggests the viability of this BMP for the site. While the majority of the hillside is heavily eroded, the small regions which have been “terraced” by the OEC staff appear to be recovering. Expanding and updating the terracing will not only further the erosion control that the current terraces provide, but also help to slow and direct stormwater flow from the parking lot. Additionally, this option will create more aesthetic beauty and remove more nutrients from stormwater than a series of trenches would. Frisbee golfers will also enjoy greater mobility on the hillside with a series of terraces than with a series of trenches.

Just as there are many reasons supporting terracing the hillside, there are several reasons that a small series of retention ponds should be implemented at the site. A small series of interconnected retention ponds would benefit the site more than a larger pond or wetland because smaller ponds are less likely to become vector breeding grounds. While wetlands and retention ponds have similar rates of removal of nutrients and pollutants, smaller ponds have a much shorter residence time. This will help prevent mosquitos, ticks and other vectors from breeding as rapidly and as successfully. As an additional benefit, small ponds will serve to hold water that will later drain into the large retention pond. This will ease some of the nutrient and pollutant removal burden on the large pond, as well as limit or prevent flooding around the large pond during times of heavy rainfall.

The combination of terracing and small retention ponds will better stormwater treatment by decreasing the amount of erosion on the hillside, reducing the burden of nutrient and pollutant removal on the large pond, and ensuring that visitors can use the site similarly to its present function. For these reasons, these stormwater management practices are the most practical and will provide the greatest benefits to the hillside site.
4.3 **Pond and Surrounding Areas**

Improving the pond and replacing the entry road’s concrete gutters with swales present the two best options for improving this site’s stormwater management from both an economic and environmental perspective. All water at the OEC eventually flows into the pond, so improving it should be a top priority. Since a large pond already exists, funds can be directed at improving its functionality as a habitat and as a remover of nutrients and sediments. Expanding the perimeter slightly, planting new wetland vegetation, and deepening small areas within the pond can significantly improve the quality of water flowing into Jordan Lake from the OEC. The construction of small retention ponds at the bottom of the hill, as discussed in Section 3.2, can act as the forebay and remove debris and large sediments before they even enter the pond. These two BMPs, working together, will boost the capacity of the pond to manage stormwater.

Removing the concrete gutters along the entry road and replacing them with vegetated swales presents another simple but effective addition to the OEC’s stormwater management plan. Exchanging impervious surface for a porous one will drastically increase nutrient removal and infiltration. The vegetation and rocks placed in the swale will slow water flow down the slope. This will weaken the force with which water enters the woods and play field, consequently reducing the rate of erosion at these outflow sites. This will further abate the amount of sediments that eventually end up in the pond and significantly benefit the stormwater quality.
These two suggested BMPs will greatly improve the quality of water leaving the OEC at relatively low construction costs. The strength of both recommendations lies in that they are natural solutions to stormwater management. They mimic the surrounding environment and will thus work seamlessly into the landscape of the OEC and even beautify the site. Additionally, they do not have any complicated pipes or unnatural features that require frequent maintenance. This ensures a low yearly maintenance cost and reduces the likelihood that the BMP will break and require repairs. Implementing these two practices would enhance the stormwater management plan while providing aesthetic beauty and improved habitats and without spending an inordinate amount of money.

Figure 32. This aerial map displays the locations and relative sizes of the recommended BMPs. The green line represents the grassy swale at the entryway; the purple rectangle is the bioretention island; the orange rectangles are the rain gardens near the parking lot; the yellow lines are the 9 terraces along the hillside. The blue ellipses are the retention ponds at the bottom of the hill; the green ellipses are areas of proposed wetland vegetation; the red circles are areas of the pond that should be made deeper.
5. Summary

The site specific recommendations above are the final product of this group’s research. This section will talk about further suggested efforts in this area and discuss the Capstone.

Further possible improvements are many and varied. A future capstone may take the data compiled here and attempt to numerically quantify the actual impact of these BMPs. This would require access to a lab and materials to quantitatively determine the amount of nitrogen and phosphorus loading that occurs on UNC campus. Presently, the UNC stormwater office does not have data on either of these nutrient problems. Another possibility for a future Capstone project would be to actually help oversee the implementation of these BMPs and quantify their impact on the OEC landscape. Stormwater management will always be a concern at UNC because of the disproportionate mix between impervious and natural surfaces on campus. Future Capstones can benefit the campus by continuing to address this issue.

Adopting the stormwater recommendations outlined in the previous proposal also present the OEC with a unique educational opportunity. Signs placed at each BMP describing its function and environmental benefits can inform the community about stormwater management issues, especially nutrient loading, and potential solutions to these problems. OEC visitors will learn more about the landscape around them while enjoying the beauty of the center’s rolling hills and trails. Printed visitors guides with a site map that describes each BMP could be placed at the entrance and afford visitors with even greater access to information.

Improving the stormwater management plan at the Outdoor Education Center will provide numerous ecological and biological benefits for surrounding areas. Most notably, it will improve the water quality of surrounding bodies of water, most notably Jordan Lake. Additionally, implementing BMPs at the OEC will prove easier than making changes to UNC’s
heavily-used main campus and will significantly improve the overall quality of stormwater leaving UNC. It will also offer groundskeepers and stormwater engineers more flexibility regarding the amount of nutrients originating from the main part of campus. They can, therefore, continue to mow the historic quads without fearing significant changes aimed at reducing nutrient loads from these areas.

The overall experience with this Capstone project was positive, however, there were a few problems that made some of our calculations and attempts at quantifying the impact of the potential BMPs difficult. Even though the group had the knowledge and the skill set to quantitatively measure nitrogen and phosphorus, it was not possible for us to make these measurements due to a lack of access to a lab and materials. Greater access to labs and chemicals would allow for better quantitative results, as they are desired by many clients. Nevertheless, the analysis and suggestions laid out in this final report should serve as a helpful guide for future endeavors.
Works Cited


