AN ANALYSIS OF BUNKER DESIGN AND CONSTRUCTION'S IMPACT ON GOLF COURSE MANAGEMENT

by

DARYN M. SOLDAN

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Approved by:

Major Professor
William P. Winslow, III, FASLA, RLA

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Abstract

Sand bunkers serve multiple roles as components in the game of golf and golf course design. Bunkers began on early Scottish linksland courses as natural areas of exposed sand. However, as golf has grown since those early beginnings centuries ago, bunkers have become designed, constructed and maintained elements of the course. Significant resources are now used to build and maintain bunkers, in some cases more than are used on greens. As economic factors cause those in the golf business to search for opportunities to be more efficient, bunker maintenance and management plays a key role. This study identifies and analyzes the factors that are most important to bunker design, maintenance and management. It also examines the bunker design – management relationship and the impacts that bunker design decisions have on golf course management.

A survey questionnaire targeted toward golf course designers and golf course superintendents was used to obtain opinions and statistical data pertaining to the study. A total of 109 completed surveys were returned. Survey responses were used to determine:

1. The importance of bunkers
2. Bunkers' roles and characteristics
3. The most important factors related to bunker design and maintenance
4. The reasoning behind undertaking bunker modification projects
5. The degree of involvement among parties involved in bunker design and construction.

Additional analysis was undertaken to determine potentially important differences or disconnects between the responses of the two survey groups – golf course architects and superintendents.

Survey results and analysis indicate that the primary roles of bunkers are intended for player strategy and course aesthetics. The most important factors in bunker design and construction are their; location, visual appearance, drainage and structural quality, all of which directly impact a bunker's overall maintainability. The results of the study and literature review show that the bunker design – management relationship appears to play

a significant role in the playability and continued quality of bunkers over the long term. Issues that arise related to bunker maintenance and management can often be traced back to less than thoughtful decisions or actions made during design and construction.

Conclusions are also presented regarding limitations of the study and potential areas for future related research. Additional exploration regarding the specifics of bunker design, construction and maintenance, as well as the associated resource expenditures, would be of relevance to professionals practicing in golf course architecture and maintenance. Future research also might focus on golf course components beyond bunkers using methodology similar to that set forth in this study.

Table of Contents

List of Figures

List of Tables

Acknowledgments

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The professionals in the golf industry that provided me with advice, information and insight must also be thanked. Without their involvement this study would not have been possible. Specifically I would like to thank David Gourlay and Forrest Richardson for their contributions to my knowledge of golf course architecture, maintenance and management.

Finally, I would like to thank my parents for their unwavering support of my academic endeavors. As educators they have always instilled in me the importance of curiosity and scholarly activity. Additionally, they have always been very understanding, through good times and bad. Their encouragement and support has meant more to me than I could ever hope to express.

Chapter 1 – Introduction

This thesis describes a study which analyzes the impacts of bunker design and construction on golf course management. The study seeks to identify the factors which influence bunker design and maintenance, and the resulting impact on golf course management. The study also explores the relationship between the parties involved in bunker design, maintenance and management.

The Design – Management Relationship

Professionals in all design fields, whether they are architects, engineers, product designers or planners, must design in a way that facilitates the creation, maintenance and long-term sustainability of their designed elements. The relationship between designers and those who are tasked with maintaining and managing their creations can be a contentious one. Often designers are innovative, progressive and sometimes revolutionary. The same creativity that allows great designers to find solutions to problems that had not been previously considered or developed can cause significant difficulty for construction, maintenance and management professionals. These professionals must make a designer's solutions work from a pragmatic standpoint. No design is bound for greatness, much less acceptance, if it cannot serve its function on an everyday basis when put in practice.

Within the context of the design and management of golf courses, the relationship has taken on new importance with the current declining economic conditions and the emphasis on sustainability. Golf course managers are trying to do more with less, meaning the resources dedicated to maintenance of all golf course components are under close scrutiny. Many of these components may have been designed and built without the foresight necessary to account for their sustainability in these changing times. Bunkers have been one of the golf course components receiving the most attention from managers as a result of golfer expectations and their resulting labor intensive maintenance requirements. Opportunities exist for parties on both sides of the design – management relationship to improve the way bunkers are designed, built and maintained with regards to lowering continuing costs while maintaining a high standard of play.

The Importance and Significance of Bunkers

With current economic dynamics slowing the growth in golf rounds played while at the same time increasing operations costs for golf courses, management must find ways to reduce costs while still providing a desired product. Many existing courses have faced serious financial issues, bankruptcy or closure. The past several years have also seen a significant decrease in the number of new golf courses opening in the United States. Economics and over-building are likely the two most influential factors in this trend. The overall extravagance seen during the golf boom of the past two decades has slowly been replaced by a very reserved outlook. Through all of this difficulty, necessary steps must be taken just to keep the doors open at many golf course facilities. Removal and modification of bunkers has been a popular trend in lowering maintenance costs. On new golf courses design considerations should be given to the impact that bunkers will have on the long-term maintenance practices and continuing maintenance costs over the long term.

Bunkers are a golf course component worth studying due to their historic roles within the game of golf, their frequent usage as key elements of design expression by golf course architects, and the increasing attention they are receiving from golf course management personnel as a result of the financial implications of their maintenance. Bunkers are synonymous with golf courses to the point that it is very rare to see a new golf course built that does not showcase bunkers as a prominent design feature. Over time golfer's expectations of the strategy introduced by bunkers, bunker conditioning, and bunker aesthetics have risen. Today many golf courses expend the same resources on the maintenance of bunkers as they do on greens (Moore, 2007). This is an astounding fact when one considers the fact that bunkers are defined as hazards.

Study Components

Information for this study was obtained from two major compilations of source – 1) the writings and observations of professionals practicing golf course architecture, as well as those charged with construction, maintenance and management of golf courses – and 2) the responses of golf course architects and superintendents to the survey that was developed and administered for this study.

Written resources for this study were gathered from a variety of areas. The review of published works of golf course architects and architectural historians were valuable in establishing the historical context for the study and the significance of bunkers as a golf course component. The details of the design and construction process were also gleaned from these resources in addition to the experience of the author. Information on maintenance and management also came from articles by professionals in the golf course industry as well as the publications of several professional associations and industry observers. The experiences of golf course architects, superintendents and managers who were contacted for this study provided a practical view to the overall context of the design – management relationship. Their insights and advice were invaluable to this study.

The survey questionnaire was developed to obtain quantitative and qualitative data in six categories – description of respondents, golf course components, bunker roles and characteristics, bunker design, management and maintenance, new bunker design and construction, and bunker modification. Questions in each of these categories were developed to provide information relevant to the objectives of this study. Survey respondent data was analyzed and the results categorized following a survey analysis model structure developed for this study (Figure 3.1). The key to the survey analysis model is that it is structured to allow for analysis of data within each question and across the entirety of the survey respondent groups.

Study Objectives

The goal of this study is to provide information and analysis regarding bunker design, construction, maintenance and costs, both initial and continuing. This information is relevant to those studying and practicing in fields related to golf, specifically golf course architecture, maintenance and management.

Identify and Analyze the Most Important Factors which Influence Bunker Design

Using data gathered through the survey of design and maintenance professionals, the most important factors which influence bunker design will be identified. These factors will be ranked by importance, pending their statistical significance and differentiation. Each factor will then be further analyzed individually using the background information gathered for this study. The usefulness in identifying and

analyzing these bunker design factors lies in gaining a better understanding of the thought process and design intent of golf course architects.

Better Understand the Bunker Design – Management Relationship

Through comparison of survey data from design professionals and management professionals, differentiation on key issues will be identified. Once identified these differences will be analyzed to determine why the differences exist and what the resulting impacts on golf course facilities are. It is important to understand if there are differences in the perceived roles and impacts of bunkers between designers and managers, and what the causes and effect of these differences may be. If differences are determined to be in conflict between the design – management components, or are otherwise creating inefficiencies in maintenance or increasing continuing costs, potential solutions will be developed and presented.

Provide a Decision Making Resource

Ideally, the results of this study will provide professionals in the fields of golf course design and management with a decision making reference tool regarding bunker design and maintenance. Potential pitfalls in the design – management relationship will be identified and presented to all parties involved. Additionally, a better understanding of the relationships between professionals and the reasoning behind their decision making processes will only benefit those involved in bunker design, construction and management.

Create a Model for Related Future Studies

Bunkers are just one component of golf courses that may be analyzed through the methods of this study. Future researchers may use this study as a model or reference for other studies to analyze golf course components and their influence on the design and management of golf courses. Additionally, this study may provide the basis for further research on bunkers, their future roles on golf courses, and the impact of their design and management on the golf course industry.

Chapter 2 – Background

Golf Course Architecture

The major differentiation between golf and other sports begins and ends in one place, the playing field. Golf is played upon courses that vary in nature immensely, while the fields, pitches and courts of other athletic endeavors are constrained by essential dimensions that may vary only slightly, if at all. In golf, the only set dimension is that of the 4.25" diameter hole. This dimension itself was arbitrary until 1891 when the governing body of golf at the time, the Royal and Ancient Golf Club of St. Andrews, decreed that the hole's size should be the same at golf courses everywhere, and settled on the still used 4.25" diameter.

Since golf's beginnings, the courses, or routes, over which the game is played have been shaped to some extent by the hand of man. This process is known as golf course architecture or golf course design. However, one should not oversimplify or pigeon-hole the term golf course architecture. Contemporary golf course design involves a myriad of economic, environmental, social, psychological, legal and ethical inputs that must be studied and accounted for during the course of any given project. Golf course architects must utilize skills related to business, civil engineering, land planning, and landscape architecture while maintaining stewardship of their most important resource, the land. Today's golf course architects are expected to deal with issues that probably would not have fallen under the professional scope of many of their predecessors. Better understandings of environmental sustainability as well as the incorporation of golf courses into the social fabric of communities are just two areas that have seen significant growth in golf course architecture. Golf course architects are also taking on additional business and economic responsibilities, in many cases out of necessity.

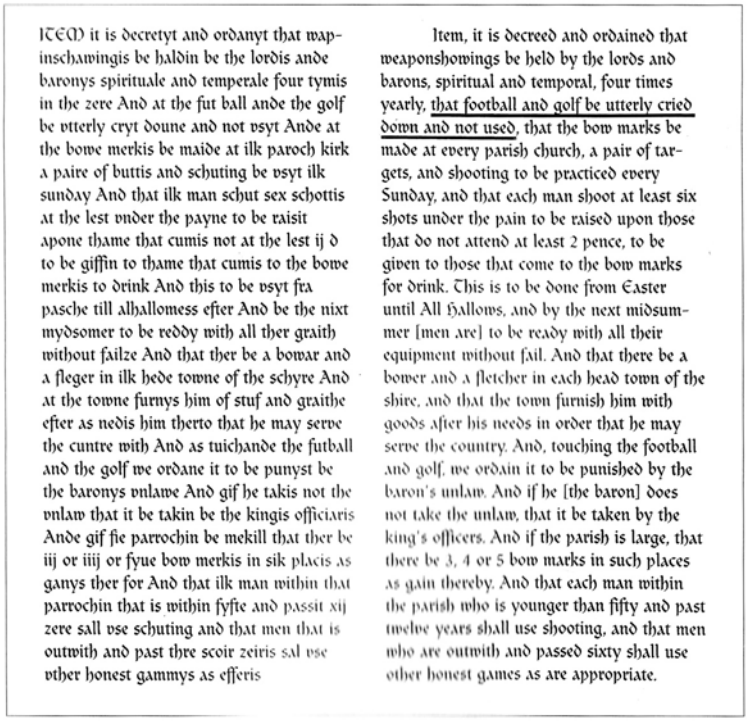
Despite the steady, decades-long growth seen in golf course architecture, the current economic situation is negatively impacting golf course development in all corners of the earth. In the United States alone, golf course closures outpaced openings in 2006 for the first time in decades. This disturbing trend has continued through 2008 as the total number of courses opening continues to go down while the number of course closures rises. This data, combined with the fact that the trend in total number of golf rounds

played has stagnated and even decreased, is not good news for those involved in developing, designing and managing golf courses (National Golf Foundation, 2008). As new and existing golf courses struggle to gain a foothold and survive, professionals in golf-related fields must now focus their efforts on the long-term economic sustainability of golf facilities. An important aspect of this effort involves golf course architects designing courses that maintain the components necessary to challenge and engage golfers while setting up developers and facility managers for future lasting success.

Due to the breadth and complexity of issues currently facing those in the field of golf course architecture, a historical analysis of the field is necessary to better understand the specific elements of golf course design and the role that design plays in the contemporary landscape of golf. This understanding of where the practice has come from is essential and must be used as a basis for study on where it should go in the future. The following is an overview of the beginnings, growth and evolution of golf course architecture.

Early Beginnings

Much debate has taken place as to the origins of the game of golf. Scholars have found similarities to modern day golf in several ancient European games including, kolven, choule and pall-mall. However, none of these games seems to provide a direct descent to golf as we know it today. The earliest mention of the term “golf” can be found courtesy of King James II. A 6 March 1457 Act of Parliament bans golf and other pastimes due to their interference with regular archery practice (Figure 2.1). Interestingly, not long after King James II forbid the playing of golf, King James IV was documented as being an avid golfer (Richardson, 2002).



ITEM it is decretyt and ordanyt that wapinschawingis be haldin be the lordis ande baronys spirituale and temperale four tymis in the zere And at the fut ball ande the golf be vtterly cryt doune and not vsyt Ande at the bowe merkis be maide at ilk paroch kirk a paire of buttis and schuting be vsyt ilk sunday And that ilk man schut sex schottis at the lest vnder the payne to be raisit apone thame that cumis not at the lest ij d to be giffin to thame that cumis to the bowe merkis to drink And this to be vsyt fra pasche till alhallomess efter And be the nixt mydsomer to be reddy with all ther graith without failze And that ther be a bowar and a fleger in ilk hede towne of the schyre And at the towne furnys him of stuf and graithe efter as nedis him therto that he may serve the cuntre with And as tuichande the futball and the golf we ordane it to be punyst be the baronys vnlawe And gif he takis not the vnlaw that it be takin be the kingis officiaris Ande gif fie parrochin be mekill that ther be iij or iiij or fyue bow merkis in sik placis as ganys ther for And that ilk man within that parrochin that is within fyfte and passit xij zere sall vse schuting and that men that is outwith and past thre scoir zeiris sal vse vther honest gammys as efferis

Item, it is decreed and ordained that weaponshowings be held by the lords and barons, spiritual and temporal, four times yearly, that football and golf be utterly cried down and not used, that the bow marks be made at every parish church, a pair of targets, and shooting to be practiced every Sunday, and that each man shoot at least six shots under the pain to be raised upon those that do not attend at least 2 pence, to be given to those that come to the bow marks for drink. This is to be done from Easter until All Hallows, and by the next midsummer [men are] to be ready with all their equipment without fail. And that there be a bower and a fletcher in each head town of the shire, and that the town furnish him with goods after his needs in order that he may serve the country. And, touching the football and golf, we ordain it to be punished by the baron's unlaw. And if he [the baron] does not take the unlaw, that it be taken by the king's officers. And if the parish is large, that there be 3, 4 or 5 bow marks in such places as gain thereby. And that each man within the parish who is younger than fifty and past twelve years shall use shooting, and that men who are outwith and passed sixty shall use other honest games as are appropriate.

Figure 2.1 – 1457 Act of Parliament Banning Golf (Richardson, 2002)

The first known and recorded golf courses took shape over rumpled linksland, the undulating sandy ground neat the sea shore, along the eastern coast of Scotland. While other areas may have been home to early golf courses, it is the linksland that became synonymous with the growth of the game. While the romantic notion is that linksland was the most interesting and challenging place to play golf, it is likely that due to the linksland's unsuitability for other uses it was most easily used for recreational purposes.

By the 1700s actual golf courses, a series of defined holes, were mapped and recorded in Scotland. The make-up of these early golf courses varied considerably. One of the earliest formalized golf courses, the Leith Links, had five holes and a "round" consisted of three trips around the course. Meanwhile, Prestwick had 12 holes arranged in a crisscrossed manner and St. Andrews had 22 holes. In 1764 several of the shorter holes at St. Andrews were combined into longer ones and the standard of 18 holes was born (Richardson, 2002).

Figure 2.2 – St. Andrews Golf Links Circa 1892 (Richardson, 2002)

Initially, the human influence on golf courses was limited. Golf course architect and writer Tom Doak explains the early relationship between golf, golfers and golf courses in his book *The Anatomy of a Golf Course*:

> The links were not designed for golf; at least, not by the hand of man. Natural forces of tide and wind produced the endlessly undulating contours in the sand, and animals provided the seeds for swards of turf and the scrapes that became enlarged into the bunkers. The equipment and rules of golf were designed to deal with the challenges found on the links. (p. 7)

As golf courses became more formalized and standardized, the duty of making improvements fell to the early private golfing societies and their greenkeepers. For the first time, management of the golf course became a priority, even if it was very simple by today's standards. Old Tom Morris was among the first greenkeepers, overseeing and managing the grounds at St. Andrews (Figure 2.2). In addition to being a greenkeeper and champion golfer of the highest level, Morris would go on to lay out multiple courses. However, the title of first golf course architect usually falls to Allan Robertson. Robertson oversaw numerous changes at St. Andrews beginning in 1848 and consulted on the routing of several other well-known courses nearby. The actual use of the term golf course architect did not really come about until much later. C.B. MacDonald is credited with "inventing" the term in the early 1900s and used it to title himself. (Cornish & Whitten, 1993)

Formalized Design

In his book, *Routing the Golf Course*, Forrest Richardson defines early golf architecture as *"the period in which courses began to be laid out instead of found."* It was during this time period, roughly the last three decades of the 1800s, that golf's popularity grew substantially throughout the world. This was due in large part to Scottish emigrants taking the game with them to new lands. Golf clubs were established in New Zealand (1871), Canada (1873), Australia (1882), Belgium (1888), the United States (1888), Spain (1891), Switzerland (1892), Holland (1893), Germany (1895), Russia (1895), and Italy (1898). (Richardson, Routing the Golf Course)

This period saw golf professionals, usually of Scottish descent, take over the primary role of routing new golf courses. For probably the first time conscious efforts were made to route golf courses on set parcels of land and the holes were built, usually using hand labor and horses. Many of the quirks of the original linksland courses began to disappear including crossing holes like those seen at Prestwick and the out-and-back along the same playing corridor routings similar to St. Andrews. Trends in golf course routing that are still seen today developed at places like Muirfield, two nine-hole loops with one contained inside the other, and Portmarnock, side-by-side returning nine-hole loops (Figure 2.3). (Richardson, 2002)

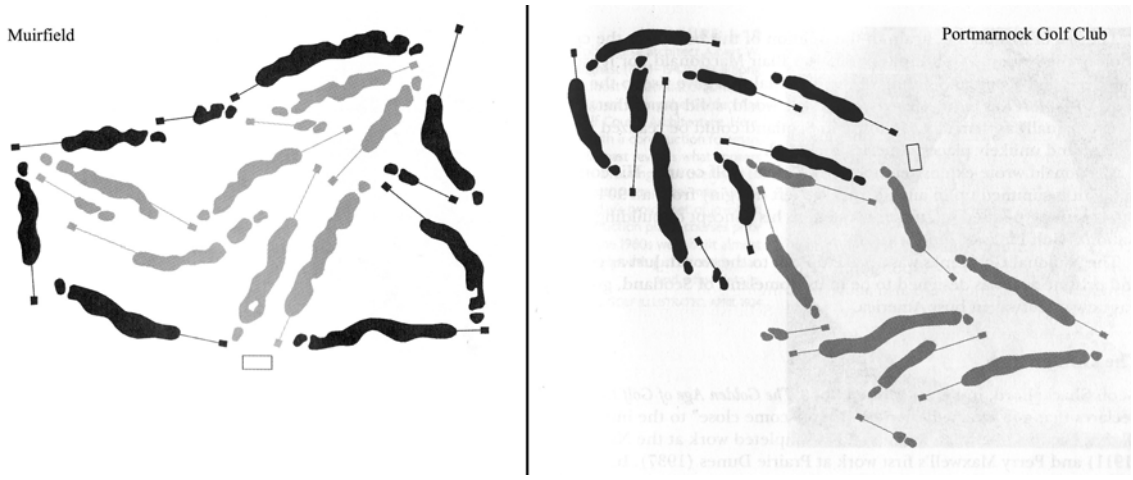


Figure 2.3 – Routing Diagrams of Murfield and Protmarnock (Richardson, 2002)

Move to America

It was in the United States that golf saw a boom in popularity and course construction during the early 1900s. Following the founding of the country's first golf

clubs in 1888, the United States Golf Association was founded in 1894. Although early courses were by today's standards primitive, they showcased a style different than that of their predecessors in Scotland. Unlike the Scottish courses, the new American courses were built most often on less undulating parcels of land. Additionally the creation of built hazards such as bunkers, pits and berms was a contrast from the "found" hazards of early linksland golf (Figure 2.4). These built features were created to add interest, strategy and penalty to the game.

Figure 2.4 – Artwork Showing Bunker at Royal North Devon (Hurdzan 2005)

From a management perspective there were also different considerations from those of linksland courses. Where the links courses consisted of mostly undisturbed native turf, the new American courses were constructed and the turf seeded or sprigged. Ongoing maintenance was necessary to maintain a reasonable playing surface. The built features, although often crude, also required the hand of man to maintain.

Few courses from this era remained in their original form for long. Advancements in technology including the introduction of the Haskell ball led to significant golf course modifications to keep up with the capabilities of golfers. However, it was during this time of initial growth that the development of American golfers and golf courses laid the framework for the game's impending stateside explosion.

The Golden Age

A quick review of any major golf publication's ranking of top golf courses in the United States will reveal a depth of entries dating from the 1910s, 20s and 30s. This period, known as the Golden Age of golf course architecture, saw rapid growth in the quality and quantity of golf courses being built. It also ushered in an era of golf course design professionals. These men took the game to all corners of the country and produced world-class golf courses on all types of terrain. In many cases these golf course architects had seen and studied the best that Scottish linksland golf had to offer.

Advances in technology during this period also led to new construction techniques. For the first time specialized golf course construction companies were formed to build the large number of new golf courses taking shape across the country. Steam power and mechanized labor began to make inroads into golf course construction during the Golden Age. Machinery allowed for broader scale land clearing and earth moving in addition to allowing for construction on more difficult sites. However, it should be noted that during this period the large majority of finishing and detail work on golf courses was still done by hand or with the use of horse or mule drawn equipment (Figure 2.5).

Figure 2.5 - Shaping the 11th Green at St. George's Golf and Country Club, Ontario, Canada (golfclubatlas.com)

The 1920s saw the practice of cultivating and smoothing fairway seed beds during construction become common. This allowed for better conditioned courses almost immediately after opening. Golf course maintenance was advanced during this time by

the development of gang units for fairway mowing and the golf course tractor for pulling them. Special greens mowers with extra blades also were developed and gained widespread use. By the late 1920s golf course irrigation took its first major step toward commonplace with the introduction of quick coupling irrigation systems that were used on greens, tees and fairways. (Cornish & Whitten, 1993)

The top golf courses produced during the Golden Age had a level of sophistication not previously seen in the United States. Man-made elements were carefully planned and in many cases built to look as natural as possible. The best of the Golden Age architects took great care in analyzing and implementing strategic merits in their designs. Hazards were painstakingly placed and intended to challenge the golfer. The visual impact of design also took a step forward in this era. Many of the great courses were designed to fit into their surroundings as opposed to simply laid over the top of them. It was a unique time in golf course design and construction. Technology had developed to a point that allowed for greater manipulation of the land. Where applied judiciously, this ability allowed for site engineering that not only improved the physical state of golf courses, but also increased the challenge and enjoyment had by golfers (Figure 2.6).

The courses of the Golden Age became the standard going forward. In *Routing the Golf Course*, Forrest Richardson provides a short list of the significant designs that defined the Golden Age of golf course architecture. While by no means comprehensive, this list is impressive in its breadth. It includes public courses, private country clubs,

resorts, courses by world-traveled professional designers, and masterpieces by "one-hit-wonder" amateur architects. The list is as follows:

National Golf Links – Southampton, NY – C.B. Macdonald & Seth Raynor, 1911
Pebble Beach – Pebble Beach, CA – Jack Neville & Douglas Grant, 1918
Pine Valley – Clememton,NJ – H.S. Colt & George Crump, 1918
Baltusrol – Springfield, NJ – A.W. Tillinghast, 1922
Merion – Philadelphia, PA – Hugh Wilson & William Flynn, 1924
Bel-Air – Los Angeles, CA – George Thomas, 1926
Riviera – Pacific Palisades, CA – George Thomas, 1927
Cypress Point – Pebble Beach, CA – Alister MacKenzie & Robert Hunter, 1928
Seminole – N. Palm Beach, FL – Donald Ross, 1929
Pasatiempo – Santa Cruz, CA – Alister MacKenzie & Robert Hunter, 1929
Augusta National – Augusta, GA – Alister MacKenzie & Bobby Jones, 1933
Prairie Dunes – Hutchinson, KS – Perry Maxwell, 1937
Pinehurst No. 2 – Pinehurst, NC – Donald Ross, 1903-1940s (a work in progress)
Oakmont – Pittsburg, PA – Henry & William Fownes, 1903-1940s (a work in progress)

While the Golden Age was putting the United States on the world golfing map, one must not forget that it was a time of significant golf course design everywhere. In Europe, Herbert Fowler and Tom Simpson formed a partnership and designed many of the best courses on the continent. At the same time, the firm of Harry S. Colt, Alister MacKenzie and Charles Alison flourished in Europe before expanding their efforts to countries worldwide. Colt and MacKenzie in particular became very successful in the United States.

Figure 2.6 – Golf Course Architects Alister Mackenzie and Robert Hunter on the 15th Hole at Cypress Point Golf Club (Shackelford, 2000)

The Golden Age growth of golf and golf courses was unprecedented. In 1916 there were 742 courses in the United States. That number grew to 1,903 by 1923 and to 5,648 in 1929. That was an average of nearly 600 new courses opening per year from 1923 to 1929. Remarkably there were only a few dozen professional golf course architects practicing at the time. A good number of the new courses were laid out and

built by locals or immigrants, many who also served as golf professionals and greenskeepers. (Cornish & Whitten, 1993) Unfortunately the Golden Age was slowed considerably by the financial crisis of the Great Depression and then halted completely by the onset of World War II. Many golf courses were closed or left unkept during the Depression and the war years that followed. Several prominent courses in the British Isles were directly impacted by wartime bombing while others, like British Open Championship host Turnberry, were turned into military airfields.

In the United States many of the established clubs survived the Great Depression but the newer clubs, established during the good times of the 1920s, were often financially overextended. Money was not available for operational and maintenance expenses or construction fees owed to architects and contractors. These new golf clubs closed in great numbers throughout the country. During the 20 years between 1932 and 1952 only 200 new courses opened for play in the United States. At the same time nearly 600 courses closed their doors forever. Other courses that managed to survive the 1930s were hit hard by the onset of World War II. Well known courses closed for the duration of the war due in large part to the scarcity of petroleum products and labor. Remote courses became more expensive to get to and without oil, fertilizer and manpower courses were nearly impossible to maintain. Among the casualties were Maidstone Club on Long Island, Boca Raton Club near Palm Beach, Florida, Olympia Fields in Chicago, Interlachen in Minneapolis, and even Augusta National. Fortunately these fine facilities managed to reopen following the war. Interestingly most public and municipal courses managed to stay open during these tough times even though they were poorly funded and maintenance suffered. The boom of the 1920s and the bust that followed in the 1930s illustrated a lasting lesson in golf course design and management. It showed that the most magnificently designed courses would not remain magnificent for long without adequate funds for upkeep and maintenance. (Cornish & Whitten, 1993)

A golf course architecture trend that came out of the 1930s, and tends to get repeated during times of economic hardship ever since, was the remodeling of numerous existing courses. While the 1920s produced some of the world's greatest golf courses, many projects did not involve a golf course architect and tended to be very crude. Little attention had been paid to strategy, including bunker placement and other elements that

created design interest. Professional architects were hired to rectify problems and eliminate features that were deemed unnecessary.

Post World War II – The Modern Era

By the mid and late 1950s the popularity of golf in the United States was again on the rise. This was due to several factors. Chief among them was the post World War II economic boom and the resulting increase in disposable income that could be used for recreational purposes. Golf's popularity also benefited from the development of televised golf tournaments and golf professional Arnold Palmer. Televised professional golf tournaments showcased the best players and best courses to a captive audience around the world. Palmer's rise as a professional golfer in the television age and the coinciding increase in the game's popularity were closely related. In Palmer, golf had a great champion that brought interest to the game from golfers and non-golfers alike (Figure 2.7). His go-for-broke style, good looks and general affability played perfectly to television audiences. Additionally, his rivalry with fellow American Jack Nicklaus and South African Gary Player, golf's big three, captivated sports fans for decades.

Figure 2.7 – Arnold Palmer at the 1962 Masters Tournament (Harry Fry)

As golf became a favored leisure pastime among many Americans, the demand for new golf courses followed suit. Courses began popping up in towns both large and

small. The 1950s and 60s saw a boom in all types of golf courses; public, resort and private. Across the country housing developments and subdivisions were planned and built with golf courses as their focal point. This relationship between the housing markets and golf became very important, leading to many of the successes and failures seen in golf course development over the ensuing half century.

With the large number of new golf courses opening across the country, more designers were making a living from golf course architecture. The mid and late 1950s saw an average of around 100 new courses being opened every year. That number grew to over 400 per year by the mid 1960s. In the early 1960s there were still numerous courses being designed and built by non-architects. But by the end of the decade the majority of new courses were being laid out by professional golf course architects.

Although very few of the Golden Age architects were still practicing, architects with lineage dating to the greats of the Golden Age continued to move the profession forward in the decades following World War II. Chief among these were Robert Trent Jones, Sr. and Dick Wilson. However, the process of designing and building a golf course had changed significantly since the building boom of the Golden Age. Post World War II golf course architects had technology at their disposal that allowed for golf course to be built almost anywhere. Most influential among these technologies were better earth-moving machinery, advanced irrigation systems, improved greenkeeping (agronomic) techniques, and the development of the electric golf cart. (Richardson, 2002)

During the Golden Age it often took the work of hundreds of men with limited, if any, mechanized equipment, two to three years to build a golf course. By 1960 courses were being built in a few months by only a dozen workers using equipment that was not all that dissimilar to what is used today (Figure 2.8). Other advances in grass types, fertilizers, chemicals, and irrigation greatly altered golf course maintenance. Automatic irrigation and nearly universal adoption of fairway irrigation in the 1950s improved playing conditions as well as golfer expectations. Overall, the turfgrass management for golf courses became more scientific as a better understanding of exactly how grass grows was reached. Greenskeepers were increasingly going by the title of golf course superintendent and were taking advantage of the latest materials and equipment to do their jobs. (Cornish & Whitten, 1993)

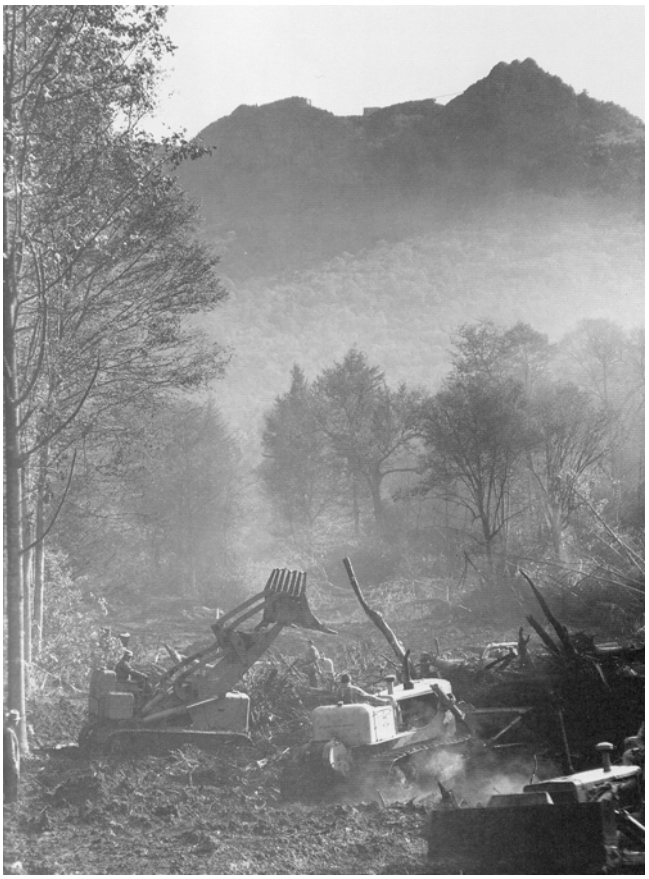


Figure 2.8 – 1960s Era Clearing and Earthmoving, Grandfather Golf and Country Club, North Carolina (Cornish, 1993)

Because of the use of new technologies, no longer was golf course development confined to sites that required little from the hand of man to make ready for golf. Mountainsides, floodplains, dense forests and deserts all became sites for first-rate golf courses. Large scale earthmoving projects had taken place previously to enable golf course development. Lido on Long Island was built on land that was reclaimed from Long Island Sound during the 1920s. Although no longer in existence, it is still considered one of golf course architecture's most compelling feats of creativity and engineering. However, the use of new technologies beginning in the 1950s meant that golf courses could be engineered and built from nearly any topography on a regular basis. A new generation of golf courses saw hilltops leveled and valleys filled, replaced by gently rolling fairways and beautifully situated houses. At the same time, mounds, lakes, streams and trees began to appear on sites that were flat or offered little in the way of

interest prior to development. Expectations for golf course conditioning also changed as improvements in golf course care were made and golfers were exposed to the bright green fairways and white bunkers of courses seen on television.

The onset of the Modern Era of golf course architecture is most closely linked to one man, Robert Trent Jones, Sr. Jones, one of the few men who's careers spanned from the Golden Age to the Modern Era, really came to the forefront of the profession following World War II. He marketed himself as a designer of "signature" championship courses and his courses are still today known for their broad shoulders. His most recognized early work, the redesign of Oakland Hills for the 1951 U.S. Open, was described by winner Ben Hogan as a "monster." Most Jones courses were longer, often coming in at over 7,000 yards, and more difficult than their predecessors. Fairway landing areas and large greens pinched by ominous bunkers were a signature of many Jones courses, as were long "runway" tee boxes.

Several of these features were widely used as a result of more modern mechanical maintenance methods like the use of gang mowers and mechanized bunker rakes. Runway tees were a departure from the multiple small teeing areas often seen until this time. They had two distinct advantages as well, flexibility and maintainability. Due to their long continuous nature, runway tees allowed for more variance in daily setup of tee locations. Additionally, runway tees, with their constant widths, were easier to maintain. Instead of having to mow multiple teeing areas of varying shapes and sizes, course staff could simply make a few passes with the mowers up and down the length of a runway tee.

Bunkers also saw significant changes during this time that related to maintenance practices. The use of mechanized rakes in bunkers encouraged the design and construction of bunkers that accommodated the turning radius of the equipment being used. Round bunkers or bunkers with large sand lobes, 16-20 feet in diameter allowed for easy coverage and turning. Bunkers with entry and exit points for mechanized rakes also became more popular. The result of these influences was usually relatively large and simply shaped bunkers (Figure 2.9). Additionally, the steep faced bunkers and irregularly shaped bunkers so often associated with the Golden Age of golf course architecture fell out of favor and in many cases were modified.

Figure 2.9 – Bunker with Simple Shape, Bergkramerhof Golf Club, Bavaria, Germany (Daley, 2003)

Much argument has been made that while the boom in golf course design and construction in the middle of the last century grew the game significantly, the quality of the product provided to the American golfer was sacrificed. This has been referred to as the onset of "freeway golf." Freeway golf is characterized by uniformity and simplicity. Examples sprung up throughout the United States beginning in the 1950s. Golf courses that featured parallel fairway edges, geometric forms, single rows of trees separating holes, and repetitive placement of hazards were the result. The popularity of these cookie-cutter courses was a result of the increased demand for the game by the American public. The resulting push to satisfy market demand for new courses too often focused on building courses quickly, cheaply, and devoid of impediments that might slow down the dawn-til-dusk march of golfers. (Hurdzan, 2006)

This was a boom time for those in the golf course architecture and construction business. Unfortunately, the approach taken by many golf course architects during this period flew directly in the face of what had been done during the last boom period, the Golden Age. New golf course architects entered the field at a record pace but not always with the knowledge or background of their predecessors. Strategic design was often an afterthought as hazards were moved to the periphery of golf holes to facilitate

maintenance and pace of play. Length became the main challenge on many of the new golf courses built during this time.

The desire for difficulty and pristine conditioning led to a level of standardization among American golf courses. Challenge was usually equated with length, championship courses being of at least 7,000 yards. Gone in many cases were the strategic elements and quirks that defined challenge on the Scottish links and the best Golden Age designs. Tom Doak states in *The Anatomy of a Golf Course:*

> The downside of modern construction is that many of the subtle contours of the natural landscape which make older courses so interesting are lost during the mass grading of modern layouts… Even features which might have been the cornerstone of a unique natural golf hole are sometimes bulldozed out of existence to make room for an artificial hazard concocted from the architects mind. From the standpoint of the construction companies, the modus operandi which my friend Scott Pool jokingly described as "rape it, shape it, and grass it" (referring to the land, of course) has become the norm. (p. 11)

A danger introduced in the Modern Era, and continuing today, is one of overusing the technologies available. It can be argued that golf courses have been built and maintained that no longer reflect their ancestry as natural settings over which a game is played. Where to draw the line is one of personal and professional preference as each golfer and golf course architect has their own opinion on the matter. Another contentious subject related to the use of technologies and golf courses is that of course conditioning. Since early in the Modern Era conditioning played an important role in course standardization as the "Augusta National Syndrome" took over. This was caused by golfers wanting to see immaculate conditions like the ones they saw on television from the Masters Tournament each April. Wall-to-wall irrigation, excessive tree planting and widespread pesticide use have all been related back to this effort.

Another reason for the increased attention paid to golf course conditioning is the fact that for many residents in golf course communities, the course is their back yard (Figure 2.9). As such there has always been an expectation of the appearance and upkeep of golf courses bordering housing areas. The residential component of golf course

development undoubtedly contributed extensively to the growth of golf. Unfortunately, it too may have had its downside from a quality standpoint. Golf courses were, and are, often relegated to the less desirable parcels of land within large developments. Additionally, many golf courses have been simply seen as “green space” for the development and may not have been planned or constructed to a high enough standard. The large number of lawsuits over the years as a result of wayward golf balls wreaking havoc in backyards, on houses, and on roads should be reason enough to ensure that proper foresight is given to planning the relationship between a golf course and its surrounds.

Figure 2.9 – Housing Development and Golf Course (emporia.edu)

The 1970s and 80s saw continued growth of the principles put in place during the post World War II years of the Modern Era. In general, golf courses continued to get longer and more difficult. One man, Pete Dye, can be credited with laying the foundation for a shift back toward the strategic design that has been embraced by some of the most successful contemporary designers. His background was shaped by his own prowess as a player and the influences of the classic Scottish links courses that he studied carefully. Dye first came to prominence in the mid 1960s and in the time since has created

numerous distinctive golf courses. Well known Pete Dye courses include Crooked Stick Golf Club, Harbor Town Golf Links (Figure 2.11), the TPC at Sawgrass (Figure 2.10), the Stadium Course at PGA West, and Whistling Straights. For the first several decades of his design career Dye typically took on only a few projects at a time, often living on site during the construction process. This attention to detail was a departure from the way that things were done by many of his peers at the time.

Figure 2.10 – 9th Hole at the TPC Sawgrass, Ponte Vedra Beach, Florida (Golf Digest Magazine)

Dye's golf courses did not derive their challenge from pure length, but instead focused on playing angles, unique hazards, and varied options of play for the golfer to decipher. Dye was deeply influenced by the golf course features he had observed in the British Isles. One of these features was the use of sleepers, or railroad ties. On the links courses sleepers were often used to shore up the faces of large bunkers, providing them with increased structural stability. Many of Dye's designs have become synonymous with the use of sleepers on bunker faces, abrupt grade changes, and water hazard edges (Figure 2.11). Other features that became widely associated with Dye were the use pot bunkers

and large, flat waste bunkers, often situated diagonal to the line of play. Both the visual appearance of Dye's golf courses and their unique playing characteristics were in stark contrast to vast majority of other courses produced in the post World War II era.

Figure 2.11 – 13th Hole at Harbour Town Golf Links, Hilton Head Island, South Carolina (golfclubatlas.com)

Contemporary Design

The past two decades of golf course design have seen variety become the norm. Golf course development has continued to spread to all parts of the world and taken place on increasingly complex sites. World class golf courses have been built on pure sand dunes perched on ocean cliff tops but also on landfills and reclaimed industrial sites (Figure 2.12). As land becomes more precious in many high-density parts of the world, identifying options for golf course locations has required a bit more creativity than in the past. Like in the past, trends in golf course architecture tend to closely follow economic factors. Some have compared the widespread and extravagant construction of the 1990s with the boom seen in the 1920s. With over 300 new courses opening per year in the United States there were cries for the industry produce a course-a-day. Resort courses, high-end public courses, and destination golf retreats all flourished. Although the recent

economic downturn has greatly limited the number of new courses being produced, development of courses with a variety of styles and target markets continues.

Figure 2.12 – Bayonne Golf Club, Bayonne, New Jersey (Michael Light) – The golf course was built on a former industrial site using material dredged from the shipping channels of New York Harbor

The last decade has seen a move toward what some have termed minimalism. This move was likely in response to the over-built and manufactured courses of the 1980s and 90s. For a period extravagance was the norm with massive amounts of earth being moved on golf course projects. Huge mounds, expansive lakes and large white bunkers were commonplace, no matter the preexisting setting for the course. Golf course maintenance and management strived for clean lines and edges, wall-to-wall turf, and lush green everywhere. Good economic times allowed designers like Tom Fazio, Rees Jones, Robert Trent Jones, Jr. and Jack Nicklaus to command huge design fees and even larger construction budgets to build these courses (Figure 2.13).

Figure 2.13 – 16th and 17th Holes at Jack Nicklaus Designed Cabo Del Sol Ocean Course, Mexico (golfclubatlas.com)

Designers like Jack Nicklaus have changed the face of contemporary golf course architecture. These "celebrity" designers, current or former professional golf greats, lend a level of name recognition to a new project and have been very successful at wooing high end developers. In addition to Nicklaus, Arnold Palmer, Gary Player, Tom Weiskopf, Greg Norman, Ben Crenshaw, Tom Watson, Tiger Woods and others have created golf course architecture firms, often large ones, as part of their business ventures. The level of involvement by the "name" architect varies greatly among the professional golfers in golf course design. While some have been known to be intimately aware of the details of design and construction, others have to be shown where the first tee is on opening day. Either way, the rise of the name architect, branded to the degree it has become, likely changes the dynamic among golf course architects. From a job procurement and marketing standpoint, name recognition helps raise prestige, create interest, and sell memberships and housing lots.

While there are still new golf courses being built that showcase the excessive traits seen 10 or 20 years ago, the overall trend has been toward a much more reserved and natural look (Figure 2.14). Interestingly, even the firms that were at the forefront of

the previous movement seem to have toned things down a bit. Some who have been termed minimalists would argue that the term is over-generalized and simply bantered about now as a marketing term. After all it is easy for a designer to say they want to work harmoniously with the land and then bulldoze an entire site once construction has started. In reality minimalism tends to simply be a return to the principles that made the great designers of the Golden Age successful and lasting.

Figure 2.14 – 17th Hole at Bandon Trails Golf Course, Bandon, Oregon (Author)

Tom Doak and the team of Bill Coore and Ben Crenshaw have been given credit with leading the minimalist movement. Doak describes his definition of minimalism and how it impacts his firm's design and construction process:

> For the most part, minimalism is just good common sense, a refusal to let design ideas out of thin air outweigh the realities of the site. Instead of reshaping a severe slope, we try to figure out how to use it to make a golf hole interesting. If it's just too severe, we'll try a sequence of holes which avoids it entirely. The bulldozer is our third and last option.

Restraint in earthmoving sets off a chain reaction of savings in the overall project budget. Natural areas not only add local character to a golf course, they don't have to be irrigated or seeded or maintained for the life of the course (Figure 2.15). We never create pockets which have to be artificially drained when the natural surface drainage will suffice. Every contour that can be left alone saves topsoil stripping and replacement.

We do understand how to move earth when the need arises, whether it's to add interest to a flat site or to soften a steep one (Figure 2.16). In fact, you have to be really good at moving earth to conceal what you've done, when the surrounding landscape is untouched. Any edge of disturbance, be it a clearing line or a major earthwork, is strenuously examined and finessed until it is blurred beyond recognition. This is the key to producing a new course that looks like it's been there for 75 years.

The greatest compliment we can receive is for someone to look at our work and say, "Well, they had a great site so they didn't really have to do very much, the course was laying there already." The truest test of ability is to make the work look easy. (www.doakgolf.com)

Figure 2.15 – 7th Hole at Ballyneal Golf Club, Holyoke, Colorado (golfclubatlas.com) – The Tom Doak designed Ballyneal Golf Club was built with minimal earthwork and features the preservation of native vegetation.

Figure 2.16 – Rawls Course at Texas Tech University, Lubbock, Texas (Texas Tech University) – This Tom Doak design involved massive amounts of earthwork to transform a flat cotton field on the west edge of Lubbock, Texas.

As the number of new golf courses being produced has dwindled, many golf course architects are turning to renovation, remodeling and restoration projects for work. In these tough times many clubs are looking to boost membership and more public courses are competing for fewer golfers. The result is an increase in course improvement projects. In some cases this involves a complete overhaul or redesign. Other times the changes may be more subtle like a bunker or greens renovation. Restoration projects have also gained a niche in the golf course architecture market as courses choose to restore features that have evolved or been lost over time. There are practicing architects that specialize in such work, often marketing themselves as experts on a particular past designer's work. This particular part of the field can be somewhat contentious as restoration work on classic courses involves many interpretations of the original architect's intent. While the use of historic photographs and design drawings should be done when possible, they are not always available or consulted. More questions arise when considering to what state to restore the golf course – its original condition or that at some particular point in its history. In many cases it becomes a judgment decision on the part of the architect as to which features are restored and to what extent. Some architects use the term "restovation" to describe projects that take a course's history and the supposed original design intent into account but are not true restorations.

Renovate, Remodel, Restore

For as long as new golf courses have been built, existing golf courses have been modified. A telling example is St. Andrews, the home of golf. Originally made up of 22 holes, the Old Course at St. Andrews evolved and changed over centuries to reach the form it is currently in. The reasons behind golf course modifications are as diverse as the modifications themselves. At some points in history economic hardship has forced the elimination of golf course features. During the Great Depression of the 1930s noted golf course architect A.W. Tillinghast toured the country as a course inspector for the Professional Golfers Association (PGA) of America. He often recommended the removal of many of the bunkers built on courses during the roaring 1920s. Tillinghast claimed to have eliminated some 7,427 useless bunkers over a two year period. Many of these were penal fairway bunkers or cross hazards, both of which make golf very difficult for most players. The result of Tillinghast's efforts were significant, both in money saved by the golf courses on upkeep and increased player enjoyment. (Cornish & Whitten) Bunkering has long been one of the most popular golf course features to modify. Alistair MacKenzie, during his tour of Australia, routed and drew plans for several well known golf courses in addition to trapping or bunkering several other existing courses in his unique style (Figure 2.17).

Figure 2.17 – Mackenzie Bunkering at Royal Melbourne West Course, Melbourne Australia (royalmelbourne.com.au)

Robert Trent Jones, Sr. began a trend with his remodel of Oakland Hills for the 1951 US Open Championship. His use of deep bunkers to pinch fairway landing areas and entrances to greens was the forerunner to major remodels of many classic championship courses in an effort to add difficulty for major tournaments. This trend has

been continued today as Jones's son, Rees Jones, is known as the "Open Doctor" for his work on several prominent United States Open venues. Perhaps the most well known major tournament course to undergo significant modifications is Augusta National, home of the Masters Tournament. Originally designed by MacKenzie and champion amateur golfer Bobby Jones, Augusta National has undergone significant modifications, facelifts and changes to its playing characteristics. There have been periods where, for better or worse, Masters competitors were greeted with new golf course changes on nearly a yearly basis.

Modifications are by no means confined to well known golf courses or those of prolific golf course architects. A large number of modifications to golf courses occur in small, sometimes unnoticed, steps. These are often the result of, among other things, projects initiated by greens committees and/or golf course superintendents, changed maintenance practices over a period of time, and suggestions by users. An often overlooked aspect of golf course modifications is the ever changing face of the golf course itself. Because golf courses are made up of millions of living organisms and subjected to the full compliment of nature's forces, there is an evolutionary nature to their being. Trees grow, grass types and mixes change, bunker edges erode – every day brings a new set of factors that over time can significantly change a golf course. Often, modification efforts are the direct response to these slow but steady changes that have taken place over time.

Golf course modifications tend to fall into one of two categories – redesigns or restorations. While these terms are often used somewhat interchangeably in marketing efforts or press releases, each has a unique and different intended outcome. To avoid confusion and ensure the effectiveness of a project, care should be taken to differentiate between the terms when discussing golf course modifications.

Redesign involves deliberate change to the design of a hole or course. This process may be relatively benign, changing only a few features, or it may consist of a whole-scale overhaul of the existing course. Sometimes the term renovation is used to describe a redesign. Renovation usually refers to work that is done to update a golf course in response to changes in course conditioning, equipment, or standards of play. One example is the recent obsession with adding length to many classic golf courses in an

attempt to keep up with modern technology and provide challenge to top-notch golfers. While adding length is often the response to such issues, it has also had negative impacts on the character of many courses. Holes that once tested finesse rather than length have been stretched simply to add overall length to the scorecard. These holes were never designed or meant to play as long holes. In many cases significant dollars have been spent by courses to lengthen holes and move fairway hazards downrange. Unfortunately, this isn't always the correct approach. In most cases nearly all golfers were sufficiently tested by the holes at their original length and fairway hazards were originally located in response to topography. The changes tend to be in response to the abilities of only a few golfers while significantly altering the aesthetics and character of an entire golf course for all golfers.

Despite some troublesome cases, many redesigns greatly improve golf courses and the golf experience for golfers. There are numerous golf courses that were built with little thought given to aesthetic quality and strategic challenge. Many of these courses are uninteresting and could be dramatically improved, bringing newfound enjoyment to their users. However, care should be taken when deciding on a redesign or renovation project. While course weakness is often cited as the reason for undertaking work, in many cases vanity or the desire to follow the latest trends in golf course architecture are the real driving forces. Over the years there have been many trends that seem to sweep the nation with significant numbers of courses adopting a certain look. These have included bulkheads around pond edges, large scale tree planting programs, grassing or flashing bunker faces, or softening green contours. Such changes may change, even improve, a course's aesthetics but will never turn a simple course into a great one. Those involved in redesign or renovation projects should aim to ensure that proposed changes will improve strategic interest, not just appearance. (Doak, 1992)

Restoration is the changing of a hole or course with the intention of returning the holes to their original form and character. Restoration should always be considered by a course when exploring golf course changes. It should be noted that in many cases restoration of the original character of a course may not be the proper choice. There is no reason to restore a sub-par course to its original sub-par design as some original plans are not worthy of restoration. However, in many cases quality courses have changed for the

worse over time. This is often the result of neglect, poor design changes, or simple growth. In such cases there is reason to explore the course's history and identify lost features which should be restored. The restoration process must be done with care. Not all original golf course features can feasibly be restored, nor should they. Problems arise when major changes are made on the grounds that the original architect might have done the same thing if in the current situation. While this may indeed be the case, it is often simply an excuse for heavy-handedness on the part of the architect or other involved parties. Good restoration requires a setting aside of egos, proper perspective, and an in-depth understanding of the original designer's work.

Bunkers are one of the most common targets when in comes to making golf course changes. This is due to the key role they play both aesthetically and strategically on a golf course. Also it tends to be easier to relocate, add or remove a bunker than it is to rebuild a green or address other strategic shortcomings of a golf hole. Like most golf course features, bunkers have gone through many fads over the years. At one time clean-edged bunkers with simple shapes were all the rage. This was likely in response to what golfers saw on their televisions every spring during the Masters Tournament. Today the pendulum appears to have swung toward more natural, rough-edged bunkers. In either case care must be taken to not judge the quality of golf course changes, particularly bunkers, simply by their visual characteristics.

A sometimes forgotten component of golf course changes relates to maintenance issues. Many times changes are made, particularly by superintendents and greens committees, with the goal of making the golf course easier to maintain or in response to particular maintenance problems. This can be a double-edged sword as the features that are viewed as difficult to maintain are often the ones with the most character and strategic influence. Again bunkers make a good example. The simplification of bunker shapes or removal of specific bunkers altogether generally results in fewer maintenance requirements. It also limits the design intent of the golf course architect who initially located the bunkers and changes the character of the course, often not in a good way. A balance must be found that ensures the long-term strategic quality and character of golf course features while presenting them in a way that makes maintenance feasible. In some

cases golf course changes are made that will knowingly increase maintenance requirements.

In the case of Mission Hills Country Club in Kansas City, Kansas, the bunker work done as part of a golf course renovation and redesign requires exclusive hand raking and hand mowing of many surrounds. The Keith Foster renovation and redesign that the club undertook in 2006 included adding significant character to the course by making the bunkers a more prominent feature. The bunkers were expanded, deepened, a new sand used, and sand flashed onto the bunker faces. The result is bunkers and bunker surrounds that require extensive hand labor and are overall more labor intensive than before. In this case the additional work required to maintain the bunkers was deemed acceptable because of the strategic and aesthetic improvements that the new bunkers provide. Because of the relative short length of the course it was decided that bunkers would be one of the key strategic components. Those involved in undertaking golf course changes should always be aware of the impacts that the changes will have on golf course maintenance and management. Like with new golf course construction, the involvement of the golf course superintendent during the design and construction phase will likely help to identify potential issues. Long-term costs associated with maintaining the changes made to a course should be considered in addition to the up-front cost of the redesign, remodel or restoration. At Mission Hills Country Club, the golf course superintendent was consulted and gave input prior to the project specifications going to bid. He understood the maintenance requirement that would be necessary following project completion. Additionally, he served as project manager with an emphasis on quality control during the construction process. (B. Gray, personal communication, September 28, 2008)

While many courses still choose to complete all aspects of projects in-house, the benefits of involving a golf course architect are many. Haphazard in-house redesign, often driven by a greens committee or the result of ignoring natural changes, has led to mismatched design styles and aesthetics on many courses. By involving a golf course architect a course is likely to see benefits in all stages of the project, from planning and design to the final product as it relates to golfer enjoyment and technical soundness. Within the current landscape of golf course architecture, redesign and restoration projects

inhabit a particularly important, and lucrative, niche. As the total number of new golf course projects has dwindled, many golf course architects are turning to the redesigns and restorations in hopes of finding work. Other golf course architects have already established themselves as experts on particular past architects, styles or project types, and market their services accordingly.

Many times golf course modifications are driven by necessity. Golf courses are made up of living, changing features. The impacts of natural forces and constant wear caused by golfers also factors into subtle changes that, over time, can significantly alter the face of a golf course. Often golf course modification projects are undertaken in response to “worn out” golf course features. In many cases there are technical issues that arise with age that impact the quality and maintainability of golf course components. The American Society of Golf Course Architects has put together a golf course life cycle chart that establishes general life spans for golf course components and features (Figure 2.18). Some of the life spans provided are rather broad as variation can be caused by a number of factors. These include but are certainly not limited to climate, use, and construction quality. The life cycle chart does a good job of driving home the point that built golf course features simply do not last forever. Because modifications are expensive, it also demonstrates the importance of proper golf course construction, maintenance and management. Establishment of features that do not need to be modified or replaced as frequently can result in major cost-savings in the long run.

Figure 2.18 – ASGCA Life Cycle Publication

Golf course changes are often outlined and undertaken as part of a master plan. Ideally master planning is done by a golf course architect, involves golf course stakeholders in the process, and is sensitive to the goals and objectives of the involved parties. The process of master planning should not be confused with a master plan, usually the presented end result of the process (Figure 2.19). While a colorful and detailed master plan may look nice hanging on the clubhouse wall, without a proper planning process behind it, the plan is likely to be nothing more than an illustration.

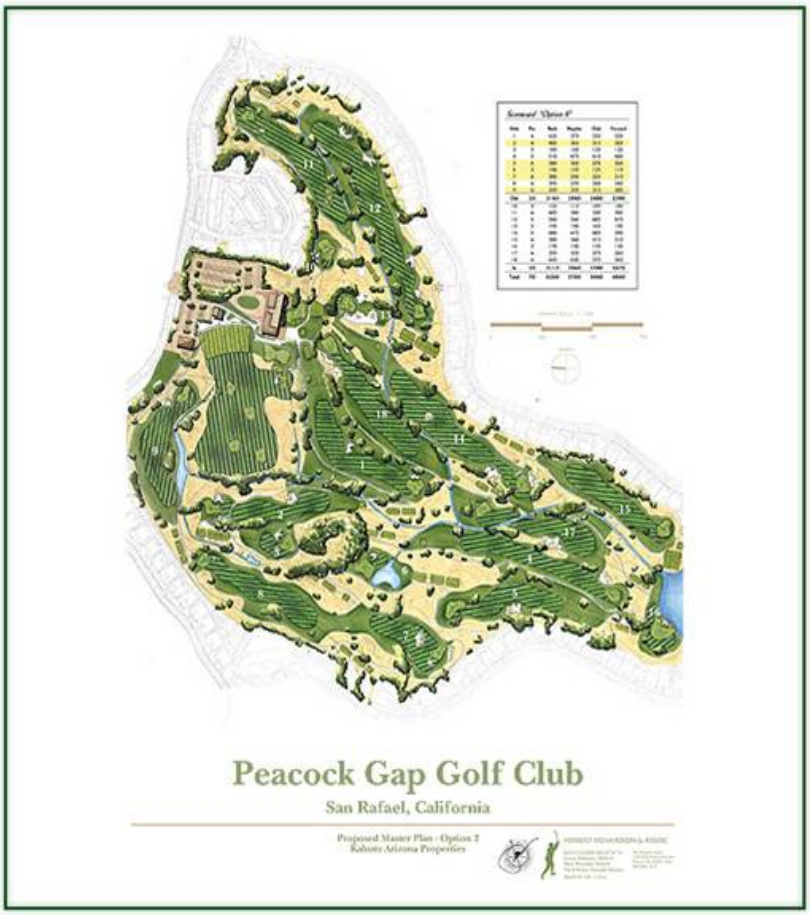


Figure 2.19 – Master Plan for Peacock Gap Golf Club, San Rafael, California (Forrest Richardson & Associates)

While all master planning processes will differ slightly to fit certain situations, most successful ones follow the same general outline. Prior to any action, the golf course architect needs to obtain information that will be relevant to the design process. This usually includes a recent scaled aerial photograph, topographic maps, and maps indicating site features like property lines, existing buildings, rights-of-way, easements, utilities, floodplains, and wetland information. Additional testing of soils, lakes, subsurface conditions may be necessary in some instances. Using this information the golf course architect can make an initial site evaluation. Other professionals or consultants may be brought in during this phase to lend their expertise. It is also important that the architect involves the golf course stakeholders early-on in the process. This helps ensure that all issues are identified and goals for the project are agreed upon. Because the financial situation of the project is important to its completion, discussions regarding finances should also take place during these early communications. Once

analysis has been completed, the architect will enter the preliminary planning phase. The result of this phase is schematic and preliminary feature design studies. These should be presented to the stakeholders for review and approval. This stage of the process often takes several revisions before approval. Following approval a preliminary plan, the master plan is produced and presented. Many times this is the first and only product of the process that golfers or members see. Unfortunately they do not always understand or realize the amount of background work that goes into bringing the process to this point.

Clubs and courses can make a big mistake by stopping the process with the illustrative master plan. Instead they should continue the process by having the architect prepare written descriptions of the proposed changes, create a phasing plan, generate cost estimates, and create a presentation that describes and explains the changes. Written descriptions of the work to be done can help avoid less thoughtful changes made by future greens committees. They will also help promote the overall balance, design and theme of the course as set forth by the master plan. A phasing plan details which improvements should be undertaken and when. Often financing does not allow the entire project to happen at once so efficient phasing of the project is necessary. Other times pressing needs require immediate attention in certain areas while less time sensitive issues can be dealt with later. Cost estimating is determined by the phasing of the project, scope of work, and the nature of the work, in-house versus contracted. Before undertaking the golf course changes in a master plan, the course stakeholders need to be aware of the overall construction cost. The golf course architect should be adept at estimating construction costs by making area or volume estimates and applying unit pricing from similar projects. Finally a presentation describing and visually showing the changes to be made can be used to answer questions and as a marketing tool. It is important to communicate the intent of the plan while “selling” it to facility stakeholders and users. In the end, master planning is usually the most effective and efficient way to go about initiating and making golf course changes. The process requires the input of many people and communication among the involved parties is essential.

The Future of Golf Course Architecture

The trend toward variety found in contemporary golf course architecture can be expected to continue into the future. Even in the current economic tough times, there still appears to be a market for super high-end golf course projects. At the same time, many architects are choosing, or being forced into, a more subtle minimalistic approach. Regardless of the factors influencing the scope and scale of golf course projects, it is good to see the architectural and strategic merits of golf courses regaining an important place in the golf discussion.

There are a variety of issues that can be expected to weigh heavily on the practice of golf course architecture going forward. Many of these fall into the environmental and economic categories. On the environmental side, water use has become a major factor in many locations. As water resources have become limited and more valuable, some locations, particularly in the southwestern United States, have implemented limits on the acreage of irrigated turf that a golf course can have. There have been a number of developments in response to water use on golf courses. In addition to limiting or reducing the amount of turf to be irrigated, many locations now use reclaimed or non-potable water. In costal locations desalination options are being explored to utilize seawater as an irrigation source. Additionally, turfgrasses like seashore paspalum are now being used on golf courses in warm coastal climates (Figure 2.20). Seashore paspalum is a coastal grass that can be used for all golf course applications: tees, fairways, roughs and greens, and is able to withstand water with a much higher salt content than other golf course grasses.

Figure 2.20 – Use of seashore paspalum on a Coastal Golf Course (Forrest Richardson & Associates)

Economic factors closely influence the overall development picture in the golf business. However, there are also impacts to the design aspect of golf course architecture that are becoming more pronounced. Changing development types and land use priorities will closely impact golf course design in the future. The traditional residential golf course model evolved due to the economic benefits of selling housing lots with golf course frontage. Currently, the long-term feasibility of this model is being called into question largely due to the recent hits the housing market has taken. While the housing market will likely recover at some point, there are questions as to whether golf courses will ever play as large of a role in housing developments as they have over the past several decades. There are several possible scenarios for the future as this relates to golf course design. Because the economic viability of many golf course projects is directly tied to housing lot sales, there may just be fewer golf courses built. Industry experts tend to think that fewer golf courses, even if markets improve, is a likely scenario. Bill Kubly, owner and founder of golf course builder Landscapes Unlimited says, “Unfortunately, the United States golf course business will never be over 100 courses per year again no matter how good our economy gets.” (golfclubatlas.com)

Another alternative is that more new course development returns to core routings without the internal housing component. It is also possible that even with a housing market recovery, the demand for golf courses may be outweighed by other green space and recreation options. This is a scary scenario for those in the golf business, but one that was already beginning to take shape in many areas, even before the recent housing market downfall. Parks and trail systems have taken precedent over golf courses for many developers due to less space requirement, greater use by residents, and a larger value-added component.

As mentioned, water use limitations have led to regulations on irrigated turf acreage. This is not only an environmental issue as it also has serious economic repercussions for the golf business. From a design standpoint water use impacts both the golf course routing and the strategic intent of the architect. Width has always been one of the key components of strategic design as it allows for multiple options of play. With limited irrigated turf areas it is more difficult to obtain desired playing corridor widths. The routing of courses is also influenced as irrigated turf areas are limited. The result is

often the typical desert golf course routing with relatively narrow playing corridors separated by native vegetation, or in many cases, housing lots.

Another economic impact related to water use involves existing golf courses removing irrigated turf, often along the periphery of the course, and replacing it with a landscape that requires limited or no irrigation. This is most often accomplished by changing grass types, xeriscaping, or a replanting of native vegetation. In these situations the cost and maintenance resource savings can be great. Sonoma Ranch Golf Course in Las Cruces, New Mexico chose to replace acres of high water-use turfgrass along the course's perimeter with buffalograss. The buffalograss does not require regular irrigation, responds well to the severe summer heat, and is allowed to go dormant in the winter months. Under the guidance of golf course architect Forrest Richardson the Wigwam Resort in Litchfield Park, Arizona undertook a renovation program that included removing 26 acres of managed turf on 36 holes of the 54-hole facility (Figure 2.21). Approximately half of the turf acreage has been removed during the first phases of the project and replaced with low or no-maintenance landscaping that fits naturally with the desert climate. Wigwam officials estimate that they will see a cost savings of over $300,000 over a ten year period as a result of the changes. That figure includes the 20.5 million gallons of water that would have been required to irrigate the turf. Additional savings will result from the need for less mowing, overseeding, fertilizing, and weed, insect and disease control. (Bouts,2009)

Figure 2.21 – Low Water-Use Vegetation, Wigwam Golf Resort, Litchfield Park, Arizona (Forrest Richardson & Associates)

Water use is a perfect example of the important relationship between design and management in golf course architecture. Water use regulations often have a direct impact on the physical design of new golf courses. Water resources also influence the daily decision making of maintenance and management professionals. The result is water use being a factor that can severely hamper both the long-term economic and environmental sustainability of a golf course if not properly considered during the design and construction phases of a golf course project.

As illustrated by the water use example, the environmental and economic factors that will impact the future of golf course architecture should not be considered mutually exclusive. The need for environmental consciousness and stewardship has come more to the forefront in golf course architecture recently. Many golf course architects are now marketing themselves as being “green” and promoting their new platforms on environmentally sensitive golf course design. However, the practices promoted as part of this trend are not new. Many in the golf industry have long endorsed design and management practices that are environmentally responsible. The reason for this is often economically based as many of these practices not only help protect the environment, but cost less as well. Looking to the future, it will be in the best interests of golf course designers, superintendents and managers to carefully consider both the environmental and economic repercussions of their actions.

Advancing technologies will also play a role in the future of golf course architecture. Most designers already use computer software for the drafting and graphics components of the design process. Advances in the use of computer aided drafting have allowed for more precise construction documents and calculations. Additionally, graphics software now allows architects to present very realistic representations of their work prior to a single shovel of dirt being moved. The combined use and development of these resources will continue to make the design and construction process more efficient. It will allow architects to better communicate their design ideas to all parties involved in the golf course development, design and construction process.

Technology is also playing a key role in helping architects ensure that their design intent finds its way into the ground. Global Positioning System (GPS) guided grading and finishing equipment can create landforms in the field that very closely match those drawn

in plan. GPS technology is also being used to document existing contours and golf course component locations. This information can then be used to recreate key components when modifications are made. Another valuable application is to thoroughly map and document new golf courses. Due to the ever-changing nature of a golf course, things like mowing lines, hazard boundaries, and even green contours will inevitably change over time. The use of detailed GPS mapping allows for incredibly detailed as-built documents which will prove valuable in maintaining, or restoring, golf course features in the future.

Golf course architect Mike Nuzzo has been at the forefront with regards to using GPS technology throughout the golf course design and construction process. Nuzzo's background as a NASA aerospace engineer likely played a key role in his willingness to explore the benefits of using such technology in golf course architecture. On his recent Wolf Point project, located along the Texas gulf coast, Nuzzo created very detailed iterations of multiple routing plans as the design evolved and took shape. During construction he used computer generated plans that had been transferred to a hand-held GPS unit to ensure accurate installation and take-offs (Figure 2.22). These same detailed plans were used for cost estimation and material quantity orders as well. He was also able to document the as-built golf course precisely for future record. Nuzzo touts the importance of balancing careful field work with technological know-how and expertise. His system's benefits combine the freedom and creativity of drawing by hand with the precise, technological rigors and rote number-crunching abilities of computer aided design. While on site he is able to draw and locate features onto a tablet which directly transfers the information onto a base map that is accessible through a hand-held GPS unit. Identification of the exact location of particular site features while in the field allows for more detailed design and construction. The availability of editable detailed plans and maps while in the field also allows for instant computations of important data like feature areas, cut and fill volumes, and a bill of materials. (mnuzzo.com) Examples of technology usage like that by Mike Nuzzo shows the opportunities for utilization that can lead to more efficient and effective design. In turn, the same technology and applications can be used not only by designers, but by those who maintain and manage golf courses as well.

Figure 2.22 – Use of GPS Hand-Held Unit During Construction at Wolf Point Club, Port Lavaca, Texas (mnuzzo.com)

Bunkers

Portrayed in its simplest form, the game of golf consists of the golfer beginning each individual golf hole at a specified point, the tee, and working their way to a final destination, the green – specifically the hole. Along the way any number of hazards and obstacles may influence a golfer's path, intent, and mindset. Greens are the endgame of a golf hole, the place where each golfer ends up regardless of the path, and its length, that they took to get there. Greens also garner the most attention from golfers when analyzing their impact on the game and the importance of their conditioning. According to a 2005 Golf 20/20 survey, conditioning of greens and bunkers was the number one factor in golfer enjoyment and likelihood of return play. Not coincidently, from a maintenance standpoint greens and bunkers are usually the two most labor intensive and resource sapping aspects of a golf course.

The inclusion of bunkers and their conditioning as a differentiating component of golf courses deserves additional attention. After all, bunkers are defined as hazards in the Rules of Golf. The USGA defines a bunker as: a hazard consisting of a prepared area of ground, often a hollow, from which turf or soil has been removed and replaced with sand or the like. There was a time when the terms "bunker design" and "bunker maintenance" would have been very foreign to a golfer's vocabulary. Early bunkers were simple patches of exposed sandy soil that were afforded no formal maintenance or upkeep. Over

time, expectations of bunker design, quality, and maintenance have changed. Now bunkers have become the second most tended after component of a golf course behind greens. The result of this shift in expectations and the ensuing changes to bunker design and maintenance practices has had a profound impact on the game of golf from both a playability and economic standpoint.

History and Evolution

Had golf courses not originated amongst the sand dunes of Scotland, bunkers as we know them may not exist. Originally bunkers were exposed sandy areas found amongst the dunes (Figure 2.23). These early bunkers had no formalized shape or structure. In fact, they evolved over time, ever changed by shifting winds, animals and even golfers traipsing through them. Maintenance of these early bunkers simply did not exist. Golfers played their ball as it lay in the bunkers not matter the difficult condition. It was not until years later, usually in an effort to control erosion, that railroad sleepers or stacked sod were used to form bunker faces and edges. These early bunkers provided a true hazard, a place to be avoided, as golfers played their way over and between the dunes.

Figure 2.23 – Early Natural Bunker (Richardson, 2005)

Because of the role that bunkers played on the early linksland golf courses, they were recreated as new golf courses were built inland. Bunkers on the early inland golf courses would be considered very crude today. Usually very plain in shape, they were the result of limited earthmoving capabilities and constrained budgets. Bunker construction consisted of digging out a depression in the ground and depositing the excavated material

in front of, with regards to the line of play, the bunker (Figure 2.24). While not particularly attractive or complex, these bunkers were incredibly important to the development of golf course architecture. Today it is rare to find a golf course with no sand bunkers. Had bunkers not made the transition from the linksland to inland golf courses one of golf's most recognizable hazards may have simply never existed.

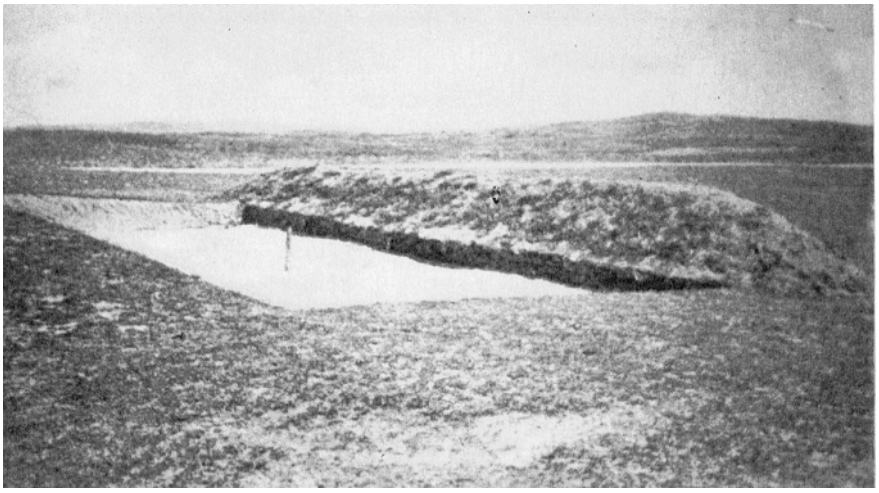


Figure 2.24 – Early Geometric Built Bunker with Earthen Berm

As golf course architecture became more developed and complex, bunkers again evolved. By the Golden Age efforts were made by golf course designers to create bunkers that mimicked the shape and style of those found naturally. Jagged edges and free-form shapes were all the rage. Bunkers were also located to fit or sit into the land, much like the early bunkers amongst the dunes. Canadian golf course architect Stanley Thompson's sentiments toward bunker design reflect the feelings of many of that days top designers (Figure 2.25):

> "Nature must always be the architect's model. The lines of bunkers and greens must not be sharp or harsh, but easy and rolling. The development of the natural features and planning of artificial work to conform to them requires a great deal of care and forethought." (geoffshackelford.com)

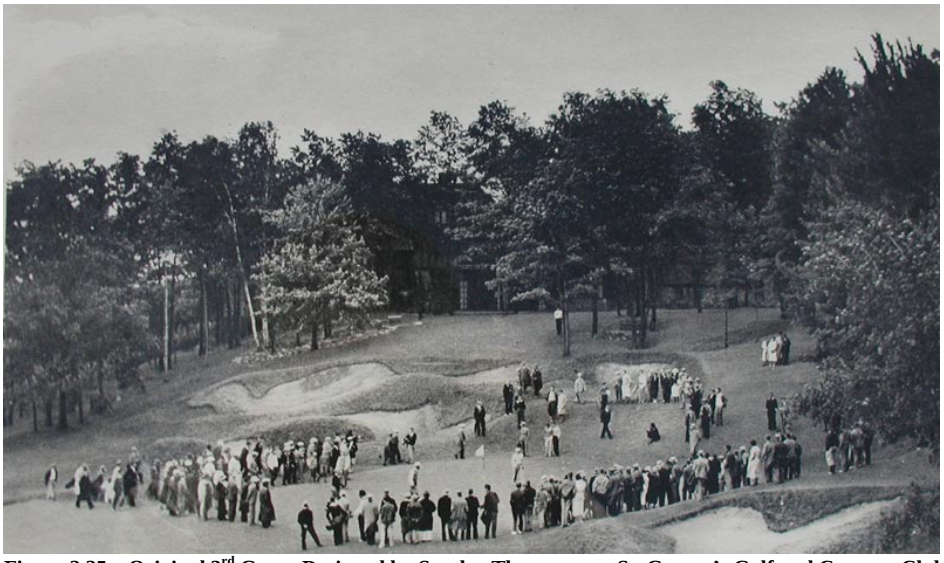


Figure 2.25 – Original 3rd Green Designed by Stanley Thompson at St. George's Golf and Country Club, Ontario, Canada (golfclubatlas.com)

The aesthetics and form of bunkers began to play as large of a role as the bunker's function. Prolific bunkering of golf courses, sometimes hundreds on a single course, became common. Golf course architects of the time such as Alister MacKenzie and Goerge Thomas are still known today for their epic bunker designs (Figure 2.26). Even Seth Raynor, whose bunkers looked engineered and geometric, designed courses where bold bunkers were the primary hazards.

Figure 2.26 – George Thomas Designed Bunker at Riviera Country Club, Los Angeles, California (golfclubatlas.com)

Unfortunately the trends in bunker design followed those of golf courses in general after the end of the Golden Age. The 1950s saw the proliferation of rather simplistic bunkers that while not particularly interesting, were easy to build, maintain and get out of. The role of bunkers as a feared hazard had been somewhat diminished by this time. Some of this was due to the development and proliferation of the sand wedge which made play out of bunkers more manageable for most golfers. However, the design and maintenance of bunkers were most responsible for the change in bunkers' roles. More than at any point in the history of golf, bunkers had become eye candy for the golf course. Instead of being placed along the line of play to challenge the golfer, bunkers were pushed to the perimeter of holes and located to provide pretty backdrops behind greens. The push to create bunkers inspired by nature had also dropped off. Bunker conditioning and appearance became the new priorities. Much time and effort was given to maintaining bunkers with crisp edges, smooth shapes, and bright white sand. For better or worse this trend continues in many places today. Of course there were exceptions to the simplistic bunkers, and golf courses, seen following World War II. Robert Trent Jones and Dick Wilson both designed numerous first-rate courses during the post-war modern era. However, the majority of new golf construction featured bunkers without the clout of their best of their predecessors from the Golden Age.

Bunker Types and Roles

Bunkers come in a plethora of shapes, sizes and styles. In the words of Ron Whitten:

> Bunkers are far more than just sandy holes in the ground. They're a state of mind, setting the tone for the round, disclosing the character of the course, revealing the attitude of the architect. Bunkers can be saviors or executioners, beacons of surprises, annoyances or eye candy. (2008)

In a November 2008 Golf Digest article (pp. 112-117) Whitten identified and described 25 types of bunkers. While there are no doubt other bunker types and styles, some having existed for decades and some likely being developed today, Whitten's list and its examples provides a broad and informative look at bunkers around the world. See figures 2.27 – 2.30 for the corresponding pictures.

1. Pot Bunker – Royal St. George's, England – The original art form, carved from rolling linksland by animas huddling against winter winds, further excavated by hackers over countless summers. Pot bunkers remind us that golf can be a cruel game.
2. Cop – Wentworth, England – When man began digging bunker, piling earth in front of the hole to form a "cop" (a ridge or mound) was an efficient way to add severity without digging too deep.
3. Strip – Bellport, New York – First utilized by C.B. Macdonald to generate fill for tees and greens, or as steps down extreme slopes, strip bunkers usually run parallel to the fairway or green.
4. Cross – TPC, Boston – Invented more than 100 years ago, when golf was mostly a steeplechase game, cross bunkers are making a comeback as a means of forcing the game's long hitters to hold back off the tee.
5. Stacked Sod – Carnoustie, Scotland – Also invented more than 100 years ago on sandy links. Strips of sod were stacked in near-vertical fashion to keep buker faces from collapsing. Known as revetted bunkers in the U.K.
6. Grassed-Faced – Westhampton, New York – The earliest American bunker style featured flat sand with an inclined face of clumpy fescue. Once Americans began routine irrigation in the 1960s, grass faces posed mowing problems.
7. Bulkhead – The Golf Club, Ohio – On a trip to Scotland in 1963, Pete Dye saw many clubs using railroad "sleepers" instead of stacked sod. Once home, he introduced abrupt changes to bunkers and water hazards.
8. Moon Craters – Lost Tracks, Oregon – Popularized back in the 1960s, oval bunkers – carefully matched to the turning radius of a motorized sand rake – are the easiest to maintain and mow around.
9. Capes and Bays – 3 Creek Ranch, Wyoming – More artistic than crates but not ridiculous to maintain, particularly if bays of sand accommodate power rakes.

10. Walkways – John's Island West, Florida – Bunkers need to be hand-raked after every shot. Tom Fazio often elongates his capes so golfers never have to rake more than a few yards of sand.
11. Mackenzie – Augusta National, Georgia – The artistic Alister Mackenzie primarily used a bunker style based on the ebb and flow of wind-swept sand dunes. His most famous, on the 10th fairway, lost its ragged edges decades ago.
12. Thomas – Bel-Air, California – George C. Thomas Jr., an equally artistic Mackenzie contemporary, likewise tried to emulate sand dunes on his handful of California designs. His many jagged edges, once lost, are being restored.
13. Trent Jones – Metedeconk National, New Jersey – His jigsaw-puzzle pieces capture the sand-dunes look, but many of the hard-to-maintain "feathered edges" have been chopped away.
14. Thick Lip – California Golf Club of San Francisco, California – Labor-intensive jagged edges are making a comeback, as are short, abrupt vertical edges that some designers call "heavy eyebrows."
15. Sculptured – Atlanta Athletic Club, Georgia – The goal is to mesh artistry and playability with practical maintenance. But with capes and bays as well as jagged edges, is it a Henry Moore sculpture or a kitchen sink?
16. Flashed Sand – The Vintage Club, California – Tom Fazio uses "plaster sand" to achieve near-vertical faces; balls bounce off and roll to the bottom. Most architects use softer sand over a fiber drainage mat to create steep slopes that won't was away.
17. Blow Out – Sand Hills, Nebraska – Bill Coore and Ben Crenshaw gouged holes into sand hills, then let winter winds shape them into natural bunkers. Problem was, as the wind blew, the bunkers grew.
18. Hybrid – Dakota Dunes, Saskatchewan – The most popular style today is a hybrid, meant to look like a "blow out" bunker but with capes, bays and edges precisely carved and stabilized.

19. Ragged and Woolly – Black Sheep, Illinois – Another hybrid version inspired by Sand Hills, but planted in an old cornfield, is merely a jagged-edged cop bunker with tall, thick, native grasses substituting for an earthen cop.

20. Erosion – Bayside, Nebraska – The newest style of sand bunker imitates the narrow channels and rivulets created when streams of water erode hillsides. But these miniature canyons take just days, not eons, to create.

21. Beach – Kittansett, Massachusetts – The original was a ocean beach at Kittansett. The concept was reintroduced in the 1970s by Arnold Palmer, who recommended a bunker blend directly into a water hazard.

22. Buffer – Long Point, Florida – Long strip bunkers protect balls from bounding into water hazards. Critics insist these are architectural double negatives, one hazard negating the other.

23. Waste – Long Bay, South Carolina – While building Harbour Town, Pete Dye covered a sewage ("waste") pit with coquina shells. Gritty imitations followed, along with local rules allowing the grounding of a club in waste bunkers.

24. Transition – Desert Highlands, Arizona – To avoid the harsh transition between lush rough and rocky desert, in 1982 Jack Nicklaus created massive stretches of maintained sand to give high-handicappers a break.

25. Art Deco – Tullymore, Michigan – The signature style of Jim Engh, whose bays of sand and noses of turf provide a soothing comfort. (Golf Digest, November 2008, 112-117)

Figure 2.27 – Bunker Types (Golf Digest Magazine, November 2008)

Figure 2.28 – Bunker Types (Golf Digest Magazine, November 2008)

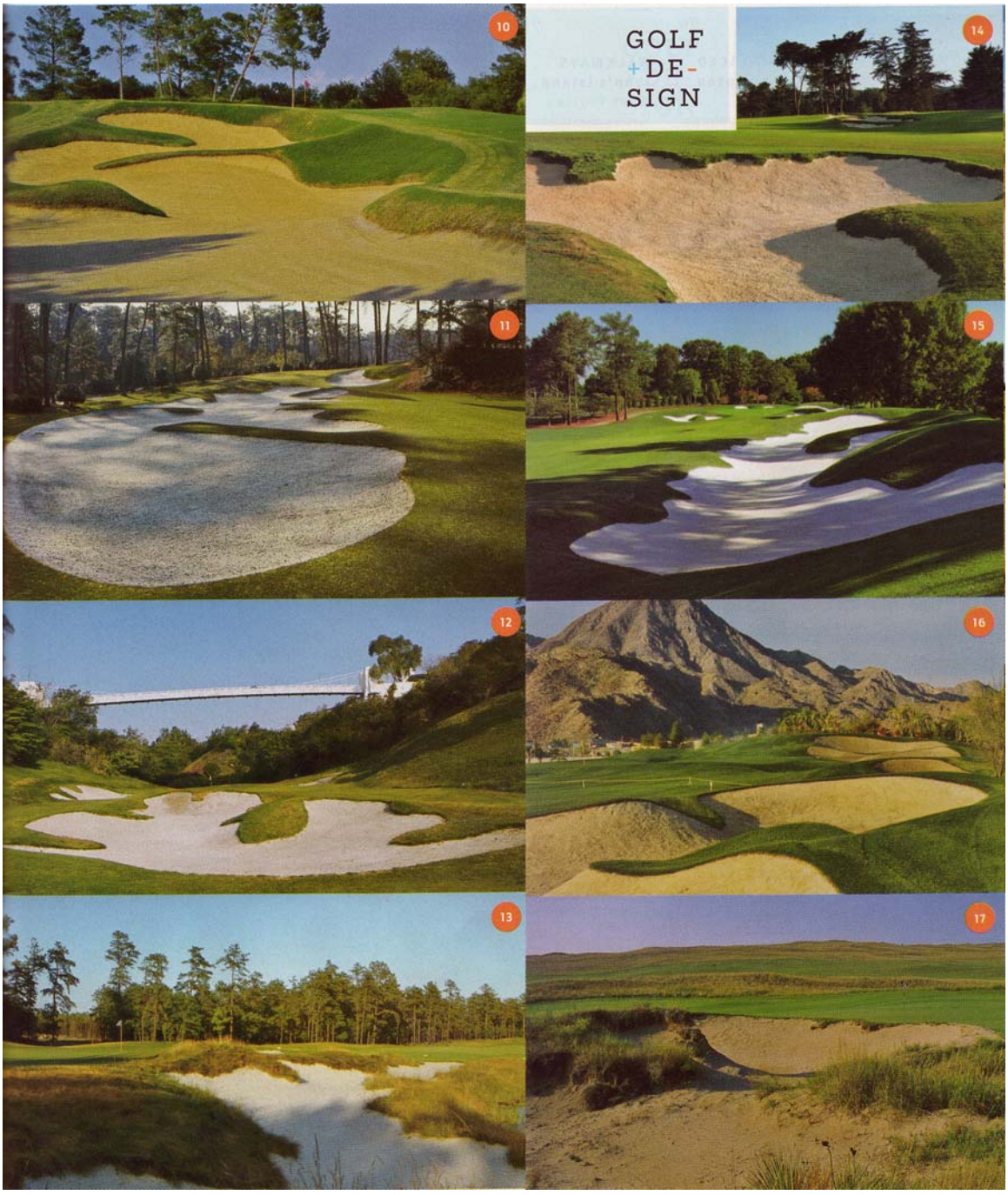


Figure 2.29 – Bunker Types (Golf Digest Magazine, November 2008)

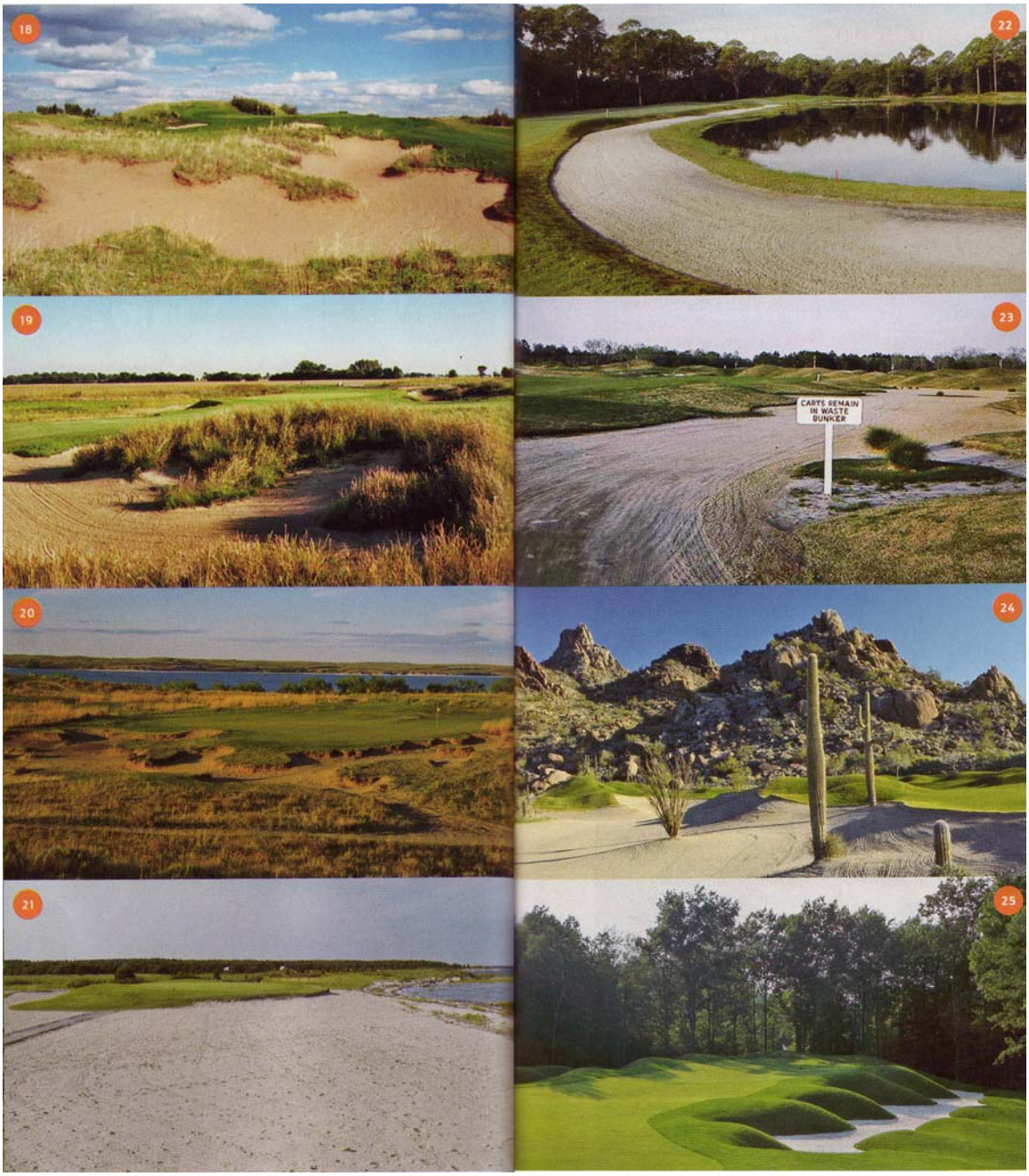


Figure 2.30 – Bunker Types (Golf Digest Magazine, November 2008)

The roles that bunkers should play are a point of debate and contention among all involved in golf. From a design standpoint bunkers may serve a variety of function that include, but are not limited to aesthetics, penalization, strategic interest and containment. While much discussion can go on trying to define the role of each and every bunker, often times the most attractive and effective bunkers do not serve a single purpose. Instead they serve multiple roles while appearing to have been naturally found where and how they currently exist. The achievement of that bunker condition may just be the secret of great bunker design.

The following bunker roles have been identified for the purposes of this study and the associated survey questionnaire. While these are by no means all of the potential roles of bunkers, they encompass the most common ways that bunkers are used.

Aesthetics – Bunkers provide aesthetic interest to golf courses. Golfers tend to remember courses for their aesthetics and conditioning so this can be a very important role. Often bunkers are the major visual component used to define a golf course style. Other times bunkers are used to highlight or emphasize other golf course features. In either case the use of bunkers can have a significant influence on the aesthetic impact of a golf course.

Penalization – Bunkers can be used to penalize golf shots that are not properly executed. When located adjacent to landing areas or greens bunkers collect wayward shots that do not find their target. The key to a bunker's role of penalization is that the golfer should suffer a consequence from finding the bunker. Bunkers meant to penalize are often more sever in their physical characteristics than those that serve other singular roles.

Strategy – Bunkers that must be challenged in order to reach the target or achieve the preferred line of play serve a strategic role. The most common strategic bunker example would be one that tempts the golfer to "bite off as much as they can chew" or play close to in order to provide a shorter approach or more preferred line of play. In theory strategic bunkers may allow for more recoverability than penal bunkers, although this is debatable.

Provide Visual Cues – Bunkers can be used to provide golfers with cues as to where to hit the ball or to steer them clear of worse trouble. Blind holes may feature an aiming bunker that indicates the preferred line of play. Some designers regularly place bunkers on the outside of doglegs to visually "turn" the hole.

Containment – Bunkers are often used to keep golf balls from finding a worse fate. On severe sites bunkers near greens and landing areas my catch golf balls that would otherwise follow the contours until far away from the playing areas. Bunkers are also sometimes used between the target area and hazards for the purpose of graduated penalty. Some designers believe that slightly off-line shots should not suffer as harsh of consequences as shots that are more wayward. Bunkers near the target area will contain the slightly missed shot, keeping it from finding the harsher hazard located further from the target.

Bunker Design

Bunker design is influenced by a multitude of factors that vary in their scope and impact depending on the project. One of the major objectives of this study is to identify these factors that influence bunker design. However, once identified, it is very difficult to quantify or rank specific factors to a finite degree. From the experiences of professionals in the design, construction and maintenance fields it is possible to identify which factors must be taken into consideration on a regular basis. These key factors will nearly always play an important role in bunker design due to their inherent importance to the role of bunkers in the game of golf and the structural integrity of bunkers as built components of a golf course. It is important to remember that nearly all of the factors influencing bunker design are interdependent. As such, they must be considered together and not as isolated components of the design process. Depending on the situation, particular factors will take precedent. However one must be careful not to diminish the importance of perceived lesser factors. Key factors identified and discussed in this section include the bunker's intended role, aesthetics, playability, and drainage.

The role that a bunker is meant to play within the context of a golf course may be one of the most important factors to consider during the design phase. The various roles,

identified previously, determine much about the desired size, shape and location of a bunker. It may also help determine the materials used in the bunker and the long-term maintenance expectations of the bunker. Because bunkers often play more than one role, it is important to establish what a bunker's priorities are. For example, a greenside bunker may be strategic, penal, and saving all at the same time. It is strategic because it influences the preferred line of play on the approach shot and may even dictate the best placed tee shot on a par 4 or 5. The bunker is penal because it is steep-faced and deep, almost guaranteeing a severe penalty for finding it. At the same the bunker is saving because it keeps slightly wayward shots from finding an unplayable fate further down the slope in thick native vegetation. The key during the design phase is to create a bunker that fulfills all of these roles to the extent desired.

Bunkers are one of the most important visual components of golf courses. Aesthetics must be considered as the golfer's initial introduction to most hazards is visual. From a design standpoint, characteristics influenced by aesthetics include bunker shape, size, location, and material makeup. The aesthetics of bunkers also play a key role in the strategic challenge presented by a golf course's design. Bunkers can serve the purpose of visual intimidation, deception, camouflage, or in some cases even lull the golfer into a false sense of security.

Drainage of both surface and subsurface water plays an important technical role in the design of bunkers. Poor drainage is probably the chief culprit when it comes to bunkers that are difficult to maintain and manage. Water that drains into a bunker from the bunker surrounds will cause erosion of sand and subsurface material in addition to compromising the overall physical integrity of the bunker. Material that is carried by water draining into a bunker will also increase the likelihood of bunker sand contamination. Additional problems arise when water that has found its way into a bunker cannot drain properly into the ground (Figure 2.31). Standing water in bunkers must either be pumped out, a labor intensive undertaking, or left to slowly soak into the ground or evaporate.

Figure 2.31 – Erosion and Standing Water in Bunker Following Rain Event (Author)

The most obvious solution to reducing surface drainage related issues in bunkers is to limit the surrounding surface area that drains into a bunker in the first place. While delightfully simple, this solution is not always perfect. Bunkers are usually found in hollows, depressions and other low-lying areas set below the grade of the surrounding land. To eliminate surface drainage into bunkers landforms redirecting water would be required around, or at least on the uphill side, of bunkers. Unfortunately, this engineered solution has been used to the extreme in some cases and results in very unnatural looking bunkers that are visually and physically cut off from their surrounds. The best option is to judiciously use landforms to keep surface drainage out of bunkers to a reasonable degree while maintaining a natural appearance.

Surface drainage can also be picked up on the high side of bunkers with catch basins and drain inlets or retained in swales. Contemporary golf course design tends to rely more heavily on the use of drains and catch basins than in the past. While technological advances have made the use of complex drain systems more attractive and less expensive, there is genius to be found in the grading and use of contours to deal with runoff on golf courses. It can also save money that would be spent on pipes, drains and the ongoing maintenance of such components. That being said, the use of drain systems

has allowed for substantial improvements in golf course conditioning and playability, particularly on sites with poorly-drained soils or little elevation change.

Internal bunker drainage can be handled in a variety of ways. Bunkers built into a well-drained sandy subgrade may require little, if any, internal drainage. On most projects, however, ensuring proper subsurface drainage in bunkers is one of the most important aspects of the construction process. Much time and money is spent to install drainage tile, gravel, liners and other materials that, although hopefully never seen by the golfer, are vital to the long-term quality of bunkers.

While the above factors' importance to the bunker design process is obvious, the way in which they are applied is not as clear-cut. The bunker design process varies significantly between different architects and different projects. Some architects carefully design bunkers in plan and rely on the project's contractor to faithfully execute those plans in the field. At the other end of the spectrum, some architects show few bunker details in their plans and rely on in-the-field time to specify exact location, size and shape. Whether the process is formalized or not, a key factor in the bunker design process is who makes the decisions regarding final bunker design. While at first glance this may seem a bit trivial, after all doesn't the designer design the bunkers, it is much more complicated.

There will almost always be a difference in interpretation of design intent between the designer, contractor, project manager, shaper, and laborer. Each of these individuals can play a major role in the decision making process during bunker design and construction. While it is assumed that the architect makes decisions related to design, an architect who does not closely monitor or observe construction may have very little say in the final product when it comes to bunkers. In such a case the construction professionals who are actually putting the design in the ground will most likely make design-related decisions unless strictly specified otherwise by plans. Even in the case of detailed plans, conditions that arise during construction often dictate changes in the design that were not foreseen. The danger in any situation like this is that the design intent of the architect

may be lost or compromised. An insightful note on the importance of the role of the golf course architect in the supervision of the construction process comes from famous Golden Age architect William Flynn:

> No club should expect and no architect should consent to submit plans and specifications and then not supervise the construction. The architect's reputation depends on what he produces. If he allows others to carry out his ideas the chances are strongly in favor of confusion that will result in a botched job. (geoffshackelford.com)

An additional, and very important, variable in the bunker design process is the structure of the design process itself. The application of the decision making resulting from design factors can take place in a variety of ways. These applications fall into two main categories – formalized design plans and in the field design. Experts in the field of golf course design and construction tend to identify with one approach or the other, although many of the most successful practitioners understand that there must be room for some gray area in-between. In other words, even the best laid plans must be open for revision if required during construction and in the field design work must always fit within the overall working plan of the golf course.

Some architects choose to make almost all bunker design decisions in the field during the construction process. In such cases, preliminary plans, if present, may not show any bunkers or bunkers may be included only as general placeholders within the routing. This approach lends itself to both increased flexibility and interpretation during the construction process. To some this is easily the preferred method and it is used to great creative success. Essential requirements of this approach include careful oversight of the process by the architect and a skillful crew of construction professionals who can effectively create the architect’s vision while ensuring sound technical and engineering practices.

One of the most important benefits to in the field design occurs when dealing with issues of scale. Often times golf course features, whether its bunkers, mounds, or water hazards, appear out of place due their not fitting in with the scale of the golf course or its surrounds. Although somewhat oversimplified, the general rule is that larger features fit best on open sites with long views and smaller features fit best on more enclosed, self-

contained sites. This does not mean that small features cannot be used on a sweeping open site. The key in such an instance is to work a smaller feature into a small or less bold existing contour in a way that it appears to fit with its immediate surroundings. The potential disconnect usually occurs when a tiny bunker or mound is fit into a large, bold existing contour. The result almost never looks natural. Mounds in such an instance look unnatural and often resemble pimples on the landscape, not an attractive feature. The benefit to designing in the field is that scale issues and their solutions are much more apparent when working in three dimensions. In plan it is difficult to get the scale of golf course features and their tie-ins to existing elements just right. Some leeway is necessary when constructing golf course features from plan to ensure that the features fit with their surrounding in a believable and visually appealing way. If leeway is not given there is a much greater chance that constructed elements look and feel out of place.

Issues with the in-the-field design approach are most likely to arise when a lack of architectural oversight results in a loss of the architect's intent. This approach lends itself to decision making by whoever happens to be close by when the time comes to build a bunker. Ideally the final decision is made by the architect or a trusted associate (Figure 3.32). However, without the proper oversight their decisions may be changed during construction or simply not sought at the proper juncture in the process. While the architect may have been present to locate and size specific bunkers, when the time comes to determine sand lines, often at a later date after grassing has occurred, the entire visual and strategic intent of the bunker may be changed without the architect's input. This is why it is so important to have a high level of oversight and communication when designing golf course elements in the field during the construction process.

Figure 3.32 – Forrest Richardson Marking Proposed Bunker Edges, Peacock Gap Golf Club, San Rafael, California (Author)

Another issue with the in-the-field design approach revolves around the arrangement that has been set up for getting the golf course built. Many architects that apply the in the field approach are closely involved in the construction of the golf course. In some cases, Tom Doak's Renaissance Golf Design is an example, this means having several design associates on site at all times who personally carry out and oversee the design, shaping and finish work. (T. Doak, personal communication, March 4, 2009) This is in contrast to the more common approach where an outside contractor is hired to build the golf course from a set of detailed construction plans provided by the designer. While the in-the-field approach can be successful with a contractor and project manager, it is much more difficult due to the ever-changing and evolving nature of the work. Most contractors would rather be presented with a set of plans and told to build the golf course from them. In such a situation cost estimating is easier and other variables are less likely to change significantly as the project progresses.

Like in-the-field design, the design approach that focuses on formalized plans has its benefits and potential pitfalls. In theory this approach makes the architect's intent more clear and leaves less room for misinterpretation during the construction process. It also allows for more precise calculation of earthwork to be done and materials needed for

bunker construction. A skilled golf course shaper can take a detailed grading plan and very closely build the designed elements (Figure 2.33). Experienced shapers are able to very accurately create desired slope percentages or grades, often by feel without the need for measurement. However, a potential pitfall arises in the nuances of construction. Each shaper and golf course contractor develops their own style and way of doing things over time. As with all steps in the construction process, oversight by the designer is necessary to ensure that what is built fits with their intent. Shapers can closely follow the plan and meet every grade stake but still create a feature that does not fit within its surrounding. In many cases this may be the fault of the architect for designing a feature that does not work, in which case it should be changed from the plan. It may also be the fault of the shaper for not understanding the nature of golf course shaping and the way features should blend together as naturally as possible.

This is illustrated by the story of the experienced highway contractor who bid and was awarded a golf course project. Although very skilled and keenly aware of the detail necessary to meet all specified grades and elevations, the contractor was not familiar with golf course shaping. The result was fairways graded nearly flat with long slopes, like you would expect to see on a roadbed. All specified elevations and grades were met and the fairways would have drained properly. However, the graded fairways obviously did not fit into a golf course and had to be redone. This story goes to show the importance of communication during the process between those who design and those who build.

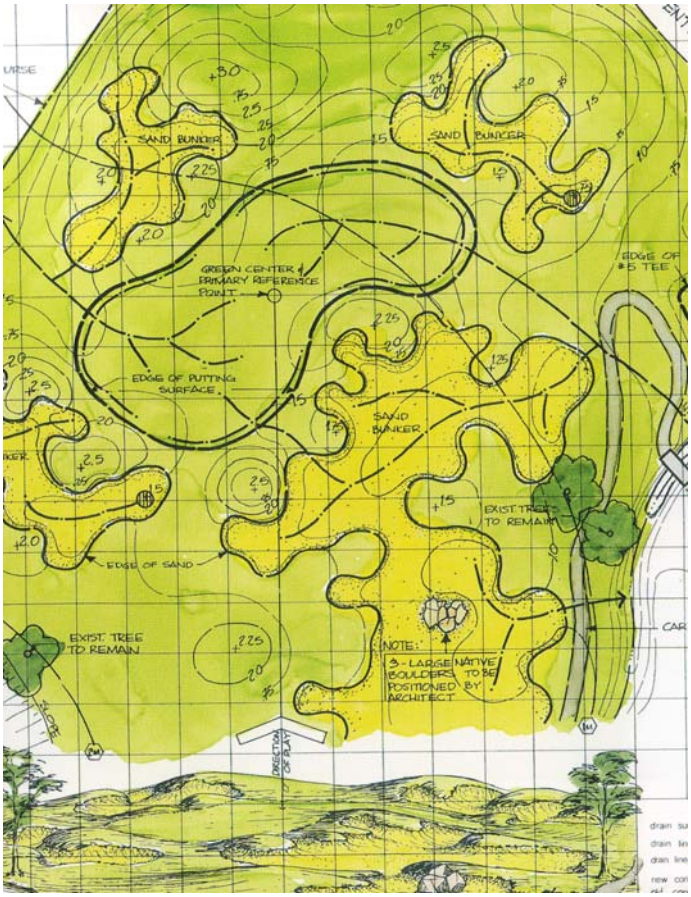


Figure 2.33 – Green and Bunker Surrounds Plan, Bali Handara Golf Course, Indonesia (Daley, 2003)

Those who design and build golf courses primarily from plan argue that plans are a key component of the communication between designer and builder. After all they say, isn't one of the major issues with designing in the field the need for constant and careful communication of intent. Well what better way to do that than with detailed plans? At the same time designers who work in the field claim that an over reliance on plans handcuffs the creativity and flexibility needed to produce the best finished product. In the end it is clear that closely followed detailed plans, if not carefully developed after significant site reconnaissance and thought, can lead to golf courses that do not fit with their surroundings and may not take advantage of all available resources. Conversely, in the field design that is not properly supervised and calculated may lead to features that while appealing, are difficult to build and lack proper technical merit. In either case it is key that the process is carried out correctly, regardless of the approach taken by those involved in the design and construction (Figures 2.34 and 2.35).

It is important to note that these two design approaches, although cleanly separated and defined here, are often applied together to some extent. In fact this happens even when the overall design approach clearly leans one way or the other. Often time detailed plans may be drawn but are tweaked in the field in response to on-site variables or to yield the intended outcomes. Specific bunker edging, the sandline, is usually painted and cut in the field and while the bunker's overall shape and size may resemble the plan, the details of its capes and bays may vary considerably. At the same time, many architects who do a significant amount of design work in the field are still required to produce plans in order to secure the permitting and approvals necessary to begin construction. Each golf course architect goes about the design and construction management process in their own way and for their own good reasons. When looking at the overall depth and complexity of a golf course project it becomes very apparent that no matter the approach, golf course construction is not simply a mater of creativity or engineering but a melding of the two.

Figure 2.34 – Architect Supervision of Bunker Construction, Hole 2 Coldwater Golf Course, Avondale, Arizona (Author)

Figure 2.35 – Bunker Following Final Shaping, Hole 2 Coldwater Golf Course, Avondale, Arizona (Author)

Bunker Construction

More so than with just about any other golf course component, it is difficult to completely separate bunker design and construction. In many cases bunker design takes place up to, and during, the bunker construction process. The previous section on bunker design includes many references and explanations of processes that could easily fall under the construction heading. This construction section will focus primarily on the technical aspects of bunker construction including specific steps of the process and the methods and materials used to create a bunker.

Golfers' expectations of sand bunker conditions have increased significantly in recent years. The professionals who maintain and manage golf courses have been forced to increase their bunker related efforts to keep up with these expectations. A very important, and often overlooked, component of a bunker's upkeep and maintenance takes place long before any golfer finds their way into it. This component is the actual physical construction of the bunker. The proper use of materials and methods in bunker construction can make or break a bunker project. A poorly constructed bunker will lead to all sorts of headaches for maintenance professionals and golfers alike. Poor playing

conditions, drainage issues and increased maintenance costs are just a few of the potential pitfalls. Poorly built bunkers will also likely require expensive modification at some point during their lifetimes. Well built bunkers, on the other hand, are attractive in their appearance, effective as golf hazards, and usually need less maintenance.

Methods

Bunkers come in a multitude of shapes and styles. There are also many different methods that can be used to construct and shape the final bunker product. However, when simplified, there are three basic methods for beginning the bunker construction process. Forrest Richardson identifies and defines these in his book *Bunkers, Pits and Other Hazards* (p. 181) *(*Figure 2.36).

The Import Method – Fill material is brought in and used to create a hillock or rise. A depressed area is left, and becomes the bunker. Planning must ensure that there is ample material available to be brought in; if it is to be robbed from somewhere else, this must be part of the plan. (a)

The Export Method – An area is dug out to form the bunker, with material taken away to other areas. In essence, this is the quintessential pit that has been carved out. Most pot bunkers are built by this method. It results in a depression, while leaving the surrounding area alone. The residual material must be dealt with. It is often needed nearby for another purpose. (b)

The Balance Method – The bunker is formed by digging out the lower portion and using excavated material to create rises behind or around the resulting low areas. On sites with minimal earthmoving and areas that are to be left undisturbed, this method is preferred. All in all, it is the most efficient if the design can accept this localized approach of borrowing and exchanging material. (c)

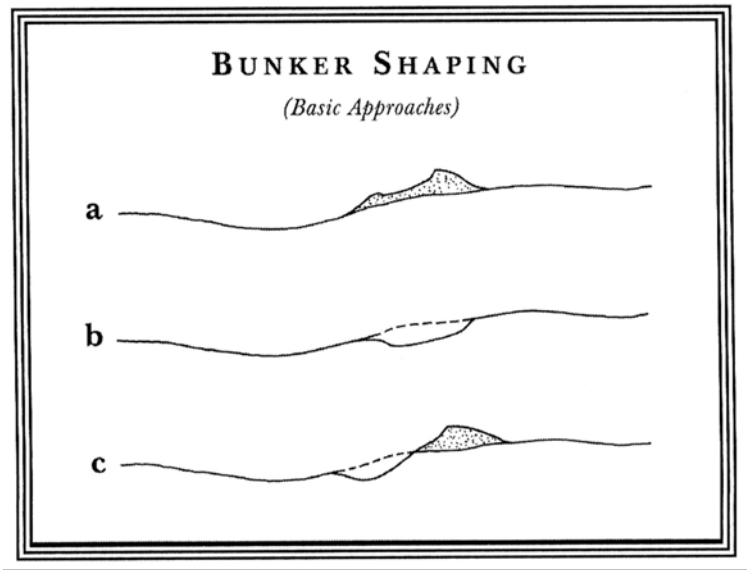


Figure 2.36 – Bunker Shaping Methods (Richardson, 2006)

The correct bunker construction process is vitally important to the quality of the finished bunker. Again, there are numerous variations on this process. However, when boiled down to the essentials, Forrest Richardson identifies the following steps which make up the most common sequence of events. (2006, pp 183-186)

1. Strategy Determination – A routing plan will drive design, and this will eventually drive the location, shape, size, and style of the bunker. Such aspects as severity, recoverability, and intimidation should be in mind at this point. In a nutshell, at this stage the bunker is being brought to life by the golf architect, even though its design may still be fluid.
2. Specifications – A bunker should be appropriate for its locale. Drainage, soil types, and play intensity will all affect how it needs to be built. At some point in the development of the plans for the golf courses, the specifications will be solidified and there will be more detailed plans or even renderings for the style of the bunker. The specifications and plans will spell out how the bunker is to be constructed. Ultimately, this will determine the quantity of materials, costs, and resources required. The golf architect thinks about this for each and every bunker, for it is a sure bet that the golf course contractor will do so.

3. Field Verification – Once a project is approved for construction, it is customary that the location of the bunkers be identified in the field, as are all of the other features: tees, clearing limits, greens, and so on. This may be done with wooden lath stakes, small flags, or outlines painted on the ground by the golf architect or his representative. Reference points are taken from plans and located on the ground. Occasionally, this is accomplished with GPS survey equipment. In the case of a mass graded site, the process of actually marking the bunker may wait until earthwork (grading) is complete, at least to a point at which the location of the bunker can be better defined. Regardless, a certain level of field verification is always done before equipment begins to transform a golf hole. (When a golf hole is built, it is common for the centerline of the hole to be established by bulldozers once the tee, angle point[s], and green are staked. This allows the golf course architect to walk the hole and fine-tune the limits of clearing, decide which trees and vegetation might remain, and adjust the location of features and hazards that have been designed into the hole.)

4. Clearing and Grubbing – The bunker work cannot continue on a wooded or covered site until the area to be worked has been cleared and grubbed. Clearing is the removal of vegetation and debris from the surface. Grubbing is the removal of roots and stones from a defined area below the surface. This defined area will vary depending on the soils and preferences. In some cases, of course there may be no need to clear or grub – the natural land might fit perfectly into the golf hole.

5. Rough Shaping – By this time, the golf architect has been joined by plenty of assistants. A shaper has been entrusted to transform the lay of the land. This may be an enhancement of what was already there, or is may be something created by drawing contour lines and assigning target elevations for the heights of landforms, mounds, and low areas. However it is communicated to the shaper, the area of the bunker and the bunker itself have now come to life. If we assume that the bunker described here

is a depression with a slightly raised back, then we can envision a useful trick described by Robert Trent Jones, Jr. in his book Golf by Design: "Sometimes we place white bed sheets in the bunker to test their visual qualities." Jones is referring to how the bunker reads from the tee or origin of the various shots that might be played around, over, or into it. Jones's tip has been passed down by generations of golf architects, and it works rather well. The key at this stage is approval of the bunker. The balance of work to be done should not be contemplated until the basic formation, relationships of grades, and general shape is accepted by the golf architect. Visibility is often a priority.

6. Drainage and Irrigation – The plumbing is next in our sequence. Drainage is installed by a variety of means, with the sole purpose of removing water from the bunker. The most prevalent source of water intrusion in bunkers are irrigation sprinklers and, of course, rainfall. Irrigation is installed around the bunker wherever turfgrass is to be established. Ideally, it is diverted away from the bunker as much as possible. This infrastructure (the drainage and irrigation) is often destructive to the progress that has been made in forming and shaping the bunker. Although it does not sit well with irrigation workers, a favorite term for irrigation trenching, pipe laying, and equipment traversing is the irritation phase.

7. Finishing, Edging, and Stabilization – After the plumbing is installed, it is up to the finish shaper to restore the desired shaping and finalize the bunker (that is, to "finish" the bunker). In many cases, this is done by hand with crews working to trim edges, build noses and intricate shapes, and rake areas to the subsurface that will form the floor of the bunker below the sand. In terms of stabilization, the bottom and slopes of bunkers may need to be held in place by any number of means; extra compaction or special fabrics and spray applied coatings. These efforts can help to prevent sloughing of soils and erosion. Fabrics and coatings can also help

reduce sand erosion on steeper slopes by forming a base on which sand is more apt to stay put.

8. Sand Placement – After everything is finished and approved, it is time to place the sand. There are different ways to accomplish this. The most common method is to place the sand in a pile within the bunker, protecting it from the edges, where silt may intrude into the depressed area during the establishment of grass in the surrounding area. Very often, the pile of sand will be covered to keep it free from dust, which may be present across the construction site.

9. Final Edging – The detail work or establishing the edge of the bunker is completed. It may have been done even prior to Step 8, but on occasion there will be more detail work to be performed. Sod or native grasses might be laid by hand around the edge or in back of the bunker. The tie-in of fairway and rough areas may still need to be raked and floated up to the edge of the bunker.

Bunker modification projects follow a similar sequence of events. However, care must be used as modifications are taking place on an existing course rather than a construction site. Consideration needs to be given to limiting damage to the areas adjacent to bunkers receiving work. Additionally, play continues on the course during many bunker modification projects. Planning should be done to help limit the disturbance caused by construction and address any safety issues that may arise. John Connolly, golf course maintenance and management consultant and former USGA agronomist, has identified the following process as a common bunker modification construction sequence (Connolly, 2007):

1. Survey and stake according to a detailed drawing with written specifications. Determine cut, fill and soil need.

2. Prepare enough plywood or other material that will support traffic and minimize turfgrass damage.

3. Remove sod around the bunker.

4. Locate drainage exit and place a wire mesh over pipe opening.

5. Remove sand and old drainage. Stockpile contaminated sand for use surrounding the bunker.

6. Detail staking, shaping, and cut and fill as per the plan. Stockpile topsoil and import fill if necessary.

7. Install perimeter irrigation.

8. Stabilize bunker edge using plywood, sandbags or other materials.

9. Compact and smooth bunker base.

10. Install bunker liner following manufacturer's recommendations.

11. Install sand to a depth of five to six inches, then compact wet sand.

As with new bunker construction there is no single method or sequence for bunker modifications that is used every time. Different design influences, site conditions and project goals will result in varied approaches. However it should be noted that the inclusion of the steps identified above by Connolly form the basis for a successful and comprehensive bunker modification construction project. Without careful planning and diligent construction operations the end result of a bunker modification is bound to produce bunkers that have just as many problems as their predecessors which were supposedly being fixed.

There is a broad spectrum of equipment that can be used for bunker construction. Horse-drawn pan-scrapers and shovels were once the norm. However, since the use of modern earthmoving equipment became standard, the most common approach has been to rough-shape bunkers with a small to medium bulldozer and everything from skid-loaders to excavators to backhoes to hand-labor to finish the bunker. Even with all of the equipment available, the floors, faces and edges of many bunkers are still finished using rakes and shovels to ensure the level of detail and precision necessary.

The use of excavators to completely shape bunkers is becoming more popular. Some architects and shapers swear by the use of a single excavator to build an entire bunker as opposed to using several pieces of equipment to rough-shape and then fine tune. Excavators with "knuckle" buckets (bucket that can be maneuvered and rotated on the end of the boom) allow for more freedom of movement and the ability to create more detailed features. They also help to create bunkers into slopes or in materials that might otherwise be difficult. While pushing low moisture material with a bulldozer doesn't

work very well for shaping, if an excavator is used, material can be moved and packed in with the knuckle bucket.

As with all golf course construction, the key elements are in the details when building bunkers. Proper shaping and earthwork helps to ensure good drainage, structural quality, and even soil conditions of the surrounds. The character and aesthetic appeal of bunkers is also greatly determined by the efforts made during construction. It is often the bunkers that look most natural and "found" that require the most careful, and sometimes complex, construction.

Jim Moore of the USGA identifies three key points related to bunker construction that hold true no matter the approach or methods employed (Moore, 2007). They are:

1. All good bunkers involve extensive drainage
2. All bunkers must be periodically redone (modified, renovated or restored)
3. No construction method completely eliminates the need for extensive maintenance labor

Some of the specialized bunker construction techniques are very complex. For example the "Billy Bunker" method, named for former Augusta National superintendent turned golf course architect Billy Fuller, essentially creates a subsurface layering using gravel and goetextile liner that acts similar to that of a USGA specified green. Other construction techniques involve forming bunker faces with sandbags and then wrapping and stapling sod strips to them in order to obtain a menacing "bullhead" look. Some architects and builders have even started using concrete like sand mixes on steep bunker faces. These near vertical faces are not meant to be playable but provide a gravity-defying flashy visual effect. (Moore, 2007)

Materials

The materials used in a bunker's construction play a major role in the bunker's effectiveness, maintainability and life span. The two materials that get the most attention when preparing for bunker construction are bunker liners and sand (Figure 2.37). Bunker liners are not used in all bunkers but have become increasingly more common. Bunker liners serve multiple purposes. Chief among these are to limit contamination from non-sand materials and improve sand stability by controlling erosion.

Early bunker liners were made from plastic or woven materials. Over time non-woven polyethylene liners were developed. Older non-woven liners were very effective as a barrier and prevented contamination from underlying soils. Unfortunately, issues arose with water permeability and maintenance difficulty. Drainage was often compromised due to the liner's poor water related performance qualities. Additionally, bunker rakes, both hand-held and mechanical, would often snag the liners. This resulted in decreased performance due to tearing and unsightly exposure of liners above the sand's surface.

Most liners currently being used are woven goesynthetics. They tend to be relatively thick, 0.25" to greater than 1", and are manufactured from man-made materials. In addition to providing a physical barrier to limit contamination, these new liners are very effective at erosion reduction. This effectiveness is accomplished in two ways. First, water flows through the liner before reaching the base of the bunker. This base is usually compacted subsoil material, often clay. Because of its low permeability, the water permeates the compacted subsoil more slowly than it flows through the sand. The water then flows along the surface of the compacted subsoil causing erosion of the sand from below. Once the lower layers of sand begin to erode, sagging and slippage occurs on the sloped exterior surfaces of the sand. With an effective liner this erosion is limited as the water flowing along the surface of the compacted subsoil does not come in contact with the sand.

Figure 2.37 – Installation of Bunker Liner and Sand (sandmat.com)

The second way that current liners reduce erosion is by increasing the sand's angle of repose. The angle of repose is an engineering property of granular materials. It is the maximum angle of a stable slope determined by friction, cohesion and the shape of the particles. This is most commonly demonstrated when granular materials are poured onto a horizontal surface and they form a conical pile. The internal angle between the surface of the pile and the horizontal is the angle of repose. Related to bunker sand, the higher a sand's angle of repose, the more easily it will stay on the steep sand face of a bunker without eroding. Very angular sand has a higher angle of repose than sand with more rounded particles. Also, sand with ideal moisture-holding capacity has a higher angle of repose than sand that is very wet or very dry. Bunker liners help increase a sand's angle of repose by providing a rough surface, more friction, for the sand to be piled upon. As a result, when used properly liners can help to reduce the severity of erosion and washouts due to rainfall and irrigation while allowing for steeper slopes in bunkers.

A recent trend in bunker liners is the use of polyurethane based liquids that are sprayed onto the surface of the prepared bunker cavity (Figure 2.38). These liquid spray-on liners permeate and bind soil particles in the bunker cavity. They cure to strong polymers that bind and stabilize soils and aggregates by essentially gluing them together. The major selling point of spray-on liners is that once applied, stones and other contaminants cannot migrate up from the sub-grade to contaminate bunker sand. Another selling point of spray-on liners is the lack of a material layer in the bunkers. Where geosynthetic liners can become snagged by maintenance equipment or work their way free from the subgrade, spray-on liners are marketed as being much more sturdy and worry-free.

Figure 2.38 – Spray-on Liner Application (klingstone.com)

Like traditional goesynthetic liners, spray-on liners also help with erosion and drainage. Drainage is often improved due to the lack of material contamination in the sand. Water will run through the clean sand down to the polymer layer. It will then run along the polymer layer to the drainage system installed in the bunker. Spray-on liners do allow for some percolation of water through them but it will occur at a much slower rate than with geosynthetic liners. For this reason, the installed drainage system in the bunker, whether it be perforated pipe, gravel, or sump, is key to the overall success of the bunker's drainage.

Although much attention has been given here to bunker liners, they are definitely not always required or needed. In situations were erosion is unlikely, such as flat bottomed grass faced bunkers, a well constructed and compacted clay base may be used. There are many very accomplished practicing professionals, both architects and superintendents, who choose not to use bunker liners at all and obtain excellent results. It should be noted that whether liners are used or not used, the bunker base construction process must be thorough to ensure quality results.

Sand selection is one of the most important of any steps in the process of bunker construction. There was a time when bunker sand was almost exclusively obtained locally. Unfortunately, the sand found at most sand pits or quarries does not have characteristics that are conducive to quality bunkers. As expectations of bunker appearance and upkeep have increased, it has become necessary to be more selective when it comes to bunker sand.

The USGA considers a list of eight factors when selecting bunker sand: particle size, particle shape, crusting potential, chemical reaction and hardness, infiltration rate, color, penetrometer value and playability. When dealing with a specific project, the importance of these individual factors will vary slightly based on location and climate. See Appendix B for definitions and more information regarding the eight sand selection factors.

Most of today's premium bunker sand is manufactured although some mined from natural deposits is still used. Manufactured sand is produced by processing course sand or rock in a mechanical crusher. While this process yields bunker sand with desirable characteristics, it is expensive. Typically, manufactured sand costs about twice

what mined sand does. Even with the increased sand cost and additional shipping charges, manufactured sand has gained widespread use on golf courses over the past decade.

Manufactured sands often look and feel very similar to mined sand. However, there are significant differences that impact its effectiveness as bunker sand. Manufactured sand has particles that are very angular. There also tends to be a large distribution in the size of particles. For the best results in bunkers it is important to ensure that the fine and very fine particles have been screened out before use. It is also important to have manufactured sand tested as all varieties are not the same. Lab testing of potential bunker sand should be done prior to beginning a bunker project to ensure the best fit with the factors identified by the USGA.

Bunker Maintenance

Bunker maintenance includes much more than just the conditioning of sand in a bunker. Maintenance techniques, bunker edging, maintenance of the bunker surrounds, and integration of irrigation and drainage must all enter into the discussion (Figure 2.39). Just as with bunker construction, the ongoing process of bunker maintenance must not operate in a vacuum but should integrate all of these factors along with the variables introduced by play and natural forces. As discussed previously the importance of bunker maintenance has grown over the last several decades. The result has been a growing number of maintenance methods and tools that aim to best condition bunkers and their surrounds.

Figure 2.39 – Bunker Maintenance Crew (University of Hawaii)

Conditioning of bunker sand is the most obvious, and most discussed, maintenance activity. Raking of bunker sand to smooth uneven areas and provide a uniform playing surface has long been the most widely used method. Over the years different variations on the raking theme have been implemented. In its early years Oakmont Country Club in Pittsburg, Pennsylvania used heavy rakes with widely spaced tines that produced furrows in the bunkers (Figure 2.40). This was the idea of Oakmont founder Henry Fownes who strived to make his course as difficult as possible and did not like to see shots that found bunkers go unpunished. (Cornish & Whitten, 1993) In more recent times Jack Nicklaus has advocated the use of rakes that produce furrows at his PGA TOUR Memorial Tournament at Muirfield Village Golf Club in Dublin, Ohio. Despite some outcry from players these rakes were used at the tournament from 2006-2008, although they do not seem to have caught on elsewhere.

Figure 2.40 – Heavy Furrow Rake, Oakmont Country Club, Pittsburg, Pennsylvania (Cornish, 1993)

The typical maintenance raking routine involves an overall raking of bunkers by the maintenance staff at regular intervals followed by raking by individual golfers of the areas they disturb while playing from bunkers. At many high-end facilities raking of bunkers by the maintenance staff is a daily occurrence, particularly during the peak playing season. However due to the time and resources required to rake all bunkers on a daily basis, many courses are moving toward raking their bunkers no more than 2-3 times per week. Ideally this would be more than enough to maintain a quality playing surface if proper care and attention is given to raking by golfers who play from the bunkers.

Bunker raking by golf course maintenance staff falls into two categories; mechanized raking and hand raking. Mechanized raking usually involves the use of a small vehicle often referred to as a sand pro (Sand Pro is a mechanized rake model produced by the Toro Company) (Figure 2.41). These mechanized rakes allow for raking of a large area of sand in a timely manner and provide easy mobility to all parts of a golf course. Additionally, most mechanized rakes are equipped with a front plow that can be used to push eroded sand back onto bunker faces should the need arise. Obviously mechanized rakes can drastically reduce the number of man-hours required to rake all of the bunkers on a golf course. However, the use of mechanized rakes can lead to some potential issues. Chief among these is the entry and exit points to bunkers. Repeated entry and exit over time will destabilize bunker edges and often leads to bunker erosion and unsightly turf damage to the surrounds. Another issue that arises is the inability of mechanized rakes to access all parts of a bunker. Steep slopes and narrow or small areas that do not allow for the turning radius of the rake most often have to be raked by hand. The use of mechanized rake in bunkers with liners can also become an issue. If the sand layer covering the liner is not very thick, the mechanized rake may catch on the liner, tearing or displacing it. In many cases where geosynthetic liners are used golf course superintendents have chosen to rake bunkers exclusively by hand.

Figure 2.41 – Mechanized Raking of a Bunker (smithco.com)

Hand raking is much more labor intensive than mechanized raking but is often necessary. Most golf courses have found a balance of the two methods that allows for mechanized raking of the floors and gently sloping sections of bunkers while the steeper areas and edges are raked by hand. However, as mentioned, with the increase in the use of bunker liners there has been a shift back toward overall hand raking. Additionally, many high end facilities will hand rake all of their bunkers. Many believe that this leads to a more attractive and uniform surface while avoiding potential structural damage from mechanized rakes. Even if strictly hand raking is used, wear at the point of entrance and exit can occur. This is most frequent when a bunker has limited access points. Usually access is limited due to vegetation or extreme slopes (Figure 2.42).

Figure 2.42 – Bunker Wear Caused by Entry and Exit, Bandon Trails Golf Course, Bandon, Oregon (Author)

Some hand rakes are usually left in or near bunkers to be used by golfers (Figure 2.43). Facilities have experimented with hiding these rakes in below-ground chambers or attaching them to golf carts but the most common presentation continues to be simply leaving them in or around bunkers. From a bunker maintenance standpoint this can create several issues. Many courses advocate golfers leaving the rakes inside of the bunkers. When done properly, this keeps the rakes out of the way of mowing equipment. The United States Golf Association actually recommends placing rakes next to bunkers, not in them. Unfortunately, golfers do not always effectively, if at all, rake the areas which they have disturbed. A facility may work very hard to ensure bunkers that are in excellent condition only to be undermined by golfers who fail to rake. The result is bunkers with footprints, uneven areas and divots. Because bunker condition plays such an important role in many golfers' opinions of a course, it is vital for the golfers to do their part in maintaining the quality conditions presented by the maintenance staff. Superintendents and golf course managers are continuously looking for ways to motivate golfers to better rake bunkers. Several of the most common methods include signage around bunkers, reminders on scorecards, and messages on in-cart GPS systems.

Figure 2.43 – Golfer Raking Bunker

Sand maintenance, while the most visible and discussed aspect, is only one component of the overall picture of bunker maintenance. Additional factors that impact bunker maintenance are mostly related, directly or indirectly, to the bunker surrounds. The bunker surrounds include the vegetation adjacent to or in bunkers, irrigation systems for this vegetation, surrounding slopes, and drainage systems. Each of these components plays a part in the appearance and playability of the bunker while impacting bunker maintenance methods.

The relationship between a bunker and the surrounding vegetation can go a long way to determining a bunker's style and role. For example, there was a time where most fairway bunkers had short grass leading all the way to the bunker lip on their fairway side. This made it easier for golf balls to roll into the bunkers. In fact, on many of the links courses of Great Britain the fairway bunkers tend to be small collecting bunkers, with the surrounding vegetation mowed short and the ground contours funneling balls into the bunkers. Most modern designs feature a strip of rough between the fairway and fairway bunkers. Golf balls tend to catch up in this rough, thus limiting the potential

impact of the bunker. Some designers and superintendents have been moving back toward bunkers with short grass on at least one side (Figure 2.44). This approach definitely increases the impact and strategic value of bunkers. They become more of an integral part of the golf course when not surrounded by heavy rough.

Figure 2.44 – Bunker Surrounded by Fairway, Ballyneal Golf Club, Holyoke, Colorado (golfclubatlas.com)

The point where the surrounding vegetation meets the sand surface of the bunker is known as the bunker lip. Maintenance of the bunker lip is called edging and can take several forms. The structural integrity of the lip is important to maintaining bunker shape and size as well as to the visual appearance of the bunker. This visual appearance of bunker edges or lips was not always as high of a priority as it is today. Many courses now place great emphasis on having very clean and sharp bunker edges. This edging is usually done by hand with a shovel or string trimmer to ensure its precision (Figure 2.45).

Figure 2.45 – Bunker Edging with String Trimmer, Cog Hill Golf Course, Lemont, Illinois (chicagobusiness.com)

A trend that has come back into fashion over the last decade is bunker edges that have a more natural look (Figure 2.46). This look, once the norm, involves letting the vegetation, particularly on the sides of the bunker away from play, to grow uninhibited.

Figure 2.46 – Rough-Edged Bunker, Hole 1 Cuscowilla Golf Club, Eatonton, Georgia (golfclubatlas.com)

However, even in these situations some bunker edging is usually needed. This is to ensure that surrounding vegetation does not encroach on the sand area of the bunker. Vegetation encroachment tends to be more of a problem on golf courses with creeping

grass types like bermuda, zoysia and kikuyu. In addition to edging practices, some golf courses use physical barriers placed along the bunker lip to limit vegetation encroachment and material contamination. These barriers are usually strips of bendable plywood or some type of landscape edging that can formed to the edge of the bunker (Figure 2.47).

Figure 2.47 – Plywood Used for Bunker Edge Stability (clubandresortbusiness.com)

The slopes surrounding a bunker have two major impacts on maintenance. One is the maintenance of vegetation growing on these slopes and the other is water run-off into the bunker. Steep slopes around bunkers can be some of the most difficult areas of a golf course to maintain. However one must use caution before decrying all difficult to maintain areas as related to bunkers and their surrounds. In truth, it is usually these difficult to maintain areas that provide bunkers, and golf courses, with much of their character. As some of the cookie-cutter designs of the past that catered to ease of play and maintenance have shown, a golf course without character and challenge will usually fall from favor. The key for design and maintenance professionals is to work together to create golf courses and golf course features that inspire and challenge while still being maintainable, even if some additional effort by both parties is required.

Specialized equipment and methods are often required to maintain the vegetation on steep slopes around bunkers (Figures 2.48 and 2.49). It is generally held that standard mechanized mowers can handle slopes up to about 33 percent before the need for

specialized, more labor intensive equipment arises. To limit the mowing necessary on slopes surrounding bunkers, many superintendents choose to apply growth regulators to the grass in these areas. The growth regulators slow the growth rate of the grass thus reducing the frequency of mowing required.

Figure 2.48 – Flymowing Steep Bunker Slopes (outandback.net, Dave Zinkand)

Not only are steep slopes around bunkers tedious to mow, they also tend to dry out due to increased run-off and lack of water infiltration. Often times steep bunker faces require specialized garden-scale spray or drip irrigation systems. These systems can add additional cost to the irrigation installation budget. Additionally, care must be taken with all irrigation systems to limit potential water run-off into bunkers and the waste created by irrigating bunker sand areas.

Figure 2.49 – Steep Bunker Surrounds Designed by Pete Dye, Austin Country Club, Austin, Texas (Hurdzan, 2005)

While bunker sand erosion from major rain events is an obvious maintenance issue, the erosion caused by irrigation of bunker surrounds can also create problems. Ideally irrigation run-off into bunkers is limited. It can be largely controlled by properly locating irrigation heads, restricting their spray coverage, and designing bunkers that drain a limited turf area. However, due to the irregular shapes of most bunkers it is impossible to completely limit irrigation spray into bunkers and keep run-off out. Usually it is not the spray into bunkers that causes the biggest problem. Instead the run-off from bunker surrounds into bunkers at a few concentrated points causes most irrigation related sand erosion. The major issues related to maintenance appear when normal watering of areas near bunkers leads to bunker erosion that must be dealt with on a regular basis. This additional sand replacement and raking takes time and effort on the part of the maintenance staff that could more efficiently be used elsewhere.

Significance

The future for golf course architecture and golf course development has become difficult to predict. Current economic issues have greatly curtailed the number and scope of projects worldwide. Prior to the recent downturn, significant new markets had been developing in China, Mexico, the Caribbean, and Eastern Europe (Figure 2.50). Time will tell if economic hardship nips these growing markets in the bud or simply delays their once predicted golf explosions.

Figure 2.50 – New Golf Chinese Golf Course Development by Robin Nelson (golfclubatlas.com)

Stateside, it is likely that golf course development may never again reach the levels that have been enjoyed over the past few decades. During the 1990s golf experienced significant growth, both in number of golfers, rounds played, and number of new golf courses. Recent years have seen a leveling off of the numbers of golfers and rounds played. The latest data from the National Golf Foundation (NGF) shows that rounds played in the United States in 2007 were down 0.5% from 2006. While this decrease is small, it is in stark contrast to the positive growth rates seen in earlier years. This is troublesome news as it points toward additional golf course growth creating an "overbuilt" situation. Some experts have said that recent increase in golf course closures indicate the United States has already reached that point.

At the same time as rounds are decreasing, the number of new courses has declined and course closings have actually outpaced new course openings. According to the NGF numbers, the year 2007 saw 113 new 18-hole equivalents open for business while 121.5 18-hole equivalents closed. This net loss of 8.5 courses followed a net loss of 26.5 courses in 2006. Looking at the data from the past five years combined, there have been 678.5 openings and 491.5 closures. This net gain of 187 courses, or 37.4 per year, equates to less than three-tenths of a percent of total supply being added per year. (National Golf Foundation, 2008) Bill Kubly of Landscapes Unlimited summarizes the situation:

> We saw this slow-down coming many years ago, but the business continued pretty good for some years, but since 2001 it has plummeted, mainly due to over-supply, not 9-11. I believe that there will be less than 25 new course construction starts this year (2009) vs. the 125+ from 3-4 years ago and 350 from 10 years ago. We are doing a lot of renovation of existing courses, but that work is also down considerably. (golfclubatlas.com)

Factors Influencing New Development

Financing for new golf courses, like with most development projects, is simply not available in the current economic climate. The final few months of 2008 saw Textron Financial, Capmark and GE Real Estate, the "Big 3" of golf-related lending, halt their golf financing businesses completely. Although the golf development business has its

problems, the reason behind the retreat of the major traditional institutional golf lenders lies in the fact that they and their parent companies have taken such colossal losses in other forms of real estate or subsidiary investments. The golf divisions are not lucrative enough to justify capital investment while other divisions are in financial trouble. For those involved in buying existing golf courses or golf course developments, financing is now mostly done through the seller or by deposit-based local or regional banks. The hope is that as the economy recovers credit for new golf course development will free up. Because golf has traditionally been a good lending opportunity for the major financiers, experts are predicting that the current situation will eventually pass. In the meantime, however, new golf course development will continue to be significantly hampered. (Dunlap, 2009)

The model on which much golf course development has been based will probably have to adapt and change to be successful in the future. Golf development's close ties to the housing market have been both a blessing and a curse. During the good times golf courses have been an integral part of housing subdivisions in all parts of the country. Golf courses were built and course-fronting lots then sold to pay for the development. In nearly all cases it was the residential component of the development that financially allowed for the building of the golf course. However, even prior to the current economic downturn many housing developments that would have included a golf course 10-15 years ago were considering other green-space alternatives and recreational amenities.

During the 1990s and early 2000s a large sector of new golf course development centered on upscale daily-fee facilities. These public "country clubs for a day" aim to offer high quality services, facilities and golf for a price, often easily exceeding $100 per round. The combination of a souring economy, less disposable income and limited time dedicated to recreation has led to tough times for some high-end public facilities. Many such facilities have been forced to lower prices or offer significant discounts.

At both high-end public facilities and many private facilities there are a host of other internal issues that also cause problems in the current climate. Chief among these are expensive clubhouses and extravagant, but not always prudent, plans for growth. Davis Senza addressed both of these issues in an October 2008 article in Golf Digest. Senza has over 35 years of experience in the development, ownership and operation of

hotels, golf courses and restaurants, and currently serves as the president of LaQuinta Resort & Club and PGA WEST, both in Palm Springs, California. He is deftly to the point when addressing the issues confronting many clubs today.

> Ninety percent of the clubhouses today are overbuilt and underutilized. This is because memberships [or owners] tend to build for their busiest day of the year rather than for the other 364. Members often blame their disenchantment with their club on the facilities rather than looking deeper to realize that the club should be about the camaraderie of their membership, with a professionally trained staff serving great food, ice-cold beer and a reasonably priced wine list. Most clubs could save millions of dollars by not competing with the Joneses. Instead, they should recognize the charm of their clubhouse and fill it with an incredible hospitality experience. The same is true for golf courses. Many clubs are compelled to renovate or reinvent their courses, when 95 percent of golfers don't play regulation golf and can't perform an architect's prescribed shot on each hole. For these players the conditioning and aesthetics of the course are much more important than the design--and the costs are far less to improve the conditions rather than renovate.

Senza's comments are of particular interest as they apply to golf course changes. It is unfortunate that numerous clubs and courses undertake so many ill-conceived golf course "improvement" projects. These projects are usually driven by committees, ownership interests or management groups which will likely change, thus leading to different ideas and starting the expensive process over again. Well planned and executed golf course renovations can be very beneficial to a golf course and result in improved course quality and maintainability. Problems arise when a golf course undertakes a never-ending series of projects whose merits and scope changed depending on the makeup of the golf course committee or who has the ear of management and ownership. These issues drive home the importance of the decision making climate at golf courses as it relates to management.

Factors Influencing Management and Maintenance

As many golf courses struggle to remain profitable and keep their doors open, the need for efficiencies in management has become even clearer. Management covers a wide variety of operations, both golf and non-golf, when it comes to golf course facilities. As noted previously, clubhouses and their operations play a major role in overall golf course facility management. Clubhouses usually include food and beverage services, merchandizing, event hosting facilities, and other user amenities like swimming pools and locker rooms (Figure 2.51). Depending on the effectiveness of these amenities, the overall effect of a clubhouse may be to greatly hamper or help the financial status of a facility. There are additional management operations at most golf course facilities that do not have a direct physical impact on the golf course. These include marketing efforts and member or user services. Before looking into the golf-related management operations it is important to note that with the variety of operations taking place at any given golf course facility, there is bound to be a hierarchy with some operations taking precedent over others. This can be seen at some clubs where swimming pools and dining options are the main focus and the golf course is a secondary or tertiary amenity. Other facilities exist where golf is the main focus and any other services are simply amenities for golfers. It is vital to analyze these overall management priorities when looking at golf course management, particularly related to making changes on an existing golf course.

Figure 2.51 – Golf Clubhouse and Associated Amenities, San Rouque, Spain (sanrouque.com)

Because of the unique and varied backgrounds of many golf facility and golf club managers, it is not uncommon to have professionals with a background in one area of a facility's management overseeing other areas as well. Golf professionals or superintendents who become general managers are often overseeing product ordering and hiring food and beverage service employees. At the same time many private club managers come from food and beverage backgrounds like hotel and restaurant management. These professionals may not have a background in golf course management or maintenance but are called upon to oversee those operations as well. The key point for those involved in golf course design or management is to understand what the facility's priorities are and what viewpoints the decision makers in the process have. When golf course changes are being considered, there will often be additional education and explanation that must be done on the part of the designer and golf course manager or superintendent. This is a key component to gaining the support of members, users, management and ownership. It is best that those who manage and use a golf course facility know specifically what changes are being made, why those changes are necessary, and what the end results of the changes will be.

The majority of golf-related management operations focus around golf course maintenance. A variety of factors exist that influence the golf course management decision making process. These factors include labor costs and competency, equipment and material expenses, and fuel and chemical costs. However, the most influential factor is likely not physical, but is instead the expectation of golfers. When looking at the economics of golf, golfers are the consumers and their expectations tend to drive the product which is supplied to them. Golfers, at least in the United States, tend to expect and want well conditioned courses with lush green turf and clean white bunkers. As a result the overall focus of golf course maintenance is to provide these conditions. After all, if two golf courses are located side-by-side and one is lush and green while the other is brown and scraggly, most golfers would likely choose the lush green golf course regardless of any other golf course quality considerations. This is likely not as true in the United Kingdom where most of the highly esteemed courses are links and general maintenance practices involve less water use and firmer turf conditions. However, even there, inland American-style resort courses have taken a foothold. Interestingly, the areas

of the world that are primed for future golf course development tend to have a more American view of golf course condition expectations. Golf course architect Robin Nelson has been involved in projects throughout the world but with a particular focus on Hawaii, Southeast Asia and China. Discussing the expectations of Asian clients and golfers he says:

> In places like China raw and natural are not what the clients or players are looking for - generally they are looking for courses that are highly maintained and green (if you can talk them out of the waterfalls and windmills that is a plus). Lush and over-watered is sometimes the result of this… In Asia, wild and unkempt means the owner does not have enough money and would receive less prestige for the course. While we would like to do more raw and rugged style courses where it suits, it will take time for the locals' tastes to develop. Over a number of years, the local golfers will appreciate a wider range of golf course styles, but it will take some time. (Nelson, 2009)

In the United States there has been somewhat of a renaissance over the past decade with regards to more natural or rugged styles of maintenance. Some of this has been driven by necessity in areas, particularly the desert southwest, where water resource issues may no longer allow for the wall-to-wall irrigation of turf. The result has been fewer acres of irrigated turf and more use of native landscaping and drought resistant grasses that may not be lush and green year-round. Another factor behind this shift away from excessively green and manicured golf courses has been the designers and design styles behind several prominent new courses. Courses like those at the Bandon Dunes Golf Resort in Oregon or Sand Hills Golf Course in Nebraska have achieved a very high status while appearing and playing more like the links courses of the United Kingdom (Figure 2.52). Golf course architects Bill Coore, Tom Doak, Gil Hanse, David Kidd and others have worked with their clients to build courses that highlight this rustic look that showcases ragged bunker edges, large areas of relatively unmaintained native vegetation, and turf that is meant to be maintained to play fast and firm. In many cases this look has even caught on with architects that were previously known for their designing courses that were meant to be sharply manicured and pristine.

Figure 2.52 – Native Vegetation and Blow-Out Bunkers, 17th and 18th Holes, Sand Hills Golf Club, Mullen, Nebraska (golfclubatlas.com)

However, when looking at the overall golf course business the seeming advancement of the "natural look" does not seem to have shifted the general consensus among golfers away from green and manicured course conditions. One might say that a perfect example of this is the 2009 ranking of the top 100 golf courses in the United States by Golf Digest. Topping the list is Augusta National Golf Club, home of the Masters Tournament and likely the most green and manicured of all courses (Figure 2.53).

Figure 2.53 – Bunker at Augusta National Golf Club During 2009 Masters Tournament, Augusta, Georgia (masters.org)

The bar has been set high when it comes to golf course maintenance expectations. Many golf course superintendents are faced with a seemingly no-win situation when it comes to course conditioning. Members or users of their course constantly compare the course conditions with those at other facilities they have played or seen on television. Often these other facilities may have a much higher maintenance budget or access to additional resources but that does not stop the demand for like conditions. Unfortunately, many superintendents who do an admirable job in the situations they are presented with are forced to face these expectations regularly.

As shown by the Golf 20/20 (Last, 2005) study, conditioning of greens and bunkers is of the greatest influence and importance to golfers. As expected these areas tend to garner the most attention from both golfers and golf course superintendents. Poor green conditions can be a recipe for disaster at an otherwise quality golf facility. Many superintendents and golf course managers know the bottom-line dangers of poorly conditioned greens that can be caused as word-of-mouth testimonials spread the bad news among golfers. The same can be said about bunker conditioning. All it takes is a golfer finding their ball in a washed-out bunker face or in an unraked footprint. Suddenly the

golfer's opinion of the golf course focuses on perceived bad conditioning and not much else matters.

It is important to remember that professionals in both golf course design and management are providing consumers, the client and users, with a product, the golf course, and its associated services. Golf will continue to be consumer driven as golfers have a wide array of golf courses to choose from. It will be up to those in the golf course business to find ways to keep the price of development, construction, maintenance and management at a feasible level while still providing golfers with a desirable product.

Looking to the Future

The current economic issues facing golf have slowed new construction and deeply impacted the stable of existing golf courses. Looking to the future it is likely that facilities will continue to close in the face of economic pressure and an overall downsizing within the golf course business may take place. One question that must be raised: is it possible to cut back while still maintaining the expected levels of quality? Because golfer expectations ultimately drive much of the management decision making, this can be difficult to do.

Improving technology has and will continue to play a major role in golf course maintenance and management. One of the primary reasons that golfers' expectations of course conditions have increased is the ability of today's equipment to produce conditions so superior to those of decades past. In addition to better equipment, technology has helped to improve golf course irrigation systems and their efficiency. Superintendents can more effectively distribute the correct amount of water to all areas of a golf course. Water waste is cut down through control of individual heads in a system as well as better overall system design. The efficient distribution of water allows for better turfgrass quality while saving water. Additionally, newly developed turfgrass varieties are bred to be most effective in certain climates and for specific golf course applications (Figure 2.54). These advances have been instrumental in improvements in both golf course maintainability and overall conditioning. Of course it is these very conditioning improvements and the expectation that they be carried out to their full potential that puts many golf course managers and superintendents in a difficult position.

Figure 2.54 – Turfgrass Research Plot (Kansas State University)

One potential solution involves attempting to change the expectations that golfers have of golf courses, particularly related to physical appearance and conditioning. Some would argue that the ideal that many golfers hold is not the ideal at all and should be altered. This could be accomplished through education efforts on the part of golf associations, industry organizations, and major publications. In some areas of the country this has been taking place out of necessity due to water regulations. The replanting of perimeter areas of golf courses that were once lush green grass with native vegetation or drought resistant grasses is an example. Aesthetically this makes a significant difference as the replacement vegetation does not have the manicured appearance of well-watered turfgrass. Some golf courses have undertaken education programs that attempt to convey to golfers, and surrounding homeowners, why the browner natural look is necessary and better in the long run. This is not always met with appreciation or understanding. Much like golf course architect Robin Nelson indicated about his clients and golfers in China, the sight of unkept or natural looking golf courses tends to indicate limited prestige of the facility. (Nelson, 2009) Even in areas of the country where environmental stewardship is at the forefront the most popular golf courses are usually the ones with large maintenance and irrigation budgets and the resulting acres of lush green turf highlighted by perfect white bunkers.

While it may be difficult, although hopefully not impossible, to change the basic golf course conditioning expectations of golfers, there are likely steps that can be taken

that will improve the situation for management without sacrificing the golfers' ideals. These include better designing and managing the areas of golf courses that require the most attention. In times of economic struggle within the golf business, bunkers are usually one of the first golf course components sent to the chopping block. The 1930s and the 1970s both saw tough times for golf courses and the number of bunkers and bunker maintenance decreased. Some schools of thought on golf course architecture see the considerations of the practice as a triangle of aesthetics, playability and maintenance. In practice this triangle is usually not equilateral. In boom times more attention tends to be given to aesthetics while designing for maintenance is seen as less necessary and definitely not as fashionable. When times are more difficult the essential economic needs of maintenance are more likely to be considered and the triangle again shifts. Golf course architect Jeff Brauer makes this point and supports it by saying:

> As maintenance costs escalate because of inflation, and courses have trouble finding more new players or charging existing ones more to cover costs, architectural features will continue to suffer because economics dictates doing what's necessary to survive. In this case, it's the money, not the principle. Bunkers might become as rare as the buffalo, and the number of bunkers might depend on how many can be raked before noon. Some sand bunkers will be converted to grass bunkers. There might be a trend toward bunkerless greens that are furthest from the maintenance area to reduce travel time. Bunkers also will be flatter to minimize sand washing because players want a perfect playing surface and superintendents hate the unscheduled maintenance after rainstorms. (2005)

Brauer goes on to discuss how many golf course managers have sought his expertise to assist with removing bunkers that were considered marginally necessary, sometimes on courses he had originally designed. Colbert Hills Golf Course in Manhattan, Kansas, is a perfect example of this. He also indicates that while his typical budgeting bunker plug-in number for new courses was 100,000 square feet, he has since cut that number in half.

Bunkers will continue to be at the forefront of golf course features targeted as management attempts to control costs. As with all golf course features, bunkers

cannot be looked at simply from the design perspective or from the point of view of those managing and maintaining the golf course. Too often bunker design decisions have been made without enough care given to how, and to what extent, they will be maintained. At the same time, maintenance and management decisions regarding bunkers often go in the face of the design intent of the architect. Ideally the two viewpoints must be considered together. An effective relationship between design and maintenance considerations will lead to more efficient bunker management and in turn, additional cost savings.

The Design – Management Relationship

The relationship between design and management can be compared to a professional football team where a general manager and player personnel people are in charge of drafting and putting together a group of talented players, essentially designing the team. It is then up to the coach to prepare the team, utilizing the strengths of each player, in a way that gives the team the most chance for success come game time. This process is more likely to work if the players on the team have strengths that fit into the preferred playing style of the coach. It does no good to have, and pay, an all-pro running back if they never get to run the ball. Of course what most teams do is involve the coach in the process of determining which players will be playing for the team. The hoped for result is that the players that are brought in will fit into the system more effectively, thus leading to a greater chance of success.

Issues with the Current Relationship in Golf

In the same way as the football example, the golf course architect is designing the golf course and then handing it over to the superintendent. The superintendent is responsible for nurturing the course and getting the most out of it. Ideally the designer has the task of the superintendent in mind during the design and construction phase. Most projects involve a superintendent during construction, whether it is the superintendent who will be overseeing the facility once open for play, or a “grow-in” superintendent who is responsible for the maturation process of the course during and immediately following construction (Figure 2.55).

Figure 2.55 – Golf Course During Grow-In Phase (Hurdzan, 2006)

It is very important not to overlook the grow-in stage of a golf course as it is vital to the long-term success of a facility. Grow-in involves the establishment and maturation of turfgrass throughout the course. No matter the creativity of the design or the soundness of construction, if a course is not covered with a strong and healthy layer of grasses it will not be appreciated by the general golfing public. Most golfers tend to place more importance on maintenance than design and judge golf courses accordingly. Although grow-in is usually the point in the process where the burden of care shifts from the golf course architect and contractor to the superintendent, it is in the best interests of all parties that grow-in is efficient and effective. The finished golf course following grow in reflects on the architect and contractor, even if they did not have a direct hand in the agronomic maturation process. (Hurdzan, 2006) Conversely, mistakes made during design and construction can greatly hamper the grow-in process. Erosion and poor soil conditions are two of the most common pitfalls during the grow-in period. This is why it is so important for the designer to identify problem areas related to soils and drainage early on in the process. Poor soils must be amended to help ensure a successful stand of grass and appropriate drainage can help alleviate some of the threat of large-scale erosion during the critical period before and during turfgrass establishment. Proper construction practices are also important to giving grow-in a helping hand. Topsoil should be stripped and stockpiled prior to grading and shaping and then replaced. In order to avoid compaction issues, heavy construction equipment should be kept off of key areas when

possible. In the words of Dave Wilber, a respected golf course agronomy consultant, fairways are not haul roads, they are fairways. (Urbina, 2002) Sometimes these details may seem trivial during the construction process but they can make a huge difference in the long-term maintainability and quality of a golf course.

Prior to even reaching grow-in, unforeseen on-site situations will always arise during construction of a golf course. Examples include areas with poor soil or drainage, microclimates within the site that make turfgrass establishment and growth difficult, and even regulatory or environmental issues that were supposedly dealt with prior to construction. The key in such circumstances is to remedy these issues on-the-fly while not creating a situation that may lead to future trouble. If dealt with improperly, shortcomings or oversights in design and construction often become apparent and begin to cause problems during grow-in. Unfortunately, these are likely precursors to ongoing long-term issues.

A key to dealing with issues that arise during construction and grow-in is to involve a golf course superintendent in the process from an early stage. At exactly what point this happens likely depends on the circumstances of the project. Fortunately the trend in golf course construction has been to bring a superintendent on-board earlier than was the norm in the past (Figure 2.56).

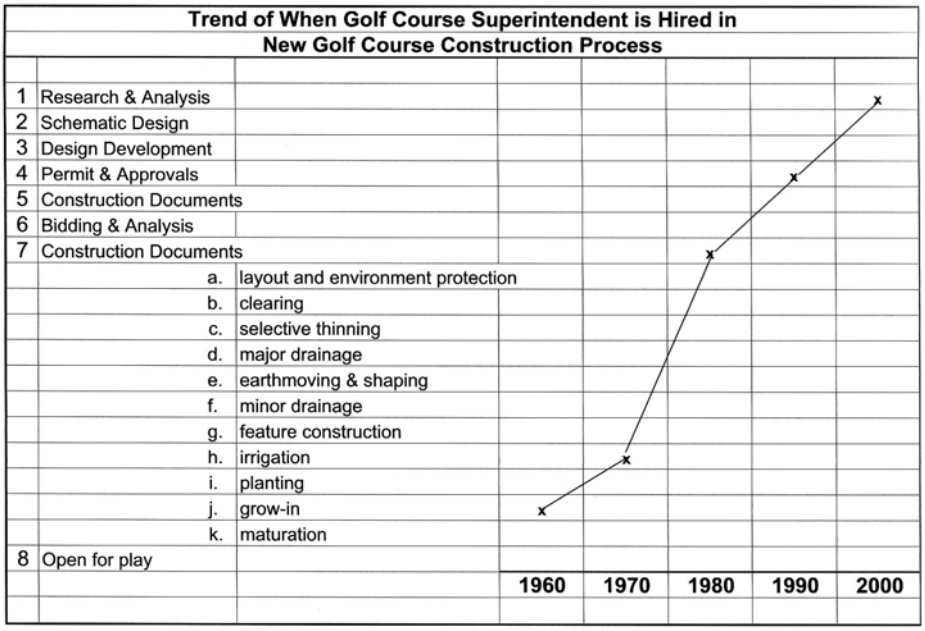


Figure 2.56 – Superintendent Hiring Trend for New Golf Course Construction (Hurdzan, 2006)

There are specific qualifications that are preferred in a superintendent who is part of construction and overseeing grow-in. In many cases the superintendent and their staff are integrally involved in the finishing aspects of the golf course construction process. Additionally, knowledge and experience with grow-in is preferred due to the unique nature of establishing and nurturing new turfgrass. Just like a designer who fails to properly manage construction, trouble can arise when a superintendent does not effectively manage grow-in. Grow-in tends to be a time-sensitive balancing act that requires the superintendent to transition the property from a construction site to a golf course while carefully managing the agronomic needs of new turfgrass and the often impatient expectations of ownership. For this reason, many golf course contractors and management companies have superintendents on staff that specialize in new golf course grow-in. These professionals usually have significant experience in golf course construction and maintenance. As a result they may be more prepared to handle the exceptional circumstances presented by the grow-in phase of golf course development.

No matter the specific personnel used during construction and grow-in, one major key to success lies in proper communication and teamwork among those involved in design, construction and maintenance. All of these parties work for the project owner, but under different contractual obligations. The relationship between the involved parties varies depending on the project and those involved, but the following is a description of a typical relationship. Usually the golf course architect has been hired to design golf course features and commit the design to plans and specifications that communicate to the contractor what is to be done. The contractor is legally bound to the owner to provide materials and labor to build the golf course per the construction documents, with changes authorized by formal change orders. Change orders are legal amendments to the contract documents that are signed off on by the contractor, architect and owner prior to the work being done and at an agreed upon price. Change orders can slow down the construction process and are usually not used for small items. However care should be taken by all parties, particularly the contractor, as without change orders they may not have a basis for a claim of payment on changes that were made.

Although legally the superintendent’s only conduit to the contractor is usually through the architect or owner, the reality is that during the construction process the

contractor and superintendent must work closely together to ensure a smooth project (Figure 2.57). The superintendent and contractor should have the same common goal: to build the best golf course possible within the limits of time and money provided by the owner. Often times, especially as construction nears completion, the superintendent and contractor will share equipment and even combine labor forces. Although the lines between the two parties' roles may become less clear, they should always respect the legalities of construction work and document their agreements and joint-decisions. (Hurdzan, 2006)

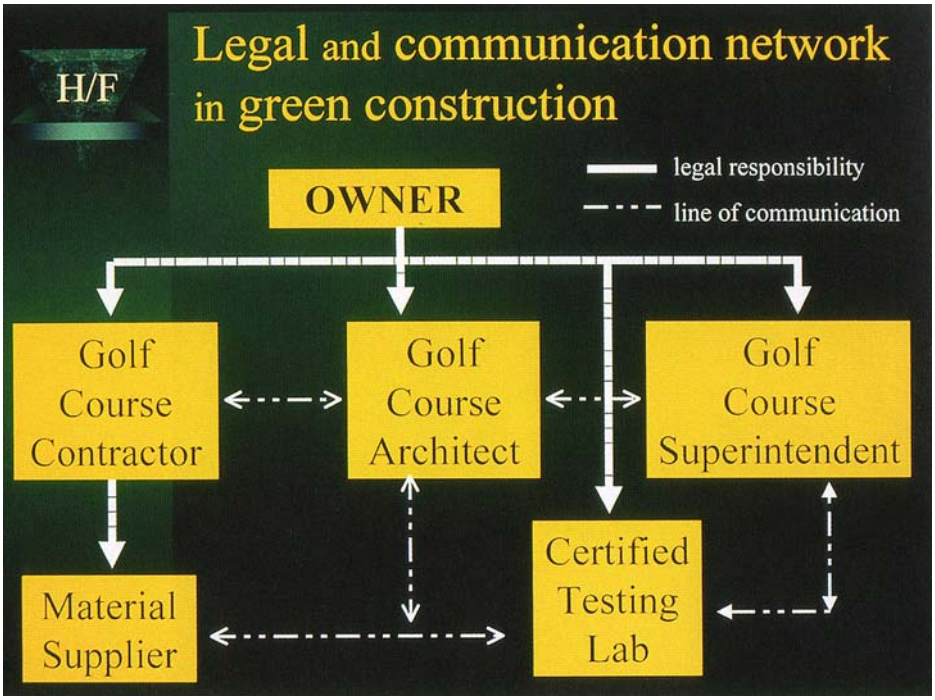


Figure 2.57 – Golf Course Construction Legal Relationships (Hurdzan, 2006)

With all of the involved parties working together with a common goal in mind, great things can happen. An example is the construction of Pacific Dunes in Bandon, Oregon (Figure 2.58). Tom Doak and his team from Renaissance Golf Design designed and built the esteemed course in 2000. Jim Urbina, Doak's lead design associate personally spent 168 days on-site while overseeing, and integrally participating in, the construction of the course. The following comments from Urbina describe the construction process and some of those involved in it. They really illustrate the

importance of communication and input from those involved in all facets of the project as well as the interconnection of each individual's roles.

> We built this course and we didn't use a golf course contractor. Our labor force was mostly local kids just out of high school and it fell into my hands to teach and direct everyone involved as to how we wanted to design and build this course. With all due respect to the last 100 years of golf course architecture, all golf course designers must concede that without a team of good, interested and talented people, the designs of the best of the dreamers could never have been done. We had no one on the construction crew who had preconceived notions about what our work should be. The design wasn't something we had to protect. It became something we grew into daily.
>
> The success of this course is certainly due to many things. Some things are obvious, like the dramatic land and the great routing that Tom did. No question the location and the area will take your breath away even when the weather is bad.
>
> Some things are a little less obvious, but certainly noticeable if you look. I can't say enough good about Ken Nice, the golf course superintendent at Pacific Dunes. He was totally and is today truly dedicated to our design and to the principles of links golf that the site requires. Ken was with us all the time and he never gave the usual mumbo jumbo about not being able to mow something or not being able to get us the look we wanted. He simply said he would do everything he could to figure out a way. I have so much respect for Ken and from him, I've learned that growing grass is much harder than we all believe it is and growing grass our way on our design may seem like we are asking for less, but in fact we are asking for the superintendent to be as creative as we are. Ken Nice worked his butt off during construction. He gave the project every bit of his attention and the construction crew busted their butts as a result of his leadership. Ken has quite a challenge for the future. He's an American growing turf for links golf and it is not always a surface that people who haven't been

> exposed to understand. He's going to get a ton of pressure to make things too green and to maintain or water when he should do nothing. I'm glad he's there.
>
> Everyone loves the bunkers at Pacific Dunes. Tony Russell was a local dairy farmer and small dirt contractor and his brother is Troy Russell, the first superintendent at Bandon Dunes and now the Resort's agronomy director. Tony became our ace in the hole and he showed me a whole new way to do bunker work without even knowing that what he was doing was total cutting edge. Tony doesn't golf. He didn't want to debate the merits of bunker design with us. He did help us understand how to be more efficient moving dirt, even though I thought I was about as efficient as anyone at getting dirt moved. Of course Tony knows everyone in the area, so he was able to find us some good people for other heavy equipment operator jobs. We would have definitely been hurting without Tony Russell and not too many people would ever know that. (2002)

When the individuals involved in a golf course project are committed and able to work together like at Pacific Dunes, great things can happen. Of course everything on that project was not simple and easy. It never is. Urbina addressed the scope of the difficulties they faced at Pacific Dunes by saying,

> Not everything was easy. We had some tough issues to work out. The agronomy alone was incredible. We ran into some areas that were not blessed with great soil and we had to figure out how to make things right. I think I could write a whole book on the everyday trials of building that course. (2002)

Figure 2.58 – 3rd Hole, Pacific Dunes Golf Course, Bandon, Oregon (Author)

It is important to remember that the reason the design – management relationship is so important is because there are countless potential pitfalls during every step of the process. Those who have become successful practicing professionals are usually adept at facing the numerous issues that arise and avoiding the pitfalls along the way. Good designers seek to solve every problem at each critical decision making juncture in the process. At the same time those in construction are problem solvers in their own right, finding the most efficient and effective way to build something that is sound and lasting. Finally those in management and maintenance roles are tasked with taking the result and making it economically sustainable and enduring. After all, the initial vision of the designer will never come to fruition without proper oversight, nurturing and care.

Unfortunately, the design – management relationship on many golf course projects is not always as effective or efficient as it should be. It should be noted that this is not necessarily the fault or intent of a particular individual or party; designers,

construction professionals, superintendents, or general managers. While a bad apple in the group can definitely be harmful to a project, the individuals involved are usually performing up to their capabilities. Trouble arises when the goals or intents of the different parties do not fit together in a way that is compatible or feasible. For example the designer may have an eye on securing future projects and furthering their career by designing extravagant features that look good on the glossy pages of a magazine. The 1980s and 90s probably saw an overuse of bunkers for this reason. These bunkers' role was to provide visual drama and a design signature. They were justified because they looked good (Brauer, 2008). Unfortunately, these features are not always maintainable in the long term. As a result many golf courses see some level of physical alteration or change in maintenance practices early on in their lifetime. This process is often driven by finances and in itself may costs significant amounts of money.

Colbert Hills Case Study

The following case study of the situation at Colbert Hills Golf Course provides a window into a scenario that is telling but regrettably, not unique.

Current Issues

Problems with the bunkers at Colbert Hills began to arise within the first year of operation. Major rain events washed out bunker faces leaving exposed soil and rock (Figure 2.59). With each event and the subsequent maintenance efforts required to make the bunkers playable again, the quality of the sand became further compromised. The sand, already possessing properties that made it less than ideal for bunker use, became contaminated with soil and rock from the subgrade. The structural integrity of the bunkers also suffered. The worst of the wash-outs would erode the bunker lips, edges and faces. Over time the size and shape of some bunkers has changed dramatically. Bunker surrounds have also suffered as a result of eroded material being deposited outside of the bunkers. Poor turf quality and additional maintenance requirements have been the result. Wind erosion has also caused problems in several locations where regular deposition of wind-blown sand on green surfaces and bunker surrounds has physically changed the playing surfaces.

Figure 2.59 – Bunker Erosion, Colbert Hills Golf Course, Manhattan, Kansas (Author)

The issues with the bunkers cause two major problems from a management perspective. The first relates to playability. The poor condition of the bunkers makes them difficult, if not impossible for golfers to play out of. After rain events, most of the bunkers are reduced to muddy pits dotted with significant amounts of exposed rock. Even in areas that appear to be sand, pieces of rock near the surface can cause dangerous situations. Because of poor drainage due to contamination the bunkers also retain water and golf balls can actually be lost in the resulting "lakes" (Figure 2.60). The time and effort required to fix the bunkers following a rain event forces golfers to deal with these poor conditions for several days. Aesthetically, the bunkers also suffer. When washed out they do not even look like bunkers. The expectations of golfers, particularly when considering that the facility is ranked as the best public golf course in the state, are not met. Golfers place significant importance on the conditioning of a course and will take

their business elsewhere if they feel they are not getting what they pay for at a particular facility. In order to attract and retain business it is important that Colbert Hills presents a golf course that is in excellent condition and is aesthetically pleasing.

Figure 2.60 – Bunker Erosion and Standing Water, Colbert Hills Golf Course, Manhattan, Kansas (Author)

The other management related problem involves the cost of maintaining the bunkers. Due to limitations in the maintenance budget, extensive bunker maintenance is simply not feasible. Regular bunker maintenance consists of mechanized raking of the bunkers with hand raking along bunker edges and on steep slopes. The sheer number of bunkers, 106, also makes regular maintenance very resource and time consumeing. Management has estimated that it takes around 100 man-hours to fix the bunkers at Colbert Hills following a major rain event. This process involves removing rock and mud from the sand where possible, pushing sand back onto the bunker faces, and smoothing and raking the surface. Usually this is done by a crew of 4-5 workers using rakes, shovels

and motorized equipment. During some times of the year it is not uncommon to get at least one rain event per week that causes significant damage to the bunkers. Such was the case during the spring and summer of 2008 when a steady stream of storms wreaked havoc on the condition of the bunkers. When regular fixing of the bunkers is required, and it usually is, other aspects of golf course maintenance are likely to suffer or be curtailed.

History

The underlying issues with the current bunker problems at Colbert Hills can be traced back to the design and construction of the course. Initially the facility was to be managed by the PGA TOUR as part of a series of collegiate courses. Differences in expectations regarding the maintenance budget of the golf course led to a parting of ways with the original management group. Discussions at the time indicated a need for a $1.2 million budget for maintenance of the course. For financial reasons this was simply not feasible. Today the maintenance budget for Colbert Hills is barely one-quarter of that amount. It is likely that many of the golf course features, including bunkers, were designed with a much larger maintenance budget than currently exists in mind. This conclusion is made assuming that maintenance budget was a consideration during the design of the course. The recollections of several parties involved indicate that maintenance budget may not have been discussed until later, well into the construction process.

Construction of the bunkers at Colbert Hills likely had the greatest impact on the current situation. Several key bunker components were cut out of the construction budget by the contractor early on as cost-saving measures. These included bunker liners and proper sand. Due to the rocky nature of the existing soil, bunkers without liners or additional subgrade preparation can be expected to have problems with material contamination and the migration of rock into the sand layer. Unfortunately, sand was placed into the bunkers with only limited subgrade preparation and drainage installed. The result has been rock and subgrade material contamination in the sand from very early on. This situation has only worsened with regular wash-outs of the bunkers. Each time a bunker washes out, pure sand is lost to erosion and additional subgrade material is introduced into the sand layer (Figure 2.61).

Figure 2.61 – Bunker Subgrade Material Contamination, Colbert Hills Golf Course, Manhattan, Kansas (Author)

The sand used in the bunkers has also caused considerable problems. The sand is local sand, native to Kansas, and can be categorized as a round mason sand. It is commonly referred to as Kansas River sand. The sand's qualities, particularly the fact that it does not compact easily on slopes, makes it ideal for use in golf course greens mix. Unfortunately, this same quality makes it very poor for use in bunkers. Ideally a bunker sand will compact for stability while at the same time allow for quick water infiltration through the sand layer. Sands with angular characteristics tend to do this much better than rounder sands like the one used at Colbert Hills. Round sands do not compact enough, leading to poor stability and the propensity for "fried egg" lies. The extreme material contamination in the bunkers only made the situation worse by further slowing water infiltration thus promoting additional erosion.

The end result has been bunkers that drain very poorly and tend to wash out easily and often. Several attempts to improve the bunker conditions have been undertaken but proved ineffective. In 2006 sand was removed from many of the bunkers, liners put in place, and the sand screened and replaced. Unfortunately, due to the nature of the sand extreme erosion continued to be a problem. The bunker liners were compromised and in many cases simply washed out of bunkers all together. Additional issues occurred when erosion led to uneven sand depths with liners near the surface or exposed. The liners often caught on the tines of the mechanized rakes used for maintenance, causing tears and further exposing the liners.

Bunker Renovation

Efforts to address the bunker issues at Colbert Hills are currently under way as a bunker renovation project has begun. The goals of this project are to improve the playability of the bunkers while decreasing the cost needed to maintain them. Three key factors were identified that play a major role in the success of this project. They are sand selection, construction techniques and maintenance techniques. Proper sand selection is vital to guarantee improved playing characteristics and limiting future wash-outs. Construction must be carried out with attention to detail and in a way that ensures an aesthetically pleasing final product. Likewise, maintenance techniques must be tailored to the bunkers' characteristics and done as efficiently as possible.

Prior to any physical work taking place, an analysis of existing bunkers was done to determine changes that needed to be made. Several bunkers were deemed unnecessary and eliminated completely. Other bunkers' sizes were reduced or their edges reshaped. See Appendix C for the Colbert Hills Bunker Renovation Plan.

Care has been taken to ensure that the internal contours of the renovated bunkers will be maintainable. The existing sand is being removed from all bunkers and replaced. The new sand is a manufactured angular sand from Arkansas. It compacts well, providing a firm playing surface, while maintaining a very high infiltration rate. As a result, the sand does not wash-out easily. In addition to the sand, bunker liners and new drainage pipe are being added to all bunkers. In some bunkers the existing drainage pattern is being reworked to deal with trouble areas and more effectively move water off of the bunker faces. Two types of liners are being used, one on steep slopes and the other on the

remainder of the bunker floors. The liners will eliminate rock and soil contamination from the subgrade and also add stability, reducing erosion. Bunker playability will improve dramatically as the sand surface is much improved and large-scale wash-outs no longer occur in the renovated bunkers (Figure 2.62).

Figure 2.62 – Renovated Bunkers, Colbert Hills Golf Course, Manhattan, Kansas (Author) – This image was taken following the same rain event that caused the significant damage seen in Figures 2.59 – 2.61)

From a financial standpoint the bunker renovations will be a significant improvement due to the greatly reduced maintenance requirements. Management estimates that following major rain events, the fix-up time for the bunkers will be reduced from over 100 man-hours to fewer than 10 man-hours. Regular maintenance will be limited to touch-up once per week with complete raking occurring much less frequently. Because of the liners that are being installed, all sand raking will be done by hand. While this initially appears to be more labor intensive, it is not. Because raking will be required less often and current practices already require significant hand-raking of bunker edges,

the overall impact will be much less time spend on bunker maintenance with a greatly improved result. Additionally, following the implementation of the bunker renovation plan there will be less bunker area to maintain. Figure 2.63 shows work on one of the tenth hole's fairway bunkers. Nearly one-third of the bunker's sand area was replaced with turf that will maintained in the same fashion as adjacent bunker surrounds. In addition to maintenance savings, construction cost savings are seen by lowering the overall sand area. Limiting the amount of sand and geosythetic liner used leads to significant savings. With the new sand costing $72 per ton, compared to less than $10 per ton for the original sand, every opportunity to lessen unnecessary sand area is analyzed.

Figure 2.63 – Bunker Area Replaced with Turf, Colbert Hills Golf Course, Manhattan, Kansas (Author) – Red dots indicate the bunker edge prior to renovation.

Lessons Learned

Several important lessons can be learned from the Colbert Hills example. Chief among these is the management consequence of decisions made during the design and construction phases of the project. Poor sand selection and cost cutting during construction have both led to ongoing bunker issues. These decisions have had a direct negative impact on the quality of the golf course and resulted in a significant expenditure of resources directed at bunker maintenance. The current renovation project is very expensive and labor intensive itself (Figure 2.64). Over one-million dollars are being spent on the first phase of the project alone. Estimating a total renovation project cost of over two-million dollars, an amount equal to nearly 15 percent of the original construction budget for the entire golf course will be spent to fix the bunkers. However, this expenditure has been deemed necessary to improve bunker conditions and limit future maintenance costs. Had more forward thinking decisions been made earlier on in the project, many of the current issues related to bunkers may have been avoided.

Figure 2.64 – Bunker Renovation Construction, Colbert Hills Golf Course, Manhattan, Kansas (Author)

Additional lessons to be learned from Colbert Hills also focus on the design – construction – management relationship. Current management suggests that a better relationship between the superintendent and construction company early on in the process may have helped with identifying and anticipating potential issues like those that have been seen with the bunkers. Also, the reconciliation of a proposed maintenance budget with maintenance expectations at some point during the design process may have led to better decision making regarding both design and construction. It has been suggested that considering the course's actual maintenance budget, the design should have focused more on the strategic placement of fewer bunkers as opposed to the significant number, many for aesthetic purposes only, that were put in.

All About the Money – Management Costs

The management decisions that golf course operators make not only impact facilities on an individual level, but essentially shape the landscape in which golf course architects operate. Architects perform their services at the discretion of their clients. As a result, the courses that are produced come about in an environment constrained by the client's wishes and their available resources. Financial considerations are nearly always at the forefront of management decisions, during good times and bad. At the very least, even at facilities where money does not appear to be an issue, all golf course operations must fit within an established financial framework. In difficult times management decision making tends to focus even more on the financial consequences of physical golf course features and the operations necessary to maintain them. The question that is now being asked is whether these evolving management decisions which already have had impacts in the consumer direction, will garner a response from the design field. Jeff Brauer thinks they already have and predicts that the financial side of golf course management will be the major driving force behind course development and architecture in the near future:

> Practicality will prevail for the next several years. If no one has played from a bunker in recent memory, why spend money maintaining it? While a bunker might provide beauty, beauty doesn't appear on the balance sheets. Most courses will be built – or rebuilt – with profit and practicality in mind. Design features will be scrutinized closely again to see how much

> they contribute to play and reduce maintenance or speed of play. Inefficient features that don't serve many functions won't survive in many places. The bottom line of golf course design will be the bottom line. That's been true whether times are good and designs are extravagant, or the economy is poor and designs are practical. Perhaps the saddest part is that we forgot the lessons of the past. (2005)

Future Efficiency Needed

Brauer's point about forgotten lessons of the past is a good one. Time and time again throughout history examples of money driving change can be seen. When times are good this change is often viewed as progress while during bad times it is seen as a setback. These examples need to be learned from in a way that allows for smarter growth or progress during good times that does not impede success when times slow down or turn bad. With the existing economic situation, much of the perceived growth from the recent boom is exactly what is currently dragging the golf business down. Prolific development and golf course features that are incredibly labor intensive and resource sapping were doable, and often desired, not that long ago. Many courses were built, and in some cases continue to be, with hundreds of acres of maintained turf and extravagant bunker complexes. These same features now are an unneeded burden to those who maintain and manage them. Unfortunately, in the competitive golf market, when times are good all the stops are pulled out to provide a unique product. The problem is that this product is not always sustainable in the long-term. This sustainability can be looked at in several ways by architects and golf course managers. The financial sustainability of many courses has come into question as fewer rounds are played, new members quit signing-up, or housing lots don't sell. The business model, in many cases created during good financial times when many new golf courses are founded and built, must be tweaked or overhauled as a result. Like during similar times in the past, many golf courses will not survive the current economic squeeze.

From an environmental perspective, long-term sustainability is also vital to golf courses. This is an issue that has not always been provided any more than lip-service by those in the golf business. However, as rising costs of fuel, chemicals and water drive maintenance costs higher, alternative approaches must be explored. Golf courses that use

fewer of these resources, or use them more efficiently, can save significant amounts of money. As noted previously, financial savings will drive the golf business and in this case, hopefully make it more environmentally friendly.

Golf course development as a whole is already being impacted by a history of environmental practices that have not always been prudent. It is likely that in many arid regions there will simply not be enough water available to continue development at the recent pace. This is an issue that applies to much more than golf courses. As with most consumer-driven actions, change will not occur unless forced by regulation or economics. In the case of water and development, when it becomes too expensive to get huge amounts of water to very dry places, development in those locations will literally dry up. Amenities like golf courses can be expected to be among the first casualties due to their accessory nature and considerable water use. Environmental regulation of golf courses in some regions has already limited the amount of water that can be used. Such regulation will continue to become more widespread and probably more stringent.

Bunkers as a Key Component

While not having the large-scale social impact of a variable like water use, bunkers will play a significant role in the future of golf course design and management. Bunkers tend to be one of the easiest golf course features to change. Because of the ever increasing price to manage and maintain bunkers, their ability to be changed, or removed, makes them an attractive target for cost savings. Bunkers also occupy a unique place within the framework of a golf course. From a design perspective they provide strategic and aesthetic interest and give the architect opportunities for expression. A bunker renovation can significantly alter the face of a golf course, improving it aesthetically and adding strategic challenge for golfers. A good example of this was done at Peacock Gap Golf Club in San Raphael, California (Figures 2.65 – 2.67). This $4.8 million remodel and redesign by Forrest Richardson focused on tees, bunkers and greens. Extensive thought was given regarding how to best restore a sense of character to the golf course. It was decided that bunkers would play a major role. The result is a remodeled golf course that is visually stimulating and responds well to its setting on the edge of San Francisco Bay.

Figure 2.65 – 3rd Hole Peacock Gap Golf Club Prior to Remodel Project (Forrest Richardson & Associates)

Figure 2.66 – 3rd Hole Peacock Gap Golf Club During Construction (Forrest Richardson & Associates)

Figure 2.67 – 3rd Hole Peacock Gap Golf Club Following Remodel Project (Forrest Richardson & Associates)

In addition to determining the character of many courses, bunkers are typically considered essential from a design perspective and are entrenched within the game to the point where many golfers would look down on a course if it was devoid of bunkers. At the same time, the scope, scale and structure of bunkering can have serious impacts on the bottom line for golf course managers and in turn the financial sustainability of golf facilities.

A balance must be found, and it will be variable, that permits the continued effective use of bunkers on golf courses while not allowing bunkers to undermine financial sensibilities of golf course management and maintenance. The proper relationship between bunker design and golf course management should involve this financial sensibility from very early on in the process. This study looks not only at the impact that bunkers have on golf course design, management and maintenance, but also at the impacts those practices will have on the future of bunkers. It is hoped that by further exploring this topic potential issues can be identified and the lessons learned can be applied to promote the future financial sustainability of golf facilities and those who design, manage and maintain them.

Background Summary

Bunkers have played a significant role in the growth of the game of golf and the evolution of golf course architecture. Bunkers themselves have evolved considerably since they first appeared as natural sandy hollows on early golf courses among the seaside dunes of Scotland. Today's bunkers come in a variety of shapes, sizes and styles. Some are clean-cut and manufactured in appearance while others try to recreate the look of their linksland ancestors. However what really sets most of today's bunker apart is the fact that they undoubtedly receive more attention than their predecessors.

Maintenance of bunkers has become a key issue due to the rising expectations of golfers and the large sums of money spent on maintenance to meet these expectations. All golf course features have seen improvements in maintenance due to advances in techniques and equipment. Golfers have now come to expect excellent conditioning and it plays a major role in their enjoyment of a golf course. Bunkers in particular have seen a shift in the way they are viewed. No longer are they simply sandy, or sometimes muddy, pits in the ground. Modern bunkers feature carefully designed, engineered, and built

features that promote consistency and fairness while providing a visually striking product. From a maintenance perspective, the continual upkeep of these features can put a severe strain on the maintenance budget of a golf course. This is particularly true in the current economic situation as maintenance costs like labor and fuel are increasing while many superintendents are being asked to trim budgets. It is important for the future of the golf business, from both design and maintenance standpoints, to analyze the impacts of labor intensive bunkers.

The study of bunker issues on existing golf courses indicates that there may be disconnects in the relationship between the design and maintenance of bunkers. In many cases bunkers have been designed and built that can no longer be properly maintained given current financial constraints. Although the roles of bunkers are well established, their place on golf courses comes into questions considering the burden that they are in many cases. Many golf course superintendents and managers have decided that bunkers that cost too much to maintain or are simply too labor intensive must be addressed. The result that has been observed involves significant amounts of bunker modification, repair, or redesign as a result of maintenance and management related issues. These difficult management decisions, driven by the facility's financial bottom line, may have been avoidable with additional forethought during bunker design and construction.

Design consideration must be given to the expected role of bunkers on a golf course. The long-term impacts on golf course maintenance and management must also be considered during design. However, no matter the care taken during design or the quality of maintenance on the built product, bunkers will cause problems if not constructed properly. Construction techniques and construction quality play a major role in the success or failure of bunkers. Although no bunker will last forever in its built state, basic structural quality and integrity should allow for longer lifespan, increased playability, and manageable maintenance. Drainage and construction materials are very important to ensuring bunker quality. Poor decision making regarding these components during design and construction will almost guarantee bunker related problems. Also, without the proper maintenance of these components, bunkers conditions will rapidly deteriorate and aesthetics and playability will suffer.

As those tasked with golf course maintenance and management face the repercussions of the economic downturn, cost savings and operating efficiencies will be required. Bunkers are one area that is being studied closely and the overall approach to bunker design and maintenance may well change as a result. The cost of bunker maintenance is now playing a major role in bunker design for both new and existing courses. Professionals on both sides of the bunker design – management relationship will need to be aware of the impacts of their decision making on the ability of others to effectively operate. Designers must always consider the maintainability and necessity of their bunkers while those in maintenance and management should employ practices that retain the importance of bunkers while providing golfers with an entertaining product. The next step of the evolution of bunkers will likely be determined by the ability of these professionals to reach mutual points of understanding within the context of bunker design and management.

Chapter 3 – Methodology

The intent of this study is to assess the design and construction of golf course sand bunkers and analyze the resulting impacts on bunker maintenance and management. Literature reviews, a survey questionnaire and case studies were used to gather pertinent information. The results of the survey questionnaire were coded and the data statistically analyzed. The assembled information was then studied and an analysis of the relationships between key factors in bunker design and construction and commonly occurring issues related to bunker maintenance and management was undertaken. Conclusions drawn from this analysis were used to form recommendations to improve the bunker design-construction-maintenance-management process at all levels. As this study is a component of a Master's Thesis in landscape architecture, a design field, particular interest was paid to the golf course design process and its consequences relating to maintenance and management.

Information Collection

Existing documentation and previously conducted studies were used to establish the historical, intrinsic, and economic importance of bunkers on golf courses. This established background of importance is a key component when analyzing the role and impact of bunkers in the current economic landscape of golf course development and management.

Because the perceptions and expectations of the consumer – golfers – influence many golf course management decisions, a vital component of this study is the importance placed on bunkers by the golfer. Research done by the National Golf Foundation (NGF) and Golf 20/20 (Golf Digest) has helped to quantify the importance of bunkers and their related characteristics to golfers. This information is used as the basis for the importance of the analysis of bunkers as related to this study.

The evolution of bunkers along with historical maintenance and management practices were studied in order to better understand why and how current perceptions of bunkers have been developed. This historical context also helps to better understand the roles that bunkers play on a golf course and how these roles may vary or change over time. The writings of golf course architects, golf course architecture critics, and golf

course architecture historians were particularly useful in this pursuit. Additionally, resources from the United States Golf Association (USGA), American Society of Golf Course Architects (ASGCA), and Golf Course Superintendents Association of America (GCSAA) provided valuable historic and contemporary information that has been analyzed and subjected to the review of experts in the fields of golf course architecture, construction, and maintenance.

The importance of the economic impact of bunkers has been heightened in recent years due to a variety of golf course market conditions along with increasing labor and maintenance costs. NGF studies have analyzed the golf course market and factors that impact golf course management on a micro and macro level. These studies were used to better understand current market conditions and analyze trends over a period of time. Resources from the USGA and the GCSAA were utilized to gather information on resource allocation for bunker maintenance and construction.

All of the gathered resources and literature review were helpful in identifying issues that have arisen related to bunker maintenance and management. Once identified, these bunker issues were used as a key component in the development of the survey questionnaire.

Survey Questionnaire

The purpose of the survey is to collect quantitative data related to bunkers from professionals in golf course design, construction, maintenance, and management. Identification of important bunker issues and key influencing factors related to bunker design and construction was one of the major goals of the survey. Another goal was to identify the involved parties and actions at each step in the bunker design-construction-maintenance-management process for both bunkers on new golf courses and bunkers undergoing modification on existing golf courses.

A key component of the survey is the ability to compare and analyze the responses of professionals in different classifications. Areas of incongruent responses and conflicting priorities were identified and studied for importance and their potential impact on the overall bunker design-construction-maintenance-management process. Without further study it is somewhat difficult to know the exact reasons behind differences in

responses between the survey groups. However, efforts were made to understand the differences utilizing the information and resources gathered for this study.

The information gathered in the survey was used in all aspects of the study. Relationships between the survey questions and the overall study components can be seen graphically illustrated in Figure 3.1. A breakdown and descriptions of survey question sections can be found under the Survey Development heading. The final version of the survey and cover letter as sent to study subjects can be found in Appendix A.

Survey Development

The survey was developed based upon the need to identify and analyze the relationships between the factors influencing the design, construction, maintenance and management of bunkers. Bunker issues and key factors influencing bunker design, construction, maintenance and management were identified through background research. These issues and key factors were grouped and organized in the survey questions to allow for comparison and analysis of responses to individual questions, between multiple questions, and by classification of the respondents.

Survey response options vary by question. Some questions ask the respondent to "rank" based on importance or involvement level while other questions ask the respondent to "rate" based on importance. Some questions have simple yes/no response options and others ask the respondent to select responses from a list. An important component of the survey responses is the option for the respondent to provide additional comments after all questions. This option was included to allow for the explanation of answers and/or the inclusion of additional information by respondents. Such explanation and/or additional information are expected due to the differing areas of expertise of the respondents and the broad nature of the subjects being addressed by the survey questions.

The survey contained a total of 22 questions. The survey questions were grouped into the following four sections:

<u>General Respondent Information</u> – These questions were used to identify the roles that respondents had held within the golf course business and to classify respondents into one of four categories – golf course architects, golf course construction professionals, golf course maintenance professionals, or golf course management professionals.

Classification for the purpose of survey response analysis was based upon the response to Question 2.

1. Select all roles within golf course business
2. Select current role within golf course business

Bunkers and the Golf Course – These questions address the importance of bunkers and the key factors and characteristics that impact bunker design, maintenance, and management. Questions 3 and 4 compliment the background research related to establishing the importance and role of bunkers. Questions 5-7 identify the most important characteristics of bunkers, particularly as related to design and maintenance/management. Questions 8 and 9 identify the most important factors influencing bunker maintenance.

3. Rate importance of golf course components
4. Rank importance of roles of bunkers
5. Rate importance of bunker characteristics
6. Rank bunker characteristics – golf course design
7. Rank bunker characteristics – golf course maintenance and management
8. Rate importance of factors related to bunker maintenance
9. Rate importance of factors related to long-term bunker quality

New Bunkers – These questions address the parties involved in bunker design and construction for new golf courses.

10. Involved in bunker design/construction for a new golf course – yes or no
11. Rank parties involved – design
12. Rank parties involved – construction

Bunker Modification – These questions address bunker modifications and reasons for implementing them in addition to the parties involved in initiating bunker modifications, designing bunker modifications, and constructing bunker modifications on existing golf courses. Questions 14-16 identify the parties involved in three key steps of the bunker modification process. Questions 17 and 18 identify the major reasons for undertaking bunker modifications and what bunker modifications most commonly occur. Question 19 identifies the most common age range of existing bunkers on modification projects and

Questions 20-22 address other golf course changes and master planning done in conjunction with bunker modifications.

13. Involved in bunker modification on existing golf course – yes or no
14. Rank parties involved – initiating bunker modifications
15. Rank parties involved – design
16. Rank parties involved – construction
17. Rate importance of reasons considering bunker modifications
18. Rank bunker modifications based on most common occurrence
19. Select most common age range of existing bunkers on modification projects
20. Were other golf course changes also considered – yes or no
21. Were bunker modifications part of a golf course master plan – yes or no
22. Select additional golf course changes associated with bunker modifications

Following initial survey development, the survey questions and survey format were reviewed by a selection of golf course industry professionals. These professionals were selected because of their experience with the topics being studied and their relation to the survey study groups. Each survey question was developed to provide information relevant to specific areas of the study. Figure 3.1 illustrates the relationships between questions and their applications to the study model.

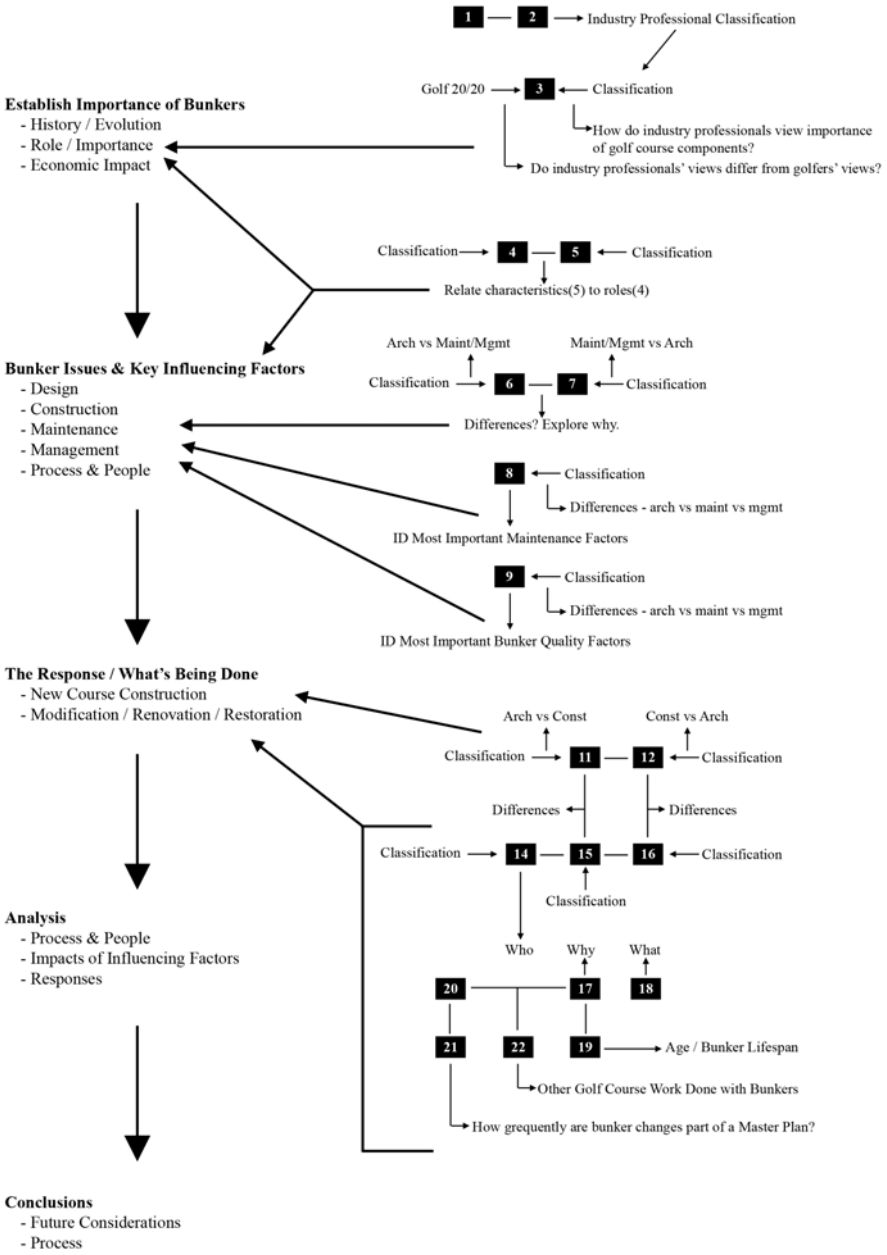


Figure 3.1 – Survey Questionnaire Methodology Diagram – Numbers in black boxes correspond with survey questions

Survey Administration

Following approval by the Kansas State University Committee for Research Involving Human Subjects (IRB), the survey was sent to 104 golf course superintendent subjects in October 2008 and 216 golf course architect subjects in January 2009. Survey subjects were identified by membership in professional organizations related to golf course architecture, construction, maintenance and management. Golf course superintendent subjects were members of the Kansas Chapter (KGCSA) of the GCSAA. A contact list of these superintendents was obtained directly from the KGCSAA. Golf course architect subjects were members, and their associates, of the ASGCA. A contact list of golf course architects was developed using the membership list of the ASGCA and then searching member websites for associate information.

Surveys were five pages long and printed on white 8.5" x 11" paper. Each mailing envelope included a self-addressed stamped envelope for the purpose of returning the survey. A cover letter explaining the study and the importance of the research was also included in the mailing envelope with each survey. Additionally, the cover letter made subjects aware of their option to complete the survey online. Online survey questions were identical to those on the mailed paper version. The option to complete the survey online was included with hopes that the ease of completion and the ability to share with coworkers and associates would increase the number of subjects completing the survey. The online survey was developed and administered using Axio Survey through the Office of Mediated Education at Kansas State University.

A total of 320 surveys were mailed and 109 surveys were completed and returned for a response rate of 34.1%. Nine of the returned surveys were completed using the online survey option. Raw survey results were coded and input into a Microsoft Excel spreadsheet developed for this study. Answer coding was organized as follows:

Yes / No questions – Yes=1, No=2

Rank questions – potential answers assigned rank number of 1-X based on importance/occurrence, an input of 0 indicates no importance/occurrence

Rate questions – potential answers assigned rating of 1-5 with 1 being least important and 5 being most important

Survey Analysis

Survey results were analyzed using the process outlined in Figure 3.1. The main goals of the survey analysis were to determine the key factors influencing bunker design, construction, maintenance and management, and to identify statistically significant differences in responses from the different classifications of respondents.

Statistical analysis consisted primarily of running standard t-tests using Microsoft Excel. The use of the t-test allows for comparisons of mean values that are deemed statistically significant when the t-value is greater than the critical t-value for the sample sizes degree of freedom and level of confidence (alpha level). A level of confidence of 5% (a = 0.05) was used for all t-tests in this study. By using a confidence level of 5%, it can be said that the differences in mean values for the samples tested had a 5% or less probability of occurring by chance alone.

Additional statistical analysis consisted of basic cross-tabulation and ranking of influence/importance based upon mean values derived from the survey results. The comparisons made using all analysis methods during the survey analysis phase of this study are presented in table format for ease of organization and understanding. Examples of the table formatting and presentation can be seen in Tables 3.1 – 3.3.

Mean Rating of Importance of Golf Course Components			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Greens	**4.98**	4.97	5.00
Irrigation	**4.50**	4.32	4.91
Turfgrass	**4.48**	4.37	4.73
Fairways	**4.20**	4.07	4.52
Tees	**4.16**	4.07	4.36
Bunkers	**4.08**	4.32	3.55

Table 3.1 – Example Mean Rating Table

Difference in Golf Course Component Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Greens	Architects	4.97	76	1.424	<	1.992	**NO**
	vs.						
	Superintendents	5.00	33				
Irrigation	Architects	4.32	76	6.390	>	1.982	**YES**
	vs.						
	Superintendents	4.91	33				
Turfgrass	Architects	4.37	76	2.701	>	1.990	**YES**
	vs.						
	Superintendents	4.73	33				
Fairways	Architects	4.07	76	3.129	>	1.996	**YES**
	vs.						
	Superintendents	4.52	33				
Tees	Architects	4.07	76	2.068	>	1.994	**YES**
	vs.						
	Superintendents	4.36	33				
Bunkers	Architects	4.32	75	3.968	>	2.010	**YES**
	vs.						
	Superintendents	3.55	33				

Table 3.2 – Example Difference in Response between Architects and Superintendents Table

Ranking of Importance of Bunker Roles - All Respondents							
	Avg. Rank	**Ranking Occurrences**					
		1	**2**	**3**	**4**	**5**	**No Importance**
Strategy	**1.30**	85	14	9	0	0	0
Aesthetics	**2.40**	24	40	16	12	8	8
Provide Visual Cues	**2.95**	14	17	33	26	7	10
Penalization	**3.07**	21	12	22	19	21	13
Containment	**3.78**	6	9	13	23	31	26

Table 3.3 – Example Ranking Table

Case Studies

Case studies of an individual golf courses complimented literature review and background research, and were used to identify bunker issues and the key influencing factors related to bunker maintenance and management. Additionally, the information gathered in the case studies was vital to establishing the importance of the economic impact that bunkers have on the overall landscape of golf course development and management.

The case studies consisted of researching the conditions and parties involved in the design, construction, maintenance and management of the golf courses and in particular their bunkers. A review of existing documentation of these processes was completed and supplemented by communication with the individuals involved. When possible, golf course bunker related issues were documented with photographs and diagrams. Maintenance and management responses to bunker issues were also observed and documented. The golf courses identified for the case studies were selected based upon familiarity to the researcher along with ease of physical access and access to documentation of the design-construction-maintenance-management process. The golf courses selected for case study were:

Colbert Hill Golf Course – Manhattan, Kansas

Mission Hills Country Club – Mission Hills, Kansas

Peacock Gap Golf Club – San Raphael, California

The case study of Colbert Hills consisted of multiple site visits to inventory and document bunker conditions. Information was also gathered through conversations with General Manager David Gourlay and Golf Course Superintendent Matt Gourlay. Additionally, a bunker renovation plan for holes 10-17 was completed by the author (Appendix C). Construction on the bunker renovations covered by the renovation plan began in late 2008 and were observed and documented for this study.

The case study of Mission Hills Country Club was less intensive than the study undertaken at Colbert Hills. The Mission Hills study consisted of a site visit in the fall of 2007 to observe the bunker modification that occurred as part of an overall golf course redesign and renovation project. The project was designed and overseen by golf course architect Keith Foster. Follow-up email correspondence with Mission Hill superintendent

Brad Gray answered several questions about his involvement in the process, the changes to the bunkers, and the resulting impact that they have had on golf course maintenance.

The case study of Peacock Gap was done during the summer of 2007 as a component of the author's internship with golf course architecture firm Forrest Richardson & Associates. The project was a remodel and redesign focusing primarily on the tees, bunkers and greens. Additionally, several holes were rerouted to address safety issues. A construction management site visit was made in June 2007. Further information regarding this project was obtained through personal communication with involved parties and from the records of Forrest Richardson & Associates.

Conclusions and Recommendation Development

Study conclusions were drawn based upon survey analysis results, information gathered from interviews and the case study, and background collected from existing literature. Key information garnered from the survey analysis included the perceived importance of factors relating to bunker design, construction, maintenance and management, as well as the statistically significant differences in responses to specific questions by the separate respondent classification. Red flags raised by these differing responses indicate areas of potential conflict within the overall bunker design-management process.

Conclusions focus on three areas; factors influencing the bunker design-management process (influencing factors), parties involved in the bunker design-management process (process and people), and actions taken related to issues that arise in bunker maintenance and management (response). The conclusions were used to formulate recommendations for those involved in the design, construction, maintenance and management of bunkers. Recommendations deal with aspects of the entire design-management process but focus mainly on the importance of understanding influencing factors in design, utilizing the process and the associated people in an efficient and effective manner, and responding to management issues with decisions that identify and address influencing factors that may have changed, been misrepresented, or overlooked initially.

The goal of the conclusions and recommendations that result from this study is to address potential problem areas in the bunker design-management process while

providing professionals with information that can be used to assist with informed decision making regarding bunkers. It is also hoped that these conclusions and recommendations will encourage others to take a closer look at the bunker processes studied here and find ways to improve bunker design and management methods for the betterment of the game of golf. Opportunities that exist for future study of this topic include, but are not limited to, in-depth analysis of resource allocation related to bunker maintenance and additional study of the impacts of bunker construction on bunker maintenance and management.

Chapter 4 – Survey Results and Analysis

Survey respondent data was analyzed and the results categorized following the structure illustrated in the Survey Questionnaire Research Model (Figure 3.1). The model is structured to allow for analysis of data within each question and across the survey respondent groups.

Questions that ask the respondents to rate the importance of specific variables regarding bunker design, construction and maintenance were analyzed for average variable rating and differences in response between golf course superintendents and golf course architects. Average variable rating is obtained by calculating the mean respondent rating for each variable. Differences between the responses of the two respondent groups are analyzed using a Standard t-Test. The Standard t-Test determines whether there is a statistically significant difference in the mean ratings of specific variables between the two respondent groups.

Questions that ask respondents to rank the importance or involvement of specific variables were analyzed for average ranking, rating occurrence, and differences in response between the two respondent groups. Average rankings are determined by calculating the mean non-zero rankings for each variable. Ranking occurrences are also tabulated and presented to illustrate distribution of rankings and show the number of zero rankings. Finally, differences in ranking order between the two respondent groups are analyzed to identify potential points of interest or differences in priority among like variables.

Analysis results are organized into six categories – description of respondents, golf course components, bunker roles and characteristics, bunker design, management and maintenance, new bunker design and construction, and bunker modification.

Description of Respondents

Survey administration took between in October 2008 and January 2009. A total of 320 surveys were mailed to golf course architects and golf course superintendents. Golf course superintendents were identified through the Kansas Chapter (KGCSA) of the Golf Course Superintendents Association of America (GCSAA). Golf course architects and their associates were identified through the American Society of Golf Course Architects (ASGCA). Additional information regarding survey administration can be found in Chapter 3 – Methodology.

The 320 surveys that were mailed consisted of 216 directed at golf course architects and 104 directed at golf course superintendents. A total of 109 completed surveys were returned, 76 from the golf course architect directed mailing and 33 from the golf course superintendent directed mailing (Table 4.1).

Survey Questionnaire Response Rate								
Total			**Golf Course Architects**			**Golf Course Superintendents**		
Surveys Mailed	**Surveys Returned**	**Response Rate**	**Surveys Mailed**	**Surveys Returned**	**Response Rate**	**Surveys Mailed**	**Surveys Returned**	**Response Rate**
320	**109**	**34.1%**	216	76	35.2%	104	33	31.7%

Table 4.1 - Survey Questionnaire Response Rate

Table 4.1 shows the overall response rate of 34.1%. This completed survey response rate was better than initially expected. Using a larger golf course superintendent sample size, one more closely resembling that of golf course architects may have been beneficial. In theory this might have led to a more similar number of responses from both groups of respondents.

In addition to marking their current employment position, respondents were asked to identify all golf course business related positions that they have held (Table 4.2). This question helps to illustrate the employment background and relevant experience of these particular professionals.

Survey Respondents' Professional Experience				
Golf Course Architects			**Golf Course Superintendents**	
Construction Professional	36%		**General Manager**	21%
Superintendent	16%		**Construction Professional**	12%
Owner	11%		**Owner**	9%
General Manager	1%		**Golf Professional**	9%
Golf Professional	1%		**Golf Course Architect**	3%

Table 4.2 - Respondents' Previous Experience

Over one-third of golf course architect respondents indicated that they have experience as golf course construction professionals while 16% have been golf course superintendents. It was surprising that these percentages were not higher. Expectations were that more golf course architects would have been involved in construction. That being said, they may have been involved with on-site operations at some point in their career, but did it as employees of a golf course architecture firm or consider it under the umbrella of golf course architecture.

21% of the superintendent respondents have been or are general managers. Several respondents indicated that they serve as both the superintendent and general manager at their facility. This situation is likely more common among the superintendents targeted by this survey, many of whom are at facilities in small Kansas towns, than it would be for superintendents at larger facilities or in metro areas. It is a concern that the demographic of the superintendents targeted by this study may not reflect the larger population as a whole.

Golf Course Components

The Golf 20/20 study referenced earlier identifies the most important golf course components as they relate to golfer enjoyment and return play. Conditioning of greens and bunkers were identified as the most important component by golfers in that study. In this study golf course architects and superintendents were asked to rate the importance of multiple golf course components (Table 4.3).

Mean Rating of Importance of Golf Course Components			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Greens	**4.98**	4.97	5.00
Irrigation	**4.50**	4.32	4.91
Turfgrass	**4.48**	4.37	4.73
Fairways	**4.20**	4.07	4.52
Tees	**4.16**	4.07	4.36
Bunkers	**4.08**	4.32	3.55
Trees/Vegetation	**3.06**	2.95	3.31
Cart Paths	**2.72**	2.51	3.18
Water Features	**2.59**	2.51	2.75

Table 4.3 - Mean Rating of Importance of Golf Course Components – where 5 = very important and 1 = not important

The ratings of golf course components show three relatively distinct groups of components. Greens are obviously the most important golf course component. All superintendent responders rated greens as “5 - very important” while architects averaged a rating of 4.98. Irrigation, turfgrass, fairways, tees and bunkers are all ranked near the high end of the importance scale and fall within one-half (.5) of a factor rating of each other. Finally, trees/vegetation, cart paths and water features are the least important of the identified golf course components, ranking near the middle of the importance scale.

It was expected that greens would be considered the most important golf course component as previous research has identified their importance to golfers. It is somewhat surprising that the other turf-related elements – turfgrass, fairways and tees – all rated above bunkers in this study. It should be noted that all turf-related elements were rated higher by superintendents than by architects. Meanwhile bunkers were rated much higher by architects than by superintendents. Some of this difference can be attributed to the fact that bunkers tend to be one of the main tools used for architectural expression.

Another surprise was the relatively low rating of cart paths. While cart paths may not be among the most desirable golf course components, they do serve a very necessary purpose on most courses due to the high percentages of golfer that use carts. Cart paths allow for the limitation of cart-related damage during wet course conditions and help promote convergence of cart traffic in necessary areas. The low rating of cart paths may be an indication that when considering importance, the desirability of specific components also comes into play.

The analysis of the differences between the two respondent groups is a key aspect of this study. Issues and conflicts between architecture and management/maintenance may arise if the perceived importance of golf course components differs between the two groups of professionals.

Table 4.4 shows that there is a statistically significant difference in the mean golf course component ratings between architects and superintendents for all identified components except greens and water features. These two components also are rated as the most important and least important respectively.

Difference in Golf Course Component Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Greens	Architects	4.97	76				
	vs.			1.424	<	1.992	**NO**
	Superintendents	5.00	33				
Irrigation	Architects	4.32	76				
	vs.			6.390	>	1.982	**YES**
	Superintendents	4.91	33				
Turfgrass	Architects	4.37	76				
	vs.			2.701	>	1.990	**YES**
	Superintendents	4.73	33				
Fairways	Architects	4.07	76				
	vs.			3.129	>	1.996	**YES**
	Superintendents	4.52	33				
Tees	Architects	4.07	76				
	vs.			2.068	>	1.994	**YES**
	Superintendents	4.36	33				
Bunkers	Architects	4.32	75				
	vs.			3.968	>	2.010	**YES**
	Superintendents	3.55	33				
Trees/Vegetation	Architects	2.95	75				
	vs.			2.053	>	1.990	**YES**
	Superintendents	3.31	32				
Cart Paths	Architects	2.51	76				
	vs.			3.400	>	1.989	**YES**
	Superintendents	3.18	33				
Water Features	Architects	2.51	76				
	vs.			1.115	<	1.998	**NO**
	Superintendents	2.75	32				

Table 4.4 - Difference in Golf Course Component Ratings between Architects and Superintendents

Irrigation, turfgrass, fairways, tees, bunkers, trees/vegetation and cart paths all exhibit a statistically significant difference in mean ratings between architects and superintendents. As the focus of this study is on bunkers, it is disturbing that there is such a difference in the bunker importance ratings between the two respondent groups. Again, desirability may play a role in ratings as superintendents have been faced with a plethora of issues related to bunkers. They may find them to be less desirable, and less important, golf course features while architects view them as both important and desirable.

Bunkers Roles and Characteristics

Bunkers can serve many purposes on golf courses (Table 4.5). From a pure golf standpoint they may provide strategic interest or function to penalize poorly played shots. In some cases they may actually help a golfer by providing containment and stopping a ball from finding a worse fate. Aesthetically bunkers are a key component to golf courses as their visual appearance often defines the "style" of the course. Bunkers may also provide the golfers with visual cues by indicating direction of play or highlighting other golf course features. Survey respondents were asked to rank the importance of these different roles of bunkers. While bunkers may play all of the identified roles, the goal was to identify the roles which the respondents fell are most common or important.

Ranking of Importance of Bunker Roles - All Respondents							
		Ranking Occurrences					
	Avg. Rank	1	2	3	4	5	No Importance
Strategy	**1.30**	85	14	9	0	0	0
Aesthetics	**2.40**	24	40	16	12	8	8
Provide Visual Cues	**2.95**	14	17	33	26	7	10
Penalization	**3.07**	21	12	22	19	21	13
Containment	**3.78**	6	9	13	23	31	26

Table 4.5 - Ranking of Importance of Bunker Roles - All Respondents

Strategy was easily the most highly ranked role of bunkers. All respondents ranked strategy first or second in importance while none of them felt that the strategy role held no importance ("0" ranking). Aesthetics received an overall ranking of second behind strategy and the role of providing visual cues was ranked third. The ranking of these three roles as the most important makes sense as they tend to be interrelated. Much of the strategic value of bunkers lies in their physical location and their appearance. The visual cues provided by bunkers may be strategic in nature but nearly always rely on the bunkers' aesthetics to communicate.

Penalization was consistently inconsistent in its rankings. A like number of respondents placed it in almost every ranking position. This speaks to the difference in opinion among respondents to the role of bunkers in providing penalization. This is a debate that has been going for a long time. Initially, bunkers on golf courses tended to be very penal in nature. However, over time they have become less penal - some might say because they are more strategic while others claim they have simply "lost their teeth." Many designers and superintendents lament the fact that bunker conditioning requires so much attention, particularly because they are defined as hazards and should be played as such. The results of this survey show that there continues to be a broad range of opinions on a bunker's role as a penalization tool. While many respondents felt it is the most important role a bunker can play, a similar number felt it was the least important of all the roles identified. Overall, penalization ranked ahead of only containment in this study. It should be noted that due to the nature of the study, it should not be inferred that lower ranked roles are not important; they are simply not viewed to be as important as the roles ranked above them. In the case of bunker roles it is likely that most golf courses have bunkers that fulfill all of these roles.

Analyzing the differences between the responses of the two respondent groups helps determine what priorities designers and superintendents have regarding the roles of bunkers (Tables 4.6 and 4.7). Major differences in the rankings of the roles may indicate a disconnect between the two groups. Issues may arise when bunkers are designed with a certain intent but are managed or maintained to play a different role.

Ranking of Importance of Bunker Roles - Architects Only							
	Avg. Rank	Ranking Occurrences					
		1	2	3	4	5	No Importance
Strategy	**1.19**	65	6	4	0	0	0
Aesthetics	**2.40**	16	32	10	10	5	2
Provide Visual Cues	**3.00**	8	14	27	14	5	6
Penalization	**3.50**	7	7	15	17	18	11
Containment	**3.85**	2	7	12	15	23	16

Table 4.6 - Ranking of Importance of Bunker Roles - Architects Only

Ranking of Importance of Bunker Roles - Superintendents Only							
	Avg. Rank	Ranking Occurrences					
		1	2	3	4	5	No Importance
Strategy	**1.55**	20	8	5	0	0	0
Penalization	**2.19**	14	5	7	2	3	2
Aesthetics	**2.41**	8	8	6	2	3	6
Provide Visual Cues	**3.03**	6	3	6	12	2	4
Containment	**3.61**	4	2	1	8	8	10

Table 4.7 - Ranking of Importance of Bunker Roles - Superintendents Only

Judging from the survey results, architects see strategy as the most important role of bunkers and likely design bunkers with this strategic intent in mind. 87% of the architect respondents ranked strategy as the most important bunker role and all architect respondents ranked it among the three most important roles. Fortunately superintendents also view strategy as the most important bunker role. It was also most frequently ranked first by superintendents and always ranked in the top three. No architects or superintendents deemed the role of strategy to have no importance. Overall there were not any large differences in rankings of bunker roles between architects and superintendents. None of the roles had a difference of more than one

position ranking between the two groups. Strategy was seen as most important by both respondent groups and containment was least important. Containment also saw the most rankings of no importance.

Physical characteristics of bunkers were rated based on their overall importance as well as being ranked based upon their importance related to golf course design and golf course management and maintenance (Table 4.8). As with other ratings and ranking in this study, the differences in responses between the two respondent groups were studied to determine if variation exists that may impact the effective design and management of bunkers.

Mean Rating of Importance of Bunker Characteristics			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Location	**4.82**	4.89	4.64
Drainage	**4.76**	4.80	4.68
Visual Appearance	**4.40**	4.51	4.14
Sand Type	**3.66**	3.63	3.71
Depth	**3.53**	3.62	3.32
Shape	**3.38**	3.45	3.21
Surface Uniformity	**3.30**	2.97	4.04
Size	**3.27**	3.28	3.25

Table 4.8 - Mean Rating of Importance of Bunker Characteristics – where 5 = very important and 1 = not important

Bunker location, drainage and visual appearance were rated as the most important bunker characteristics. All of the remaining characteristics were rated in the upper half of the importance scale but were grouped well behind the top three. The fact that location is the most important bunker characteristic fits well with strategy being ranked as the most important bunker role. Location tends to be the major factor that determines a bunker's strategic value. It was somewhat surprising that bunker size was not rated higher as it also impacts a bunker's strategy, although to a much lesser degree than location. The high rating of visual appearance also relates to the high

ranking of aesthetics as an important bunker role. It makes sense that if bunkers serve an important aesthetic role that their visual appearance is one of their most important characteristics.

The differences in the mean rating between the two respondent groups proved to be statistically significant for only three characteristics (Table 4.9).

Difference in Bunker Characteristics Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Location	Architects	4.89	74	2.230	>	2.032	**YES**
	vs.						
	Superintendents	4.64	28				
Drainage	Architects	4.80	74	1.015	<	2.017	**NO**
	vs.						
	Superintendents	4.68	28				
Visual Appearance	Architects	4.51	74	2.404	>	2.013	**YES**
	vs.						
	Superintendents	4.14	28				
Sand Type	Architects	3.63	73	0.406	<	2.004	**NO**
	vs.						
	Superintendents	3.71	28				
Depth	Architects	3.62	74	1.555	<	2.017	**NO**
	vs.						
	Superintendents	3.32	28				
Shape	Architects	3.45	74	1.076	<	1.997	**NO**
	vs.						
	Superintendents	3.21	28				
Surface Uniformity	Architects	2.97	71	4.479	>	2.005	**YES**
	vs.						
	Superintendents	4.04	28				
Size	Architects	3.28	74	0.158	<	2.011	**NO**
	vs.						
	Superintendents	3.25	28				

Table 4.9 - Difference in Bunker Characteristics Ratings between Architects and Superintendents

Statistically significant differences existed for location, visual appearance and surface uniformity. Both architects and superintendents rated location highly and the difference in mean ratings, although statistically significant, is not a reason for concern. The same can be said for

visual appearance which was rated highly and among the three most important by both groups. There was quite a discrepancy between the mean ratings for surface uniformity. Architects gave it a mean rating of 2.94 – near the middle of the importance scale. Superintendents rated it much higher giving in a mean rating of 4.04 – near the top of the importance scale. The likely explanation for the differences in ratings has to do with the expectations put on superintendents by golfers for well maintained and consistent bunkers. Superintendents are likely to be subjected to criticism if their bunkers do not exhibit a reasonable level of surface uniformity. Architects, as noted by many of the survey comments, would like to see bunkers play more like true hazards and do not think surface uniformity is all that important. While the survey comments indicated that many superintendents feel the same way about bunkers as hazards, they are more likely to face issues in their profession when bunkers are not maintained up to the level expected by golfers.

Bunker Design, Management and Maintenance

The ranking of bunker characteristics as they relate to golf course design and golf course management and maintenance allows for comparisons between design and construction Tables 4.10 and 4.11) as well as between the views of the two respondent groups (Tables 4.12 – 4.15). Issues may arise if for example, a specific characteristic is rated as very important to management and maintenance but is not important to design. In this case the architect may not be paying a characteristic much heed but it will prove very important later when the superintendent must deal with it.

Ranking of Bunker Characteristics Based on Importance to Golf Course Design - All Respondents											
	Avg. Rank	Ranking Occurrences									
		1	2	3	4	5	6	7	8	9	No Importance
Location	**2.00**	58	11	12	4	4	2	1	1	1	6
Visual Appearance	**2.91**	29	28	9	7	11	6	2	2	2	4
Drainage	**3.45**	25	13	16	15	8	4	8	5	1	5
Maintainability	**4.04**	17	17	8	17	11	9	4	4	8	5
Structural Quality	**4.63**	13	5	12	16	7	5	12	9	5	16
Shape	**5.10**	10	1	11	9	12	12	9	8	7	21
Sand Type	**5.29**	10	5	3	8	15	15	8	10	8	18
Depth	**5.32**	12	5	5	10	4	14	16	12	7	15
Size	**5.91**	6	3	4	9	9	11	10	17	10	20

Table 4.10 - Ranking of Bunker Characteristics Based on Importance to Golf Course Design - All Respondents

Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance - All Respondents											
	Avg. Rank	Ranking Occurrences									
		1	2	3	4	5	6	7	8	9	No Importance
Maintainability	**1.93**	56	20	8	9	1	2	0	2	0	2
Drainage	**1.95**	49	25	15	5	5	1	0	0	0	0
Structural Quality	**3.19**	15	19	23	14	6	2	4	1	2	14
Sand Type	**4.26**	11	3	13	21	19	7	8	3	1	14
Size	**4.90**	9	7	6	10	16	16	7	7	5	17
Depth	**5.12**	10	4	5	9	14	15	14	10	2	17
Shape	**5.31**	7	5	5	6	10	16	19	7	2	23
Visual Appearance	**5.93**	8	4	5	5	5	11	7	13	16	26
Location	**6.21**	12	2	4	2	1	6	2	17	21	33

Table 4.11 - Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance - All Respondents

Interestingly, location and visual appearance rank as the most important characteristics to design but as the least important characteristics to maintenance and management. The discrepancy is understandable with location as it is very important in the strategic role of bunkers. However, the case of visual appearance is more puzzling. One would expect visual appearance to rank higher in importance to management and maintenance as significant time and resources are used to ensure that bunkers look good. Again it should be noted that the low ranking of visual appearance does not mean it is not important, in fact it was rated very highly in overall importance (Table 4.8) In this case it was not as important as the other characteristics when considering golf course management and maintenance.

Shape, depth and size were all characteristics of bunkers ranked toward the bottom of the list with regards to design. This shows that while locating bunkers is the most important aspect of their design, their other spatial characteristics are not as critical. This is somewhat surprising due to the high ranking of the importance of aesthetics as a bunker role and the high rating of the importance of visual appearance. It would seem that spatial characteristics like shape, depth and size play a major role in aesthetics and might rank higher as a result. It could also be expected that they would have ranked higher when considering bunker management and maintenance. After all, the size, depth and shape of a bunker can all have a significant impact on the bunker's ease of maintenance.

Maintainability and drainage rank as the most important bunker characteristics related to management and design. Good drainage in bunkers plays a key role in the conditioning and long-term maintainability of bunkers. It should be noted that the term maintainability as it relates to this section of the study may not have been the wisest use of terminology as it is out of context and redundant. The other characteristics are physical qualities while maintainability is more of a summation that results from the quality of these physical characteristics. Also, it can be expected that "maintainability" will be ranked highly when looking at its importance related to management and maintenance. (see Conclusions – Study Methodology – Survey Questionnaire)

Ranking of Bunker Characteristics Based on Importance to Golf Course Design - Architects Only											
		Ranking Occurrences									
	Avg. Rank	1	2	3	4	5	6	7	8	9	No Importance
Location	**1.70**	52	5	8	1	2	1	1	1	0	1
Visual Appearance	**2.80**	19	23	9	7	7	3	0	1	2	1
Drainage	**3.40**	16	12	10	13	6	3	4	3	1	4
Maintainability	**4.40**	6	13	5	15	9	7	4	4	5	4
Structural Quality	**4.90**	7	5	8	9	6	4	7	8	5	13
Shape	**5.12**	6	1	7	8	10	9	6	5	5	15
Sand Type	**5.37**	7	2	2	8	10	12	6	8	5	12
Depth	**5.39**	7	4	5	7	2	9	14	8	5	11
Size	**6.07**	5	3	3	5	9	6	8	12	9	11

Table 4.12 - Ranking of Bunker Characteristics Based on Importance to Golf Course Design - Architects Only

Ranking of Bunker Characteristics Based on Importance to Golf Course Design – Superintendents Only											
		Ranking Occurrences									
	Avg. Rank	1	2	3	4	5	6	7	8	9	No Importance
Location	**2.91**	6	6	4	3	2	1	0	0	1	5
Maintainability	**3.15**	11	4	3	2	2	2	0	0	3	1
Visual Appearance	**3.20**	10	5	0	0	4	3	2	1	0	3
Drainage	**3.59**	9	1	6	2	2	1	4	2	0	1
Structural Quality	**4.00**	6	0	4	7	1	1	5	1	0	3
Shape	**5.05**	4	0	4	1	2	3	3	3	2	6
Sand Type	**5.09**	3	3	1	0	5	3	2	2	3	6
Depth	**5.13**	5	1	0	3	2	5	2	4	2	4
Size	**5.95**	1	0	1	4	0	5	2	5	1	9

Table 4.13 - Ranking of Bunker Characteristics Based on Importance to Golf Course Design - Superintendents Only

Tables 4.12 and 4.13 show the rankings of bunker characteristics as they relate to golf course design for each of the two respondent groups. The only major difference between the groups is that superintendents rank maintainability higher than architects. Three potential conclusions can be drawn from this. One is that architects are more qualified to rate the factors as they relate to design and the ratings of the superintendents should not carry as much weight as a result. Of course if this is the case the same thinking should be applied to the ranking of the characteristics as they apply to management and maintenance. Another potential conclusion is that architects simply see maintainability as less important related to other characteristics than superintendents do. This may be the case as superintendents are faced with maintenance issues on a daily basis and would be expected to place more importance on characteristics that so closely impact them. The third possible conclusion is that the difference between the two respondent groups should be ignored due to the fact that maintainability may be out of context with the other characteristics. It can be argued that because of the problems noted with the "maintainability" terminology, the characteristic should not be included in the rankings.

Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance - Architects Only											
		Ranking Occurrences									
	Avg. Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**No Importance**
Maintainability	**1.87**	39	16	5	8	1	0	0	1	0	2
Drainage	**1.94**	35	18	11	4	4	0	0	0	0	0
Structural Quality	**3.17**	8	15	17	10	4	2	3	1	0	12
Sand Type	**4.06**	8	3	12	16	13	2	7	2	0	9
Size	**4.82**	7	5	4	9	13	8	5	5	4	12
Depth	**5.25**	6	2	4	6	10	12	12	5	2	13
Shape	**5.33**	4	5	4	2	7	14	13	5	1	17
Visual Appearance	**5.98**	6	3	4	3	5	4	5	10	13	19
Location	**6.39**	9	1	1	2	1	5	0	14	16	23

Table 4.14 - Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance – Architects Only

Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance - Superintendents Only											
	Avg. Rank	Ranking Occurrences									
		1	2	3	4	5	6	7	8	9	No Importance
Drainage	**1.96**	14	7	4	1	1	1	0	0	0	0
Maintainability	**2.07**	17	4	3	1	0	2	0	1	0	0
Structural Quality	**3.23**	7	4	6	4	2	0	1	0	2	2
Depth	**4.79**	4	2	1	3	4	3	2	5	0	4
Sand Type	**4.78**	3	0	1	5	6	5	1	1	1	5
Size	**5.13**	2	2	2	1	3	8	2	2	1	5
Shape	**5.27**	3	0	1	4	3	2	6	2	1	6
Location	**5.72**	3	1	3	0	0	1	2	3	5	10
Visual Appearance	**5.81**	2	1	1	2	0	7	2	3	3	7

Table 4.15 - Ranking of Bunker Characteristics Based on Importance to Golf Course Management & Maintenance – Superintendents Only

Tables 4.14 and 4.15 show the rankings of bunker characteristics as they relate to golf course management and maintenance for each of the two respondent groups. Only one characteristic, depth, differs more than one position ranking between the two groups. Superintendents rank depth slightly higher in importance than architects do. This is understandable as increasing bunker depth would likely increase the difficulty of maintenance. Superintendents may have more experience with this situation than many architects.

Looking specifically at maintenance, respondents were asked to rate the importance of factors that impact the bunker maintenance process (Table 4.16). The goal of this question is to identify the most important factors, especially those determined by superintendents.

Mean Rating of Importance of Bunker Maintenance Factors			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Drainage	**4.80**	4.81	4.79
Education of Maintenance Staff	**4.33**	4.42	4.14
Material Contamination	**4.11**	4.12	4.07
Edging and Weed Control	**3.96**	3.84	4.25
Number of Bunkers / Sand Area to Maintain	**3.86**	3.81	3.96
Sand Type	**3.83**	4.01	3.43
Raking Methods	**3.81**	3.91	3.61
Irrigation of Bunker Surrounds	**3.74**	3.66	3.93
Maintenance of Bunker Surrounds	**3.70**	3.54	4.07

Table 4.16 - Mean Rating of Importance Bunker Maintenance Factors – where 5 = very important and 1 = not important

Drainage is easily rated as the most important bunker maintenance factor. This is consistent with the results from Table 14.11 that rank drainage near the top of bunker characteristics that are important related to golf course management and maintenance. In addition to the extreme importance of drainage, a key point to take away from this information is the high ratings of all the bunker maintenance factors. While the two factors related to bunker surrounds are rated the lowest, they are still both rated high enough to be considered very important.

Both architects and superintendents give drainage the highest mean importance rating. Only edging and weed control, sand type, and maintenance of bunker surrounds exhibit a statistically significant difference in the mean importance rating between architects and superintendents (Table 4.17).

Difference in Bunker Maintenance Factor Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Drainage	Architects	4.81	74				
	vs.			0.269	<	2.009	**NO**
	Superintendents	4.79	28				
Education of Maintenance Staff	Architects	4.42	74				
	vs.			1.491	<	2.023	**NO**
	Superintendents	4.14	28				
Material Contamination	Architects	4.12	74				
	vs.			0.258	<	2.007	**NO**
	Superintendents	4.07	28				
Edging and Weed Control	Architects	3.84	74				
	vs.			2.237	>	2.004	**YES**
	Superintendents	4.25	28				
Number of Bunkers / Sand Area to Maintain	Architects	3.81	73				
	vs.			0.822	<	2.000	**NO**
	Superintendents	3.96	28				
Sand Type	Architects	4.01	74				
	vs.			2.703	>	2.014	**YES**
	Superintendents	3.43	28				
Raking Methods	Architects	3.91	74				
	vs.			1.463	<	2.010	**NO**
	Superintendents	3.61	28				
Irrigation of Bunker Surrounds	Architects	3.66	73				
	vs.			1.446	<	2.004	**NO**
	Superintendents	3.93	28				
Maintenance of Bunker Surrounds	Architects	3.54	74				
	vs.			3.071	>	1.998	**YES**
	Superintendents	4.07	28				

Table 4.17 - Difference in Bunker Maintenance Factor Ratings between Architects and Superintendents

Architects rate sand type as more important than superintendents do while superintendents give a higher rating to edging and weed control and maintenance of bunker surrounds. In this case more weight might be given to the responses of superintendents as they likely have more experience and are more involved in the every-day maintenance of bunkers.

Factors influencing bunker maintenance were also analyzed on a more macro level. Respondents were asked to rate the importance of factors related to long-term bunker quality (Table 4.18). These factors can be tied to general design, construction and management actions.

Mean Rating of Importance of Factors Related to Long-Term Bunker Quality			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Construction Quality	**4.72**	4.75	4.67
Maintenance Practices	**4.56**	4.56	4.55
Maintenance Budget & Resources	**4.35**	4.32	4.42
Construction Techniques	**4.29**	4.29	4.27
Design Feasibility	**4.03**	4.03	4.03
Level of Use	**3.47**	3.55	3.30

Table 4.18 - Mean Rating of Importance of Factors Related to Long-Term Bunker Quality – where 5 = very important and 1 = not important

All of the factors had a mean importance rating above four with the exception of level of use. Both architects and superintendents gave level of use the lowest rating of all the factors. A higher rating from superintendents might have been expected as a result of their daily dealings with the results of levels of use, but the importance rating for level of use from superintendents was actually slightly lower than that of architects. Not surprisingly construction quality and maintenance practices were rated as the most important factors on long-term bunker quality. Like with bunker maintenance factors, all of the factors impacting long term bunker quality were rated toward the high end of the importance scale.

A comparison of the differences in rating means between architects and superintendents shows no factors with a statistically significant difference (Table 4.19). This is a good sign, indicating that both groups tend to concur with regards to what factors are important to long-term bunker quality.

Difference in Factors Related to Long-Term Bunker Quality Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Construction Quality	Architects	4.75	75	0.627	<	2.008	**NO**
	vs.						
	Superintendents	4.67	33				
Maintenance Practices	Architects	4.56	75	0.110	<	1.997	**NO**
	vs.						
	Superintendents	4.55	33				
Maintenance Budget & Resources	Architects	4.32	75	0.691	<	1.991	**NO**
	vs.						
	Superintendents	4.42	33				
Construction Techniques	Architects	4.29	75	0.115	<	2.002	**NO**
	vs.						
	Superintendents	4.27	33				
Design Feasibility	Architects	4.03	71	0.013	<	1.991	**NO**
	vs.						
	Superintendents	4.03	33				
Level of Use	Architects	3.55	75	1.265	<	1.995	**NO**
	vs.						
	Superintendents	3.30	33				

Table 4.19 - Difference in Factors Related to Long-Term Bunker Quality Ratings between Architects and Superintendents

New Bunker Design and Construction

Survey respondents were asked if they had been involved in the bunker design and construction process for a new golf course (Table 4.20). All of the golf course architects had been involved in at least one such project while only 52% of the surveyed superintendents had.

Involvement in Bunker Design and Construction for a New Golf Course			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Yes	**86%**	100%	52%
No	**14%**	0%	48%

Table 4.20 - Involvement in Bunker Design and Construction for a New Golf Course

The respondents who had been involved in bunker design or construction for a new golf course were asked to rank the involvement of various parties in the design and construction process (Table 4.21). While some of the parties would not be expected to be involved in certain phases of a project, they are included in the list for the sake of completeness and continuity (the same questions related to initiation, design and construction on bunker modification projects are asked as well).

Ranking of Involvement of Parties in Bunker Design for a New Golf Course - All Respondents										
		Ranking Occurrences								
	Avg. Rank	1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.08**	86	2	1	1	0	0	0	0	1
Superintendent	**2.63**	9	30	23	13	3	0	0	0	13
Owner	**3.01**	8	23	17	15	7	1	2	0	18
Contractor	**3.97**	4	18	10	10	10	9	0	7	23
Golf Professional	**4.49**	1	4	6	19	9	13	3	0	36
Board of Directors / Greens Committee	**4.90**	3	4	7	6	10	7	7	6	41
Golfers / Facility Users	**5.40**	2	4	4	4	2	10	9	7	49
General Manager	**6.00**	0	2	1	1	9	10	12	5	51

Table 4.21 - Ranking of Involvement of Parties in Bunker Design for a New Golf Course - All Respondents

As would be expected, golf course architects are overwhelmingly the highest rated party based on involvement in bunker design on a new golf course. The timing of bunker design can be variable due to different design styles. On some projects an architect may design the bunkers early on and they are then built closely following plans. In other cases bunker design does not take place until well into construction. This process might involve only the architect but more often other parties, specifically the owner, superintendent or contractor, offer input.

There are no differences in the ranking of parties between architects and superintendents (Tables 4.22 and 4.23).

Ranking of Involvement of Parties in Bunker Design for a New Golf Course - Architects Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.05**	72	2	1	0	0	0	0	0	0
Superintendent	**2.74**	5	23	20	11	3	0	0	0	13
Owner	**3.03**	5	20	13	14	7	0	1	0	15
Contractor	**3.96**	2	17	7	7	9	8	0	5	20
Golf Professional	**4.52**	0	3	5	15	7	10	2	0	33
Board of Directors / Greens Committee	**5.00**	2	3	5	6	7	6	6	5	35
Golfers / Facility Users	**5.36**	2	4	3	3	0	7	8	6	42
General Manager	**5.94**	0	2	1	1	6	8	9	4	44

Table 4.22 - Ranking of Involvement of Parties in Bunker Design for a New Golf Course - Architects Only

Ranking of Involvement of Parties in Bunker Design for a New Golf Course – Superintendents Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.20**	14	0	0	1	0	0	0	0	1
Superintendent	**2.19**	4	7	3	2	0	0	0	0	0
Owner	**2.92**	3	3	4	1	0	1	1	0	3
Contractor	**4.00**	2	1	3	3	1	1	0	2	3
Golf Professional	**4.38**	1	1	1	4	2	3	1	0	3
Board of Directors / Greens Committee	**4.50**	1	1	2	0	3	1	1	1	6
Golfers / Facility Users	**5.56**	0	0	1	1	2	3	1	1	7
General Manager	**6.22**	0	0	0	0	3	2	3	1	7

Table 4.23 - Ranking of Involvement of Parties in Bunker Design for a New Golf Course - Superintendents Only

Like with bunker design, architects are ranked as the most involved party in bunker construction for a new golf course (Table 4.24). Surprisingly, the contractor is ranked second behind the architect. It was expected that the contractor would be considered the most involved party in this phase of the project. However, the involvement of architects in construction supervision and administration likely accounts for their high ranking. Another factor may be the fact that survey respondents were primarily golf course architects. Had golf course contractors been surveyed the results may have been different. Overall, architects, contractors and superintendents make up a clear top three for involvement in the bunker construction phase.

Ranking of Involvement of Parties in Bunker Construction for a New Golf Course - All Respondents										
		Ranking Occurrences								
	Avg. Rank	1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.31**	69	14	7	0	0	0	0	0	1
Contractor	**2.03**	31	38	8	7	0	0	0	2	5
Superintendent	**2.56**	11	20	54	3	0	0	0	0	3
Owner	**3.89**	1	9	3	37	9	4	0	0	28
Golf Professional	**4.78**	1	2	4	15	11	14	1	2	41
Board of Directors / Greens Committee	**5.60**	1	1	1	4	10	11	10	2	51
General Manager	**5.85**	0	0	2	2	12	12	8	4	51
Golfers / Facility Users	**7.00**	0	0	0	3	1	3	10	14	60

Table 4.24 - Ranking of Involvement of Parties in Bunker Construction for a New Golf Course - All Respondents

The only difference in ranking between the respondent groups is a small one. Superintendents rank superintendents ahead of contractors while architects have the order of those two parties reversed. (Tables 4.25 and 4.26)

Ranking of Involvement of Parties in Bunker Construction for a New Golf Course – Architects Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	1.27	59	12	4	0	0	0	0	0	0
Contractor	1.96	24	35	5	5	0	0	0	1	5
Superintendent	2.65	6	15	49	2	0	0	0	0	3
Owner	3.96	0	5	3	34	9	1	0	0	23
Golf Professional	4.85	0	1	4	12	8	12	1	1	36
Board of Directors / Greens Committee	5.66	0	0	1	4	9	10	7	1	43
General Manager	5.90	0	0	1	2	8	10	6	3	45
Golfers / Facility Users	7.12	0	0	0	2	1	1	9	12	50

Table 4.25 - Ranking of Involvement of Parties in Bunker Construction for a New Golf Course - Superintendents Only

Ranking of Involvement of Parties in Bunker Construction for a New Golf Course - Superintendents Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.53**	10	2	3	0	0	0	0	0	1
Superintendent	**2.13**	5	5	5	1	0	0	0	0	0
Contractor	**2.38**	7	3	3	2	0	0	0	1	0
Owner	**3.55**	1	4	0	3	0	3	0	0	5
Golf Professional	**4.55**	1	1	0	3	3	2	0	1	5
Board of Directors / Greens Committee	**5.38**	1	1	0	0	1	1	3	1	8
General Manager	**5.70**	0	0	1	0	4	2	2	1	6
Golfers / Facility Users	**6.50**	0	0	0	1	0	2	1	2	10

Table 4.26 - Ranking of Involvement of Parties in Bunker Construction for a New Golf Course - Superintendents Only

Bunker Modification

Survey respondents were asked if they had been involved in efforts to make modifications to bunkers on an existing golf course (Table 4.27). Both respondent groups had a high level of participation in such projects as 100% of the architects and 91% of the superintendents had been involved with bunker modifications.

Involvement in Efforts to Make Modifications to Bunkers on an Existing Golf Course			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Yes	**97%**	100%	91%
No	**3%**	0%	9%

Table 4.27 - Involvement in Efforts to Make Modifications to Bunkers on an Existing Golf Course

There are many reasons why a golf course might undertake bunker modifications. Respondents were asked to rate the level of importance of various reasons for bunker modifications (Table 4.28).

Mean Rating of Importance of Reasons for Considering Bunker Modifications			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Drainage	**4.72**	4.70	4.76
Maintenance	**4.57**	4.59	4.52
Strategy	**4.19**	4.45	3.60
Bunker Age	**4.02**	3.99	4.08
Design Flaws	**3.98**	3.97	4.00
Aesthetics	**3.93**	4.04	3.68
Restore Design Character	**3.89**	3.97	3.71
Economic Factors	**3.52**	3.53	3.50
Safety	**3.50**	3.55	3.38
Pace of Play	**3.33**	3.29	3.42
Circulation	**3.09**	3.18	2.86

Table 4.28 - Mean Rating of Importance of Reasons for Considering Bunker Modifications – where 5 = very important and 1 = not important

The two most important reasons for making bunker modifications are related to bunker management. Drainage has already been identified as a very important bunker characteristic and as ranking highly based on its importance to golf course management and maintenance. Here it is identified as the most important reason for considering bunker modifications. Poor drainage can be the bane of good bunker maintenance and management, causing a myriad of other issues. General maintenance was rated as the second most important reason for making bunker modifications. This is no surprise as many golf courses are making changes to bunkers in an effort to reduce maintenance efforts and costs. All of the reasons for making bunker modifications that were listed in the survey were rated in the top half of the importance scale. This goes to show not only the variety of reasons for bunker modifications, but also the breadth of issues related to bunkers that can arise and require attention.

The only statistically significant difference in mean ratings of reasons for making bunker modifications between architects and superintendents is for strategy (Table 4.29). Architects rate strategy as being more important than superintendents do when considered as a reason for bunker modifications. This may indicate that architects are more likely to consider strategy when designing bunker modifications. As the results of party involvement in bunker modification phases (Tables 4.37, 4.40 and 4.43) indicate, superintendents are often very involved in the initiation, design and construction of bunker modifications. If this is a trend that holds true over an entire population, it can be theorized that bunker modification projects overseen primarily by golf course architects are more likely to factor strategy into design than those overseen primarily by superintendents.

Difference in Reasons for Bunker Modifications Ratings between Architects and Superintendents

		Mean Rating	Observations	t		Critical t Value	Significant
Drainage	Architects	4.70	74	0.448	<	2.009	**NO**
	vs.						
	Superintendents	4.76	25				
Maintenance	Architects	4.59	74	0.460	<	2.023	**NO**
	vs.						
	Superintendents	4.52	25				
Strategy	Architects	4.45	74	5.105	>	2.017	**YES**
	vs.						
	Superintendents	3.60	25				
Bunker Age	Architects	3.99	72	0.449	<	2.005	**NO**
	vs.						
	Superintendents	4.08	24				
Design Flaws	Architects	3.97	73	0.148	<	2.020	**NO**
	vs.						
	Superintendents	4.00	24				
Aesthetics	Architects	4.04	74	1.976	<	2.010	**NO**
	vs.						
	Superintendents	3.68	25				
Restore Design Character	Architects	3.97	73	1.211	<	2.019	**NO**
	vs.						
	Superintendents	3.71	24				
Economic Factors	Architects	3.53	73	0.146	<	2.010	**NO**
	vs.						
	Superintendents	3.50	24				
Safety	Architects	3.55	74	0.632	<	2.017	**NO**
	vs.						
	Superintendents	3.38	24				
Pace of Play	Architects	3.29	73	0.643	<	2.017	**NO**
	vs.						
	Superintendents	3.42	24				
Circulation	Architects	3.18	71	1.893	<	1.998	**NO**
	vs.						
	Superintendents	2.86	22				

Table 4.29 - Difference in Reasons for Bunker Modifications Ratings between Architects and Superintendents

In addition to analyzing reasons for undertaking bunker modifications, the types of modifications were looked at as well (Table 4.30). Respondents were asked to rank the types of modifications based upon the current trends they have observed in the golf course business.

Ranking of Most Common Bunker Modifications - All Respondents							
		Ranking Occurrences					
	Avg. Rank	1	2	3	4	5	6
Bunker Restoration or Repair	**1.53**	77	7	10	4	0	3
Bunker Relocation	**2.72**	15	44	15	15	5	7
New Bunkers Added	**3.28**	7	25	26	21	14	6
Bunkers Removed	**3.65**	9	12	21	30	19	9
Reduction of Bunker Sizes	**4.28**	4	11	15	14	35	21
Expansion of Bunker Sizes	**4.86**	3	6	12	9	20	49

Table 4.30 - Ranking of Most Common Bunker Modifications - All Respondents

Bunker restoration or repair ranked as the most common bunker modification and easily had the greatest number of individual rankings of most common. Bunker restoration and repair tends to be an ongoing process at many golf courses due to the nature of bunkers and the fact that many factors are at work that lead to bunker disrepair. Bunker relocation ranked as the second most common modification. There are multiple reasons for bunker relocation but most often they are moved to change the playing characteristics of a golf hole. This generally strategic reason for change may also be the response to new technologies that have increased driving distances, particularly among accomplished golfers. Many older courses, particularly those that regularly host competitions and tournaments, have moved fairway bunkers down-range to try and retain their relevance.

It was slightly surprising to see that the addition of new bunkers was ranked ahead of bunker removal. Generally speaking courses have been looking for ways to reduce bunker maintenance and management costs and the removal of bunkers that are deemed unnecessary is a popular solution. It should be noted that the rankings for bunker addition and bunker removal are

very similar across the board. There is likely not a large enough difference to draw any definite conclusion from this study regarding the difference in occurrence between the two.

Superintendents did rank bunker removal ahead of bunker addition as compared to architects who ranked addition ahead of removal (Tables 4.31 and 4.32). However, again the differences are so small that there is probably not a reason to draw any conclusions.

Ranking of Most Common Bunker Modifications - Architects Only							
		Ranking Occurrences					
	Avg. Rank	1	2	3	4	5	6
Bunker Restoration or Repair	**1.60**	54	5	7	3	0	3
Bunker Relocation	**2.27**	13	40	11	6	2	1
New Bunkers Added	**3.20**	4	18	22	16	9	2
Bunkers Removed	**3.76**	5	6	15	25	17	4
Reduction of Bunker Sizes	**4.42**	2	6	11	11	26	17
Expansion of Bunker Sizes	**5.10**	1	2	9	5	14	40

Table 4.31 - Ranking of Most Common Bunker Modifications - Architects Only

Ranking of Most Common Bunker Modifications - Superintendents Only							
		Ranking Occurrences					
	Avg. Rank	1	2	3	4	5	6
Bunker Restoration or Repair	**1.38**	23	2	3	1	0	0
Bunkers Removed	**3.36**	4	6	6	5	2	5
New Bunkers Added	**3.50**	3	7	4	5	5	4
Reduction of Bunker Sizes	**3.89**	2	5	4	3	9	4
Bunker Relocation	**3.89**	2	4	4	9	3	6
Expansion of Bunker Sizes	**4.25**	2	4	3	4	6	9

Table 4.32 - Ranking of Most Common Bunker Modifications - Superintendents Only

Bunker age was rated among the more important reasons for undertaking bunker modifications. In addition to being a reason in itself, increased bunker age can lead to other issues related to drainage, structural integrity, aesthetics and material contamination. Survey respondents were asked to indicate the most common age of existing bunkers when bunker modifications were implemented (Table 4.33).

Most Common Timeframe for Bunker Modifications			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
0-5 years	**3%**	1%	7%
5-10 years	**15%**	11%	26%
10-20 years	**53%**	61%	33%
older than 20 years	**29%**	28%	33%

Table 4.33 - Most Common Timeframe for Bunker Modification

Respondents indicated that 82% of bunker modifications were implemented on bunkers that were older than 10 years. The most common response was the 10-20 year old time frame. A greater percentage of superintendents tended to select newer bunkers as having modification made on them than did architects. Architects had been involved in modifications on bunkers that were nearly always at least 10 years old. One aspect of the process that this study does not explore is when previous modifications may have taken place. While the general age of bunkers being worked on is likely to be known, the full history of the bunkers – past modifications, renovations, additions or subtractions – may not be as clear.

It is common for other golf course changes to be considered along with bunker modifications. Survey respondents were asked, considering the most common scenario from their experience with bunker modifications, whether other golf course changes were also considered simultaneously (Table 4.34).

Were Additional Golf Course Changes Considered with Bunker Modifications?			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Yes	**84%**	100%	41%
No	**16%**	0%	59%

Table 4.34 - Were Additional Golf Course Changes Considered with Bunker Modifications?

All of the architects surveyed indicated that other golf course changes were considered along with bunker modifications as compared to only 41% of the superintendents. The reasoning behind this difference probably lies in the fact that superintendents are often making bunker modifications in direct response to specific bunker related issues at their facility. Architects are usually addressing a number of golf course components when designing golf course modifications. When there are a number of golf course changes or modifications under consideration, a master plan is often put together by a golf course architect to show the comprehensive changes and their relationships. Master planning, if done correctly, can be a very helpful process in guaranteeing the effectiveness of a project and ensuring that all necessary inputs are considered.

Survey respondents indicated that bunker modifications were considered as part of a master plan 83% of the time (Table 4.35). All but one golf course architect responded that bunker modifications were part of a master plan. Only 33% of superintendents responded in the affirmative, likely for the same reasons as described previously for consideration of other golf course changes in conjunction with bunker modifications.

Were Bunker Modifications Considered as Part of a Master Plan?			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Yes	**83%**	99%	33%
No	**17%**	1%	67%

Table 4.35 - Were Bunker Modifications Considered as Part of a Master Plan?

When bunker modifications were considered as part of a golf course master plan, greens were the most common golf course component also considered, followed by irrigation (Table 4.36). Respondent comments indicated that this is due to the fact that green and bunker renovations usually consist of a reworking of the entire green complex – green surface, bunker, surrounds and the associated irrigation and drainage.

Golf Course Changes Associated with Bunker Modifications in a Master Plan			
	Total	**Golf Course Architects**	**Golf Course Superintendents**
Greens	**88%**	91%	63%
Irrigation	**85%**	87%	63%
Tees	**80%**	83%	50%
Surrounds	**79%**	82%	50%
Fairways	**70%**	76%	13%
Cart Paths	**67%**	70%	38%
Turfgrass	**61%**	62%	50%
Trees / Vegetation	**60%**	64%	13%
Water Features	**42%**	43%	25%

Table 4.36 - Golf Course Changes Associated with Bunker Modifications in a Master Plan

The analysis of the bunker modification process and the parties involved looked at more than just bunker design and construction. Respondents were also asked to rank the level of involvement of parties in initiating bunker modification (Table 4.37). This was done to pinpoint where such efforts get their start and also to help determine if those involved in initiating bunker modifications are also involved in the design and construction of the changes.

Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course - All Respondents										
		Ranking Occurrences								
	Avg. Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**No Importance**
Superintendent	**2.00**	43	24	17	5	4	1	0	0	3
Board of Directors / Greens Committee	**2.89**	19	27	11	11	3	6	4	1	15
Owner	**3.09**	15	15	15	20	7	2	3	0	20
Golf Course Architect	**3.40**	30	7	6	3	10	10	10	1	20
Golfers / Facility Users	**4.06**	10	11	8	9	13	8	5	5	28
Golf Professional	**4.16**	5	8	9	25	17	7	3	3	20
General Manager	**4.69**	3	4	10	13	14	17	9	0	27
Contractor	**6.35**	1	7	1	0	0	10	10	22	46

Table 4.37 - Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course – All Respondents

The party ranked highest in their involvement in initiating bunker modifications was superintendents. Superintendents had the highest average ranking by a wide margin and were the only party to not be given numerous “no importance” rankings. Their regular involvement in golf course management and maintenance puts them closer to issues that may arise with bunkers. They are also the most likely party to communicate issues with golf course management or ownership. Other parties with invested interests in the golf course, the board of directors or greens committee and the owner, were ranked second and third.

As can be seen in Tables 4.38 and 4.39 there were some major differences in rankings between architects and superintendents. Some of this may be due to the scenarios that the

superintendents come from. Superintendents gave all of the parties except superintendents a higher percentage of "no importance" ratings than any other rating.

Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course - Architects Only										
		Ranking Occurrences								
	Avg. Rank	1	2	3	4	5	6	7	8	No Importance
Superintendent	**2.17**	26	19	17	4	3	1	0	0	3
Board of Directors / Greens Committee	**2.61**	19	21	10	9	1	3	2	1	7
Owner	**2.97**	13	13	13	15	4	2	2	0	11
Golf Course Architect	**3.17**	28	5	5	3	8	7	8	0	9
Golfers / Facility Users	**4.21**	7	9	4	8	9	7	5	4	20
Golf Professional	**4.42**	1	5	9	20	17	7	2	3	9
General Manager	**5.09**	2	2	2	11	13	16	9	0	18
Contractor	**6.44**	1	6	0	0	0	6	9	19	32

Table 4.38 - Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course – Architects Only

Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course - Superintendents Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Superintendent	**1.50**	17	5	0	1	1	0	0	0	0
Golf Professional	**2.85**	4	3	0	5	0	0	1	0	11
General Manager	**3.20**	1	2	8	2	1	1	0	0	9
Golfers / Facility Users	**3.56**	3	2	4	1	4	1	0	1	8
Owner	**3.60**	2	2	2	5	3	0	1	0	9
Board of Directors / Greens Committee	**4.06**	0	6	1	2	2	3	2	0	8
Golf Course Architect	**4.54**	2	2	1	0	2	3	2	1	11
Contractor	**6.00**	0	1	1	0	0	4	1	3	14

Table 4.39 - Ranking of Involvement of Parties in Initiating Bunker Modifications on an Existing Golf Course – Superintendents Only

Golf course architects were most frequently the highest ranked party involved in bunker modification design. Superintendents ranked second behind architects (Table 4.40).

Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course - All Respondents										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.34**	76	6	1	1	2	1	1	0	10
Superintendent	**2.50**	21	32	20	7	9	0	1	0	8
Board of Directors / Greens Committee	**3.49**	3	27	14	12	9	6	3	2	22
Owner	**3.82**	2	16	15	12	8	7	5	1	32
Golf Professional	**4.11**	2	10	13	18	16	9	3	1	26
Contractor	**5.16**	4	7	7	7	8	5	6	17	37
Golfers / Facility Users	**5.33**	2	4	8	6	3	13	10	9	43
General Manager	**5.61**	0	1	5	4	14	14	12	4	44

Table 4.40 - Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course – All Respondents

Interestingly golf course architects rank themselves as the most involved in bunker modification design while superintendents rank themselves as most involved (Tables 4.41 and 4.42). From an overall standpoint architects are likely most involved in design. However, many of the superintendents surveyed are at courses that choose not to use golf course architects in their bunker modification projects. Several superintendents indicated in their survey comments that a golf course architect could not be afforded by the golf course or the work was not large enough in scope to warrant architect involvement.

Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course - Architects Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.07**	70	2	0	1	0	0	0	0	0
Superintendent	**2.85**	3	29	18	7	7	0	1	0	8
Board of Directors / Greens Committee	**3.42**	2	21	13	9	7	3	2	2	14
Owner	**3.66**	1	15	13	12	7	5	2	1	17
Golf Professional	**4.45**	0	4	12	12	16	8	3	1	17
Contractor	**5.39**	2	7	4	5	6	5	4	16	24
Golfers / Facility Users	**5.69**	2	2	3	4	2	12	10	7	31
General Manager	**5.70**	0	1	2	3	11	14	12	1	29

Table 4.41 - Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course – Architects Only

Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course - Superintendents Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Superintendent	**1.60**	18	3	2	0	2	0	0	0	0
Golf Course Architect	**2.67**	6	4	1	0	2	1	1	0	10
Golf Professional	**2.94**	2	6	1	6	0	1	0	0	9
Board of Directors / Greens Committee	**3.71**	1	6	1	3	2	3	1	0	8
Golfers / Facility Users	**4.15**	0	2	5	2	1	1	0	2	12
Contractor	**4.25**	2	0	3	2	2	0	2	1	13
Owner	**4.70**	1	1	2	0	1	2	3	0	15
General Manager	**5.20**	0	0	3	1	3	0	0	3	15

Table 4.42 - Ranking of Involvement of Parties in Designing Bunker Modifications on an Existing Golf Course – Superintendents Only

Architects also had the highest average ranking for involvement in bunker modification construction. Rounding out the top three in construction involvement were contractors and superintendents (Table 4.43). This matches with the rankings of involvement for new bunker construction from Table 4.24.

Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course - All Respondents										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.72**	52	17	13	0	0	1	1	1	13
Contractor	**2.01**	35	35	7	4	4	1	1	0	11
Superintendent	**2.28**	25	24	43	2	0	0	1	0	3
Owner	**4.37**	0	5	5	26	10	7	4	0	41
Board of Directors / Greens Committee	**4.82**	0	4	4	18	17	10	7	1	37
Golf Professional	**4.87**	1	1	5	17	12	11	5	2	44
General Manager	**5.64**	0	1	4	4	7	15	6	5	56
Golfers / Facility Users	**6.40**	0	3	2	3	2	5	8	17	58

Table 4.43 - Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course – All Respondents

Superintendents again ranked themselves as most involved in bunker modification by a wide margin (Tables 4.44 and 4.45). As explained for bunker modification design, this is likely due to the golf course scenario in which they are employed. Architects ranked themselves as most involved and also ranked contractors above superintendents. Those parties; architects, contractors and superintendents, made up a solid top three with regards to bunker modification construction.

Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course - Architects Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Golf Course Architect	**1.44**	48	15	8	0	0	0	0	0	2
Contractor	**1.81**	31	31	7	1	1	0	1	0	1
Superintendent	**2.59**	5	21	42	2	0	0	0	0	3
Owner	**4.46**	0	1	4	25	9	3	4	0	27
Board of Directors / Greens Committee	**4.88**	0	1	2	18	14	8	4	1	25
Golf Professional	**5.14**	0	0	2	14	11	10	4	2	30
General Manager	**6.03**	0	0	1	3	5	14	5	5	40
Golfers / Facility Users	**7.13**	0	0	0	1	2	4	8	15	43

Table 4.44 - Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course – Architects Only

Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course - Superintendents Only										
	Avg. Rank	Ranking Occurrences								
		1	2	3	4	5	6	7	8	No Importance
Superintendent	**1.44**	20	3	1	0	0	0	1	0	0
Contractor	**3.00**	4	4	0	3	3	1	0	0	10
Golf Course Architect	**3.14**	4	2	5	0	0	1	1	1	11
Golf Professional	**3.82**	1	1	3	3	1	1	1	0	14
Owner	**4.00**	0	4	1	1	1	4	0	0	14
Golfers / Facility Users	**4.20**	0	3	2	2	0	1	0	2	15
General Manager	**4.22**	0	1	3	1	2	1	1	0	16
Board of Directors / Greens Committee	**4.62**	0	3	2	0	3	2	3	0	12

Table 4.45 - Ranking of Involvement of Parties in Constructing Bunker Modifications on an Existing Golf Course – Superintendents Only

The results of this survey tend to support many commonly held perceptions regarding bunker design and maintenance. It is important that statistical relevance is given to these ideas. However, the survey also identified several areas of concern that relate to the differences in perception between the two survey groups. Some of the identified bunker design and maintenance issues may be the result of these differences. Conclusions regarding these areas of concern were developed using the results of the survey analysis in conjunction with information gathered though the background research phase of this study. From these conclusions, recommendations on bunker design and maintenance practices were established.

Chapter 5 – Conclusions and Recommendations

Bunker Design, Maintenance and Management

There is an important relationship between the design, maintenance and management of bunkers on golf courses as shown by the information gathered in this study. Decision making for the different operations related to bunkers cannot be done in a vacuum as each phase of a bunker's life influences the others. Golf course managers are faced with difficult decisions resulting from economic conditions that impact the golf business. Golf course features, particularly bunkers, are being scrutinized to find potential areas for maintenance and management cost savings. At the same time, those developing and building golf courses are also looking at opportunities for efficiency and cost cutting. The expectations of bunker conditioning and their roles within the context of golf course have changed over time. As a result more money, labor house and other resources are now being spent on bunkers than at any time previously. This situation makes bunkers, and the processes which lead to their creation and maintenance, a target for analysis regarding changes that may save financial and labor resources.

The Importance and Roles of Bunkers

The results of the survey show that bunkers, as a golf course component, have an average rating of over four on an importance scale where 1 = not important and 5 = very important (Table 4.3). While the survey respondents did not rate bunkers as highly as several other golf course features, it is still clear that bunkers are viewed as a very important golf course component. Interestingly, golf course architects rated bunkers as the third most important golf course component, behind only greens and turfgrass, while superintendents rated them significantly lower. The importance of bunkers rates higher for architects due to the fact that bunkers are seen as a vital design component, and serve multiple roles, in golf course design. Several architects commented that bunkers are the key factor in determining the style of a course, defining a course's character, and giving a course its signature. This ability to shape design style and intent gives bunkers significance to golf course design that is likely only superceded by greens. However, even greens do not usually have the aesthetic impact that bunkers do.

Strategy and aesthetics were ranked as the most important roles of bunkers. Several survey respondents noted that if strategy and aesthetics were properly addressed, the other roles were simply functions of strategy. This is a valid point as even penalization can be considered strategic in the sense that one must make conscious decisions to try and avoid the penalty.

As golf course owners and managers look for ways to reduce costs associated with bunker maintenance, the elimination of bunkers which do not serve a desired purpose is a common consideration. Judging from respondent comments it becomes clear that bunkers which provide strategic interest are considered necessary. Bunkers that serve primarily aesthetic purposes are considered necessary to a point, but are more likely to be targeted for removal or modification. Some of the useful comment from respondents concerning bunker roles and their utilization are:

> "Elements of strategy are the most important roles of bunkers. The use of bunkers should be sparing, many modern architects overuse them including us on occasion."
>
> "Strategic location (of bunkers) adds interest to the golf experience… If you are going to add a design element that is expensive to maintain, i.e. bunkers, then for the most part they should provide a function."

The situation explored in the Colbert Hills case study also backs up these points. The bunkers that are being considered for removal tend to be bunkers that serve only an aesthetic role. These bunkers very rarely have golf balls hit into them and are not considered "in play". As a result these bunkers have been deemed unnecessary. In addition to the bunkers currently slated for removal, several original bunkers have already been abandoned and allowed to grow over with native vegetation during the ten years since the course was built. While it is nice to have bunkers that enhance the visual character of the golf course, the costs of maintenance outweigh their aesthetic benefits in this case and many like it.

Golf course designers need to take these considerations into account during the design and construction process. It appears that the days of extreme bunkering are over, at least for now. If and when economic good times return, the cost-saving lessons learned from the current situation should be remembered. The cycle of over-built and expensive

to maintain features during good times followed by the modification or removal of these same features at a later date does not need to be repeated. Many factors influence bunker design (they are covered in the section below) and do so in a variety of ways depending on the situation. However, it should be remembered that the end result of all these inputs in the design process should be a product that serves a necessary purpose.

Factors Influencing Bunker Design

Golf course architects ranked location, visual appearance and drainage as the most important bunker characteristics related to bunker design. Each of these characteristics carries with it a number of related considerations that must be analyzed by the architect during the design process. The key to creating successful bunkers is to reconcile all of the necessary considerations in a way that leads to the proper presentation of each of these important characteristics.

Location is the most important factor in determining the strategic impact of a bunker. The actual process of locating bunkers is often driven by strategic considerations, distance from the teeing grounds, and proximity to high-use areas like fairway landing zones and greens. Bunkers used for strategic reasons are placed as obstacles that should be challenged in order to obtain the best playing angles or most desired route to the hole. Fairway bunkers, no matter their intended role, tend to be placed at intervals that correspond to average distances from the teeing grounds, the landing zone, in order to challenge most golfers. Bunkers are also frequently used as obstacles around greens where missing the target results in a challenge or penalty resulting from finding them. Bunkers can be overused in certain cases. Some courses are so heavily bunkered that no other golf course features are allowed to shine through. These courses also face mounting bunker maintenance costs that can only be expected to rise. One of the survey respondents summed up the need for restraint when locating bunkers by saying:

> "As important as having a bunker where it is needed, is not having a bunker where it is not needed."

Financial considerations regarding bunker use and location made during the design process may result in fewer bunkers on many new courses. Golf course features cost money to build and maintain, and they must be prioritized within the context of the

project budget. Golf course architect and past ASGCA president Bill Love relates his experiences:

> We're seeing a lot of municipal clients who want affordable golf – $4 to $5 million for a facility – so the number of bunkers is fewer. The price point determines the number of bunkers.

A carefully positioned bunker will effectively exert its influence on the playing options of a hole. From a pure strategic standpoint this influence should be in place no matter the conditioning or appearance of the bunker. Of course these other qualities will change the strategic influence of a bunker to some degree due to the golfer's perceptions and conditioning's impact on recoverability. Location also plays a role in determining the effectiveness of other bunker characteristics, including aesthetics and drainage. Some designers choose to locate bunkers to be visible to the golfer while others prefer to hide bunkers or parts of bunkers from the golfer's perspective. Additional effort during construction is necessary when bunkers are located in a way that they have to be made visible through earthwork operations. Similarly, bunkers that are located without proper consideration given to existing drainage pattern will require more in the way of construction and are likely to face drainage issues in the future.

The visual appearance of bunkers is created by a number of factors. Chief among these are the bunker style, bunker materials and bunker surrounds. Each of these factors is the result of considerations made by the architect. An architect may decide to create a bunker with high, flashed faces of white sand surrounded by lush green turf that is closely mown and neatly trimmed along the bunker edges. Such a bunker will contrast greatly with one that features a relatively flat sand bottom made up of local tan-brown sand and grass faces planted with native vegetation or turf that is allowed to grow with little or no maintenance. While each of these bunkers may be located in the same place and be the same size, shape and depth, the perception of each will be different. Additionally, maintenance and management practices will differ significantly between the two. The first bunker is likely more prone to washouts and requires frequent edging, hand raking of the flashed faces, and some type of barrier to reduce material contamination that may discolor the sand. The second bunker is not without its own issues. The surrounding vegetation may make access more difficult and the sand, although local and readily

available, may not have the best characteristics to ensure proper drainage and playing characteristics. Some people might look at this scenario and choose the second bunker due to its lower maintenance requirements and the fact that it probably costs less to build. Others would place more value in the fact that the first bunker is more visually striking, thus maybe elevating the course to a higher level of prestige. Still others might choose which bunker they prefer based on the context in which the bunkers, and the golf course, exist. The first bunker would appear more at home on a typical parkland course with expanses of maintained turf while the second bunker fits with more of a links style course or one that features native vegetation.

The point that should be taken away from this example is that while there are many bunker styles and there is not a right and wrong look for bunkers, care must be taken to design bunkers that utilize their aesthetic qualities in a way that is pleasing to the eye but also compliments the roles which the bunkers play. At the same time, architects, or anyone involved in bunker design or modification, must remember that seemingly small changes in the factors that create the overall visual appearance of bunkers can have a huge impact on the requirements to maintain and manage the bunkers.

Drainage is a component of golf courses that links all golf course features, from both design and maintenance standpoints. There is no golf course component that can more quickly create headaches for superintendents and general managers than poor drainage. Examples might be as seemingly harmless as areas that have less than perfect turf quality due to lingering dampness or as brutal as entire holes or golf course features washed away in a flash flood. With regards to bunkers, drainage can be viewed as external and internal. External drainage consists of the drainage of the bunker surrounds. This water should be directed away from the bunker or picked up by the course's drainage system prior to entering the bunker. It is not practical or natural, as bunkers usually occupy depressions, to divert all external surface drainage away from bunkers. The water that makes its way into bunkers from surrounds and the water which falls into bunkers from rain events or irrigation must be dealt with by the internal bunker drainage systems. Research from this study and others shows that most major problems with bunkers arises when water from outside the bunker runs into the bunker, binging with it foreign material and causing significant erosion. Methods for dealing with these issues

are covered in the bunker construction and maintenance section of Chapter 2 – Background. One of the golf course architect's most important tasks is to correctly design for and deal with general surface drainage throughout the golf course. Looking at this more closely, there are several key golf course components, namely bunkers, greens and other high use areas that must be drained properly every time. If they are not, play will be interrupted, maintenance headaches will ensue and expensive modifications may be needed.

The considerations that must be made by architects regarding drainage appear to be obvious at first glance. However, although all golf course architects and construction professionals would profess to know the importance of bunker drainage, not all bunkers are designed and built with those considerations in mind. It is likely that the reasoning behind this is often financial. The extra effort and resources needed to ensure carefully designed and constructed bunkers add costs to a project's bottom line. The Colbert Hills case study shows an example where components that might have limited the current bunker drainage problems were cut from the construction budget early on in the process.

Hopefully with the increased attention that is being paid to bunkers as a result of their potential as agents of maintenance cost savings, mistakes like this will not be made as often in the future. Survey respondents in this study identified construction quality as the most important factor related to long-term bunker quality. Obviously professionals in the fields associated with golf course design and construction understand the importance of proper construction and its impacts on maintenance and management. However, it is important that these understandings are paid more than lip service. A potential key may be to make the financial backers of projects aware of the need for proper bunker construction and its potential to save money in the long run despite the initial outlay. Long-term cost savings created by doing it right the first time will be realized in maintenance and because future major bunker modification projects will not be needed. Financial benefits will be the major selling points and drivers of any changes that are seen in bunker design and construction.

Factors Influencing Bunker Maintenance and Management

Survey respondents gave maintenance practices and the resources and budget devoted to maintenance very high importance rankings related to long-term bunker

quality. While this study has given significant attention to the need for reasonable bunker design that caters toward maintainability, such efforts must be reciprocated by those responsible for bunker maintenance. If they are not, no amount of design foresight and construction quality will guarantee successful bunkers.

Maintainability, drainage and structural quality were ranked as the most important bunker characteristics related to golf course maintenance. As discussed in the Survey Questionnaire section of this chapter, the term "maintainability" is really a factor of other physical bunker characteristics and may not have been the wisest use of terminology. However, it should not be discarded as the maintainability of bunkers does play a major role in golf course management. Generally the more difficult and labor intensive bunkers are to maintain, the more it will cost to do so. As a result, maintainability of bunkers really is one of the driving forces behind the many efforts underway to modify or remove bunkers from golf courses. One of the survey respondent's comment sums this situation up well:

> "Golf course maintenance is trending towards less mowing and fewer bunkers. Labor, fertilizer and fuel prices are forcing managers to do more with less. The removal of bunkers is very cost effective."

Golf course architect Tom Doak believes that future new golf course design will also trend toward fewer bunkers:

> It wouldn't hurt to have a lot fewer bunkers. Not that they cost that much to build. Bunkers cost so much mainly because golfers want them perfectly maintained. A lot of what is being done now is because they look pretty and photograph well for magazines. (Whitten, 2008)

Issues with bunker maintainability are frequently the result of various design and construction decisions. Steep slopes, poor structural quality, inadequate drainage and the wrong sand type are just a few of the common factors leading maintenance issues that may have resulted from the design and construction process. In an ideal world all of these factors would be sufficiently addressed at some point during the process. Unfortunately that does not always happen and maintenance and management issues continue to arise.

The importance of drainage has already been discussed in the previous section on the factors that influence design. With regards to maintenance and management, proper

drainage is a must to ensure that a golf course can remain open for play and in quality condition. After major rain events the course may be unplayable or inaccessible, resulting in lost revenues for the facility. Drainage is also an area that can cause significant maintenance problems if not dealt with correctly. Inadequate drainage leads to poor soil conditions and in turn substandard turf quality. Golf course conditioning also suffers in other ways because of poor drainage. A wet golf course is more susceptible to damage caused by regular play, foot traffic and golf carts. Golf is meant to be played on a surface that is fast and firm. Drainage is a key to achieving these conditions.

Poor bunker drainage leads to excessive washouts, standing water and poor sand quality. All of these issues result in poorer playing conditions. Properly designed and installed bunker drainage systems allow for the quick removal of surface drainage from outside and within bunkers. By limiting the flow distance of water within a bunker, the drainage system helps curb the amount of sand erosion that takes place. Also by removing water from the sand layer and directing it to a central drain or outlet, the drainage system ensures no standing water and dryer sand conditions. When washouts and standing water occur, sand quality can be quickly compromised by the introduction of outside materials. These contaminates only serve to further “choke-up” the sand layer and any drainage systems. It is important that adequate time and resources are directed at designing, installing and maintaining bunker drainage systems. As noted previously, the long-term cost savings and ease of management should more than make up for the initial costs.

The structural quality of bunkers is important because bunkers are subjected to numerous outside forces that cause them to evolve and change. Natural forces like gravity and erosion from wind and water will significantly change the physical properties of bunkers over time if not addressed. Gravity combined with erosion tends to wreak havoc on steep bunker faces and overhanging bunker lips. In some locations regular wind events can remove significant amounts of sand from bunkers and deposit it on other areas. Due to their proximity, windblown sand often finds its way out of bunkers and onto greens, essentially providing an unplanned topdressing. The results of water erosion in bunkers includes loss of sand, sand contamination, drainage system damage, general structural damage, and the aesthetic change that results from these problems.

In addition to natural forces, constant use by golfers and ongoing maintenance practices can leave bunkers looking and playing nothing like they were designed. Over time greenside bunkers tend to build up significant amounts of sand on the outside of the green-side of a bunker. This is a result of thousands of shot being played from the bunker that splash sand out onto the bunker surrounds. It is not uncommon to see elevation changes of several feet on bunker lips or faces over the course of many years due to sand being deposited and built up in this way. Golfers also tend to enter and exit bunkers in focused areas. The wear caused by this foot traffic can break down bunker lips and damage the bunker surrounds. Similar issues arise when mechanized rakes enter and exit a bunker in the same location on a regular basis. Another structural issue caused by mechanized bunker rakes is the way sand is distributed when they are used to rake bunkers in the same circular motion over long periods of time. Especially along curved bunker edges, sand is deposited along the edge building it up. Over time this build up of sand raises the immediate bunker surrounds and creates a bunker that is perched above the surrounding grade. This problem is worsened when the addition of new sand is made without removing all of the existing sand or excavating the bunker cavity back to its original depth. When done repeatedly this will raise the level of the bunker floor adding to the bunker's perched effect.

It is not uncommon to see older courses that receive lots of play featuring quality overall course conditions, but have bunkers that are abused and have evolved into perched ovals due to years of heavy use and structural neglect. One underlying fact about bunkers that this study only serves to strengthen is that they cannot simply be designed, built and then left alone if they are expected to maintain their original qualities. Some bunkers are built with evolution in mind. However, the majority of bunkers are not meant to change significantly in their shape, size, depth or location over time. To ensure that these bunker characteristics are maintained, courses interested in preservation should undertake a program that inventories the bunkers. This process might include cataloging aerial images of the course, taking photographs of bunkers and their surrounds, locating and recording bunker, green and fairway edge locations with GPS, measuring bunker depth, and documenting bunker maintenance practices. By establishing the current state

of the bunkers' physical characteristics, it will be easier to consistently maintain them and restore them in the future should it become necessary.

In addition to being asked to rank bunker characteristics based on their importance to maintenance and management, survey respondents rated the importance of bunker maintenance factors. As expected, drainage was the maintenance factor rated the highest. Education of the maintenance staff also received a very high importance rating. The reasons for drainage's importance have already been discussed. Education of the maintenance staff is vital to guarantee that the best practices are used and consistently carried out. Bunker maintenance consists of much more than just regularly raking the sand surface until smooth. Proper understanding of bunker structure, maintenance techniques and equipment operation are necessary to ensure that bunker maintenance is positively contributing overall golf course quality and conditioning. Improper maintenance techniques or misuse of maintenance equipment can seriously damage a bunker's structural quality and lead to on-going conditioning issues. Golf course superintendents need to develop and share with their staff a bunker maintenance program or routine. Additionally, experienced staff members should take the time to train those who are tasked with basic bunker maintenance. In many cases bunker raking and edging jobs are given to new members of the crew. While these are not difficult tasks, simply handing them a rake or trimmer and sending them out on the course may lead to issues with bunker edge quality, material contamination or sand depth. Care should also be taken with the use of maintenance equipment in bunkers and bunker surrounds. Wear caused by entering and exiting bunkers can be unsightly and structurally damaging. Scalping of bunker edges and surrounds can expose soil surfaces and decrease turf quality. Both of these things can increase the chance of erosion and material contamination.

Proper training and use of maintenance techniques may carry even more importance following a bunker modification project. These projects usually involve a significant financial commitment that can be quickly undermined if shoddy maintenance practices are employed. It is often not enough to simply continue the maintenance practices that were in place prior to a bunker project. Sometimes the new bunkers will actually be more labor intensive as was the case in the Mission Hills Country Club

example. Extra care is usually needed for bunkers with liners or specific features like steep faces or native vegetation. The results of many bunker projects that involved liner installation have been compromised by mechanized raking or improper sand placement. Mechanized rakes are prone to catching on the liners, tearing them or loosening them from the bunker floor subgrade. Raking equipment can also cause damage if driven recklessly over the bunker surface by displacing sand and disturbing the liner underneath. Sand displacement or improper sand placement will cause problems in bunker with liners if only a thin layer of sand is in place. This situation increases the likelihood of golfers catching the liner with their clubs, shoes or the bunker rakes. Bunkers with installed liners usually require additional if not exclusive hand raking.

It is difficult to quantify the physical and financial impacts of the factors that influence bunker maintenance and management. Golf course superintendents and managers need to have a system in place that allows them to analyze bunker problems and provides a management decision making tool. Jim Connlly, formerly a USGA agronomist and now a golf course maintenance and management consultant, recommends that courses conduct a bunker assessment program consisting of the following steps:

1. Document all maintenance costs, including grass surrounds.
2. Identify chronic problems that are adding to the annual maintenance costs. This includes washouts, sand contamination, poor drainage, sand quality and turfgrass quality around the bunker.
3. Determine the necessity of each bunker as it relates to economics, strategy and aesthetics. A golf course architect, working with a superintendent and green committee, should review the design and its impact on the maintenance budget.
4. Develop a long-range plan that includes bunker elimination and/or addition, rebuilding or renovation. (Connolly, 2007)

Once a bunkers assessment has been completed, judgments can be made by course decision makers, whether they be owners, managers, boards or committees, regarding what bunker modifications are needed to fix identified problems and how best to proceed. Due to the significant cost associated with on-going bunker maintenance and bunker modification projects, it is unwise to make decisions regarding these efforts without completing a bunker assessment program.

Bunker Modification

The results of the survey show that there are numerous reasons for undertaking bunker modifications that were rated as very important. These encompass drainage, maintenance, strategy, bunker age, design flaws, aesthetics and restoration of design character. Survey respondents pointed out that the importance of these reasons will vary greatly depending on the specifics of the project being undertaken and the intent of the project. Respondents indicated that bunker restoration or repair was the most common type of bunker modification project, and also noted that they had been involved in multiple types of projects. These include the addition or removal of bunkers, relocation of bunkers, and changes to the size of bunkers. Each of these different types of bunker modifications may be motivated by one or more reasons. Obviously a bunker project that is being undertaken in response to serious engineering or structural issues related to poor drainage will be done for different reasons that a project that aims to restore a course's bunkers to their original character or a specific architect's style. However, no matter the type of project all bunker modification efforts should strive to produce bunkers that achieve the goals of the project and are maintainable.

As part of his bunker assessment recommendations, Jim Connolly identifies the most common maintenance areas that lead to bunker deficiencies and require modifications. He also notes that it is important to understand why bunkers deteriorate to the point where rebuilding is wise economically and that knowing the cause will improve communication during the presentation of the modification program. Connolly's (2007) maintenance related reasons for bunker deterioration are:

1. The second law of thermodynamics – all things left to themselves progress from a state of order to disorder. It's unreasonable to think bunkers will last forever.
2. Improper maintenance. Mechanical rakes have damaged thousands of bunkers to the point where renovation is required around the edges. Some bunkers aren't constructed to allow bunker rakes to enter or exit, or are too small.
3. Storms and disasters. Heavy rain and floods will wipe out even the best bunker, or at a minimum, remove the sand. In September 2003, Typhoon

Maemi cut through Jeju Island on Korea with 120-mph winds and dumped four feet of rain in one day. At The Club at Nine Bridges, all 120 bunkers, which were constructed excellently, were damaged.

4. Chronic construction woes. This area can be the most troublesome and difficult to assess because it's a slow deterioration of a bunker and surrounding area. Deterioration is often a result of inferior construction methods. Chronic deterioration can be a result of:

- Improper irrigation design of grass surrounding a bunker
- A lack of or faulty drainage
- Contaminated sand from constant erosion
- Atmospheric pollution from dust contaminating sand
- Continually adding new sand, making a bunker too deep
- The surrounding area channeling water into a bunker
- A wrong bunker design for the social, economic or climatic environment.

Continual bandaging of these bunker symptoms is costly and puts a major drain on a golf course's annual maintenance budget. Once these chronic bunker disorders are identified bunker modification or rebuilding are often the best options. Although this usually involves a major financial investment, the hope is that the long term cost savings and overall bunker improvement will easily cover the up-front cost.

The survey results show that bunker modifications are most frequently initiated by superintendents, boards of directors or greens committees, and golf course owners. Golf course architects and superintendents are then most involved in the design of the bunker modifications. These two groups, along with golf course contractors, are also most often responsible for the oversight and construction involved in making the modifications. There is a lot of communication and teamwork that must go on among these parties to ensure a successful project. Issues arise when the goals and actions of one, or multiple, parties are not in-tune. Club or course politics often play a role in the scope and scale of any golf course project. This is particularly true with bunkers due to the wide variety of views on their golf related roles and different preference for their aesthetic characteristics.

Golf course architects almost always look at bunker modifications as part of an overall golf course master plan. It can be assumed that the design decisions are made within the context of the other proposed changes. This is an important point as bunker continuity and consistency throughout a golf course is desirable. Complaints often arise when bunker modifications have been made at different times, in different styles or by different parties. This can lead to a hodge-podge of bunkers that have an negative effect on the overall aesthetics and playability of a golf course. An interesting finding from the survey is that of the modification projects that the superintendents had been involved in, only one-third were part of a master plan. This may have been due to the circumstances or course types at which the surveyed superintendents work. However it is likely that this finding reflects the fact that many bunker modification projects, particularly those done "in-house," are stand alone projects. All phases of these projects are overseen by superintendents or other golf course management personnel. It must be remembered that many facilities cannot or choose not to include a golf course architect for many reasons, often financial.

The Design – Management Relationship

The process that encompasses designing, building, maintaining and managing a golf course is incredibly complex and involves many parties. However, when addressing the roles of the golf course architect and superintendent it can be simplified, or maybe oversimplified, to: designers create golf course features while superintendents are tasked with maintaining and sustaining them. Survey respondents pointed out the importance of this relationship and the consequences that can arise when there are discrepancies.

> "If the superintendent is not on board from the beginning on what the architect wants to achieve in the design the chances for success are minimal. The architect must keep in mind the style and must allow the superintendent to succeed in the maintenance of bunkers with the staff and equipment they have available."
>
> "You must build bunkers that can be maintained or the golf course superintendent will change them."

The main goal of this study is to look at the impacts of bunker design on golf course maintenance and management. It is also important to understand the relationship

that exists between the parties responsible for design and those involved in maintenance and management. The roles of these parties overlap to some extent as it is often difficult to determine exactly where creation ends and on-going care begins. Because natural and manmade forces cause evolution of all golf course features, particularly bunkers, the so called “finished product” that results from construction is in reality never really completely stable or finished. Instead, bunker design and construction should be looked at as the first stages in a bunker’s life which prepare it for the future rigors it will undoubtedly face. Bunker maintenance and management decisions are then made in response to these rigors and other regular life-cycle needs.

It is the job of the golf course architect to foresee and anticipate potential issues that bunkers may have, and design bunkers in a way gives them the best chance for success. Another responsibility of the golf course architect is to make these decisions regarding bunkers within the greater context of each golf hole, the golf course as a whole, the overall development (if there is one) which the golf course is a part of, and any relevant site or regional features. The best bunkers function not only individually but also as components of larger bunker complexes and the overall golf course. Their design should respond to the site, climate and golf course style among other considerations. This entire bunker design process, taking into consideration all of these factors, must be done with an eye toward long-term bunker quality. It is simply not enough to design bunkers that look good and play well on opening day. Bunker design should integrate decision making that works to ensure the future maintainability and sustainability of these designed and built golf course elements.

The communication and foresight in the design – management relationship must go both ways. Architects need to design with golf course maintenance considerations in mind. They also should work with other parties involved in project development to identify the project parameters early on in the process. This includes establishing an estimated maintenance budget. Golf course features, including bunkers, should not be designed in a way that will require a level of maintenance that is above what should be expected or can be afforded. A golf course superintendent, preferably one with construction and grow-in experience, should be integrally involved in the process as early as practically possible. Their insight, expertise and experience will be invaluable and will

likely help stave off future maintenance related issues that can result from improper design and construction decision making. Superintendents involved in golf course construction should not be shy about expressing concerns regarding the maintainability or management of designed golf course features. At the same time they must work in conjunction with designers and construction personnel as problem solvers, finding ways to maintain the features which are designed and built.

The Impacts of Bunker Design on Golf Course Maintenance and Management

Well designed and thought out bunkers will not always be easy or simple to maintain. Nevertheless, they should be maintainable using the resources available and under the supervision of a trained superintendent. Almost all major issues with bunkers that lead to maintenance problems can in some way be traced back to bunker design or construction decision making. This point is noted by Jim Connolly in his reasons for bunker deterioration. However, before jumping to conclusions about the incompetence of designers or construction personnel, it must be pointed out that in almost all cases the very features that give bunkers their character, aesthetic appeal and define their roles are the same features that require extra maintenance attention. Features like flashed faces, high edges, deep floors, and ragged or vegetated lips all make bunkers the vital golf course components that they are. It would be unwise to eliminate or soften all of these features simply because they are difficult to maintain. One of the key roles of a golf course architect in bunker design is to create bunkers that feature unique character and aesthetic appeal while having characteristics that allow for and promote the expected level of maintenance.

As golf course managers look for cost saving opportunities the removal of unnecessary bunkers and the reduction of bunker areas have become popular. It can be assumed that these bunkers originally had a purpose as they were included in the golf course's design by the architect. However, bunkers designed for pure aesthetic or "window dressing" reasons often do not make the cut and are eliminated or modified by superintendents and managers. The results of the survey show that strategy is the most important role of bunkers. Looking to the future, it would be wise for architects to reduce the use of bunkers for pure aesthetic reasons. These bunkers require money and resources for maintenance that could be focused elsewhere in golf course operations or may not be

available at all. This does not mean that bunkers should not be attractive or proved visual interest. All bunkers should accomplish those goals, but they must also serve a golf-related purpose, like strategy.

Bunker design also impacts maintenance and management on an expectation level. Bunkers have been used by architects as signature features that define a style or golf course "look". With the current golf course financial and management situation, it can be argued that golf course architects should use bunkers more as accessories rather than as signature features. This might decrease the expected and necessary levels of maintenance that are needed. Going along with this idea is the contention that bunkers are, at their core, hazards. As hazards they should be treated as such and perfect conditioning, consistency and aesthetics would not always be necessary. This is a very strong and sensible point and one which could do wonders for golf course maintenance and management. In fact the acceptance of bunkers as hazards that do not require ridiculous levels of care would likely reduce costs enough that other golf course features' conditioning would improve. In some cases savings may even be felt by the consumer in the form of lower greens fees. The problem with this idea's practical application is that it flies in the face of most golfers' expectations. In order for it to be widely accepted, all facets of the golf business will need to be on board to demonstrate why bunkers should function as hazards. It will be difficult to get most golfers to go along with the idea that bunkers that do not feature perfect conditions are actually good for the game of golf. Golfers will find that no matter the economic hardships faced by management, some facilities will always place a priority on perfectly manicured bunkers and use their resources accordingly. As is the case with most aspects of golf course maintenance, these facilities will be held in the highest regard by the golfing public and used as the reference against which others are measured.

Study Methodology

It is important to analyze the effectiveness of this study in gathering information pertinent to the topic and in providing conclusions that address the study goals. The conclusions made regarding the study methodology will primarily focus on the survey questionnaire. It was the major data gathering tool and the study's primary data gathering abilities are reliant on the effectiveness of the survey. Several survey shortcomings were

identified during the course of the study. Respondent feedback was one of the major indicators of issues that arose concerning the survey. Survey comments are included to illustrate the difficulty or misunderstandings that some respondents had with the survey.

Survey Administration

It is of some concern that only 30% of the respondents were golf course superintendents. This is due in large part to the fact that only 33% of the surveys sent out were targeted at superintendents to begin with. Ideally, similar numbers of surveys would have been sent to superintendents as were sent to golf course architects. Survey recipients were identified through their professional organizations. Superintendents surveyed were members of the Kansas Chapter of the Golf Course Superintendents Association of America (GCSAA). Architects surveyed were members or associates of members of the American Society of Golf Course Architects (ASGCA). The low number of superintendents surveyed could have been addressed by including another GCSAA chapter's members in the survey recipient list or selecting survey randomly selected GCSAA members from across the United States.

Another potential issue with the superintendents surveyed centers around their demographics. As members of the Kansas Chapter of the GCSAA, all superintendent respondents are located at facilities within the state of Kansas. Meanwhile, the golf course architects surveyed are located throughout the country. Due to the potential for geographic bias, the inclusion of superintendents from a variety of locations and climates in the study may have been more ideal. Also, while the types of golf facilities that the superintendent recipients are located at varies, it likely does not reflect the same make-up as many other parts of the county. The type of facility and the management structure of a facility often influences the parties involved, and those not involved, in the different aspects of the golf course. Bunker design, construction, maintenance and management can be expected to be dealt with differently at different kinds of facilities. The inclusion of superintendents from a more varied background of facilities may have led to different responses. For example, it can be theorized that facilities with bigger budgets or affiliations with large management companies would be more likely to involve a golf course architect in the bunker modification process. At the same time, many smaller or tighter budgeted facilities may be the ones most likely to look at bunker reduction or

modification as a potential source of cost savings. As with any study, it is best that the sample reflects the overall population as much as possible. In this case additional study of the facility type of the survey recipients could have been done and compared to National Golf Foundation data on the overall makeup of the golf course population in the United States. While surveying all members of the GCSAA is not necessary or practical, a larger and more varied sample size may have provided a better picture of the overall population of superintendents.

The reasoning behind surveying only member of the Kansas Chapter of the GCSAA centers on ease of access and financial concerns. Administrative operations for the chapter are run from Kansas State University and member contact information was readily available. Additional reasoning for not expanding the sample size was financially driven. Each survey cost $1.01 for outgoing postage and postage on the included return envelope. It became cost prohibitive to send out surveys to more than the Kansas superintendents and the ASGCA architect list.

Another potential area for additional survey participation was with golf course construction professionals and golf course facility general managers. It is recommended that future study of similar topics or studies using similar methodology to this one use these two study groups. Contact information for golf course construction personnel can be obtained through the Golf Course Builders Association of America (GCBAA). The information for general managers would most likely come from the Club Managers Association of America (CMAA or the Golf Managers Association (GMA). While this study analyzes differences in responses two ways – between architects and superintendents, a study could be set up to analyze response differences four ways – between architects, construction professionals, superintendents and facility general managers. By including all four respondent groups a better understanding of the design – management relationship might be obtained. In such a situation the four groups could be analyzed independently and then the architects and construction professionals (pre-opening) could be grouped together and the superintendents and general managers (post-opening) grouped together.

The issues with including these two additional groups in the survey are the same as with including a larger number of superintendents. The costs of survey administration,

at least the way it was organized for this study, would be prohibitive. Potential solutions to this problem include finding a sponsor to cover some or all of the survey administration costs or to administer the surveys in a way that does not cost as much as direct mailing. Sponsorship options could be explored through professional associations (like the ASGCA, GCSAA or GCBAA) that might have an interest or see potential value to their members in the results of the study. Some of these associations sponsor academic endeavors through scholarship programs and grant funding. A proposal for funding could be prepared for a study such as this one and presented in hopes of finding research funding that could be applied to survey administration.

Another option to address survey administration cost would be to change the administration technique. Online administration of the surveys would eliminate postage costs as well as expenses for paper, printing and envelopes. The reason that online only survey administration was rejected for this study was due to concerns over the response rate. It was decided that an online only survey would likely have a much lower response rate than a mailed paper survey. The reasoning was that the online survey link would be easy to overlook or ignore, whether it was sent via email in a paper cover letter explaining the study. However, a link to an online version of the survey was included in the cover letter that accompanied the paper survey. This was done to provide respondents with the option to complete the survey online should they choose. Only nine of the 109 survey respondents chose the online response option.

Survey Questionnaire

Survey responses and respondent comments indicated an unusual amount of confusion and misinterpretation of the questions that asked for a ranking. The ranking questions asked the respondents to rank the importance, influence or occurrence of items using “0” to indicate no importance, influence or occurrence and ranking the remaining items beginning with 1 = most important, influential or occurring. The reasoning behind the ranking questions was to identify a hierarchy of the items to be ranked while allowing the respondent to identify items which did not have any bearing on the question being asked. Unfortunately these questions caused problems for many respondents.

The most common issues with the ranking questions saw respondents provide “1-5” ratings instead of rankings (some even noted on the survey that they were rating

despite the instructions to rank), assign fraction values (between 0 and 1) to items, or rank without proper attention given to ordering due to tied items. An example of the problem with tied items occurs when two items receive a ranking of "1" and another item receives a ranking of "2". In actuality the item ranked "2" is really ranked "3" because of the two items tied with rankings of "1". Additionally, a few respondents simply did not answer most of the ranking questions. The result of these issues was inconsistencies in format of the responses to these questions. The researcher determined that it was necessary to include as many applicable responses as possible in the data and converted the numerical ratings to rankings and renumbered rankings that did not account for tied items. While this situation was not ideal, it was necessary to ensure sufficient use of respondent data.

Obviously there was some level of confusion among respondents that led to the variety of responses to the ranking questions. Some of the respondent comments on these questions included:

"I didn't understand. 0 = no importance and 1 = most important?"

"Confusing"

"???"

"I just used the rating scale from the last question."

"Don't get what you want here."

An option that could have been used to deal with the ranking question issue would have been to simply use ratings on those questions. However, the reasons for ranking instead of rating – to determine a hierarchy among items when it is likely they would all be rated as very important or to determine a ranking of involvement while allowing for a selection of no involvement at all – would have been compromised.

Not all issues with ranking questions were due to difficulty understanding the action needed to answer the question. Unfortunately, survey questions numbers six and seven – asking the respondents to rank bunker characteristics based on their importance related to golf course design and golf course management and maintenance – featured a characteristic, maintainability, which probably should not have been included. The term maintainability as it relates to this section of the study may not have been the wisest use of terminology as it is out of context and redundant. The reasoning behind including it

was as a characteristic that impacts overall golf course management. Unfortunately, such a determination probably should have been left for another question. The other characteristics in questions 6 and 7 are physical qualities while maintainability is more of a summation that results from the quality of these physical characteristics. Several respondents pointed this fact out in their comments. An example:

> "Maintainability is a factor of the other items listed. If thought is given to drainage, shape, sand type, etc., maintainability is addressed."

Aside from the issues with the ranking questions, the most common comments regarding the survey from respondents dealt with the broadness of the questions and the resulting answers. This was particularly true with the architects, many of whom indicated that they had been involved in too many bunker design and modification projects to determine specific ratings or rankings of some items. These observations were most common on the questions related to reasons for bunker modifications, frequency of bunker modification types, age of existing bunkers that were modified, and other golf course changes associated with bunker modifications in a master plan. The questions asked that the respondent indicate the most common scenario if they have been involved in multiple bunker modification projects. However, several respondents commented that all of the choices were applicable and that differentiation was difficult.

Another related line of comments was that the overall generality of the questions led to general answers and thus really didn't prove or show anything. Examples include:

> "Bunkers tend to each have their own needs depending on the intended purpose. Therefore, generalizations implied by your questions give overly broad answers."
>
> "Good golf course design is when form follows function, so what is appropriate at one facility is much less relevant at another. This makes your rankings (not ratings) data irrelevant in my opinion. How do you rank the role of bunkers at Augusta National vs. an executive course? You can't… If your aim is to theorize that one aspect of bunker design is more important than another your study will carry less weight with professionals unless you apply it to a specific course or category of courses."

These comments have a good point. Due to the varying nature of bunkers and their roles it can be dangerous to draw narrow conclusions based on broad lines of questioning. However, the questions have to be used to statistically identify some general trends and most commonly occurring scenarios. Many of these trends may be considered common knowledge to those involved in the golf business, but for the sake of providing a basis for this study they must not be assumed. It was the intent to leave the questions and items to be ranked or rated somewhat broad in hope of including most potential situations and determining overall trends in the design, construction, maintenance and management of bunkers. The practical length of the survey and the statistical usefulness of the gathered information had to be balanced against the breadth and depth of the questioning. Common sense must be used to understand that this study can in no way analyze all of the complex situations and variables related to bunker design, construction, maintenance, and management. Additional information depth beyond the survey was obtained through the Colbert Hills Golf Course and Mission Hill Country Club case studies as well as the writings of prominent professionals in both golf course architecture and maintenance. This detailed information was used to supplement general trends and differences in responses between respondent groups that were identified by the survey results and analysis. Admittedly it would have been interesting and informative to delve deeper into some of the specific areas of questioning in the survey. This is something that may be accomplished by additional research and future study of this topic.

Potential Future Research

A stated goal of this study is to provide the basis for additional research into this and other related topics. Using the results and background information from this study, further research related to bunker design, construction and maintenance could be done. Additionally, several other areas for potential future study have been identified.

Continued study of bunkers could be done that focuses on construction and maintenance techniques and the associated expenditures as they relate to bunker quality and longevity. Essentially such a study would help determine if golf courses were getting their “bang for their buck” from bunker construction, modification and maintenance outlays. Such a study could also analyze the results and consequences of different bunker construction techniques. The best format for a study like this would probably be a series

of case studies that document the process and follow up on the long-term results. Problems arise because this type of study would need to take place over a longer period of time or would have to rely on accurate documentation by someone other than the researcher of the bunker related processes that have led up to the current situation.

Another potential area for study is in golf course components other than bunkers. Studies following the methodology model set forth by this one could be done for greens, fairways, native vegetation areas, or practice ranges. Greens would be the most logical golf course component to study due to their broad influence on all parts of the game. Like bunkers, greens are a vital component of golf course design, greatly influence the opinions of golfers, and require significant resources to maintain and manage. Finding out the impacts of green design decisions on golf course management as well as the factors that are most important to green design and maintenance would provide valuable information. It would also be interesting to compare the results of a similar study on greens with the results of this study on bunkers.

The study of water resources and their impacts on golf course management would also be a useful topic of study. Water use is another area that is often looked at for cost savings on golf courses. With increased usage regulations and efforts to be more environmentally sensitive, more efficient water use on golf courses is becoming a necessity in many locales. Water use also plays an important role in the societal view and perceptions of golf courses. Golf courses are often seen as a land use that overuses water resources. Additional study into this topic may help golf courses better use water resources and help educate people on the merits of golf courses. Like with bunker maintenance, consumer expectations of golf course conditions and aesthetics drives the use of water resources in many instances. This can lead to a disconnect in the design – management relationship where the level of water use, or bunker maintenance, simply cannot be sustained at the expected and designed for levels.

References

Andrew, I. (2007). *The architectural evolution of Stanley Thompson*. Retrieved January 16, 2008, from Golf Club Atlas Web site: http://golfclubatlas.com/in-my-opinion/ian-andrew-architectural-evolution-of-stanley-thompson.html

Aylward, L. (2007). *Sand dollars*. Retrieved June 2, 2008, from Golfdom Web site: http://www.golfdom.com/golfdom/Industry+Issues/Sand-Dollars/Article Standard/Article/detail/458019

Bevard, D. S., & Zontek, S.J. (2008, July/Aug.). The Escalating Cost of Golf Course Maintenance. *USGA Green Section Record*. 46(4), 19-20.

Bouts, T. (2009). *A shrinking proposition*. Retrieved April 2, 2009, from Golf Business Web site: http://www.golfbusinessmagazine.com/pageview.asp?doc=2005

Brauer, J. (2005, May). Maintenance in mind. *Golf Course News*, 17(4), 17.

Brauer, J. (2005, Oct.). Invest in infrastructure. *Golf Course News*, 17(7), 19.

Brauer, J. (2006, Nov.). Bunker design strategy. *Golf Course News*, 18(10), 12.

Brauer, J. (2007, Jan.). Bunker maintenance in mind. *Golf Course Industry*, 19(1), 12.

Brauer, J. (2007, Oct.). Interfacing with contractors. *Golf Course Industry*, 19(9), 22.

Brauer, J. (2008, Sep.). Bunker design changes. *Golf Course Industry*, 20(9), 14.

Brauer, J. (2009, Jan.). Noninvasive procedures. *Golf Course Industry*, 21(1), 12.

Connolly, J. (2007, Jan.). Out with the old, in with the new. *Golf Course News*, 19(1), 40-43.

Cornish, G. S., & Whitten, R. E. (1993). *The architects of golf*. New York: Harper Collins.

Daley, P. (Ed). (2002). *Golf architecture: A worldwide perspective* (Vol. 1). Gretna, LA: Pelican Publishing Company.

Daley, P. (Ed). (2003). *Golf architecture: A worldwide perspective* (Vol. 2). Gretna, LA: Pelican Publishing Company.

Dixon, B. (2000). *An analysis of remodeling projects on canadian golf courses*. Manhattan, KS: Kansas State University.

Doak, T. (1992). *The Anatomy of a Golf Course*. New York: Lyons & Burford.

Dunlap, J. (2009, March/April). Lenders in retreat. *Golf Inc.*, 18(2), 10.

Fine, M. K., & Richardson, F. L. (2006). *Bunkers, pits & other hazards*. Hoboken, NJ: John Wiley & Sons.

Hurdzan, M. J. (2006). *Golf course architecture* (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Last, J. (2005). *Golf 20/20 vision for the future: perspectives from the cores*. [PowerPoint slides]. Presented November 14, 2007.

MacKenzie, A. (1995). *The spirit of st. andrews*. Chelsea, MI: Clock Tower Press.

Maloy, B. (1999, May/June). Stop bunker face erosion. *USGA Green Section Record*. 37(3), 15.

Moore, J. (1998 Jan./Feb.). How to select the best sand for your bunkers. *USGA Green Section Record*. 36(1), 9-12.

Moore, J. (2007). *Bunker Design and Construction*. [PowerPoint slides]. Presented April 2007.

Moore, J. (2008, July/Aug.). The Money Pit. *USGA Green Section Record*. 46(4), 1-6.

National Golf Foundation (2009). *Number of golfers edges lower in 2008*. Retrieved May 12, 2009, from National Golf Foundation Web site: http://www.ngf.org/cgi/whonews/asp?storyid=261

National Golf Foundation (2008). *Golf course openings continue decline*. Retrieved November 23, 2008, from National Golf Foundation Web site: http://www.ngf.org/cgi/whonews/asp?storyid=245

National Golf Foundation (2008). *Rounds down slightly in 2007*. Retrieved November 23, 2008, from National Golf Foundation Web site: http://www.ngf.org/cgi/whonews/asp?storyid=208

Nelson, R. (2009). *Feature interview with robin nelson*. Retrieved March 29, 2009, from Golf Club Atlas Website: http://golfclubatlas.com/feature-interview/robin-nelson.html

Newport, J.P. (2008, Oct. 11). Golf's new landscape. *Wall Street Journal*, p. W6.

O'Brien, P. (1999, May/June). Bunkers: the right track. *USGA Green Section Record*. 37(3), 14.

Richardson, F. L. (2002). *Routing the golf course*. Hoboken, NJ: John Wiley & Sons.

Ross, K. (2004, Feb.). Bunker Quality Factors. *Golf Course News*, 16(1).

Ross, K. (2006, Jan.). It's all about the sand. *Golf Course News*, 18(1), 46-48.

Saunders, D. (2005, Feb.). A maintained hazard. *Golf Course News*, 17(2).

Senza, D. (2008, Oct.). How to fix private clubs. *Golf Digest*, 59(10), 128-129.

Shackelford, G. (2000). *Alister mackenzie's cypress point club*. Chelsea, MI: Clock Tower Press.

Torsiello, J. (2008, April). Try to achieve perfection. *Golf Course Industry*, 20(4), 39-46.

Urbina, J. (2002). *Feature interview with jim urbina*. Retrieved November 23, 2008, from Golf Club Atlas Website: http://golfclubatlas.com/feature-interview/jim-urbina-june-2002.html

Walsh, J. (2004, Oct.). Getting Ready. *Golf Course News*, 16(5).

Walsh, J. (2004, Nov.). The future course. *Golf Course News*, 16(6).

White, B. (2009, March/April). Consistency in bunkers… what does it mean?. *USGA Green Section Record*. 47(2), 20.

Whitten, R. (2008, Nov.). Big mac, little greens + wide-open spaces: The shape of courses to come. *Golf Digest*, 59(11), 130-146.

Whitten, R. (2008, Nov.). Bunker mentality. *Golf Digest*, 59(11), 112-117.

Appendix A – Survey Cover Letter and Questionnaire

Date

Dear Name,

My name is Daryn Soldan and I am a graduate student in Landscape Architecture at Kansas State University. I am currently working with Kansas State University professors Chip Winslow and Dr. Jack Fry to conduct research for my Master's thesis on the impacts of bunker design and construction on golf course management decision making. From a practical standpoint, I believe it is important to study and understand the relationship between design and management on all built projects. Relating this to golf, I hope to better understand how aspects of management decision making such as long-term maintainability and financial budgeting are impacted by decisions make during the design and construction phases of a project.

I have chosen to focus on bunkers because of the key role they play in the golf experience and the unique management challenges they present. An important goal of this study is to help provide a basis for future research involving golf course design, construction and management. It is also my hope that the results of this, and future research, can be used by both academic and practicing professionals to better understand and improve design – management relationships.

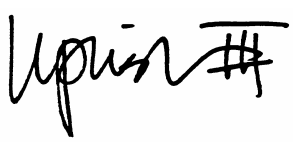
A key component of my study is the enclosed survey which is targeted to professionals in the golf course business. I anticipate that the survey will take approximately 10-15 minutes to complete. I would appreciate your participation as it will provide valuable information for this study. A return envelope with postage has been provided. Please return the completed survey at your earliest convenience. The survey may also be completed online. The online version is available at https://survey.ksu.edu/TS?offeringId=97507

Should you have any questions regarding this study or your participation in it please contact me at:

Daryn Soldan, Landscape Architecture / Regional & Community Planning, 302 Seaton Hall
Kansas State University, Manhattan, KS 66506
Phone: 785.564.2925 Email: dms4994@ksu.edu

Thank you for your participation,

Daryn Soldan
Master's of Landscape Architecture Candidate
Kansas State University



Chip Winslow
Master's Thesis Committee Chair
Professor, Landscape Architecture / Regional & Community Planning
Kansas State University

Survey Questionnaire Survey No. ____-____

Analysis of Bunker Design and Construction's Impact on Golf Course Management
Daryn Soldan Kansas State University January 2009

Your participation in this survey is entirely voluntary and should present no appreciable risk to you. You may choose not to answer any of the questions asked on the survey. Participating individuals' names and affiliations will not be identified or associated with specific answers. The results of this survey will be presented in their entirety as part of my Master's thesis and will be available upon request. If you have any additional questions regarding your rights as a subject or the manner in which this research is being conducted, you may contact the study's Principal Investigator:

Chip Winslow, Professor, Landscape Architecture / Regional & Community Planning
302 Seaton Hall, Kansas State University, Manhattan, KS 66506
Phone: 785.532.2447 Email: chipwin@ksu.edu

Please respond to the following questions – <u>questions appear on both sides of the pages</u>. Space has been provided for additional comments.

Section 1 – General Respondent Information

1. Please select all roles that you have held within the golf course business. (mark all that apply)

_____ Golf Course Architect _____ General Manager
_____ Construction Professional _____ Golf Professional
_____ Superintendent _____ Owner
_____ None _____ Other _____

2. Select your current role within the golf course business. (mark only one most applicable answer)

_____ Golf Course Architect _____ General Manager
_____ Construction Professional _____ Golf Professional
_____ Superintendent _____ Owner
_____ None _____ Other _____

Section 2 – Bunkers and the Golf Course

3. Rate the importance of the following golf course components.

Not Important				Very Important		Not Important				Very Important	
1	2	3	4	5	Greens	1	2	3	4	5	Fairways
1	2	3	4	5	Tees	1	2	3	4	5	Bunkers
1	2	3	4	5	Trees/Vegetation	1	2	3	4	5	Water Features
1	2	3	4	5	Cart Paths	1	2	3	4	5	Turfgrass
1	2	3	4	5	Irrigation	1	2	3	4	5	Other _____

Comments:

4. Rank the importance of the following roles of bunkers: (use 0 to indicate no importance, rank the remaining qualities beginning with 1 = most important)

_____ Aesthetics _____ Penalization
_____ Strategy _____ Provide Visual Cues
_____ Containment _____ Other _____

Comments:

5. Rate the importance of the following bunker characteristics.

Not Important				Very Important		Not Important				Very Important	
1	2	3	4	5	Visual Appearance	1	2	3	4	5	Surface Uniformity
1	2	3	4	5	Location	1	2	3	4	5	Sand Type
1	2	3	4	5	Size	1	2	3	4	5	Shape
1	2	3	4	5	Depth	1	2	3	4	5	Drainage
1	2	3	4	5	Other _____						

Comments:

6. Rank the following bunker characteristics based on their importance related to golf course design: (use 0 to indicate no importance, rank the remaining qualities beginning with 1 = most important)

_____ Visual Appearance
_____ Drainage
_____ Structural Quality
_____ Shape
_____ Depth
_____ Size
_____ Sand Type
_____ Maintainability
_____ Location
_____ Other _____

Comments:

7. Rank the following bunker characteristics based on their importance related to golf course management and maintenance: (use 0 to indicate no importance, rank the remaining qualities beginning with 1 = most important)

_____ Visual Appearance
_____ Drainage
_____ Structural Quality
_____ Shape
_____ Depth
_____ Size
_____ Sand Type
_____ Maintainability
_____ Location
_____ Other _____

Comments:

8. Rate the importance of the following factors related to bunker maintenance:

Not Important				Very Important		Not Important				Very Important	
1	2	3	4	5	Sand Type	1	2	3	4	5	Material Contamination
1	2	3	4	5	Raking Methods	1	2	3	4	5	Edging and Weed Control
1	2	3	4	5	Irrigation of Bunker Surrounds	1	2	3	4	5	Maintenance of Bunker Surrounds
1	2	3	4	5	Education of Maintenance Staff	1	2	3	4	5	Number of Bunkers / Sand Area to Maintain
1	2	3	4	5	Drainage	1	2	3	4	5	Other _____

Comments:

9. Rate the importance of the following factors on long-term bunker quality.

Not Important				Very Important		Not Important				Very Important	
1	2	3	4	5	Design Feasibility	1	2	3	4	5	Construction Techniques
1	2	3	4	5	Construction Quality	1	2	3	4	5	Maintenance Practices
1	2	3	4	5	Level of Use	1	2	3	4	5	Maintenance Budget & Resources
1	2	3	4	5	Other _____						

Comments:

Section 3 – New Bunkers

10. Have you been involved in the bunker design and construction process for a new golf course?

_____ Yes _____ No If yes, please answer questions 11 and 12.
If no, proceed to question 13.

11. Based on your experiences, rank the following parties based on their involvement in the design (positioning, size, shape) of bunkers for a new golf course. (use 0 to indicate no importance, rank the remaining parties beginning with 1 = most important)

_____ Golf Course Architect
_____ General Manager
_____ Contractor
_____ Golf Professional
_____ Other _____
_____ Owner
_____ Superintendent
_____ Board of Directors / Greens Committee
_____ Golfers / Facility Users

Comments:

12. Based on your experiences, rank the following parties based on their level of involvement during bunker construction on a new golf course. (use 0 to indicate no importance, rank the remaining parties beginning with 1 = most important)

_____ Golf Course Architect
_____ General Manager
_____ Contractor
_____ Golf Professional
_____ Other _____
_____ Owner
_____ Superintendent
_____ Board of Directors / Greens Committee
_____ Golfers / Facility Users

Comments:

Section 4 – Bunker Modification

13. Have you been involved in efforts to make modifications to bunkers on an existing golf course?

_____ Yes _____ No If yes, please answer questions 14 – 22:

14. Based on your experiences, rank the following parties based on their involvement in initiating bunker modifications. (use 0 to indicate no importance, rank the remaining parties beginning with 1 = most important)

_____ Golf Course Architect
_____ General Manager
_____ Contractor
_____ Golf Professional
_____ Other _____

_____ Owner
_____ Superintendent
_____ Board of Directors / Greens Committee
_____ Golfers / Facility Users

Comments:

15. Based on your experiences, rank the following parties based on their level of involvement in the design (positioning, size, shape) of bunker modifications. (use 0 to indicate no importance, rank the remaining parties beginning with 1 = most important)

_____ Golf Course Architect
_____ General Manager
_____ Contractor
_____ Golf Professional
_____ Other _____

_____ Owner
_____ Superintendent
_____ Board of Directors / Greens Committee
_____ Golfers / Facility Users

Comments:

16. Based on your experiences, rank the following parties based on their level of involvement in the construction of bunker modifications. (use 0 to indicate no importance, rank the remaining parties beginning with 1 = most important)

_____ Golf Course Architect
_____ General Manager
_____ Contractor
_____ Golf Professional
_____ Other _____

_____ Owner
_____ Superintendent
_____ Board of Directors / Greens Committee
_____ Golfers / Facility Users

Comments:

17. Listed below are reasons for considering bunker modifications. Rate their level of importance.

Not Important				Very Important		Not Important				Very Important	
1	2	3	4	5	Maintenance	1	2	3	4	5	Safety
1	2	3	4	5	Strategy	1	2	3	4	5	Aesthetics
1	2	3	4	5	Pace of Play	1	2	3	4	5	Circulation
1	2	3	4	5	Design Flaws	1	2	3	4	5	Restore Design Character
1	2	3	4	5	Drainage	1	2	3	4	5	Economic Factors
1	2	3	4	5	Bunker Age	1	2	3	4	5	Other _____

Comments:

18. Considering current trends in golf, rank the following bunker modifications based on most common occurrence. (1 – most common thru 6 – least common)

_____ New bunkers added
_____ Bunkers removed
_____ Bunker relocation
_____ Expansion of bunker sizes
_____ Reduction of bunker sizes
_____ Bunker restoration or repair

Comments:

19. When implementing bunker modifications how old were the existing bunkers? (If you have been involved in multiple bunker modification projects please indicate the most common scenario)

_____ 0-5 years
_____ 5-10 years
_____ 10-20 years
_____ older than 20 years

Comments:

20. When considering bunker modifications, were other golf course changes also considered? (If you have been involved in multiple bunker modification projects please indicate the most common scenario)

_____ Yes _____ No

Comments:

21. Were bunker modifications considered as part of a golf course master plan? (If you have been involved in multiple bunker modification projects please indicate the most common scenario)

_____ Yes _____ No

Comments:

22. If yes to question 21, what additional golf course changes were associated with bunker modifications? (mark all that apply)

_____ Greens
_____ Tees
_____ Trees / Vegetation
_____ Cart Paths
_____ Irrigation
_____ Fairways
_____ Surrounds
_____ Water Features
_____ Turfgrass
_____ Other _____

Comments:

Thank you for taking the time to complete this survey. Your responses are very valuable to ensuring the accuracy and relevance of this research.

Appendix B - Bunker Sand Selection Properties Definitions

Bunker Sand Selection Factors (Ross, 2006)

Particle size – It's recommended the majority of the particle sizing, about 75 percent or more, fall in the medium-coarse range (0.25 mm to 1.0 mm). The additional 25 percent or less should fall in the medium-fine to very fine range (0.25 mm to 0.05 mm). One factor that influences particle size when selecting bunker sand is the makeup of the root zone. Sand is blasted onto green surfaces from adjacent bunkers frequently. Therefore, sand can create problems if the particle size is significantly smaller than the root-zone makeup. So it's important to select a sand that also will integrate with the root-zone material and not cause any layering-type problems.

Particle shape – Once sand is found with the correct particle sizing, the job is only partially finished. Particle shape is the next characteristic that influences a great sand and might be the most important of all. This also is the one characteristic that influences the penetrometer value the greatest. One term frequently used when comparing sand shapes is sphericity. Sand with a high degree of sphericity is one that's round or almost round. Sand that has a low degree of sphericity is one that's elongated or flatter. The most desired shape for bunker sand is a particle shape that's angular. Therefore, it possesses many sharp and well-defined edges and has low sphericity. Sand that's smooth and has high sphericity isn't well suited for bunkers. The difference between these two sand types is the particle shape of the angular sand. It compacts well because of the sharp angular edges and elongated shapes. Round sands can't compact. Therefore, highly angular sand with low sphericity will obtain the best penetrometer reading and offer the best resistance to compression from the golf ball. This translates into a low tendency for a ball to bury in the sand, which minimizes the dreaded fried egg lie.

Penetrometer value – The penetrometer has been the test of choice for determining the potential for a ball to bury. As mentioned above, ball rotation (spin) is a factor not taken into consideration. There are other factors that can determine the ball's lie in a bunker that testing doesn't consider: shot trajectory, ball angle entry and incoming ball velocity. A ball can enter a bunker at a bad angle when its 90 degrees to the sand slope with a high trajectory. This angle offers the least reaction between the ball and the sand, and results

in the greatest possibility of a fried egg lie. The speed of the ball (velocity) when it hits the sand is another factor. Many shots, with a high ball speed when entering the face of the bunker, are destined to be buried even with the good bunker sand. When considering these factors, its understandable why, in recent years, there has been talk of determining better methods to evaluate bunker sands.

Crusting potential – Crusting is the formation of a thin, crust-like layer on the surface of the sand. This layer usually ranges from 1/16 inch to 3/8 inch. Crusting is a direct relationship to the purity (cleanness) of the sand. The crusting potential is directly proportional to the amount of silt and clay in the sand – the higher the percentage of silt and clay, the higher the crusting potential. Crusting occurs when the bunker surface receives moisture from rain or overhead irrigation. With the sophistication of sand production facilities, the cleaning (washing) process all but eliminates any crusting problems when purchased from those facilities.

Chemical reaction and hardness – Chemical reaction and hardness will determine the makeup and stability of sand. Some sand, such as calcareous sand, is prone to physical and chemical weathering. This will cause long-term problems from the breakdown of the sand and a build-up of fine particles. These fine particles will cause firmer sand that will have decreased infiltration rates. Fortunately, the makeup of most sand is quartz, which is silicon dioxide (SiO2) and resists chemical and physical breakdown.

Infiltration rate – Infiltration rate (hydraulic conductivity) is a straightforward characteristic and is usually high in most sand. This is different than root zones for greens, which normally have an organic component blended with sand that lowers the infiltration rate significantly. Bunker sand should have an initial minimum infiltration rate in the range of 20 to 30 inches per hour. If a sand meets the criteria for particle sizing and has high purity (cleanness), then meeting the infiltration rate usually isn't a problem.

Color – The color of bunker sand is subjective. Most golfers like the look of white bunker sand contrasting with green surrounds. However, white sands can cause problems on bright, sunny days, creating significant glare. Slightly off-white (light tan) might be a better choice. If local sand meets all the performance criteria for great bunker sand, color probably shouldn't be an issue.

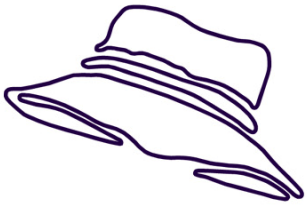
Playability – The playability of a bunker sand will differ from golfer to golfer and is another subjective component of bunker sand selection. Unfortunately, not all golfers like the same bunker sand. Tour professionals and most low-handicapped players prefer firm sand, which allows spin to be produced on the ball. A higher-handicapped player, who can't develop the clubhead speed needed to get through a firm sand bunker shot, prefers softer sand.

Appendix C – Colbert Hills Golf Course Bunker Renovation Plan

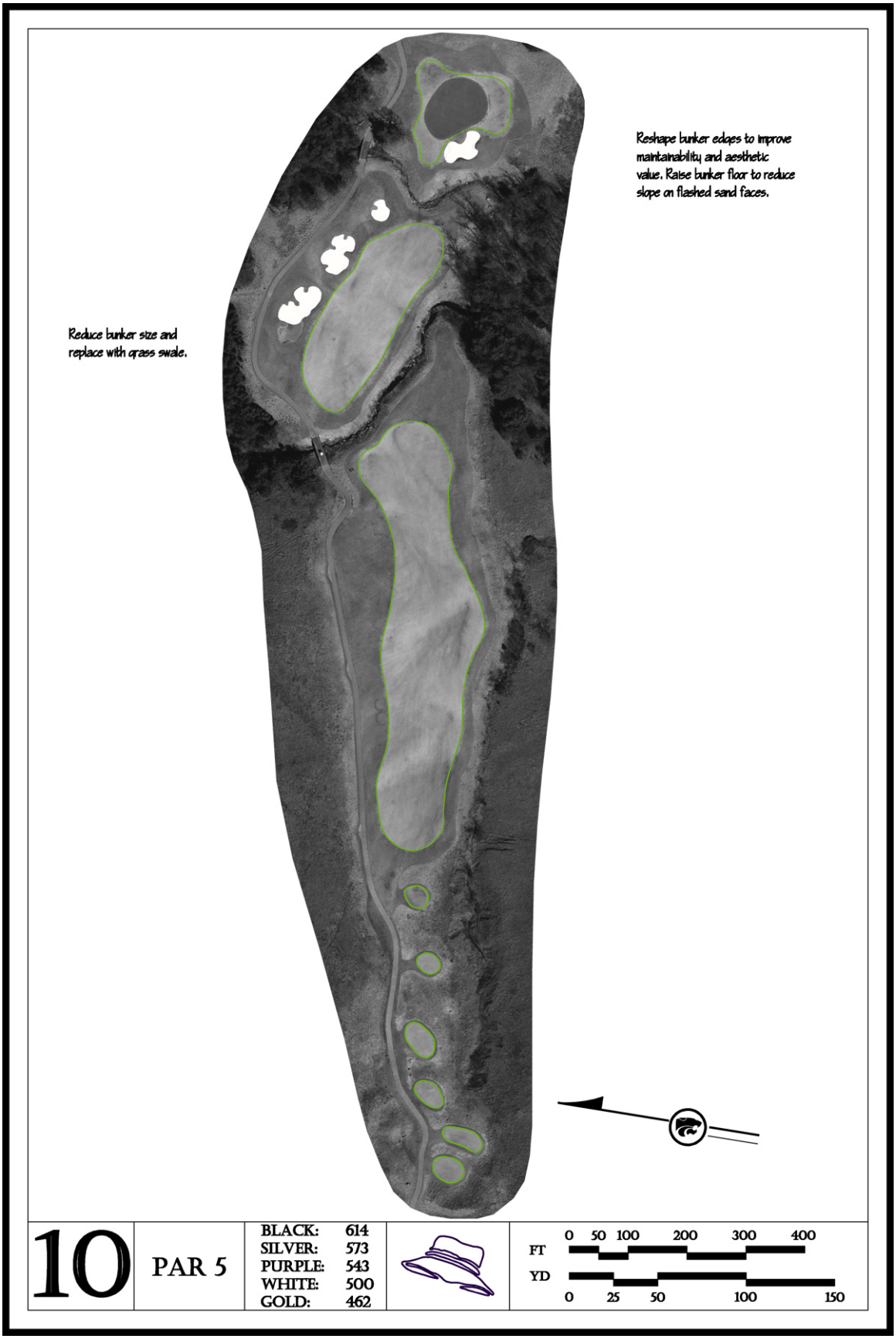
COLBERT HILLS GOLF COURSE

BUNKER RENOVATION PLAN

HOLES 10 - 17



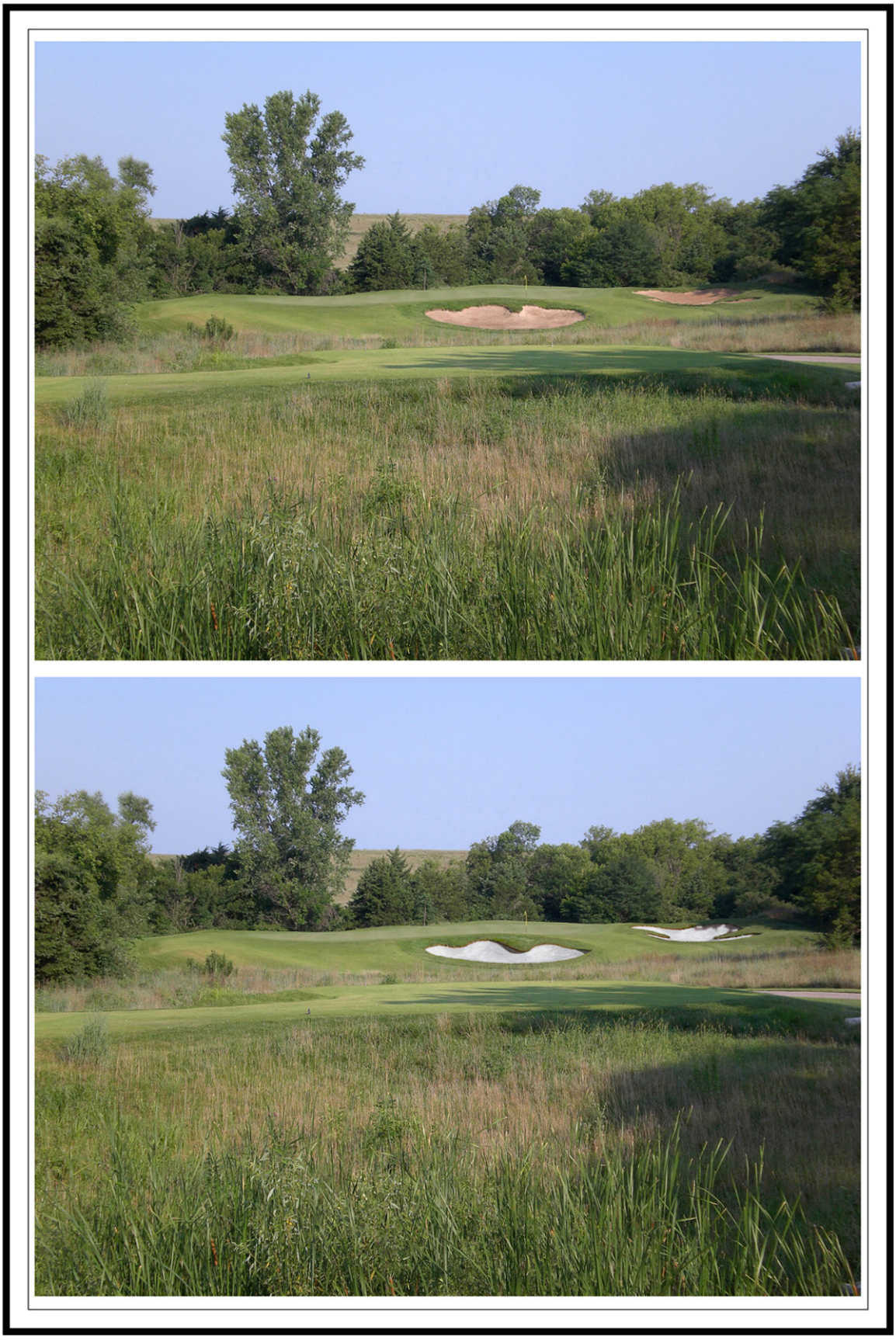
AUGUST 2008


Reshape bunker edges to improve maintainability and aesthetic value. Raise bunker floor to reduce slope on flashed sand faces.
Reduce bunker size and replace with grass swale.
10
PAR 5
BLACK: 614
SILVER: 573
PURPLE: 543
WHITE: 500
GOLD: 462
FT 0 50 100 200 300 400
YD 0 25 50 100 150

Enlarge right bunker toward tees for improved visibility.

Reshape front bunker for improved aesthetic value and maintainability. Raise bunker floor to reduce slope on flashed sand faces.

11	PAR 3	BLACK: 230 SILVER: 201 PURPLE: 145 WHITE: 145 GOLD: 104		FT 0 50 100 200 YD 0 25 50 75



Remove two bunkers nearest cartpath from greenside bunker complex. Replace with native rough area.

Reduce bunker size and replace with grass swale.

12

PAR 4

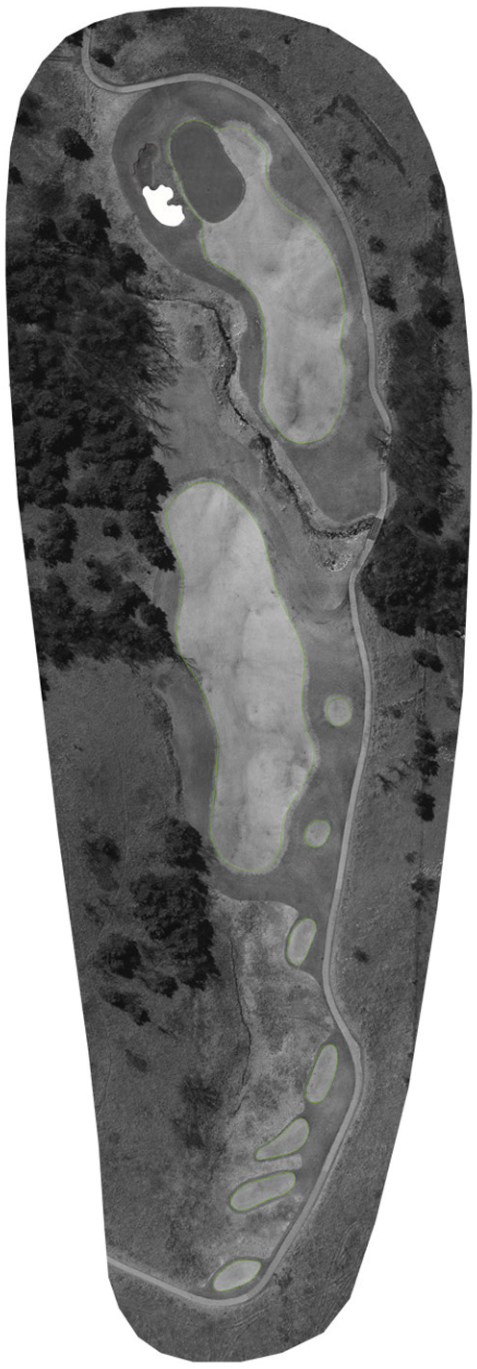
BLACK:	434
SILVER:	407
PURPLE:	390
WHITE:	369
GOLD:	285

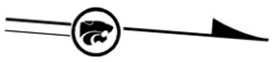
FT 0 50 100 200 300 400

YD 0 25 50 100 150


Reshape "J" bunker into two smaller bunkers which continue the series of bunkers splitting the fairways.
Reduce "C" bunker size and replace with native grass swales.
13
PAR 4
BLACK: 357
SILVER: 344
PURPLE: 316
WHITE: 316
GOLD: 261
FT 0 50 100 200 300
YD 0 25 50 100

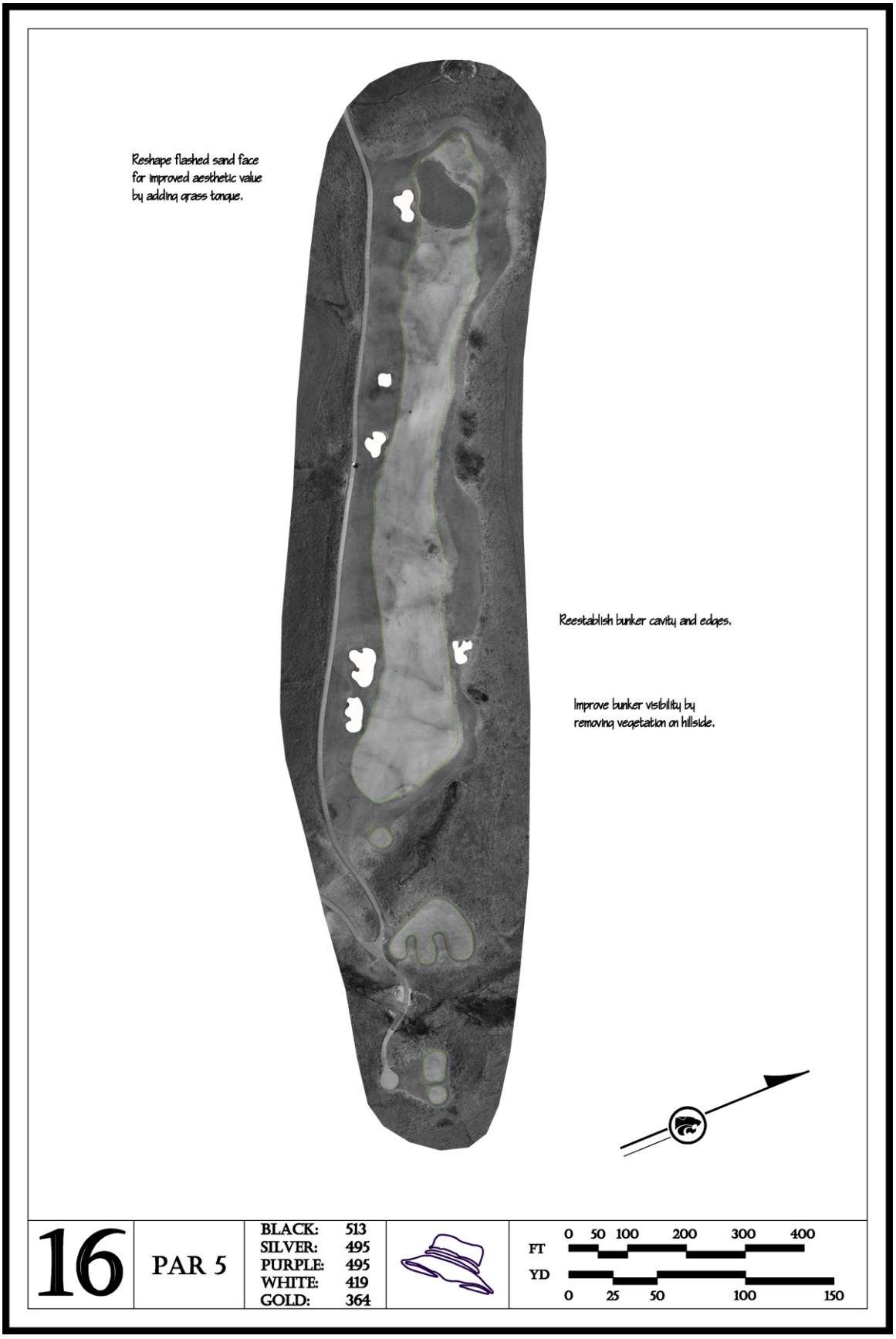
Reduce bunker size and reshape flashed sand faces. Replace upper bunker area with grass swale.

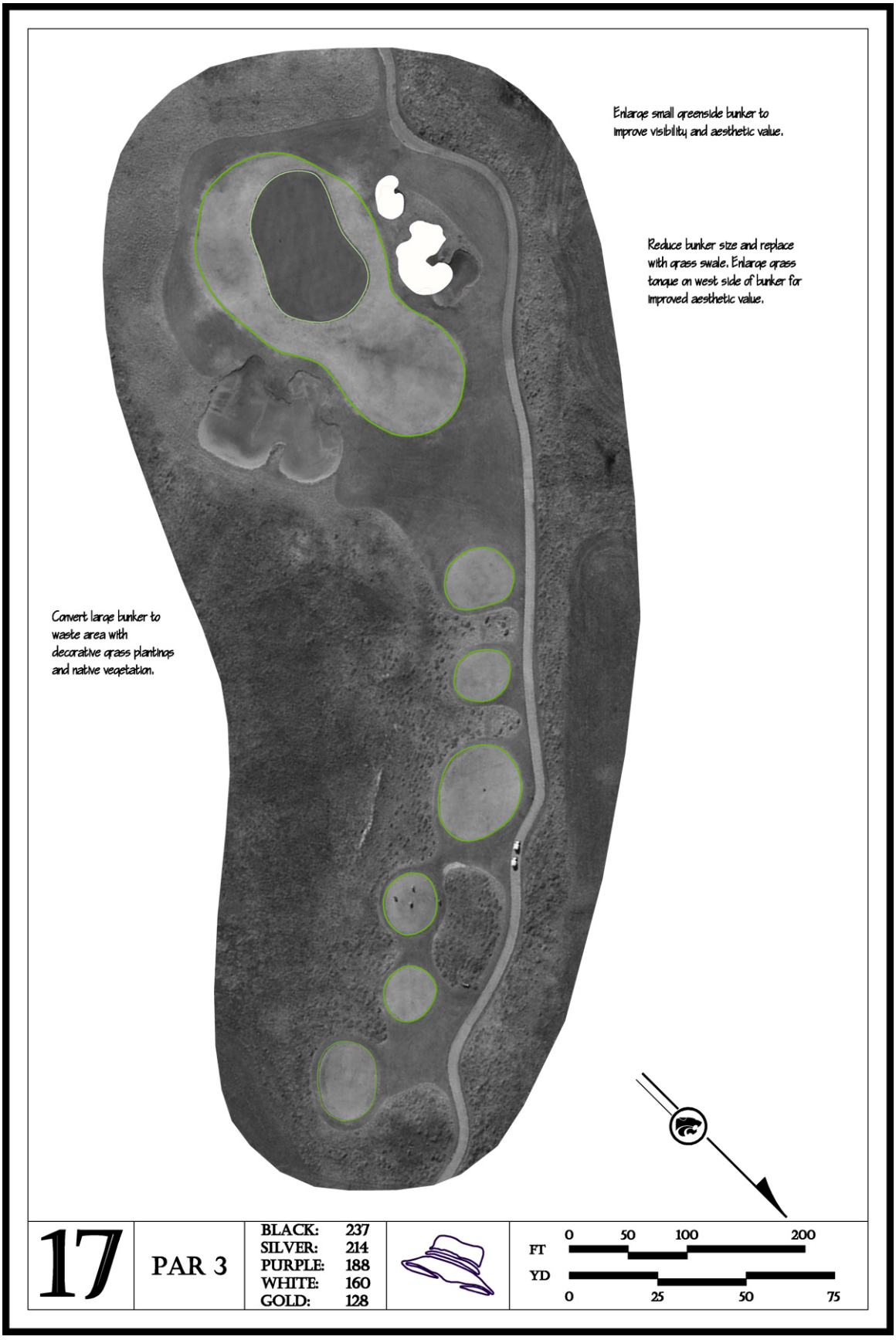




14	PAR 4	BLACK: 487 SILVER: 452 PURPLE: 432 WHITE: 350 GOLD: 307		FT: 0 50 100 200 300 400 YD: 0 25 50 100 150


Reshape small greenside bunker for improved aesthetic value and maintainability.
Enlarge and reshape fairway bunkers to improve visibility and aesthetic value.
15
PAR 4
BLACK: 375
SILVER: 365
PURPLE: 338
WHITE: 338
GOLD: 307
FT 0 50 100 200 300
YD 0 25 50 100


Reshape flashed sand face for improved aesthetic value by adding grass tongue.
Reestablish bunker cavity and edges.
Improve bunker visibility by removing vegetation on hillside.
16
PAR 5
BLACK: 513
SILVER: 495
PURPLE: 495
WHITE: 419
GOLD: 364
FT 0 50 100 200 300 400
YD 0 25 50 100 150


Enlarge small greenside bunker to improve visibility and aesthetic value.
Reduce bunker size and replace with grass swale. Enlarge grass tongue on west side of bunker for improved aesthetic value.
Convert large bunker to waste area with decorative grass plantings and native vegetation.
17
PAR 3
BLACK: 237
SILVER: 214
PURPLE: 188
WHITE: 160
GOLD: 128
FT 0 50 100 200
YD 0 25 50 75