NEXT GENERATION GOLF COURSE:

LAKESIDE HILLS SYNTHETIC TURF STUDY

by

KEVIN KROEN

A REPORT

Submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture/Regional Community Planning
College of Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2009

Approved by:

Major Professor
William P. Winslow III, FASLA, RLA

Abstract

Synthetic turf has been used extensively for football, soccer, and baseball playing surfaces as a substitute for natural turf because of its increased durability, low maintenance costs, and similar characteristics. The popularity, however, has not extended to golf courses, a seemingly appropriate application. Golf courses are prized for their aesthetic beauty, and their maintenance requires regular, detailed upkeep with particular attention to fairways, tees, greens, hazards, and the surrounding landscape. The combination of regular mowing, watering, grooming, and application of chemicals aim to strengthen the overall appearance of the golf course, but have negative effects on the ecologic and economic values of the golf course.

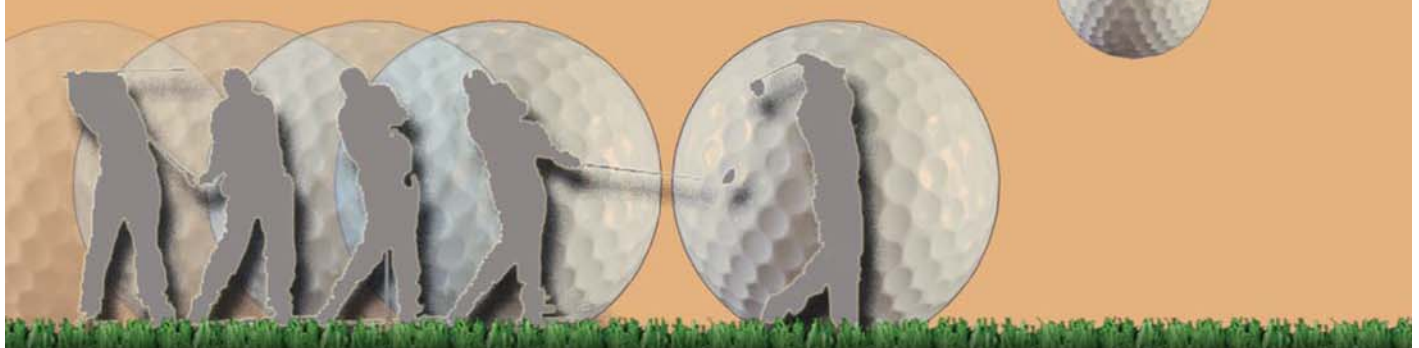
Is it possible to use synthetic turf to reduce the ecologic and economic effects of golf course maintenance, while still providing an aesthetically pleasing playing surface and environment?

This study develops three methodologies from the primary areas of concern: ecologic, economic, and aesthetic. The ecologic method uses criteria derived from the Sustainable Sites Initiative. Criteria in the economic method assist in understanding the cost efficiency of synthetic turf over time. Finally, the aesthetic method contains criteria that define characteristics that affect the look of the golf course. These methods are then organized into a metric structure with the respective evaluation criteria. Using the two re-designed options of Lakeside Hills Municipal Golf Course in Olathe, Kansas as the site for application, the methodologies are evaluated for three different scenarios, the traditional turf course, a partial replacement with synthetic turf, and a full replacement, and given a score. This score provides a quantitative value to weigh the ecologic, economic, and aesthetic benefits and constraints of synthetic turf in a golf course application, and important initial step in discovering its viability in the golf course design industry.

Next Generation Golf Course:
Synthetic Turf Study

Lakeside Hills Golf Course
Olathe, Kansas

Kevin Kroen



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Synthetic turf has been used extensively for football, soccer, and baseball playing surfaces as a substitute for natural turf because of its increased durability, low maintenance costs, and similar characteristics. The popularity, however, has not extended to golf courses, a seemingly appropriate application. Golf courses are prized for their aesthetic beauty, and their maintenance requires regular, detailed upkeep with particular attention to fairways, tees, greens, and hazards. The combination of regular mowing, watering, grooming, and application of chemicals aim to strengthen the overall appearance of the golf course, but have negative effects on the ecologic and economic values of the golf course.

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This study develops three methodologies from the primary areas of concern: ecologic, economic, and aesthetic. The ecologic method uses criteria derived from the Sustainable Sites Initiative. Criteria in the economic method assist in understanding the cost efficiency of synthetic turf the 15 year life expectancy. Finally, the aesthetic method contains criteria that define characteristics that affect the look of the golf course. These methods are then organized into a metric structure with the respective evaluation criteria. Using the two re-designed options of Lakeside Hills Municipal Golf Course in Olathe, Kansas as the site for application, the methodologies are evaluated for three different scenarios, the traditional turf course, a partial replacement with synthetic turf, and a full replacement, and given a score. This score provides a quantitative value to weigh the ecologic, economic, and aesthetic strengths and weaknesses of synthetic turf in a golf course application, and is an important initial step in discovering its viability in the golf course design industry.

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Acknowledgements

I would like to thank Professor Chip Winslow for his assistance and guidance through this challenging process. I would also like to thank Professors Melanie Klein and Dan Donelin for their input and review, and my family and friends for their help, support and confidence.

I would also like to acknowledge all of the help I received from CHA Sports in Kansas City,Missouri and Tiger Turf Americas, Austin, Texas without their assistance and patience I would have never been able to complete the process.

Project Introduction

Golf courses are recreational landscapes shaped into nature. Providing the sense of perfect, natural green turf requires regular maintenance to achieve the quality people are accustomed to seeing — and expecting — on North American golf courses (Bavier and Whiteven 2005). However, golf is not the only sport that strives for superior aesthetic quality. Football, soccer, and baseball also focus on the quality of their playing surfaces, and have been able to use synthetic turf as an alternative to natural turf with greater ease.

Synthetic turf is a polyethylene (plastic) fiber that extends through a fabric backing. These fibers, in conjunction with rubber and sand infill, share similar characteristics with natural turf. The replication of the natural turf characteristics is the primary reason for the popularity of synthetic turf. In the past, many sports have identified that the performance of synthetic turf creates a smoother playing surface than natural turf, and that synthetic turf is more ecologically, economically , and aesthetically pleasing. Yet golf course use is not as extensive as football, soccer, and baseball.

Figure 1.1 - Synthetic turf nine hole chip and putt golf course at the University of Elche in Spain (Tiger Turf 2008).

Maintaining a plush and aesthetically pleasing golf course requires a combination of regular mowing and watering, grooming of course hazards, and regular application of fertilizers and pesticides. These procedures aim to strengthen the overall appearance of the golf course, but have negative effects on the ecologic and economic values of the golf course.

For instance, golf course maintenance procedures can affect air quality as well as surface and groundwater quality. The hiring of personnel and the acquisition of proper maintenance equipment and grooming materials is also expensive, as cumulative costs can range anywhere between $400,000 and $1 million (Hurdzan 2006).

Is it possible to use synthetic turf to reduce the ecologic and economic effects of golf course maintenance, while still providing an aesthetically pleasing playing surface and environment?

Landscape architects have the responsibility of being protectors and stewards of the land. The construction and operation of golf courses is not ecologically friendly, but landscape architects are trained to be ecologically aware of sensitive areas, and to use this knowledge to minimize the negative effects of golf courses. The philosophy followed in the evaluation and design of this project acknowledges links between the ecological, the economical, and general aesthetics of a golf course, and that each of these elements cannot exist independently without the consideration of their counterparts. (Figure 1. 2).

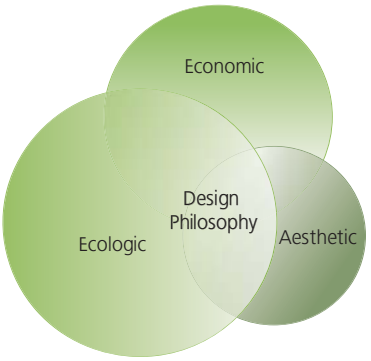

Figure 1.2 - Design Philosophy (Author, 9.30.2009)

Scope

The intent of this study is to investigate the ecologic, economic, and aesthetic properties of synthetic turf throughout its life cycle. The quantitative evaluation uses a metric structure to evaluate the viability of three turf scenarios: natural turf, partial synthetic turf, and full synthetic turf. More specifically, it will evaluate how each of these typologies function when they are applied to the redesign of Lakeside Hills Golf Course.

Project Background

Synthetic Turf

The Chemstrand Company, a subsidiary of Monsanto Industries that begin to use synthetic fiber for carpet, created synthetic turf in the 1950s. Creative Products Group, a division of Chemstrand, then evaluated the first synthetic turf for foot traction, cushioning, weather drainage, flammability, and wear resistance. After completing their assessment, Creative Products Group installed the first generation of synthetic turf, called Chemgrass, at both Moses Brown School in Providence, Rhode Island and at the Astrodome in Houston, TX.

However, the first-generation synthetic turf was flawed, as it wore too quickly, its seams did not hold, and its surface layer faded due to prolonged UV exposure. Athletes who played on the synthetic turf often complained about friction burns, blisters, and leg injuries that often occurred because of the unforgiving properties of the turf. In response to these complaints, the National Football League and the Stanford Research Institute performed a study with results that the turf was not hazardous to athletes' health.

However, the flaws that were detected in the first generation of synthetic turf signaled a reappearance of natural turf in the 1990s, as professional sports coupled nostalgia and the popularity of the outdoor stadium to market grass playing surfaces. Many sports facilities responded to such marketing and began to re-install natural turf fields, despite the fact that natural turf requires large amounts of sunlight, expensive maintenance — water, herbicides, pesticides, and mowing — and ran the risk of possible deterioration due to rainfall.

There has been much recent advancement that places new interest in the synthetic turf technology. The advances in the manufacturing of the fibers and physical properties of the synthetic turf backing have generated a better surface that looks and acts like natural turf without the costs of maintenance. (Schmidt 1990)(Figure 2. 1)

First Generation

Second Generation

Third Generation

Figure 2. 1 - Turf Generation (Easygrass, 2008)

Material

A synthetic turf system consists of drainage pipes, base material, synthetic turf, and infill. The drainage pipes are typically perforated polyvinyl chloride (PVC) or polyethylene (PE) pipes placed on a geo-textile liner separating them from the soil. The pipes are most critical to the performance and durability of the synthetic turf system as they connect to a PVC or PE non-perforated pipe that is either day lighted or connected to an existing storm water system.

Placed on top of the pipes is the base material that stabilizes the drainage pipes. The base material consists of two layers of aggregate. The first layer is typically 3 inches of a ¾-inch aggregate, and a second 3-inch layer of 3/8-inch aggregate (Synthetic Turf Council 2008)(Figure 2. 2) The aggregate base is graded and compacted for permeability and sturdiness. Compaction is important to prevent uneven settling and poor finished product.

Synthetic turf fibers are manufactured in four different forms: polypropylene, polyethylene, nylon, and monofilament plastics. Once manufacturing is finished, these fibers are secured into the primary backing through a knitting process called tufting. This backing material provides the initial stability, while a secondary backing system acts as a cushion. These two backing fabrics have a coating of polyurethane, latex, or weighted thickness depending on the individual system needs (Synthetic Turf Council 2008).

A 15-foot wide roll of synthetic turf is placed directly on the base material. The turf is then laid out and seamed together as additional turf is added. There are two types of seams: glued and sewn. The glued seam uses a paste adhesive and seaming tape. The two pieces of synthetic turf butt together over glue that lies on the seam tape. A sewn seam uses a strong synthetic yarn that directly attaches both pieces of synthetic turf. Finally, the turf is securely attached to the site, using either sod staples or turf ramsets. Sod staples, which are horseshoe-shaped pieces of metal, are most

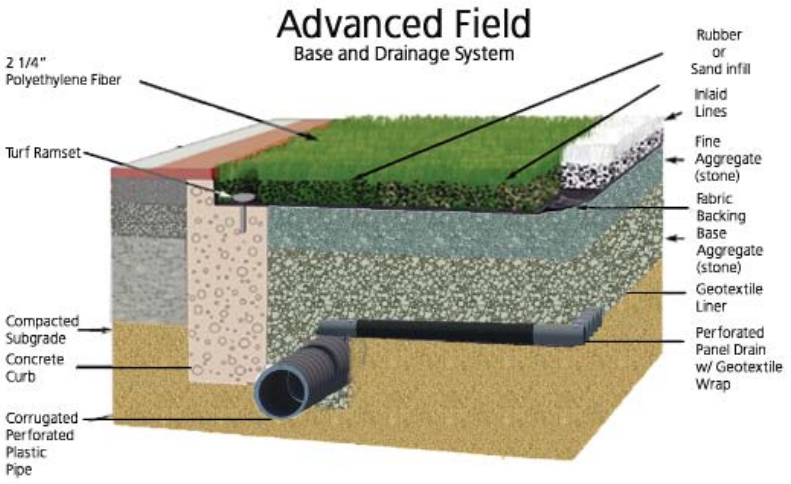

Figure 2.2 - Turf Base Drainage System (Adapted from Sun Country Systems, 2008)

commonly used (Synthetic Turf Council 2008).

Once the turf is secured to the ground, the infill process begins. Infill can consist of either sand or rubber granules, depending on the intended use of the turf. The infill is spread over the turf, and a brushing machine brushes the infill into place. Once the infill is in place, the installation process is complete.

Economic

The economic cost of installing synthetic turf is substantial. The material cost of synthetic turf can range from $1.40 to $2.30 per square foot. Including sub-base and drainage material, installation can cost as much a $9 per square foot. (Fleishman 2008).

Ecologic

Ecologically, synthetic turf and its installation have an effect on the natural environment. Installation affects the site's natural ability to handle storm water by hindering its absorption into the soil. The turf permeates at a rate of 27 in/hr, but the majority of the water ends up in the sub-surface drainage system (Fleishman 2008). The runoff must be discharged on-site to avoid affecting bodies of water off-site. The runoff from synthetic turf can displace the infill, which can end up in natural drainage systems causing clogs. Studies show the infill does not cause chemical contamination, but it is best to contain the infill before it enters natural water systems.

Maintenance

Maintenance is critical for the appearance, permeability, and longevity of the turf. The objective of maintenance is to clean, groom, and brush the surface of the turf. The normal turf maintenance schedule includes daily surface cleaning, weekly brushing, and monthly grooming (Synthetic Turf Council 2008).

Surface Cleaning

Surface cleaning removes airborne contaminants such as leaves and other debris. If not removed, these airborne contaminants can become trapped in the turf system and prevent proper drainage. While

a wide, soft broom can be used for removing turf surface debris, a mechanical sweeper that does not disturb the turf infill can also be used. It is important to note, however, that a mechanical sweeper requires careful maintenance to prevent any physical damage to the turf.

Grooming

Grooming gives synthetic turf a fresh appearance by moving and re-leveling the upper layers of its infill. A mechanical groomer prevents any premature deterioration of turf performance, appearance, and/or drainage.

Brushing

Brushing keeps the fibers of the synthetic turf aligned vertically. Regular brushing is important and should be done in different directions. In general, the turf should be brushed in the direction of the panels to prevent crossing over the main seams.

Surface cleaning, grooming, and brushing are the basic maintenance steps required to keep turf at its peak performance. Manufacturers should be consulted on the specific use of the synthetic turf so the proper maintenance procedures and the frequency with which these procedures should be performed are respected and enacted.

Replacement

The cleaning, grooming, and brushing of synthetic turf costs about 8 cents per square foot a year (Morris 2005). 8 cents a square foot for maintenance on a typical 18 hole 150 acre golf course that has 131 acres or 5.7 million square feet of maintainable turf equals $456,000 and a 9 hole - 80 acre golf course that has 69 acres or 3 million square feet of maintainable turf equals 240,000.

A square foot of synthetic turf may be replaced for $1.40 to $2.30, depending on the type of turf. The ecologic cost of replacing synthetic turf requires the disposal of the old turf. Synthetic turf has a lifespan of about 15 years, at which time replacement is necessary. The replacement of synthetic turf, however, is not as labor-intensive as its installation. Removing the synthetic turf requires vacuuming up infill, cutting the remaining turf into manageable pieces, and taking everything to the landfill. Two alternative options have been adopted. One is use in landfills as a layer separation tool. The second is re-sold for residential or commercial use.

Natural turf

Material

There are three phases in the installation of natural turf. These phases are establishing drainage, soil amending, and the installation of sod/spreading of seed. Drainage of natural turf includes surface and sub-surface drainage, and is a direct link to grading. Low spots caused by poor grading create areas where natural turf cannot live. Sub-surface drainage is a solution where grading could not solve the problem. Soil amending is the addition of organic matter into the soil. The soil's fertility is increased, which helps the sod/seed take root at a faster rate. Sod is a piece of established natural turf that is installed by hand. It takes several pieces of sod to cover large areas of ground because each piece only covers a specified amount of area (Figure 2.3). Since sod is already established, it does not take long to grow into the site. Where sod is not used, possibly because of suitability or its greater cost, grass seed can be used. Spreading grass seed by machine is the most common and efficient way of installation. The installation of grass seed covers large areas quickly, but takes a long time to germinate within the soil and grow into a playable surface.

The cost of installing a high quality sod turf is $2.35 per square foot, in addition to the cost of site preparation (Austin Farms, Kansas City, KS). Site preparation costs $1.63 per square foot, depending on existing site conditions (Morrison 2005). The seed cost of installation is $1.88 per square foot with the addition of site preparation costs.

Figure 2.3 - Sodding 18th Fairway of TPC Sawgrass (Maccurach Golf Construction, 2003)

Maintenance

The maintenance of natural turf is critical to the appearance of the turf. Irrigation, mowing, and the application of fertilizers and pesticides are the primary maintenance strategies for natural turf.

Irrigation

The irrigation system for natural turf consists of a series of sprinkler heads organized in a configuration to efficiently cover and saturate natural turf. On average, the typical turf irrigation system uses 1 million gallons of water a week per 43,560 square feet for an inch of saturation on a golf course (Hurdzan 2006)).

Fertilizers and Pesticides

Fertilizers applied to natural turf provide nutrients that may be lacking or absent in the soil. Applied using spreaders, fertilizers attempt to add nutrients that nourish and enrich the healthy appearance of natural turf and pesticides fight pests that deteriorate the quality of the natural turf. The size of the spreaders used to fertilize depend on the area of fertilization. For small areas, a walk-behind spreader is appropriate, but for larger areas it may be useful to employ a tractor with a pull-behind spreader (Bavier and Whiteven 2005), The typical application rate of fertilizer is 1 pound per square foot (Petrovic 1995).

Typical pesticide application is performed using sprayers because the pesticides are distributed in a liquid form. The different types of sprayers depend on the size of the treatment area. Backpack sprayers are for small areas and spot treatment; whereas large tanks mounted to a utility cart or tractor are for large treatment areas. Pesticide application rates vary because of the wide range of pesticide types. The rate of application ranges from 1.5 to 3.75 ounce per 1,000 square foot (Pertrovic 1995).

Mowing

Mowing trims natural turf to desired lengths. The purpose of mowing is for playability and the aesthetics of the golf course. It takes eighteen lawn mowers to mow an average 18-hole golf course, eight mowers for the greens, five mowers for the tees, three mowers for fairways, and two for the rough (White 2000 p 252). The eighteen mowers cut the turf of the tees, greens, fairways and rough at different heights and at different frequencies.

-Tees are kept at a height of 1/8-to 1/2-inch; mowed three times per week

-Greens are kept at height 1/16-inch to 1/4-inch; mowed daily

-Fairways are kept at ½-inch; mowed every other day

-Rough is kept at less than 2 inches; mowed twice per week (Bavier and Whiteven 2005)(Figure 2.4)

The difference in mowing height and frequency is linked to the importance of the tees, greens, fairways, and rough. The tees are critical to the golfer's first impression, because it is the starting point of every hole. The fairways are the second point of every hole. The fairways typically have consistent tight lies to hit the next shot. The greens are the final destination on every hole for the golfer. The greens are the most important area on the golf course because 40 percent of all golf shots are played on and around the greens (Bavier and Whiteven 2005). The greens are an area where golfers will not tolerate mediocre conditions. The area where conditions are not as important is the rough. The rough is the turf area directly in front of the tee, adjacent to the fairway, and surrounding the green. It is the function and the aesthetic importance of the tees, greens, fairways, and rough that make mowing a critical process in golf course maintenance.

Economic

Annual maintenance costs for natural turf are substantial. The regular use of irrigation, chemical application, mowing, and equipment costs an average of 18 cents per square foot, but when applied to a typical 18 - hole , 150 acre golf course that has an average of 131 acres or 5.7 million square feet of maintainable turf the cost begins to rise (Bavier and Whiteven 2005). For example, the total annual maintenance cost of the typical 18-hole golf course is 1 million dollars and a typical 9 -hole, 80 acre golf course is $630,000.

Ecologic

The ecologic costs of maintaining natural turf are significant, as each maintenance process has an ecologic effect that, if reduced, could improve the environmental impact of golf course maintenance. The natural turf irrigation system typically uses 27,000 gallons of water per 43,560 square feet for an inch of saturation each week (Hurdzan 2006). Which leads to about 1 million gallons of water

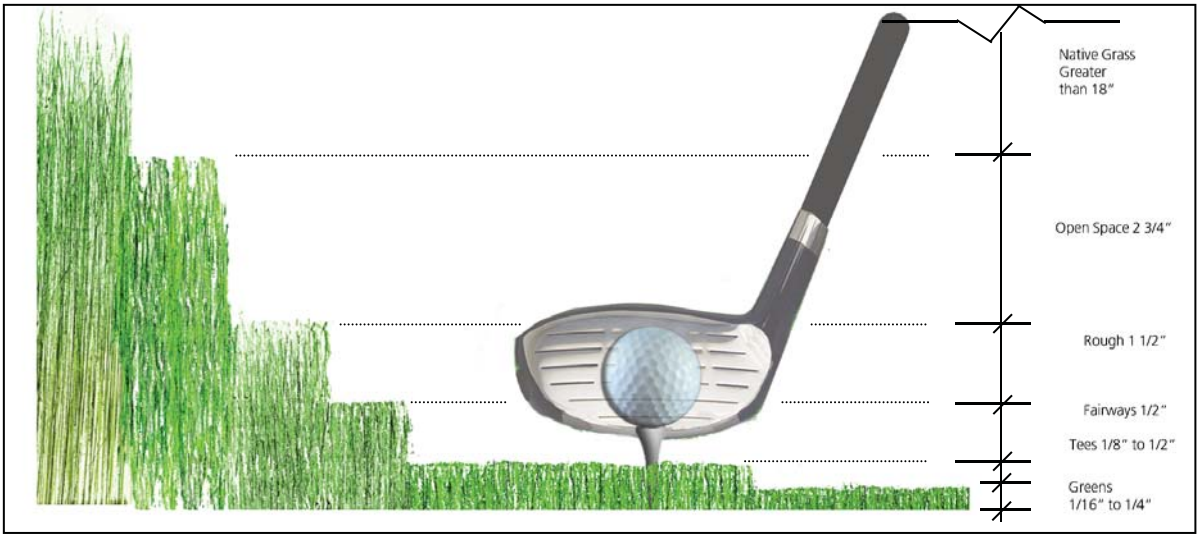

Figure 2.4 - Turf Height Diagram (Adapted from Hurdzan 2006)

being dispersed on to the golf course each year. During the irrigation process, the turf is blanketed with fertilizers and pesticides, which seeps into soil and contaminates surrounding surface and ground waters. An additional cost is mowing, which emits the high levels of CO2 into the air. The average lawn mower emits four times as much C02 as the typical car (Perry 2000).

Replacement

Replacing natural turf is a process that requires stripping turf from the top layer of soil, composting, amending the soil, and, if required, re-sodding or seeding. These procedures are costly and labor intensive.

Conclusion

The reasons for using synthetic and natural turf are similar, but both surfaces possess strengths and weaknesses. The primary strengths and weaknesses between the natural and synthetic turfs is linked to the processes of installing, maintaining, and replacing each type of turf. The difference in the processes provide the curiosity for the use of synthetic turf in a golf course application. Table 2.1 shows a summary of synthetic and natural turf costs per square foot. (Table 2.1),

Per Square foot Economic Costs of Turf				
	Material	Installation	Maintenance	Replacement
Synthetic Turf	$1.40 to $2.30 / Sq Ft	$9.00 / sq ft	$ 0.08 cents / sq ft year	$1.40 sq ft to $2.30 sq ft + labor
Natural Turf				
Sod	$2.35 sq ft	$4.35/ sq ft	$0.18 cents / sq ft year	$2.35 sq ft + labor
Seed	$1.88 sq ft	$3.88 / sq ft		$1.88 sq ft + labor

Table 2.1 - Economic Costs of Turf (Author)

Precedent Study

Echo Basin Ranch

Project: Echo Basin Ranch

Location: Mancos, CO

Date Designed: August 2003, Installation began September 2005

Size: 27.5 acres of Championship Golf Course

Owner: Dan Bjorkman, Echo Basin Ranch

Program:

22,000-square foot Driving Range

7,800-yard, 18-hole Synthetic Turf PGA Championship Golf Course

Project Context

Echo Basin Ranch is located in Mancos, CO. Mancos is a small town situated in a valley between the La Plata Mountains and Mesa Verde National Park in southwest Colorado (Figure 3.1). Echo Basin is a family-oriented vacation destination situated among ponds, streams, mountain views, and forests of aspen and ponderosa pines. Many people choose to travel to Echo Basin because of its focus on outdoor recreation. While Echo Basin allows its visitors to participate in a variety of activities such as horseback riding, camping, and hiking, it also features a nine-hole golf course and driving range.

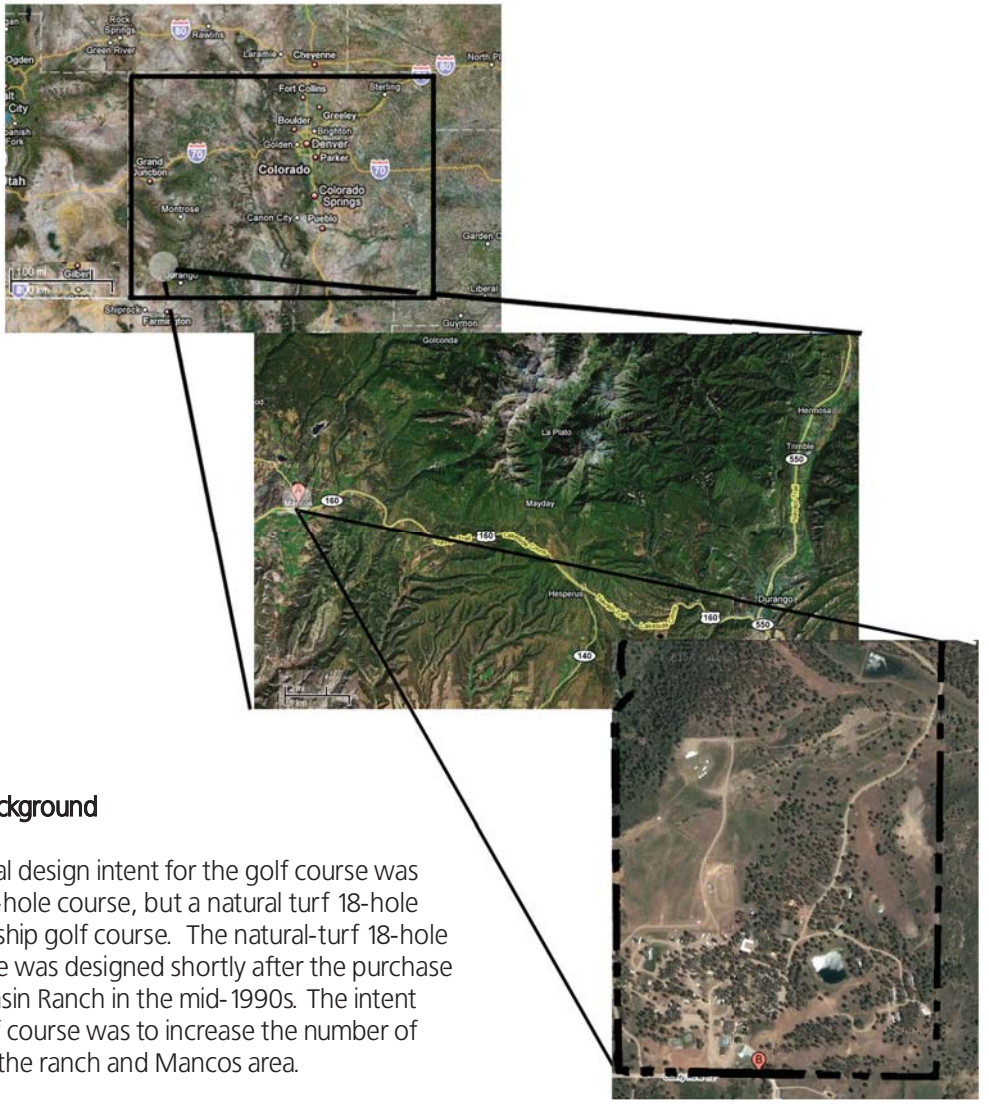

Figure 3.1 -Echo Basin and Location Maps (Google Maps)

Project Background

The original design intent for the golf course was not a nine-hole course, but a natural turf 18-hole championship golf course. The natural-turf 18-hole golf course was designed shortly after the purchase of Echo Basin Ranch in the mid-1990s. The intent of the golf course was to increase the number of visitors to the ranch and Mancos area.

Echo Basin's owner, Dan Bjorkman, began to investigate the requirements for the irrigation and maintenance of traditional golf-course turf with the assistance of his nephew, a landscape architect and golf course superintendent. However, the requirements for the irrigation and maintenance of natural turf frightened Bjorkman. With a lack of water, Bjorkman's realization became the deciding factor, which encouraged him to begin to research synthetic turf (Show 2008).

A retired software salesman, Bjorkman endeavored to learn more about synthetic turf via a sales position at Field Turf, a manufacturer of synthetic turf. Bjorkman learned about the physical attributes of synthetic turf and found that Field Turf's synthetic turf was inferior. The inability of Field Turf's product to withstand the hard wear from golf caused Bjorkman to purchase his own mill from Playfield International. He and a former employee of Playfield International began to design and test different turfs to evaluate how well they could hold

up to the rigor of the striking blow from a golf club. Many professionals and scratch golfers assessed the re-designed turf. Everybody was amazed that the synthetic turf was just like real grass (Mannix 2009). Possessing the knowledge and confidence that such synthetic turf could withstand daily golf course abuse, Bjorkman began the synthetic turf installation process on his 7,800-yard, 18-hole championship golf course.

Installation

The first step in installation of the synthetic turf on Echo Basin site was not any different from the installation process for other athletic fields:

1. Prepare the sub-grade with all elements shaped into the landscape — doglegs, long fairways, water features, and bunkers.

2. Install drainage pipe selecting proper discharge points.

The Echo Basin site also constructed leach fields for the runoff discharge. Over the drainage pipe is 6 inches of compacted ¾-inch road base that runs throughout the course to allow for permeability.

The typical synthetic turf installation steps stop at the road base. Bjorkman's installation proceeded to put three grades of Arizona silica sand over the road base. The sand provided a smooth base for the synthetic turf.

Once the base layers were in place, the fitting of the 1.2 million square feet of synthetic turf began. Bjorkman intended to use five different types of synthetic turf for putting, fairway, rough, fringe, and tee box with lengths of 5/8, 7/8, 1-¼, and 2-¼ inch for the fairway and 2-¾ inch for the rough (Mannix 2009).

Figure 3.2 -Echo Basin Ranch with road base applied (Echo Basin Ranch 2005)

Figure 3.3 -Echo Basin Ranch partial synthetic turf installation (Echo Basin Ranch 2005)

Figure 3.4 -Echo Basin Ranch completed green (Echo Basin Ranch 2005)

Maintenance

Bjorkman stated that the maintenance of the synthetic turf would only require the use of two large street sweepers. The sweepers would provide the high aesthetic quality equal to any major golf course. (Figure 3.5).

Figure 3.5 -Echo Basin Ranch and Augusta National turf comparison(Echo Basin Ranch 2005 and CBS Sports, 2009)

Challenges and Strengths

Installing synthetic turf on the Echo Basin Ranch Golf Course is both beneficial and challenging. For instance, while synthetic turf does not require excess water, it is relatively expensive to install. The installation cost for synthetic turf is estimated at twice the cost of natural turf (Mannix 2009).

As a result of this fiscal constraint, Dan Bjorkman's Echo Basin project was forced to stop construction, as his funding was quickly depleted. Bjorkman only completed 45,000 square feet of the proposed 1.2 million-square foot golf course. The initial investment for Bjorkman's project was substantial, the strengths would have been promising, had Echo Basin been completed. Requiring less water, mowing, and chemical application, the synthetic turf of Echo Basin would not only be ecologically responsible, but also economically judicious. Bjorkman estimated that by using synthetic turf to complete Echo Basin, he would have saved $1 million dollars in both water and general maintenance.

Conclusion

The Echo Basin Ranch Golf Course project, had it been completed, would have been a great feat in the golf course industry. Possessing the ability to provide an alternative turf that is ecologically responsible, aesthetically pleasing, and economically viable for golf owners and golfers, Dan Bjorkman's Echo Basin project illustrates the struggles, issues and possibilities of developing an entirely synthetic turf golf course.

Site

Lakeside Hills Golf Course is located in Olathe, KS. Olathe is the 24th-largest growing community in the nation, and the fourth-largest community in Kansas. A suburb of Kansas City, Olathe is located 20 miles southwest of Kansas City along Interstate 35 in Johnson County.

As the second-largest of 21 communities in Johnson County, Olathe has a population of 122,500 and 7 regulation golf courses within its cities boundaries (City of Olathe Website, 2007) (Figure 4. 1).

Inventory

A thorough site inventory and analysis of Lakeside Hills Golf Course has been conducted in order to determine the current conditions of the site and golf course. The inventory of existing conditions has been evaluated according to a local and a site-specific scale. The current conditions studied include location, slopes, soils, hydrology, vegetation, and the playability of the golf course.

The site analysis rates the suitability of slopes and soils and the effects the hydrology, vegetation, and playability have on the design.

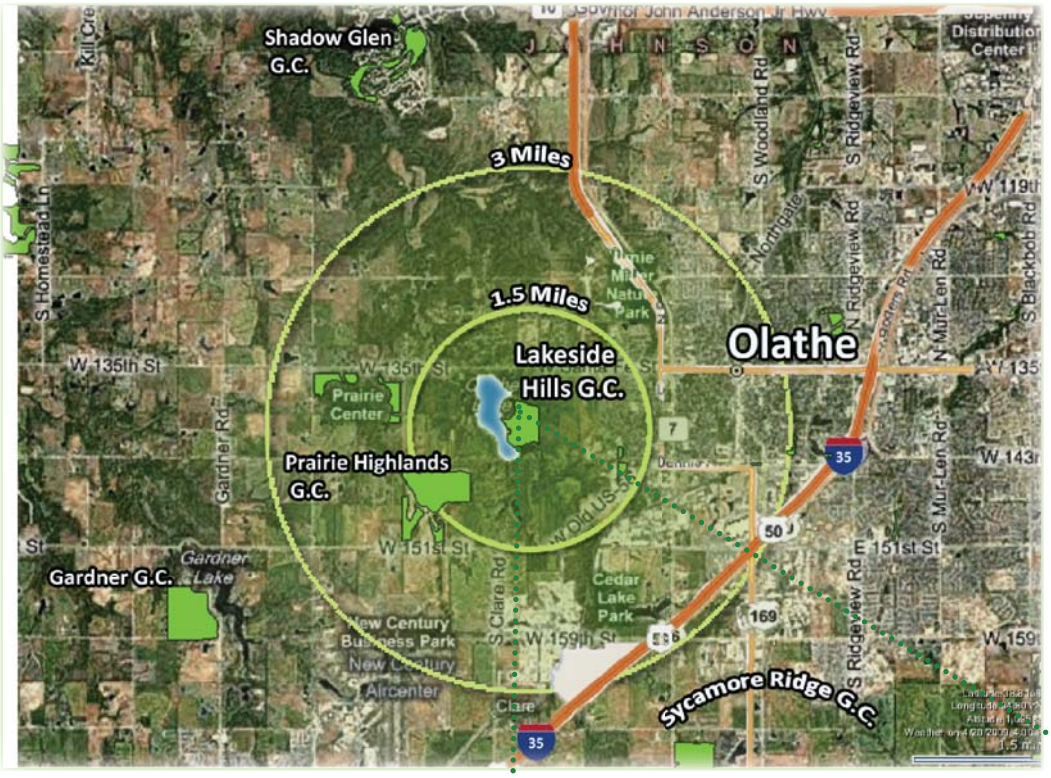

Figure 4. 1 -Location Map (Adapted from Google Maps 2008)

Figure 4. 2 - Context Map for Lakeside Hills. (Adapted from Microsoft Virtual)

Figure 4.3 Existing Conditions (Author)

Golf Course

Lakeside Hills Golf Course is a par 70, 5,975-yard municipal golf course with 18 holes built upon 105 acres of rolling terrain bordered by Lake Olathe and agricultural lands (Figure 4.2 and 4.3).

Inventory

Slopes

The slopes of the Lakeside Hills Golf Course affect drainage, design and application of turf scenarios. Ranging from 10 percent to 70 percent, the rolling terrain of Lakeside Hills Golf Course consists of mostly 10 percent slopes. The steeper 70 percent slopes are located along a band that connects the two tree masses on the south portion of the site. (For exact location of extreme slopes see Appendix A – A. 1).

Vegetation

The Lakeside Hills Golf Course vegetation consists of a mix of trees and turf. The woody plants on the course cover 12 percent of the entire site, and are composed mainly of oaks and eastern red cedar trees. The remainder of the site surface area is turf; 2 acres of bent grass, 25 acres of Bermudagrass, and 36 acres of a mix of fescue and Kentucky Blue Grass. The majority of the trees planted within the dimensions of the course are single trees that have been added to the existing routing plan (see Appendix A - A. 2).

Hydrology

The hydrology of the site consists of two bodies of water within the boundaries of the course and Lake Olathe on the borders. Lake Olathe is a 70-acre lake that is the destination for site runoff. The runoff from the golf course flows off site. Of the 11 watersheds, only five watersheds discharge into the lake. The five watersheds will collectively discharge a total of 45 cubic feet of water per second (cfs) into Lake Olathe during a 25 year, one-hour storm. (see Appendix A -A. 3 and A. 4).

Soil

The soil permeability of the site is important because of the effect that it has on drainage and course vegetation. The soils on-site are Chillicothe Silt Loam, Oska-Martin, Martin Silty Loam, Grundy Silt Loam, Sogn-vinland, and Vinland-rock. The two soils that are somewhat poorly drained are Martin Silty Loam and Grundy Silt Loam. Both of these soils only cover 14 percent of the site. The rest of soils are well drained. A well-drained soil has the ability to absorb water from the surface, while still providing enough water for vegetation to flourish. (see Appendix A – A. 5 and A. 6).

Analysis

Site analysis determines what design constraints and possibilities may be carried out from the inventory of existing conditions and the proposed applications. A playability analysis focuses on the safety and competitive standards of present golf course designs and the comprehensive analysis focuses on design constraints and possibilities.

Playability

The current size of the site limits the existing course from being safe and competitive with other golf courses in the area. The safety standards for laying out a golf course are as follows:

1. 150-foot diameter minimum to 200-foot diameter maximum around tees
2. 350-foot diameter at landing areas provides enough area for errant shots
3. 250-foot diameter around the green allots for the green and surrounding area
4. 200-foot absolute minimum distance from adjacent fairway (Figure 4.8)

Following these four standards provides proper spacing between adjacent fairways, tees, and greens. In order to improve the safety of the existing course, there must be a reduction from the existing 18 holes to nine holes because of the limited space and unsafe conditions presented on the course. This reduction will ensure that the golf course is considered a competitive course with the rest of the courses in the Olathe area (Figure 4.5).

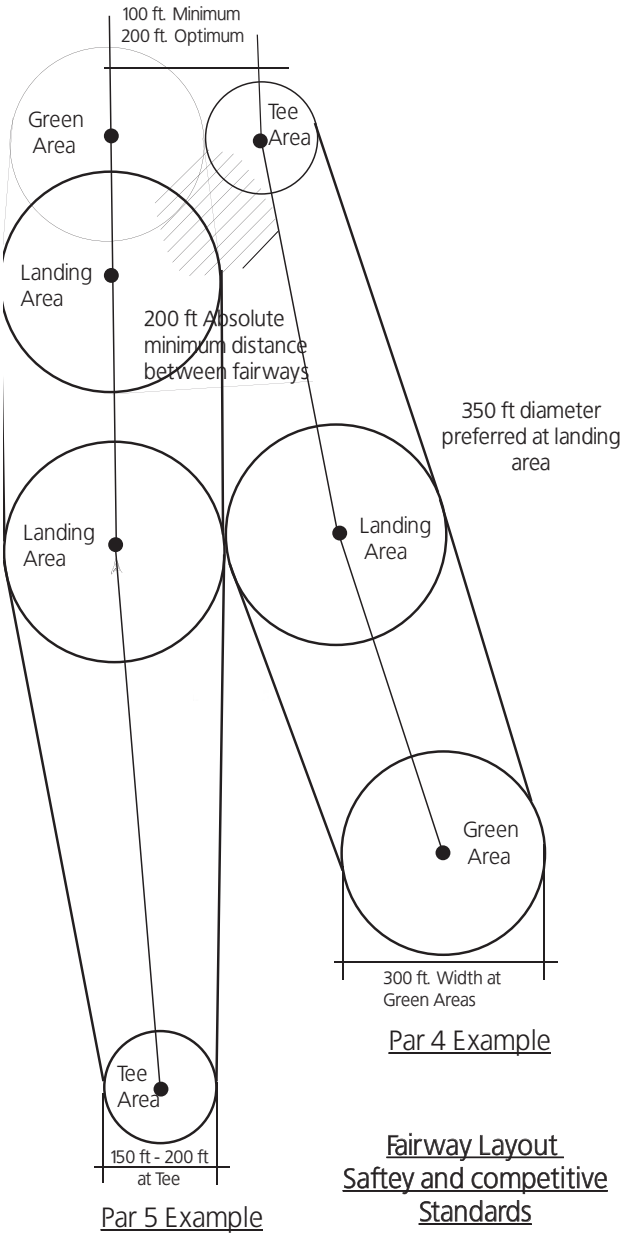

Figure 4.4 - Fairway Layout Safety and Competitive Standards (Adapted from Golf Course Planning and Design Notes 2003)

Figure 4.5 - Playability Analysis Safety Diagram -Existing Routing Plan (Author)

The safety diagram shows the existing routing plan with the safety and competitive standards applied. The areas that are unsafe are designated by the overlapping of the green shade. The darker the green shade indicates an increased probability of getting hit by an errant shot.

The natural design constraints of course vegetation and hydrology are present because of the need to not deplete vegetation and impede the hydrology on the course. The course's woody vegetation is a sensitive area because of the need to protect it from potentially harmful turf application or golf course routing. The hydrology of the site needs to stay intact because the drainage ways discharge either in Lake Olathe or onto agricultural land. Any golf course routing or turf application must not damage the function of the drainage ways. (Figure 4. 10) .

Conclusion

Combining the playability and design constraints analysis presents some design possibilities. The size of the site requires a reduction of the 18-hole golf course to a nine-hole golf course, which increases spacing between holes and allows open space. The open space has two uses a location for errant shots and for native grasses. The location for errant shots is a necessity for the safety and the enjoyment of the golf course. The use of native grasses would attract wildlife and allow the golf course to interact with the surrounding landscape.

Figure 4. 6 -Site Analysis (Author)

Re-Design

The existing 18-hole, par 70, 5,975 yard golf course has three defining characteristics that are reasons for a re-design. The first characteristic is the 18-hole golf course does not fit the existing design and design standards for the given site size. The existing design was built on 105 acres. The typical 18-hole golf course uses a minimum of 150 acres of land to provide proper spacing and length for each hole (Hurdzan 2006). The second is the lengths of the holes do not meet the intended par. One example is hole one is intended to be a par 5, but only meets the length requirements for a par 4. The third characteristic is the safety. The spacing between holes does not allow for safe environment for the golfer.

The remedy is the application of currently practiced design standards and principles. A nine-hole regulation length or a nine-hole executive golf course designs share common goals that aim to improve safety; minimize the new construction of tees, fairways, and greens; and provide an alternative to the existing golf course in Olathe and Johnson County.

Goals

The goals for the nine-hole regulation and nine executive golf course plans are:

1. To allow for an accurate evaluation of synthetic turf that can be applied to other golf courses

2. To reuse existing tees, fairways, and greens for reduction of construction costs and environmental disruption.

3. To provide a safer golf experience to allow for a more enjoyable golf outing.

4. Keep existing entry road, clubhouse, parking lot, and practice range facilities to minimize expenses and environmental disruption.

Regulation nine-hole Proposal

The National Golf Foundation defines a regulation-length golf course as a natural length and par golf course, which includes a variety of par three, par four and par five holes. A nine-hole course must be at least 2,600 yards in length, and a par 33, and an 18-hole regulation course must be at least 5,200 yards in length and at least par 66.

Concept

The regulation nine-hole proposal is a par 36, 3,300 yard golf course which implements present-day golf course design standards to focus on the golfer's safety, while re-using existing tees, greens, and fairways (Figure 4. 11). concentrating on the safety and re-use of existing tees, greens, and fairways gives the opportunity to provide a nine hole golf course that allows a different golf experience.

This golf experience with the regulation nine allows golfer's to play a quick round of golf or play the holes twice. Two elements that do not occur on a standard 18-hole golf course.

Regulation Re-Design Lakeside Hills Golf Course

Hole	1	2	3	4	5	6	7	8	9	IN / OUT
Par	4	3	4	3	5	4	5	4	4	36
Back	408	225	371	140	585	311	483	374	312	3209

Figure 5. 1 -Regulation Nine Hole Proposal (Author)

Safety

The safety improvement of the regulation nine hole redesign reduces the number of holes from 18 to nine. Reducing the number of holes allows for the proper spacing between adjacent holes and target areas. This avoids excessive dangerous areas on the golf course. The regulation nine hole proposal is not flawless, but is an improvement from the existing design (Figure 4. 12).

Figure 5. 2 -Safety Diagram Regulation Nine Hole Proposal (Author)

Re-use of existing tees and greens

The re-use of four existing tee areas and five green areas helps minimize construction costs and minimizes the ecologic effect of the course by reducing earthwork necessary to construct the features (Figure 4. 13).

Regulation Re-Design Lakeside Hills Golf Course

Hole	1	2	3	4	5	6	7	8	9	IN / OUT
Par	4	3	4	3	5	4	5	4	4	36
Back	408	225	371	140	585	311	483	374	312	3209

Figure 5. 3 Re-Use Diagram Regulation Nine Hole Proposal (Author)

Executive nine-hole proposal

A shorter, or more compact, version of a regulation-length and/or par golf course that includes a variety of par three, par four and/or par five holes; a nine-hole course is 2,600 yards in length or less and a par 32 or less. The executive 18-hole course is 5,200 yards in length and a par 65 or less.

Concept

The executive nine-hole proposal is a par 32 and a 2,505-yard golf course that uses present-day design standards for executive golf courses to increase opportunities for open space to provide native grass areas for wildlife, vegetation, and storm water management. The native grass area establishes a natural corridor that connects the two bodies of water on the golf course to Lake

Executive Re-Design Lakeside Hills Golf Course

Hole	1	2	3	4	5	6	7	8	9	IN / OUT
Par	4	4	3	4	3	4	4	3	4	33
Back	361	302	200	370	128	296	397	170	309	2533

Figure 5.4 Executive Nine Hole Proposal (Author)

Olathe. The corridor increases the possibility for interaction between the golfers,the natural environment , and wildlife. The native grass corridor could also function as a wildlife corridor and good stormwater management. (Figure 5. 4).

Safety

The routing of the executive nine hole golf course is safe because the design standards provide an increased use of shorter holes. The short holes increase the amount of space between holes, which keep golfer's away from errant shots.

Executive Re-Design Lakeside Hills Golf Course

Hole	1	2	3	4	5	6	7	8	9	IN / OUT
Par	4	4	3	4	3	4	4	3	4	33
Back	361	302	200	370	128	296	397	170	309	2533

Figure 5. 5 Safety Diagram Executive Nine Hole Proposal (Author)

Existing course re-use

The re-use of four tee areas and four green areas helps with construction costs and minimizes the ecologic effect of the course by reducing the earthwork necessary for constructing the features.

Hole	1	2	3	4	5	6	7	8	9	IN / C
Par	4	4	3	4	3	4	4	3	4	3
Back	361	302	200	370	128	296	397	170	309	25

Figure 5.6 Re-use Diagram Executive Nine Hole Proposal (Author)

Evaluation

The methodology for evaluation of the natural turf, full synthetic turf, and partial synthetic turf scenarios is divided into three categories: Ecologic, Economic, Aesthetic. The categories are derived from the requirements for sustainable development as named by the Sustainable Sites Initiative. The Sustainable Sites Initiative is a set of voluntary national guidelines and performance benchmarks for sustainable land design, construction and maintenance practices (www.sustainablesites.org). Each of guidelines and benchmarks is a credit that could possibly be earned toward achieving landscape sustainability. The Sustainable Sites Initiative credits are used to evaluate the scenarios in the ecologic category. The credits were studied and applied as evaluation criteria, however not all credits were applicable. The applicable credits are labeled with the credit's number from the Sustainable Sites Initiative.

Ecologic

The ecologic category communicates the strength and weaknesses of the turf scenarios in terms of effects on the ecologic systems linked to golf course. Through using credits from the sustainable sites initiative, site design section, the ecologic category can focus on effects on the air, water, and land.

The criteria are:

1. Preservation of plant biomass (SSI Credit 3.6)
2. Preserve water quality from chemical application
3. Preserve water use for irrigation
4. Storm water runoff – permeability
5. Heat island (SSI Credit 3.8)
6. Minimize carbon footprint, the effect on the carbon cycle
7. Minimize amount of air pollutants
8. Use of salvaged and recycled material
9. Possibility of recycling the turf when replaced

1. Preservation of plant biomass (SSI Credit 3.6)

The intent of the preservation of plant biomass credit by the Sustainable Sites Initiative is to maintain the vegetation to enhance the ecosystem through the vegetation on-site (SSI, 2008).

The preservation of plant biomass SSI credit uses the biomass density index to quantify the amounts of vegetation on a site. The Biomass Density Index can be thought of as the density of plant layers covering the ground (SSI 2008). The biomass is a tool for comparing the density of existing, proposed, and after a 10 year growth period for vegetation.

The synthetic turf study uses the criteria, preservation of plant biomass, as a tool to measure the amount vegetation on the site for each turf scenario. The Biomass Density Index (BDI) calculator is used to quantify the represented amounts of vegetation for natural turf, full synthetic turf, and partial synthetic turf scenarios for both the regulation and executive nine-hole proposals (Table 6.1 and 6.2).
The totals from the calculator illustrate the Biomass Density Index for each scenario. The BDI communicates density of vegetation on the site and compares the three scenarios of both the regulation nine-hole and executive nine-hole design proposals. The higher the composite score, the higher the biomass density, which is more ecologically beneficial.

Regulation 9-hole Golf Course

SITE BDI CALCULATION WORKSHEET (FOR USE IN CALCULATING BOTH INITIAL AND PLANNED BDI)

Vegetation cover type within zone*	Percent of total site area			BDI	Percent of total site area x BDI (column A x column B)		
	A			B	C		
	Natural Turf	Synthetic Turf	Partial Synthetic Turf		Natural Turf	Synthetic Turf	Partial Synthetic Turf
Trees with understory	22	22	22	5	110	110	110
Tall grasslands	18	18	18	2	36	36	36
Turfgrass	58	0	45	1	58	0	45
Impervious cover or bare ground not shaded by vegetation or vegetated structures	2	38	2	0	0	0	0
TOTAL (sum of all rows above)	100 percent	*62 Percent	*87 Percent	N/A	204	146	191

*The scenario will not total to 100 percent because synthetic turf application is not a natural vegetation cover type.

Table 6.1 Regulation nine hole Biomass Calculations (Adapted from SSI 2008)

Executive 9-hole Golf Course

SITE BDI CALCULATION WORKSHEET (FOR USE IN CALCULATING BOTH INITIAL AND PLANNED BDI)

Vegetation cover type within zone*	Percent of total site area			BDI	Percent of total site area x BDI (column A x column B)		
	A			B	C		
	Natural Turf	Synthetic Turf	Partial Synthetic Turf		Natural Turf	Synthetic Turf	Partial Synthetic Turf
Trees with understory	22	22	22	5	110	110	110
Tall grasslands	26	26	26	2	52	52	52
Turfgrass	50	0	48	1	50	0	48
Impervious cover or bare ground not shaded by vegetation or vegetated structures	2	38	2	0	0	0	0
TOTAL (sum of all rows above)	100 percent	*86 Percent	*98 Percent	N/A	212	162	210

* The scenario will not total to 100 percent because synthetic turf application is not a natural vegetation cover type.

Table 6.2 Executive nine hole Biomass Calculations (Adapted from SSI 2008)

2. Preserve water quality from chemical application

Evaluate the effect the turf scenarios have on the water quality as an effect of 1.5 ounce per 1,000-square feet application of chemicals (Petrovic 1995). This amount of chemical application can affect the quality of the surface and ground water of a golf course. The chemical application for natural turf, synthetic turf, and partial synthetic is different for both designs.

The regulation design proposal chemical applications are:

Natural turf	*1.2 million ounces*
Full Synthetic Turf	*less than 100 ounces*
Partial Synthetic Turf	*1.1 million ounces*

The executive design proposal chemical applications are:

Natural Turf	*700,000 ounces*
Full Synthetic Turf	*less than 100 ounces*
Partial Synthetic Turf	*541,000 ounces*

(Chart 6.3)

3. Conserve water used for irrigation

Evaluate the gallons per acre-inch water use needed to maintain the turf in each scenario. The conservation of water is important to assess because golf courses use about 1 million gallons of water per week for a golf course in the Midwest (Hurdzan 2006).

The totals for each design proposal is:

Regulation nine hole proposal:

Natural Turf	*1.1 million gallons / week*
Full Synthetic Turf-	*less than 0.5 gallons / week*
Partial Synthetic Turf	*1 million gallons / week*

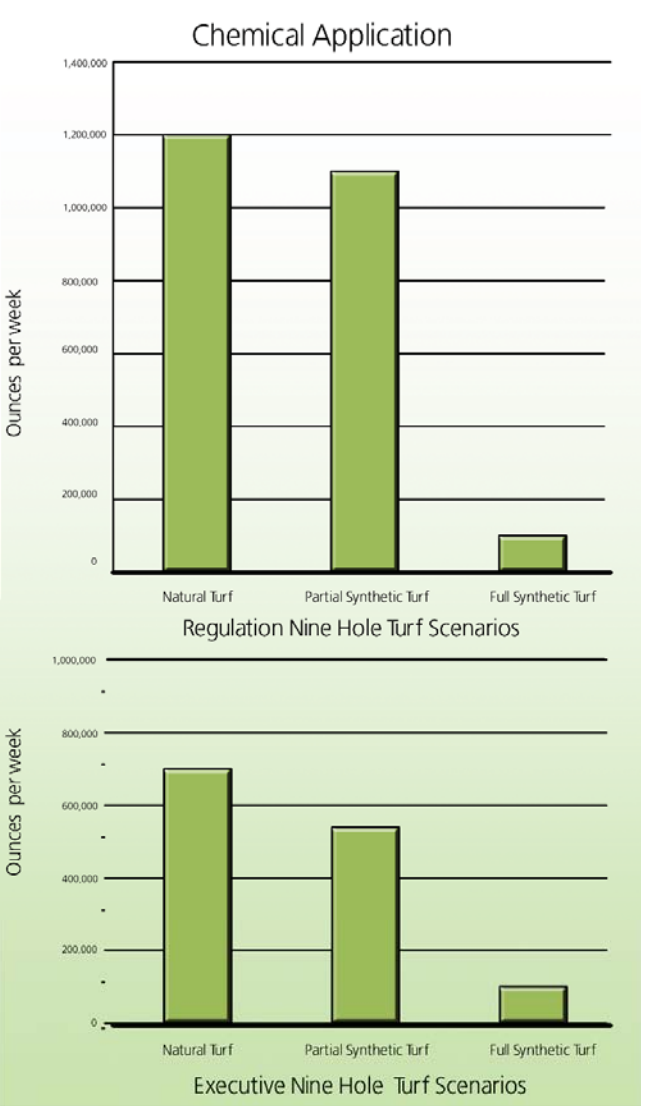

Chart 6.3 Chemical Application (Author)

Executive nine hole proposal:

Natural Turf	*999,000 gallons / week*
Full Synthetic Turf	*less than 0.5 gallons / week*
Partial Synthetic Turf	*918,000 gallons / week*

(Chart 6.4) (See Appendix – A.6 and A.7 for calculations)

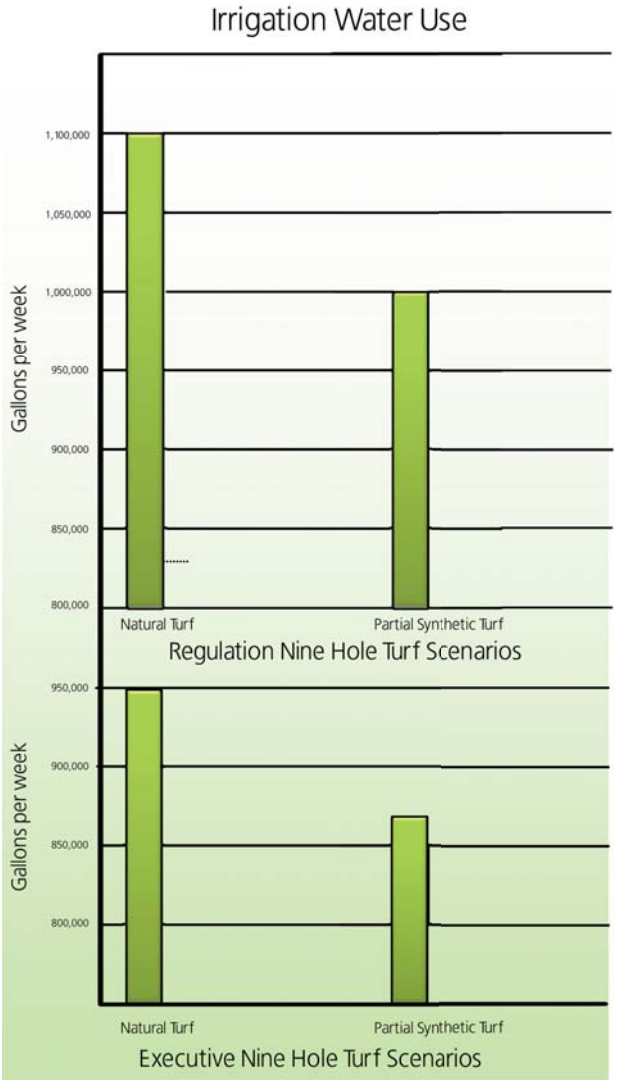

Chart 6.4 Irrigation Water Use (Author)

4. Effect on storm water runoff

The effect on storm water runoff is evaluating the permeability of the soil and synthetic turf. The permeability of the surfaces influences the velocity of the runoff and determines how and where storm water management areas should be located. Synthetic turf permeates at 27 inches / hour and the site soil permeates at rate of 4 inches / hour. The increased permeability removes the water faster, which is a strength for the golf course.

5. Effect on urban heat island (SSI Credit 3.8)

Evaluate the effect the turf scenarios have on the heat island and the effect on humans and wildlife.

This contributes to the understanding that there is an increase of temperature from synthetic turf versus natural turf. This evaluation is not based on any quantitative data, but on informal inquiries from individuals who have participated in activities on synthetic turf. There is also an understanding that the turf is not an unhealthy surface for wildlife, but with an increase in temperature, there could be a change in behavior of wildlife.

6. Minimize carbon footprint, the effect on the carbon cycle

Assess the effects on the carbon cycle.
There is not a number to quantify the exact effect synthetic turf has on the carbon footprint. The assessment is investigating the influence the synthetic turf has on the carbon cycle which is part of the figuring the carbon footprint of a site.

7. Minimize amount of air pollutants

Evaluate the relative amount of air pollutants via maintenance.

A lawn mower emits four times the amount of air pollutants than an average car running for one hour(EPA 2005). This evaluation does not quantify the amounts of pollutants, but takes in account the increase emission rate from a car.

8. Use of salvaged and recycled material (SSI 5.5)

Evaluate the use of recycled material for each turf scenario.

The infill material for synthetic turf uses recycled rubber. The estimated 27,000 tires per 58,000 square feet will cover the average soccer field. Based on the coverage for a soccer field, the tire

use for full synthetic and partial synthetic for each design proposal is:

Regulation nine hole proposal

Full Synthetic	*930,000 tires*
Partial Synthetic	*27,000 tires*

Executive nine-hole proposal

Full Synthetic turf	*756,000 tires*
Partial Synthetic turf	*45,000 tires*

9. Possibility of recycling at the replacement

Evaluate whether the turf scenario is recyclable at replacement.

This evaluation is applying the end-of-life destination for the turf scenarios. Natural turf can be composted, thus is ecologically beneficial. The synthetic turf is typically land filled, but two alternative options have been adopted. One is use in landfills as a layer separation tool. The second is re-sold for residential or commercial use.

The criteria from the ecologic category are attempting to balance out the strengths and weaknesses of the turf scenarios to achieve equal evaluation.

Economic

The intent of this category is to discover which turf scenario is more financially viable through installation, maintenance, replacement and savings from the maintenance. Each criterion is quantified using the turf areas from both design proposals.

Installation

The installation is the cost of material and labor. The installation cost for the two design proposals are:

Regulation nine hole proposal

Natural Turf	*$4. 5 million*
Full Synthetic Turf	*$ 17. 8 million*
Partial Synthetic Turf	*$ 7. 2 million*

(For calculations see appendix A. 9, A10 and A. 11)

Executive nine-hole proposal

Natural Turf	*$ 1. 4 million*
Full Synthetic Turf	*$ 15 million*
Partial Synthetic Turf	*$3. 6 million*

(Chart 6. 6) **(For calculations see appendix A. 12, A13 and A. 14)**

Maintenance

The maintenance costs are calculated using the maintenance costs of 8 cents / square foot for synthetic turf and 18 cents / square foot for natural turf. The maintainable turf for the regulation nine-hole proposal is 1. 9 million square feet and the executive nine-hole proposal is 1. 6 million square feet of maintainable turf.

The annual and 15-year total maintenance cost for the design proposals are:

Regulation nine-hole proposal

Natural Turf	*$344,995 / $ 5. 1 million – 15-year total*
Full Synthetic Turf	*$ 160,000 / 2. 4 million – 15-year total*
Partial Synthetic Turf	*$336,284 / $5 million – 15-year total*

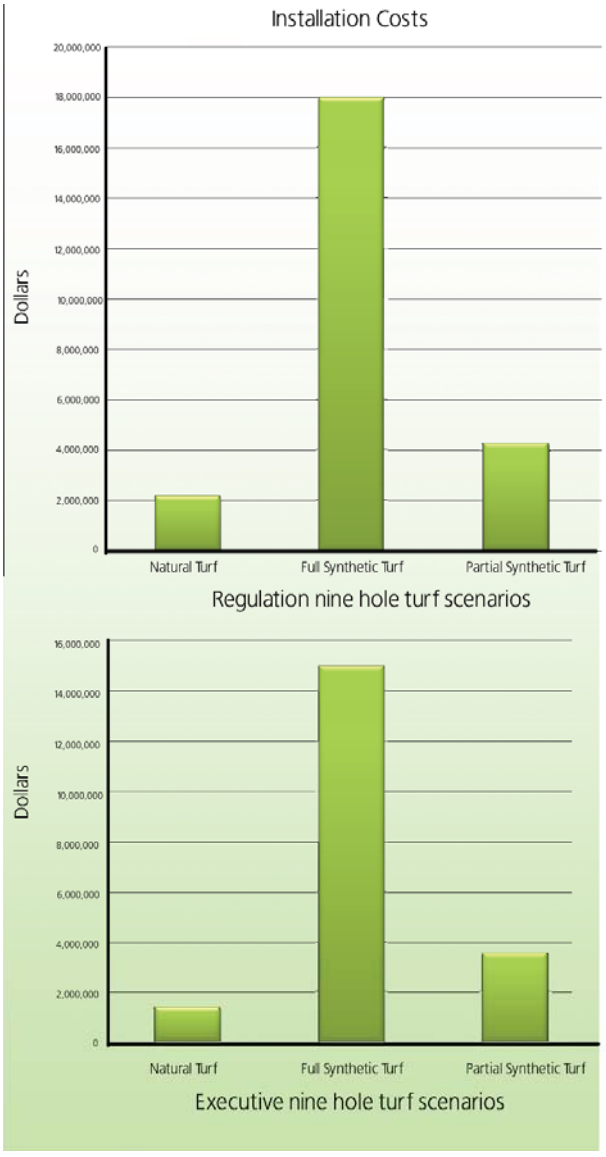

Chart 6.6 Installation Costs (Author)

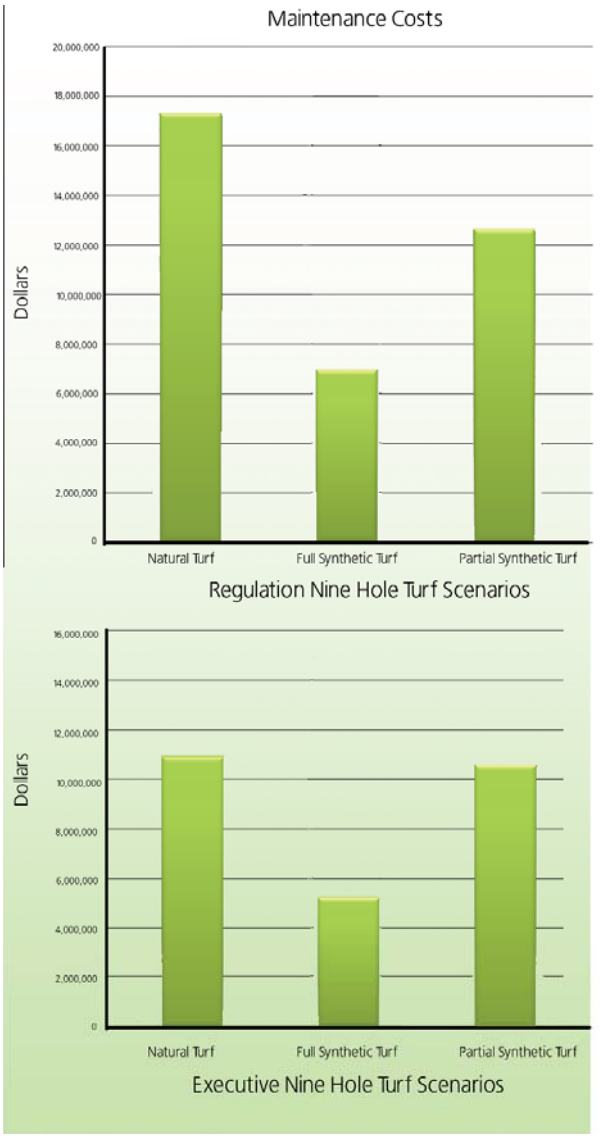

Chart 6.7 Maintenance Costs (Author)

Executive nine-hole proposal

Natural Turf *$290,000 /*
$4.3 Million – 15-year total

Full Synthetic Turf - *$128,000 /*
1.9 million – 15-year total

Partial Synthetic Turf *$216,000 /*
$ 3.2 million– 15-year total

(Chart 6.7)

Replacement

Replacement cost is figured as only 25 percent of the design proposal's total area. This is with the understanding that an entire golf course will not have to be replaced at one time. The replacement cost for the design proposals are:

Regulation nine hole proposal

Natural Turf *$600,000 + labor*

Full Synthetic Turf` $1.2 million + labor

Partial Synthetic Turf *$900,000 + labor*

Executive nine hole proposal

Natural Turf *$350,000 + labor*

Full Synthetic Turf *$1 million + labor*

Partial Synthetic Turf *$750,000 + labor*
(Chart 6.8)

Maintenance Savings

The installation, maintenance, and replacement are significant to the life-cycle economic cost. This study is intended to find maintenance savings from the comparison of synthetic turf to natural turf. The maintenance savings for the design proposals are:

Regulation nine hole proposal

Full Synthetic Turf - *$3.1 million*

Partial Synthetic Turf *$1.4 million*

Executive nine hole proposal

Full Synthetic Turf *$1.7 million*

Partial Synthetic Turf *$100,000*
(Chart 6.9)

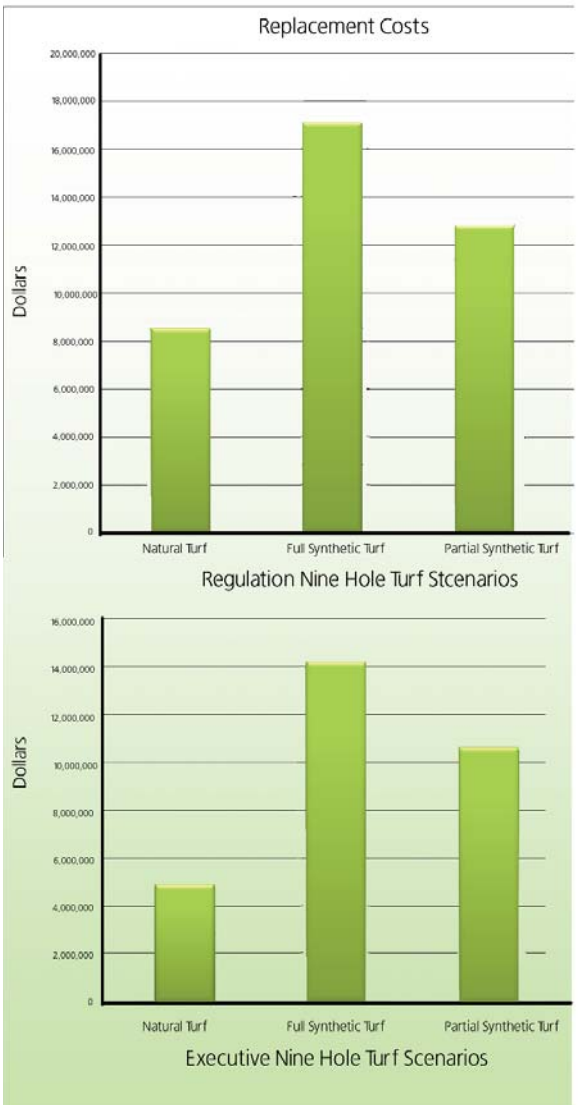

Chart 6.8 Replacement Costs (Author)

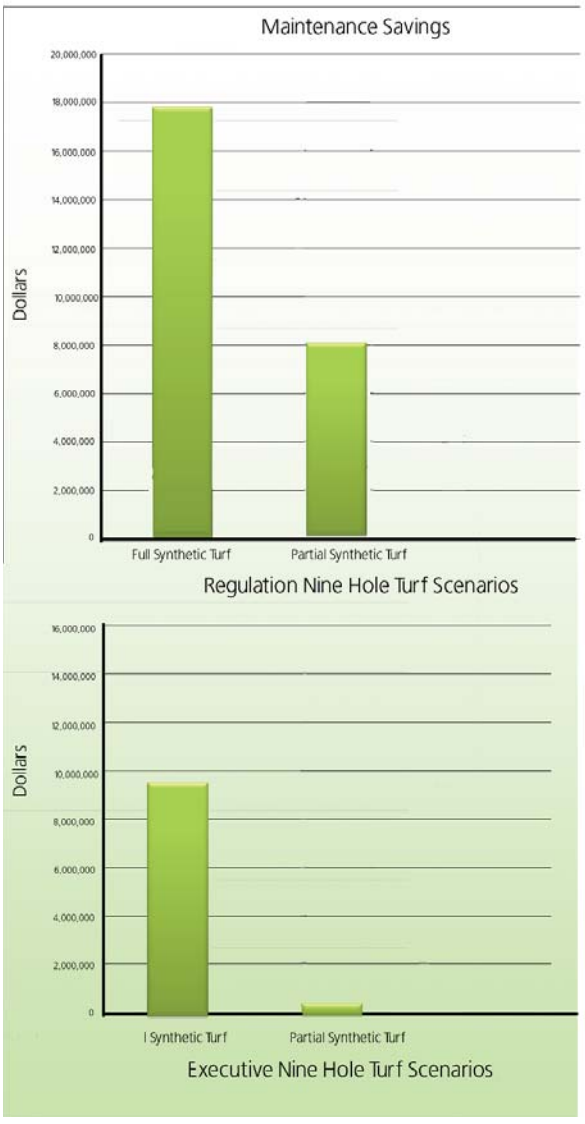

Chart 6.9 Maintenance Savings (Author)

Aesthetic

This category communicates the primary aesthetic or social aspects the turf scenarios have. The evaluation of aesthetics is opinion of the user. The criteria used in this category are elements that effect the opinion of the user.

The criteria are:

1. Vulnerability to damage
2. Influence on heat island – surface temperature
3. Consistency in aesthetics (ability to stay (green)

1. Vulnerability to damage
The vulnerability to damage can be determined based on disease vulnerability for natural turf and the ability for seams to become loose through golf-related activities.

2. Minimize the effects of heat island

Evaluate the effect the heat island has on users based on the turf scenarios.

Relative to the amount of synthetic turf on each scenario the evaluation concedes the temperature increase of synthetic turf. There is not any valid information from a non-bias source that states the average temperature increase.

3. Consistency in aesthetics (ability to stay green)

The most consistently green turf scenario based on the surface area covered by synthetic turf

Completing the evaluation is the scoring of ecologic, economic and aesthetic categories to determine the strengths and weakness of synthetic turf versus the natural turf in a golf course application.

Results

The results for the Next Generation Golf Course: Lakeside Hills Synthetic Turf Study will be presented in two sections: evaluation of the turf scenarios and a conclusion. The evaluation of turf will be structured using the evaluation categories: Ecologic, Economic, and Aesthetic. The conclusion will be structured to show the summary of the results, strengths and weaknesses of synthetic turf, possible future studies, and recommendations.

Turf Scenario Evaluation

The turf scenario evaluation metric was intended to discover the most ecologic, economic, and aesthetic turf scenario for golf courses. Each turf scenario was individually evaluated and analyzed based on the scoring system developed. The discussion that follows is the result of the quantitative scoring system used during the evaluation process.

The scoring is separated in to three rating categories: exceptional, good, and poor. Each rating category has a number assigned, five (5) for exceptional, two (2) for good, and one (1) for poor. These numbers quantify the strengths and weaknesses in each ecologic, economic, and aesthetic category. The numbers are totaled by evaluation category. The highest total is the typology with the least amount of weaknesses.

Ecologic

The result of the ecologic evaluation revealed that full synthetic turf, natural turf and partial synthetic turf provide different ecologic strengths and weaknesses. The ecologic strengths of the full-synthetic turf are lack of negative effects on water quality, water usage, chemical application, and the reduction of air pollutants. The weakness of full-synthetic turf is the effect the turf has on the existing vegetation, heat island, impact on the carbon cycle and the landfilled end of life destination. There are more strengths than weaknesses for the application of the full synthetic turf scenario for golf courses. In contrast, the application of partial synthetic turf and natural turf are not as ecologically beneficial.

The results of the natural turf found that in every category it was the direct opposite of full synthetic turf. The primary weaknesses were amount of irrigation, chemical application, and air pollutants through the mowing process. Strengths attributed to the fact that it is a natural material. The natural turf does not impede any of the vegetation on the course, interrupt the carbon cycle, and is recyclable at the time of replacement.

The partial synthetic turf scenario revealed that according to the ecologic criteria, it did not have any significant strengths or weakness. The strengths of the partial synthetic turf were not revealed in the metric, but there are some underlying strengths. The lack of extremes for or against the evaluation criteria is a strength for the partial synthetic turf scenario. The impact on carbon cycle, vegetation biomass, heat island, and disposal are all criteria that are strengths to a partial synthetic turf application. Ecologically the partial synthetic turf is more beneficial than what the metric illustrates.

The metric evaluated the ecologic strengths and weakness for each turf scenario. The total score for partial synthetic was eighteen (18), natural turf was twenty-five (25), and full synthetic turf was twenty-nine (29). According to the metric, the full synthetic turf scenario provides the most strengths for a golf course ecologically (Table 8. 1).

	Ecologic									Total
Criteria	Preservation of plant bio-mass (SSI)	Preserve Water Quality from chemical application	Preserve Water used for irrigation	Stormwater Management - Permeability of turf	Reduce urban heat island effect (SSI)	Carbon Footprint - impact on carbon cycle	Minimize air pollutants	Use of salvaged and recycled material	Possibility of recycling at the replacement (15 years)	
Full Synthetic Turf	**Poor (1)** - Plant Biomass Index is 129	**Exceptional (5)**- only limitation is the possibility of infill entering drainage ways	**Exceptional (5)** - minimal water usage for heat reduction	**Exceptional (5)** - Permeability at 27 in / hr (Fleishman) into a drainage system	**Poor (1)** - relative heat increase compared to natural turf	**Poor (1)** - affects the carbon cycle because it does not absorb any carbons	**Exceptional (5) -** No mowing	**Exceptional (5)** - 930,000 tires	**Poor (1)** - Land filled	29
Partial Synthetic Turf	**Good (2) -** Plant Biomass Index is 171	**Good (2)**- chemicals used to maintain the fairways are less in quantity and rate of application, but still can seep into ground water.	**Good** (2)- Uses 1 million gallons of water a week	**Good (2) -** Greens and Tees are 6 in / hr and Fairways and rough are 4 in/ hr	**Good (2) -** the largest amounts of turf do not increase in temperature.	**Good (2) -** absorbs some carbon	**Good (2) -** 68% mowed lawns	**Good (2) -** 27, 000 tires	**Good (2) -** Only tees and greens are land filled.	18
Natural Turf	**Exceptional (5)** - Plant bio-mass is 173	**Poor (1)** - chemicals can cause algae blooms in water bodies as a form of water pollution	**Poor (1)** - uses 1.1 millions gallons of water a week	**Poor (1)** - Site average permeability is 4 in/ hr	**Exceptional (5) -** no increase of temperature from turf	**Exceptional (5) -** does not affect the absorption of carbon.	**Poor (1) -** 71% of site uses Lawn mower	**Poor (1) -** no recyclables	**Exceptional (5)** - any traditional turf can be composted	25

Table 8. 1 Ecologic Evaluation for Regulation Nine Hole Proposal (Author)

	Ecological									Total
Criteria	Preservation of plant bio-mass (SSI)	Preserve Water Quality from chemical application	Preserve Water use for irrigation	Stormwater Management - Permeability soil profile	Reduce urban heat island effect (SSI)	impact on carbon cycle	Minimize air pollutants	Use of salvaged and recycled material	Possibility of recycling at disposal (15 years)	
Full Synthetic Turf	**Poor(1)** -Plant Biomass Index is 147	**Exceptional(5)**- only limitation is the possibility of infill entering drainage ways	**Exceptional (5)** - no water used for maintenance	**Exceptional(5)** - Permeability at 27 in / hr (Fleishman) into a drainage system	**Poor (1)** - relative heat increase compared to traditional turf	**Poor (1)** - affects the carbon cycle because it does not absorb any carbons	**Exceptional (5) -** 0% percent site uses lawn mower	**Exceptional (5)** - 756,000 tires	**Poor (1)** - Land filled	29
Partial Synthetic Turf	**Good (2)** -Plant Biomass Index is 182	**Good (2)**- chemicals used to maintain the fairways are less in quantity and rate of application, but still can seep into ground water.	**Good (2)** - Uses 540,000 gallons of water a week	**Good (2)** - Greens and Tees are 6 in / hr and Fairways and rough are 4 in/ hr	**Good (2)** - the largest amounts of turf will not	**Good(2)** - absorbs some carbon	**Good (2) -** 52% of site uses Lawn mower	**Good (2)** - 45,000 tires	**Good (2)** - Only tees and greens are land filled.	18
Natural Turf	**Exceptional (5)** - Plant bio-mass is 184	**Poor (1)** - chemicals can cause algae blooms in water bodies as a form of water pollution	**Poor (1)** - uses 1,. 5 million gallons of water a week	**Poor (1)** - Site average permeability is 4 in/ hr	**Exceptional (5) -** no increase of temperature from turf	**Exceptional (5) -** does not affect the absorption of carbon.	**Poor (1) -** 58% of site uses Lawn mower	**Poor (1)** - 0 recyclables	**Exceptional (5)** - any traditional turf can be composted	25

Table 8. 2 Ecologic Evaluation for Executive Nine Hole Proposal (Author)

Economic

The economic results revealed that through the installation, maintenance, replacement, and savings from maintenance that both the synthetic turf and natural turf are equal and partial synthetic turf is the last option for the economics for a golf course. The strengths of the synthetic turf are maintenance cost and the savings from maintenance costs. Weaknesses are the installation and replacement cost. In contrast, natural turf strengths are the installation and replacement costs and weaknesses are the maintenance cost and no savings from the maintenance. This leaves the partial synthetic turf bearing no significant strengths or weaknesses.

The metric shows that the scores were twelve (12) for both full synthetic turf and natural turf. Partial synthetic turf's score was eight (8). According to the metric, the full synthetic turf and natural turf are equal economically (Table 8.3 and 8.4).
The element that the metric does not clearly illustrate is synthetic turf is strong in the annual costs to the golf course; maintenance cost, which provides savings and the natural turf is strong in the costs that typically only occur once in the life of golf course. The annual costs keep the golf course running and any savings is usually placed right back into other services or funding the maintenance of the golf course to sustain the aesthetics (Hurdzan 2006).

	Economic				Total
Criteria	Installation Dollar amount	Maintenance Percentage of installation cost (Morris 2005 amount per year / 15 year total	Savings in Maintenance compared to Natural Turf	Replacement 25% replacement of total turf area dollar amount	
Full Synthetic Turf	**Poor (1)** - 17.8 million	**Exceptional (5)** $160,000 / 2.4million	**Exceptional (5)**- 2.7 million	**Poor (1)** $1.2 million	12
Partial Synthetic Turf	**Good (2)** - $5.8 Million	**Good (2)** $336,284/ $5 million	**Good (2)** - $100,000 replacement	**Good** (2) $900,000 + labor	8
Natural Turf	**Exceptional (5)**- $4.5 million	**Poor (1)** $344,995million / 5.1 million	**Poor (1)** - 0 savings	**Exceptional (5) -** $600,000	12

Table 8.3 Economic Evaluation for Regulation Nine Hole Proposal (Author)

	Economic				Total
Criteria	Installation Dollar amount	Maintenance Percentage of installation cost (Morris 2005 amount / year - 15 years	Savings in Maintenance	Replacement 25% replacement of total turf area dollar amount	
Full Synthetic Turf	**Poor (1)** - 15 million	**Exceptional (5)** $128,000 - 1.9 million (0.75%)	**Exceptional (5)**- savings of 12.4 million	**Poor (1)** $1 million + labor	12
Partial Synthetic Turf	**Good (2)** - $3.6 million	**Good (2)** $216,000 - 3.2 million (6%)	**Good (2)** -savings of only $1.1 million	**Good (2)**- 750,000 + Labor	8
Natural Turf	**Exceptional (5)** - $7.8 million	**Poor (1)** $290,000- 4.3 Million (16%)	**Poor (1)** -3.3 million total for maintenance	**Exceptional (5) -** $350,000 + labor	12

Table 8.4 Economic Evaluation for Executive Nine Hole Proposal (Author)

Aesthetic

The results show a close relationship between the three turf scenarios and the evaluation criteria, vulnerability to damage, heat island effect, and consistency of the aesthetics. The order of the turf scenarios is partial synthetic turf, full synthetic turf, and the natural turf. There is not a definitive strong scenario that completely outshines the other scenarios.

The scores on the metric are partial synthetic turf nine (9), natural turf eight (8), and full synthetic turf seven (7). This close scoring may not show a definitive strong scenario, but conclusions can be drawn from the evaluation of this category. The turf scenarios are all prone to damage. The partial synthetic turf and full synthetic turf are less vulnerable because of the limited effect that natural environment has on it, but the damage done to natural turf from golfers is repairable by re-growth and does not need a specialist to come out to repair it.

The natural turf also benefits the comfort of the golfer by negating the heat island effect of full synthetic turf and partial synthetic turf. The area that natural turf does not provide a benefit is the consistency of the green turf. The full synthetic turf will always look like a professional golf course, and the natural turf will always have the possibility to become diseased, dormant, or unsightly.

The aesthetics are the primary money-making entity for a golf course. The better condition a course is in, the more play it gets, and the more money the golf course can bring in. Synthetic turf provides a consistent, plush look and a consistent playing surface that is expected from golf courses.

Criteria	Aesthetics (Social)			Total	Evaluation total
	Vulnerability to damage (i.e. seams and disease	Heat Island - Surface temperature	Consistency Ability to stay Green		
Full Synthetic Turf	**Good (2)** - the amount of turf applied increases chances for damage.	**Poor (1)** - turf creates an increase of temperature.	**Exceptional (5)** - is not impacted by UV or drought conditions that cause Poor quality	8	49
Partial Synthetic Turf	**Exceptional (5)** - Greens will take less impact from golf clubs and divots than any other place on the course.	**Good (2)** - with the majority of the areas being traditional turf the increase of temperature is not drastic	**Good (2)** - the key parts of the golf course are consistently green, but the larger amounts of turf are natural and susceptible to Poor qualities	9	35
Natural Turf	**Poor (1)** - disease is a high possibility	**Exceptional (5)** - there is not any change in temperature of the golf course	**Poor (1)** - all turf is susceptible to Poor aesthetic qualities	7	44

Table 8.5 Aesthetic Evaluation for Regulation Nine Hole Proposal (Author)

Criteria	Aesthetics (Social)			Total	Evaluation total
	Vulnerability to damage (i.e. seams and disease)	Heat Island - Surface temperature	Consistency Ability to stay Green		
Full Synthetic Turf	**Good** (2)- the amount of turf applied increases chances for damage.	**Poor (1)** - turf creates an increase of temperature	**Exceptional (5)** - is not impacted by UV or drought conditions that cause Poor quality	8	49
Partial Synthetic Turf	**Exceptional (5)** - Greens will take less impact from golf clubs than any other place on the course.	**Good (2)** - with the majority of the areas being traditional turf the increase of temperature is not drastic	**Good(2)** - the key parts of the golf course are consistently green, but the larger amounts of turf are natural and susceptible to Poor qualities	9	35
Natural Turf	**Poor (1)** - 58% of site is Susceptible to disease is a high possibility	**Exceptional (5)** - there is not any change in temperature of the golf course	**Poor (1)** - all turf is susceptible to Poor aesthetic qualities	7	44

Table 8.6 Aesthetic Evaluation for Executive Nine Hole Proposal (Author)

Summary of Results

This study examined the effectiveness of three turf scenarios to evaluate the application of synthetic turf as a viable option for golf courses. The natural, full synthetic and partial synthetic turf scenarios were evaluated over the 15 year life expectancy of synthetic turf using the key stages, installation, maintenance, and replacement. By evaluating the turf scenarios effect on the ecologic, economic, and aesthetics of a golf course, the study could illustrate the strongest turf scenario between two design proposals.

The goal of using two design proposals was to show a comparison between a regulation nine-hole golf course and a executive nine-hole golf course layout ecologically, economically, and aesthetically. The regulation nine-hole proposal was the standard and the executive nine-hole proposal emphasized the open space and added a native grass corridor.

The metric was structured to show a difference ecologically and economically between the two designs, but the threshold that was set for the metric did not show any differences. The same scores were totaled in each category for both designs. The conclusion is the executive proposal was not different enough(Table 8.7 and 8.8) . The difference in the turf area was not enough of a catalyst to influence the ecological or economical categories of the metric for synthetic turf application (Figure 8.1. , 8.2) (Chart 8.9) .

The results of the metric indicate that full synthetic turf is the strongest of the three turf scenarios, but might not be the most realistic solution.

	Ecologic Total	Economic Total	Aesthetic Total	Evaluation total
Full Synthetic Turf	29	12	8	49
Partial Synthetic Turf	18	8	9	35
Natural Turf	25	12	7	44

Table 8.7 Metric Results Regulation Nine Hole Proposal (Author)

	Ecologic Total	Economic Total	Aesthetic Total	Evaluation total
Full Synthetic Turf	29	12	8	49
Partial Synthetic Turf	18	8	9	35
Natural Turf	25	12	7	44

Table 8.8 Metric Results Executive Nine Hole Proposal (Author)

Figure 8. 1
Regulation nine hole proposal site areas Diagram. (Author)

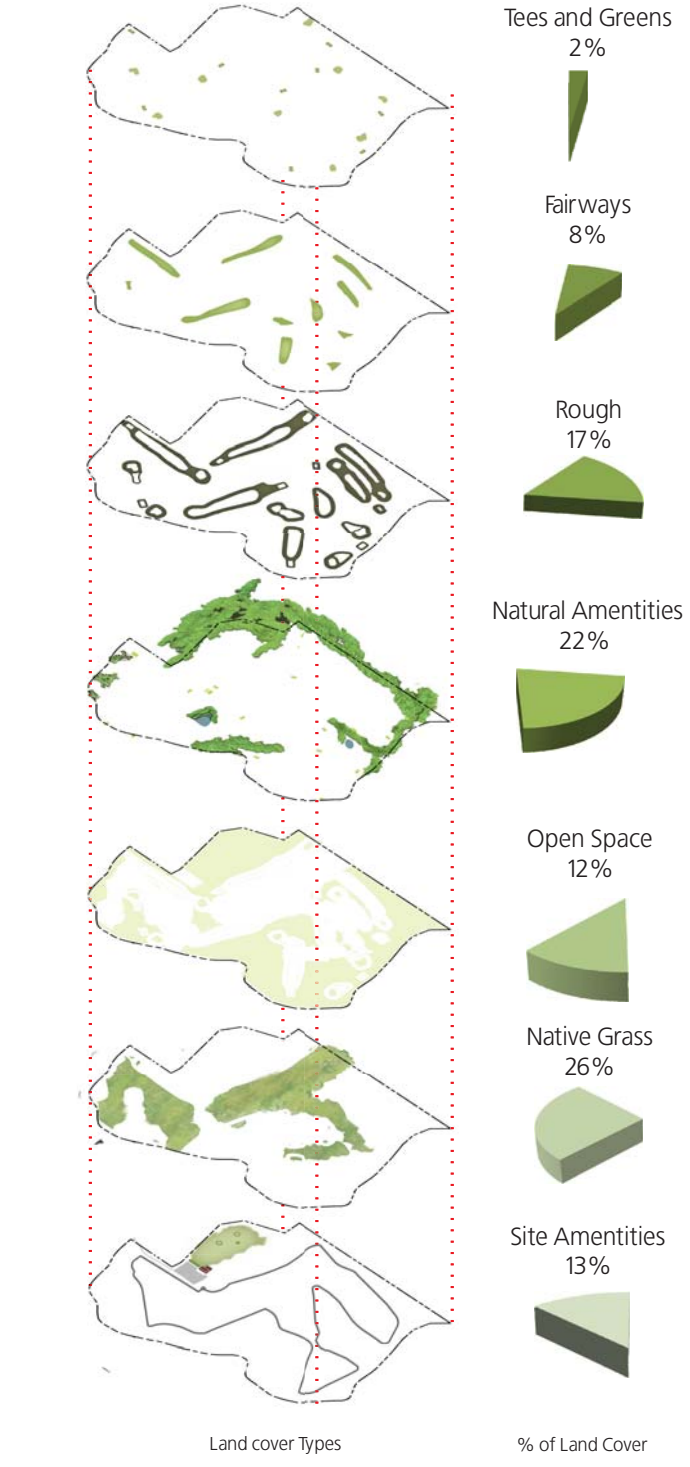

Figure 8.2 Executive nine hole proposal site Areas Diagram. (Author)

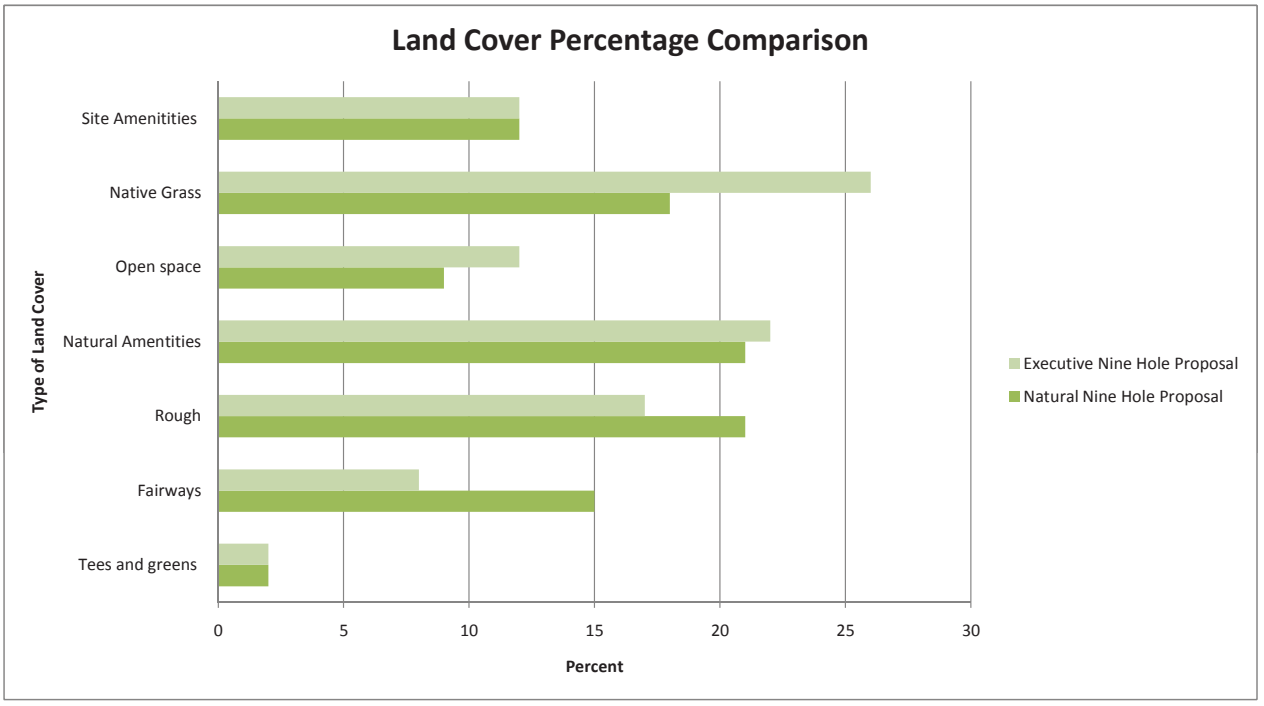

Chart 8.9 Land Cover Percentage Comparison Chart (Author)

Strengths

There are two strengths found in the study of synthetic turf for golf courses. The first strength is the ecologic benefit to the environment. The use of synthetic turf minimizes maintenance procedures of the typical golf course by minimizing water use, air pollutants, and chemical application, which have a negative effect on water quality. Synthetic turf also reuses about 27,000 used tires that would go to the landfill otherwise. The second strength of synthetic turf use for golf courses is the aesthetic benefits. The consistent look of the turf provides a great-looking golf course.

Weaknesses

There are two weaknesses of synthetic turf as applied to golf courses. The primary weakness of synthetic turf on a golf course is the amount of turf, which is linked to the cost. The costs of installing synthetic turf at $9 per square foot over 5.7 million square feet can increase the initial costs for establishing a golf course. The secondary weakness is the ongoing debate because of the public health, safety, and welfare. These debates are the reason that synthetic turf has had issues gaining acceptance by the public and golfers (Claudia 2008).

Future studies

Acceptance of full synthetic turf is going to need more than this study. This study has identified areas that need further in-depth studies to make believers out of golf superintendants, golfers, and the public. The future studies should focus on the aesthetics and social issues. Three studies could consist of how the turf wears from golf, the probability of seam separation, and how synthetic turf structure affects the golf club. These studies could help further the acceptance of synthetic turf on golf courses.

Conclusion

Synthetic turf is an evolving technology that is benefiting the ecologic, economic, and aesthetics of sports fields. The necessity to spread these benefits is growing. As observed in the study, synthetic turf is a viable option for golf courses. The study provides a base of information that would show superintendents, golfers, and the public the effect of synthetic turf when applied to golf courses. The effect did not impede the ecologic systems, saved money from the standard maintenance procedures, and maintained the aesthetic standards of the golf course.

Glossary

Biomass:	the total mass of living matter in a given unit area
Crumb Rubber:	recycled rubber infill from tires or tennis shoes
Ecologic:	characterized by the interdependence of living organisms in an environment
Executive Golf Course:	A shorter or compact version of the regulation length and par golf course that includes a variety of par three, par four and/or par five holes; a 9-hole course is 2,600 yards in length or less and a par 32 or less, and an 18-hole course is 5,200 yards in length or less and par 65 or less.
Full Synthetic turf:	The application of synthetic turf to the playable areas of the golf course (i.e. tees, greens, fairways, rough, open space)
Heat Island:	An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas
Infill:	Loosely dispersed materials that are added to the synthetic turf system, typically sand, rubber, other suitable material, or a combination thereof
Natural Turf:	Contains all natural turf grass on the playable areas of the golf course (I,e, tees, greens, fairways, rough, and open space)
Par:	the standard number of strokes set for each hole on a golf course, or for the entire course; "a par-5 hole"; "par for this course is 72"
Partial Synthetic Turf:	The application of synthetic turf on only tees and greens
Regulation Golf Course (R):	A traditional length and par golf course that includes a variety of par three, par four and par five holes; a 9-hole course must be at least 2,600 yards in length and at least par 33, and an 18-hole course must be at least 5,200 yards in length and at least par 66.
Runoff:	overflow: the occurrence of surplus liquid (as water) exceeding the limit or capacity
Seams:	location where two sections of turf join and are either glued or sewn
Sustainable Sites Initiative:	voluntary national guidelines and performance benchmarks for sustainable land design, construction and maintenance practices (www.sustainablesites.org).
Synthetic Turf:	Synthetic grass-like surface pile
Water Permeability:	The rate at which water flows through a surface or system.

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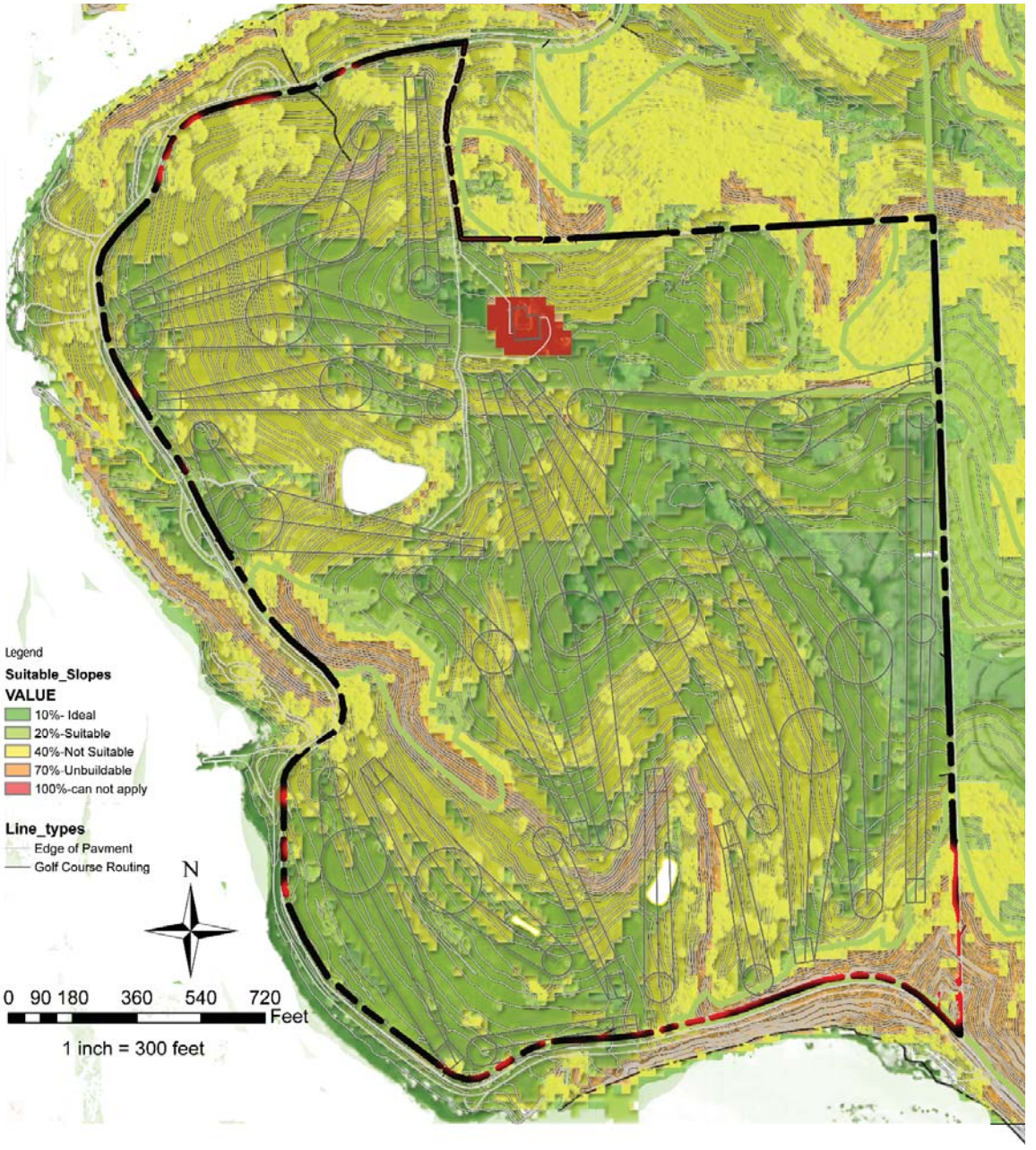
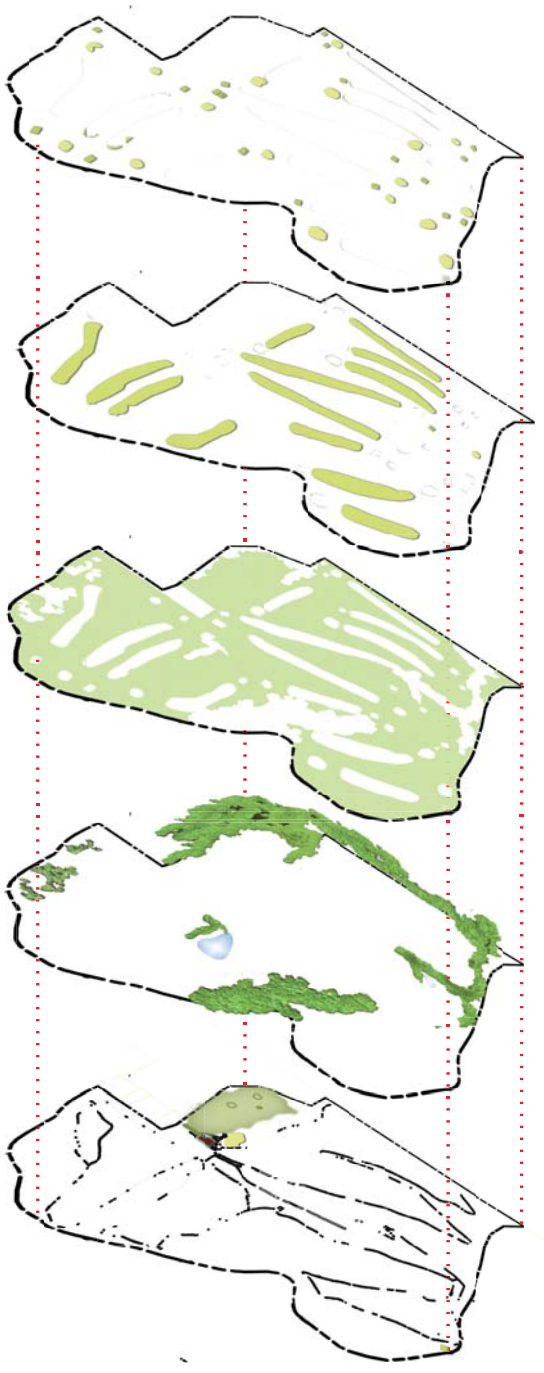
Appendix - A



A. 1 Slope Inventory

The slope inventory illustrates the location of the ideal and unsuitable slopes. The ten percent slopes are ideal because as the slopes increase in grade so does the difficulty of synthetic turf application and routing of the golf course.



Existing 18-hole Plan

Types of Land Cover

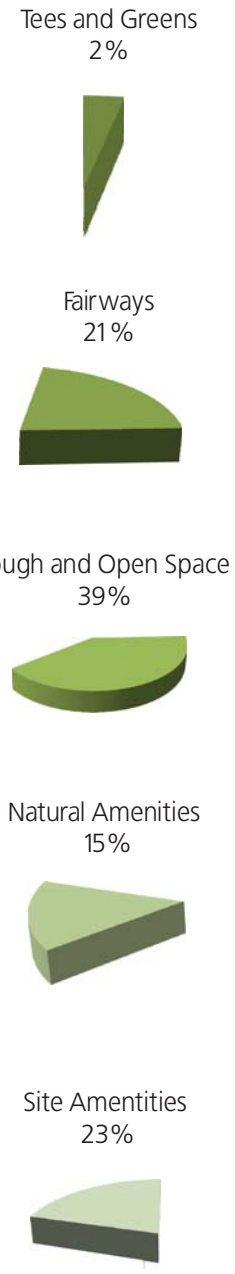
Tees and Greens
2%

Fairways
21%

Rough and Open Space
39%

Natural Amenities
15%

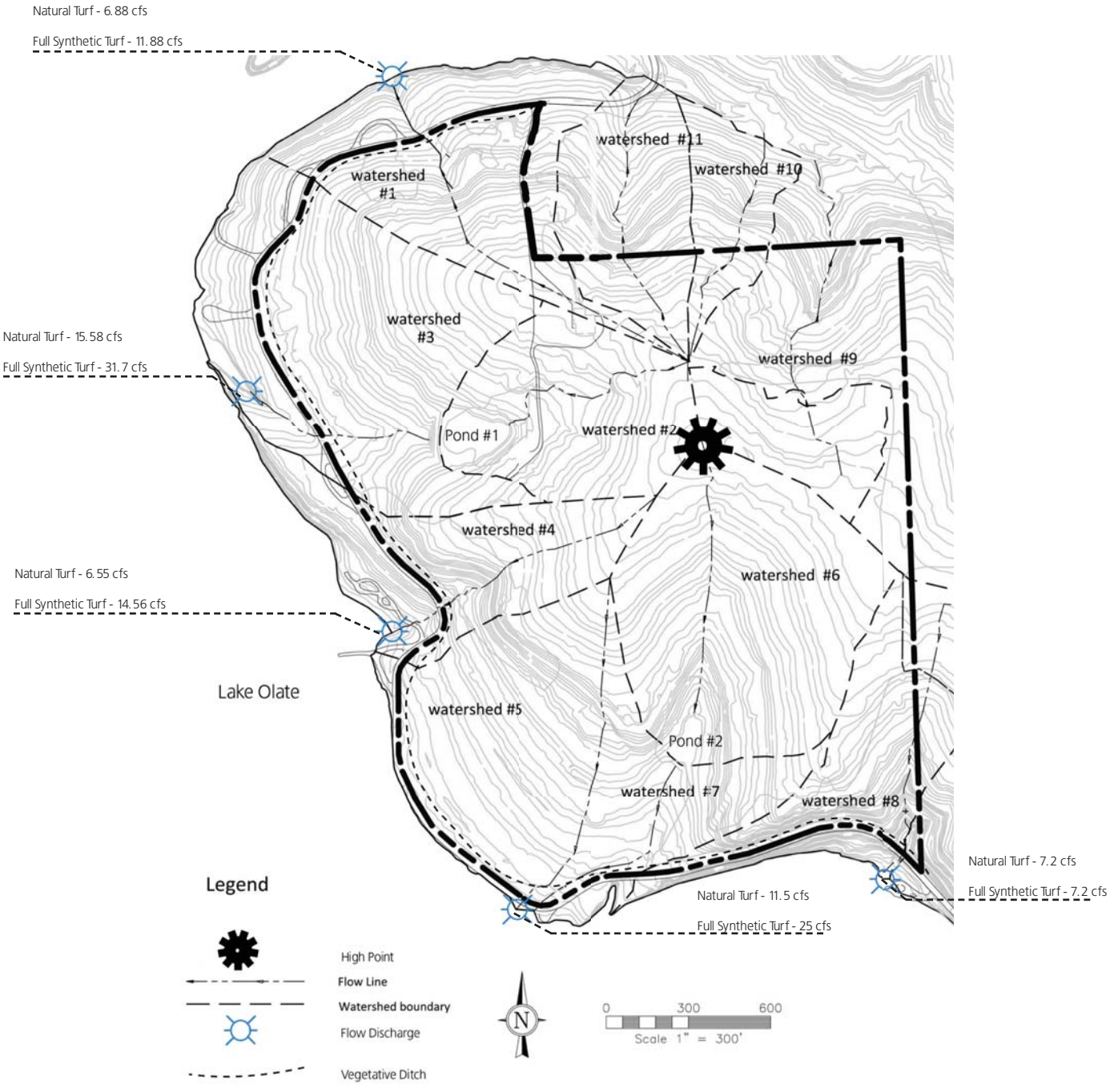
Site Amentities
23%



% of Land Cover

A.2 Vegetation Inventory

Vegetation inventory diagram illustrates the relationships between each vegetation type.



A.3 Watershed Diagram and Calculation charts

The watershed diagram shows the 11 watersheds and their discharge points. Accompanying the watershed diagram is the watershed calculations for the natural turf and full synthetic turf applications. The total cubic feet per second is calculated for each watershed on the site.

Watershed Computations - Traditional Turf						
Watershed	Area (Acres)	Overland Flow Time	Ditch Flow Time	Time of Concentration	Runoff Quantity (cfs)	
1	15.5	25 minutes	0.18 minutes	25.18 minutes	6.33	
2	11.5	23 minutes	0 minutes	23 minutes	9.1	
3	22.5	21 minutes	0.15 minutes	21.15 minutes	15.58	
4	11.6	25 minutes	0.89 minutes	25.89 minutes	6.55	
5	0.08	25 minutes	0 minutes	25 minutes	11.55	
6	20.1	25 minutes	0 minutes	25 minutes	13.2	
7	6.5	25 minutes	0.98 minutes	25.98 minutes	4.2	
8	13.2	22 minutes	0.65 minutes	22.65 minutes	7.2	
9	15.6	18.5 minutes	1.35 minutes	19.85 minutes	10.17	
10	4.8	24 minutes	0 minutes	24 minutes	2.2	
11	8.8	22 minutes	0.04 minutes	22.04 minutes	4.4	
Totals					90.48	

Watershed Computations -Synthetic Turf						
Watershed	Area (Acres)	Overland Flow Time	Ditch Flow Time	Time of Concentration	Runoff Quantity (cfs)	
1	15.5	21 minutes	0.18 minutes	21.18 minutes	11.88	
2	11.5	20 minutes	0 minutes	20 minutes	14.79	
3	22.5	17.10 minutes	0.15 minutes	17.25 minutes	31.7	
4	11.6	17.5 minutes	0.89 minutes	18.39 minutes	14.56	
5	0.08	20.5 minutes	0 minutes	20.5 minutes	25	
6	20.1	20 minutes	0 minutes	20 minutes	29.1	
7	6.5	18.5 minutes	0.98 minutes	23.98 minutes	10.24	
8	13.2	22 minutes	0.65 minutes	21.15 minutes	7.2	
9	15.6	16 minutes	1.74 minutes	17.74 minutes	15.3	
10	4.8	19.25 minutes	0 minutes	19.25 minutes	3.3	
11	8.8	22.25 minutes	0.04 minutes	22.29 minutes	5.25	
Totals					168.32	

A. 4 Watershed Calculation charts

A. 5 Soil Inventory (Author)

The soil inventory diagram illustrates the location of the most permeable soil. The permeability of the soil is important to drainage of both a natural turf and synthetic turf. The permeability rates are in the table on page 65.

SoilComplex	Slope	Soil Name (%)	Limiting Factors for Analysis			Acres of Site	Percent of Site	Inches	Permeability
			Depth to Bedrock	Depth to Water Table	Slope				
Chillicothe Silt Loam	3 to 25 %								
		Chillicothe (85%)				20	18.00%	2 to 6	Well drained
Oska-Martin	4 to 8 %					30	28%	2 to 6	Well drained
		Oska (50%)	20 to 39 inches						
		Martin (30%)		22 to 26 inches					
Martin Silty Loam	3 to 7 %					10	10%	0.6 to 2	Poorly Drained
		Martin (90%)		22 to 26 inches					
Grundy Silt Loam	1 to 3 %					4	4%		
		Grundy (100%)	12 to 17 inches					0.2 to 6	Somewhat Poorly drained
Sogn-vinland	3 to 25%					37	34%	6 to 20	Somewhat excessively drained
		Sogn (55%)	4 to 20 inches		5 to 20%				Somewhat excessively drained
		Vinland (30%)	10 to 20 inches		5 to 20%				
Vinland-rock	15 to 45%					8	7%	6 to 20	Somewhat excessively drained
		Vinland (60%)	10 to 20 inches		20 to 30 %				

A.6 Soil Suitability (Author)

Natural Turf

Regulation - 9

Fairways and Rough	
38	Acres of fairway and rough
X 1	inch in a week
38	acre-inches per week
X 27,000	gallons per acre-inch
1,026,000	**total gallons of water per week**

Greens and Tees (Including Collars and Banks)	
2	Acres of tees and greens
X 1.5	inch in a week
3	acre-inches per week
X 27,000	gallons per acre-inch
81,000	**total gallons of water per week**

Fairways and Rough	**1,026,000**
Greens and Tees (Including Collars and Banks)	**81,000**
Total	**1,107,000**

Executive - 9

Fairways and Rough	
34	Acres of fairway and rough
X 1	inch in a week
34	acre-inches per week
X 27,000	gallons per acre-inch
918,000	**total gallons of water per week**

Greens and Tees (Including Collars and Banks)	
2	Acres of tees and greens
X 1.5	inch in a week
3	acre-inches per week
X 27,000	gallons per acre-inch
81,000	**total gallons of water per week**

Fairways and Rough	**918,000**
Greens and Tees (Including Collars and Banks)	**81,000**
Total	**999,000**

(Hurdzan 2008)

A.7 Irrigation Water Use Calculations Natural Turf (Author)

Partial Synthetic Turf

Regulation - 9

Fairways and Rough	
38	Acres of fairway and rough
X 1	inch in a week
38	acre-inches per week
X 27,000	gallons per acre-inch
1,026,000	**total gallons of water per week**

Greens and Tees (Including Collars and Banks)	
0	Acres of tees and greens
X 1.5	inch in a week
0	acre-inches per week
X 27,000	gallons per acre-inch
-	**total gallons of water per week**

Fairways and Rough	**1,026,000**
Greens and Tees (Including Collars and Banks)	**-**
Total	**1,026,000**

Executive - 9

Fairways and Rough	
34	Acres of fairway and rough
X 1	inch in a week
34	acre-inches per week
X 27,000	gallons per acre-inch
918,000	**total gallons of water per week**

Greens and Tees (Including Collars and Banks)	
0	Acres of tees and greens
X 1.5	inch in a week
0	acre-inches per week
X 27,000	gallons per acre-inch
-	**total gallons of water per week**

Fairways and Rough	**918,000**
Greens and Tees (Including Collars and Banks)	**-**
Total	**918,000**

(Hurdzan 2008)

A.8 Irrigation Water Use Calculations Partial Synthetic Turf (Author)

Natural Turf Cost			
Installed cost per Squre foot			Totals
$ 3.88	836,770		3,246,668
$ 4.35	291,171.95		1,266,598
		Total	$ 4,513,266

A.9 Installed Regulation Nine Hole Calculations Natural Turf (Author)

Full Synthetic Turf Cost		
Turf installed		
Dollars / sq. ft.(Fleishman 2009)		
$9.00	$ 628,182	
$9.00	$ 52,875	
$9.00	$ 6,849,873	
$9.00	$ 8,115,075	
$9.00	$ 1,796,922	
Total	17,442,927	Synthetic Turf Installed

A.10 Installed Regulation Nine Hole Calculations Full Synthetic Turf (Author)

Partial Synthetic Turf Cost			
Syntheitc Turf			
Dollars per Square Foot			
$	9.00	$ 227,196	
$	9.00	$ 628,182	
$	9.00	$ 52,875	
Natual Turf			
Dollars per Square Foot			
		$ 2,855,109.64	
$	3.88		
		$ 3,498,499.00	
		$ 7,261,861.64	Installed

A. 11 Installed Regulation Nine Hole Calculations Partial Synthetic Turf (Author)

Natural Turf Cost			
Dollars per square foot		Square Feet	totals
$ 3.88	sq ft	1,583,927	$ 6,145,636.76
$ 4.35	/ sq ft	398,066.76	$ 1,731,590.41
		Total Installation	$ 7,877,227

A. 12 Installed Executive Nine Hole Calculations Natural Turf (Author)

Full synthetic Turf Cost			
Turf installed			
Dollars / sq. ft. (Fleishman 2009)			
$9.00	$	629,856	
$9.00	$	16,875	
$9.00	$	3,480,921	
$9.00	$	7,372,881	
$ 9.00	$	3,529,656	
Total	$	15,030,189	Synthetic Turf

A. 13 Installed Executive Nine Hole Calculations Full Synthetic Turf (Author)

Partial Synthetic Turf Cost			
Turf installed			
Synthetic Turf Dollars per square foot			Totals
$ 9.00	/ sq. ft	$	226,017.00
$ 9.00	/ sq. ft	$	629,856.00
Natural Turf Dollars per square foot			Totals
		$	1,403,225.28
$ 3.88	/ sq. yd.	$	2,823,476.00
		$	737,305.92
	Total Installed	$	5,819,880.20

A. 14 Installed Executive Nine Hole Calculations Partial Synthetic Turf (Author)