CHAPTER II: CURRENT LITERATURE AND CASE STUDIES

Introduction

This chapter will introduce principles for golf course design, construction, and management that can be used by golf course architects and superintendents for both new construction and for renovation of existing courses. It contains data from research experiments related to the environmental impacts of golf courses and discussions of case studies which provide real-world examples of the possibilities that exist for future golf course development.

The information presented in this chapter is based on an extensive literature search which utilized both primary and secondary sources. Much of the scientific data represents results from experiments conducted as part of the United States Golf Association’s Environmental Research Program. Both refereed and non-refereed sources were utilized, primarily because much of the literature related to golf course design and criticisms of golf course development could only be found in non-refereed journals.

Golf Course Design Principles

Introduction

The game of golf, which is thought to have originated in Scotland as early as 1400, has continued to evolve over a period of more than 500 years into the game that we recognize today. The earliest playing fields for the game were the linkslands of the Scottish coastal landscape, areas consisting of windswept dunes of sand and hollows where grass would grow if the soil was substantial (Cornish and Whitten, 1993). The routing of play on these early playing fields was dictated by the terrain, and there was no recognized system of tees, greens, and fairways as there are today. Terrain manipulation for golf courses started in the late 1700’s, but the first recognized golf course designer was Allan Robertson of St. Andrews, Scotland, the first of many golf course architects who would follow in his footsteps (Cornish and Whitten, 1993).

Golf course architecture involves not only the application of spatial and aesthetic principles common to golf courses (tees, fairways, greens, and hazards) but also the
considerations that help the golf course function properly such as surface and subsurface drainage, safety issues, soil preparation, selection of turfgrasses and other vegetation, and management strategies. Many of the decisions made by the golf course architect affect the playability of the course, the cost of maintenance (and therefore cost of play), and impact of the course upon the environment. Therefore, proper design is one of the most important factors that influences the development of the golf course.

Though there are many instructional books that concern golf as a sport and how to play it, there are very few in existence that deal with golf course architecture. Even fewer still have been written in the past 50 years. Most of the literature concerning the subject can be attributed to designers from the "Classical Era" of golf course design from 1900-1930. Such well-recognized names as Tillinghast, Mackenzie, Maxwell, Thomas, and others practiced their art during this era. Many of the world's most famous courses were designed by these pioneers, and several of them published books on the subject, such as *Golf Course Architecture in America* (Thomas, 1926), *Some Essays on Golf Course Architecture* (Colt and Alison, 1920), *The Links* (Hunter, 1926), *Golf Architecture* (Mackenzie, 1920), and *The Architectural Side of Golf* (Wethered and Simpson, 1929).

Interest in golf course design has experienced an unprecedented increase over the past twenty years. Accordingly, a few published works have become available that deal with the subject such as *The Spirit of St. Andrews* (Mackenzie, 1996), *Golf Course Architecture: Design, Construction, and Restoration* (Hurdzan, 1996), *Bury Me in a Pot Bunker* (Dye and Shaw, 1995), *Golf Course Development and Real Estate* (Muirhead and Rando, 1994), *Golf by Design* (Jones, 1993), *The Architects of Golf* (Cornish and Whitten, 1993), *The Anatomy of a Golf Course* (Doak, 1992), and *The Golf Course: Planning, Design, Construction, and Maintenance* (Hawtree, 1983). These texts and selected other sources will form the basis for the information presented in this Chapter related to environmental principles for golf course design, construction, and management.

Planning: Site Selection and Analysis

One of the most important considerations in discussing golf courses and environmental issues is the planning of the golf course development. Within the planning process, the analysis of the site selected is the most important step in evaluating the
potential environmental impacts of the golf course development and anticipating ways of mitigating these impacts. “Golf courses are not isolated recreational amenities but should be integral parts of larger networks of open space within the regional ecosystem.” This is the thought behind “Golf Courses as Ecologic Sanctuaries,” a concept developed by Desmond Muirhead and Guy Rando (1994). This concept is based on the premise that golf courses, as major landscape elements, offer special opportunities and potential to combine a recreational amenity with a program to improve environmental quality.

Planning with environmental concerns requires a commitment by the developer to be sensitive to all related issues, patient with the process, willing to risk “up-front” money, and open to making concessions and compromises (Hurdzan, 1994). The purchase of the land, the permitting process, and delays in the construction schedule are all probable in most development, and even more likely in cases where there are extensive environmental concerns. Ideally, developers will involve a golf course architect in this process along with a multidisciplinary team including an owner, engineer, ecologist, botanist, archaeologist, golf course architect, land planner, golf course superintendent, lawyer, and planning team coordinator (Hurdzan, 1994). Inclusion of this project team will greatly contribute to the overall success of the project.

Important physical elements of any site analysis for golf course development are required land area, soils and topography, hydrology, wildlife, and ecological concerns. Analysis of these factors will help to determine if the site is feasible for the type of development desired, and whether development is even possible or wise. It will also determine the success of the finished product as part of a healthy and functioning landscape.

**Land Area Requirements**

Golf courses are typically built to accommodate nine or eighteen holes, with each set of nine holes having two par threes, two par fives, and five par fours. The average eighteen-hole golf course requires approximately 160-200 acres of land in order to function properly. Successful courses have been built on less land, but the increasing length of travel of the golf ball over the years has also increased the length required for the golf course, hence the increasing land area required. Overall, eighteen hole course lengths are
usually greater than 6500 yards, with most courses seeking to exceed 7000 yards to increase the difficulty levels for better players.

The overall layout of the golf course is an important determining factor for design and playing flexibility, construction and maintenance expenses, safety concerns, land required for development, and home frontage (Muirhead and Rando, 1994). There are three basic layouts for golf courses; single fairway, continuous double fairway, and the core golf course. Though there are some variations on these layouts, such as with or without returning nines (this refers to whether play returns to the clubhouse after nine holes), they can be compared in these three categories.

Single fairway courses have more available frontage for homes and are most flexible for dealing with topographic problems (such as very hilly terrain), but they require more land area, are weak statements as open space, and are most expensive to maintain. They are problematic for golfers because they have limited playing flexibility (holes can only be played in a designated sequence) and because golfers would rather not play between houses, cross roads, nor travel long distances between holes (Muirhead and Rando, 1994).

In comparison, continuous double fairway designs use less land and are less expensive to maintain than single fairway courses, but they have less frontage for housing than single fairway and tend to be less safe. Core golf courses, on the other hand, have the least frontage for homes, but the frontage is of better quality. Less land area is required for core golf courses, golfers enjoy the design better (since they don’t have to play between houses and the distance between holes is less), the course makes a solid statement as an open space, there are fewer safety problems, and they are more efficient and less expensive to maintain (Muirhead, 1996). Because of these reasons, the core golf course is the concept most often used in contemporary golf course development.

Where land is limited, more modest-sized courses (25-60 acres) can be designed that utilize par threes and a few par fours to provide a variety of shot selections for golfers. Courses can also be designed with multiple tees and multiple greens that share common fairways (Fream, 1982). This type of course may only be appropriate for lower volume use because of the safety concerns such a course would raise. Although these types of golf developments on limited lands would be less expensive to build and maintain than a longer
course, they may not be wise investments considering the current growth trends in golf course use.

Donald Knott, a golf course architect with Robert Trent Jones II International, suggests that current trends of 7000 yard course lengths for 18 holes may not be healthy. He questioned whether some environmental impacts could be lessened by not always smashing 18 holes into a piece of land, and whether fewer (but better quality) holes would result in natural areas of better quality (Knott, 1994). Another environmental question related to required land area is whether golf courses should be designed to take up even more land than they currently do in order to embrace and preserve large habitat areas, or whether they should be limited to the development of rejected landfills and urban fringe lands (Pearce, 1993). Continued research is needed concerning the impacts of golf courses on native flora and fauna in order to evaluate these concerns.

Soils and Topography

Soils are particularly important in golf course development because of how greatly they impact the growth of turfgrass. No other element more greatly affects the health of turfgrass than the growing medium. This will determine the nutrient and water availability for the turfgrass plant and will greatly affect the long term maintenance success of the golf course.

Extensive field research should be conducted prior to construction to determine possible complications from soil characteristics. This should include a visit to other courses in the area to talk with superintendents and identify what grasses are best suited for the soils and climate of that area based on their past performance (Poellot, 1992). Test holes should be dug on several different areas of the site in order to determine the depth of soil to rock, the type of underlying rock, the depth of soil to groundwater, and the characteristics of the constituents of the soil horizon profile (Hurdzan, 1996). Test plots should be conducted with possible soil and grass choices made for the course before final choices are made. The management section of this research will discuss the interactions of soil and turfgrass quality in more detail.

In addition to acting as the growing medium for turfgrass, soil is a precious resource in and of itself. Because of this, there is a need for any land conversion to take into account
the impact of the development upon the soil. It is important to identify the locations of steep slopes and highly erodible soils to prevent erosion, especially during the construction of the golf course. Coarse textured or shallow soils should also be avoided in order to decrease the likelihood of pesticide and fertilizer leaching. The design of the course should be done so that intrusion upon any of these features is minimized (Klein, 1994).

The engineering characteristics of the soil are important for construction concerns, especially where the building of greens, tees, cartpaths, access roads, and structures like the clubhouse or storage areas are concerned. Areas with weak bearing capacity or extensive shrink and swell characteristics should be identified and avoided, or the soil should be properly amended (if possible) before any construction begins.

Topography is also important in assessing the suitability of a site for a golf course. Golf courses have been built on every conceivable terrain, from flat desert courses to climbing and tumbling mountain designs. In general, a slightly rolling topography is desirable from a surface drainage and visual interest standpoint. It is best to avoid steep slopes because of the erosion and maintenance concerns they cause, and also because these courses tend to produce safety concerns and are difficult to walk. On the other hand, completely flat sites are often difficult to drain and lack the visual interest that even a small hill can provide (Doak, 1992).

In general, the best soil and topography conditions for a site seem to be those with a gently rolling topography and a soil profile that is consistent throughout the site. These factors will decrease construction and maintenance costs because a minimal amount of soil will need to be moved during construction and the conditions for maintenance will be relatively consistent throughout the course. The best soil types seem to be well-drained soils, such as sandy loam, that will be resistant to compaction but will be able to retain enough moisture for plant growth. Greens and tees require separate construction methods and soil distributions because of the intense traffic and maintenance conditions required in these areas.

Hydrology

Water is the precious resource that ties together all of the elements of the golf course. Most of the criticisms that have been raised concerning golf course impacts upon
the environment have dealt with water quality degradation and excessive water use. Therefore, it is very important to identify any possible water quality impacts before construction begins. This involves an evaluation of surface water impacts as well as groundwater impacts.

Powell and Jollie, in a 1993 report for the Baltimore County EPA (Schueler, 1994), developed guidelines that require detailed evaluation of wetlands, including the approximate type and distribution of existing vegetation, evaluation of depths and sizes of standing water areas, and soil information for the area. Perennial and intermittent streams, floodplains, steep slopes, forest stands, and habitat features for a proposed course were also to be identified and evaluated prior to the design of the course. They recommended that the course should then be configured to avoid or minimize disturbance of such areas.

In order to evaluate groundwater contamination potential, Cohen et al. (1993) recommended that soil samples should be gathered to determine organic carbon content, pH, field capacity, sand and clay content, bulk density, porosity, and infiltration rate. All of these factors greatly influence the downward percolation of water through the soil profile. They also recommended that any presence or likelihood of groundwater discharges to sensitive surface water bodies be identified and protected prior to construction. In addition to these elements, the proximity of the water table to the surface is an important factor in determining potential groundwater impacts.

Water use is another issue that must be addressed in the site analysis. The ability to obtain the necessary water for irrigation will always be an important factor in golf course development because of the need to keep the turfgrass areas healthy. Hurdzan (1996) states that, in the Midwestern regions, fairways require about one inch of water per week, while tees and greens need about one and one half inches per week. These numbers seem harmless enough, but when the total amounts of irrigation water for an eighteen hole golf course are calculated (assuming thirty acres of fairways and five acres of greens and tees), it becomes apparent that the course would require 810,000 gallons of water per week for the fairways and 202,500 gallons per week for the greens and tees. Courses in arid regions may need up to three times this amount of irrigation. Obviously, the availability of water is one of the most important issues in evaluating the suitability of a site for golf course development.
Irrigation restrictions currently placed on desert golf courses may one day be applied elsewhere as well, a change that will impact course design in the future. Perhaps these design concepts related to water conservation should be implemented before water resources become a greater concern. One method would be the use of the “target” course design philosophy in the non-arid regions of the country. This concept would decrease the amount of turfgrass area on the course, thereby decreasing water consumption and maintenance expense (less chemical application, less mowing, etc.). It would also provide expanded areas that could be planted with native vegetation for wildlife habitat.

Another strategy that has been used for water conservation is the design of courses with internal collection of rainwater and irrigation runoff into holding ponds for reuse. This not only decreases the demand for potable water for irrigation of the course, it decreases the likelihood of off-site transport of nutrients and chemicals from turfgrasses. The use of effluent water is another concept that has been implemented successfully on several courses in the U.S. (Frye, 1994; Salvesen, 1996; Poellot, 1992) and may provide promise for future golf course irrigation and water treatment needs in this country. Fresh water sources will always need to be available for irrigation during times of drought when pond levels drop and also as a supplement to the use of effluent water.

Surface and groundwater resources must be carefully identified and evaluated prior to construction of the course. Any use of these resources should be planned and monitored in order to avoid water quality degradation and excessive water use. One guideline for water usage identified in the literature was that sufficient water must be available to meet the irrigation needs of the golf course without either causing a decrease of more than five percent of the seven day, ten year low-flow level of any waterway in the vicinity or substantially reducing the yield of existing wells in the area (Klein, 1994). Following this guideline will provide the irrigation water necessary for turfgrass maintenance without negatively impacting the water resources of the surrounding ecosystem.

Wildlife and Vegetation

While analyzing a site for potential development, it is important to assess the quality of habitat that exists on the site and identify the impact that the development will have on the wildlife and vegetation already present. A “Habitat Suitability Index” such as that
commonly used by the U.S. Fish and Wildlife Service can be used to numerically rank habitat and evaluate site suitability. A biological inventory should be taken that includes habitat diversity, species diversity, species of special concern, endangered or threatened species, water resources, habitat integrity, and connections between habitat areas (Smart et al., 1993). Existing vegetation should also be evaluated for its type, health, age, distribution, and impact on wildlife (Hurdzan, 1994).

Following the assessment of the wildlife and vegetation on the site, there may be additional procedures needed to avoid certain areas and to mitigate any damage that may be caused by development. Potential planning requirements and restraints may include wetlands or other sensitive surface waters that require buffers for protection and potential and existing habitats (nesting and breeding areas), particularly those used by endangered species identified on the site (Hurdzan, 1994). Once these areas have been identified, the site analysis should also assess the possibility of enhancing existing habitat and creating a more sound ecological plan for the development. For instance, the inclusion of large contiguous patches of native vegetation can be connected together to form a matrix of habitat and travel corridors for wildlife.

There is ample evidence that golf courses provide habitat for a wide variety of plants and animals (USGA report, 1996; Borland, 1988; Carrick, 1994; Danielson, 1993; Etchells and Rinehimer, 1994; Harker et al., 1993; Hawes, 1996), though concerns still exist that the types of habitats which they provide favor edge species rather than a broader range of wildlife types. Funds generated by golf course development also make it economically feasible to reuse degraded sites such as landfills, industrial waste dumps, abandoned sand and gravel mines, rock quarries, and coal mines. Examples of this include the TPC of Michigan (Hawes, 1996), Harborside International in Chicago (Thompson, 1996), Old Works Golf Course in Anaconda, Montana (Duthie, 1996), and Widows Walk in Scituate, Massachusetts (Hurdzan, 1996; Whitten, 1996). These types of development offer tremendous opportunities for the future problems associated with waste disposal from the excessive resource use of our society.

The impact of golf course development upon existing flora and fauna in previously undisturbed sites, however, has yet to be fully evaluated. More research needs to be conducted in this area in order to assess potential impacts and opportunities for improving
habitat. If a previously undisturbed site is going to be developed, the design and construction of the course should be carried out with minimal disturbance to the out-of-play areas and with very careful consideration of potential ecological impacts.

Additional Concerns

In addition to the above physical characteristics that need to be addressed in the site analysis, there are other factors that are important in assessing the potential impacts of golf course development. Social factors often play an important role, particularly in the permitting process. Many of these factors can be identified through visiting the site and speaking with area residents as well as through extensive research of historical records. If area residents highly value the proposed site in its current condition, they are more likely to resist development in that area. Another issue could be the presence of rights-of-way, easements, or zoning restrictions for that area that would limit the types of development that could take place. Previous land use, particularly as it relates to historical significance, is an important factor since some of these areas will need special consideration and may possibly need to be avoided during construction. Adjoining land uses and future plans for the development of the surrounding lands will impact how the golf course will function as a landscape element and will contribute to the playing and living atmosphere (for instance, sites in the flyway for a nearby airport will continually be disrupted by the noise levels from air traffic). Below-ground concerns such as buried utilities, mineral rights, and potential archaeological sites are also of concern in the planning stages of development (Hurdzan, 1994).

All of these issues, in addition to required land area, soils, topography, hydrology, and ecological concerns, are important items that must be identified and analyzed during the planning process. If all of these criteria are properly evaluated, the design and construction of the golf course and any accompanying development will have the most chance of success for making a positive contribution to the functioning landscape.

Surface Water Concerns

Since it is one of the most criticized aspects of golf course development, it is important to deal carefully with the subject of surface water pollution. Groundwater impacts
and surface runoff studies concerning pesticides and fertilizers from turfgrasses are detailed in the management section of this chapter. This section will deal with golf course design impacts on surface water quality.

Possible causes of waterway degradation include stream channelization (straightening of streams which causes accelerated channel erosion from increased stormwater velocity), destruction of wetlands, lack of vegetated buffer for filtration of runoff, elevated water temperature (from lack of shading vegetation, reduced groundwater flow, heated water from ponds, and heated water from runoff of impervious surfaces), reduced base flow (due to ground and surface water withdrawal), release of toxic and oxygen-deficient water from ponds, intermittent pollution (pesticides, fertilizers, and fuel), stormwater pollutants from impervious areas, elimination of scouring benefits of flooding by altering the frequency and magnitude of flooding, poor erosion and sediment control during construction, and inadequate treatment of sewage and wastewater (Klein, 1994). The following paragraphs will address these areas of concern and how golf courses can be designed for protection of these hydrologic systems.

**Wetlands**

Environmental considerations are becoming an increasingly important part of any development process due to new regulations. Obtaining construction permits now takes a tremendous amount of time and has resulted in developers using more thoughtful and environmentally conscious site selection and design practices. Developers must be much more careful in the types of land they choose for expansion and how they treat them. One of the largest issues to emerge has been the treatment of wetlands.

The presence of wetlands on a potential golf course development site has a tremendous impact upon the planning and construction phases of a project. Section 404 of the 1979 Clean Water Act defines wetlands as, "...those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." (Balough and Walker, 1992). The presence of water in wetlands creates conditions that support vegetation adapted to wet conditions (hydrophytes) and produce characteristic soils (hydric soils) that develop under anaerobic circumstances.
Wetlands are recognized as a valuable natural resource in that they provide habitat for breeding and nesting waterfowl, reptiles, amphibians, and other aquatic birds. Many mammals also occupy wetlands (either periodically or permanently) including mink, muskrat, raccoon, and beaver. Wetland vegetation provides habitat for aquatic invertebrates, which are an important link in natural food chains. Many types of wildlife utilize wetlands for only a portion of their life cycle, while others require wetlands for their entire life cycle (Thompson, 1992). In addition to wildlife habitat, wetlands provide flood control (acting as a sponge for storm runoff), improvements in water quality (acting as a "sink" for trapping sediments and nutrients such as phosphorus and nitrogen), groundwater recharge and discharge, aesthetic and recreation areas, and shoreline erosion control (Balough and Walker, 1992). The biotic mass of emergent plants in wetlands can also be periodically harvested, composted, and used to amend soil, effectively removing nutrients from the water for reuse on turfgrass areas (Muirhead and Rando, 1994).

Pete Dye, in his book "Bury me in a Pot Bunker" (1995), said that, "Based on current environmental rules, it would be impossible to build the Stadium Course TPC (Sawgrass, Florida) today. Reclaiming usable land from swamps and marshes by draining the water into lagoons was allowable then but would not be permitted today." While describing another of his projects, Harbor Town Golf Links on Hilton Head Island, South Carolina, he said, "Since the site was soggy, our crew began by dredging out narrow canals to drain off water...." These types of practices are generally no longer permitted without extensive mitigation. Many new golf courses use wetlands to their advantage by dedicating them to out-of-play areas or setting them aside as nature reserves that serve as a backdrop to the course and as a positive marketing feature.

Squaw Creek Resort in Olympic Valley, California is a good example of the integration of wetlands into an environmentally sensitive and successful golf course development. Because of the extensive amount of wetlands on the site and its location above a major source of drinking water, one of the limitations set on this course by the surrounding community was that two acres of wetlands would be preserved for every acre of tee and green built on the site. Contractors were able to do this by utilizing the existing wetland soils in the construction of new wetland areas. A tractor bucket was modified for use as a sod cutter to cut the wetland vegetation seed bank into rolls so it could be used
again elsewhere. The topsoil was removed at the new wetland location and soil was excavated below the water table to the appropriate depth for the vegetation that was to be sodded. The wetland seedbeds collected were then rolled out in the new location and the area was inundated to the desired depth. So far, these modified wetlands have performed wonderfully due to the use of the rolls of wetland seedbed in their establishment (Jewell, 1994).

Because of the positive benefits of wetlands related to water quality and wildlife habitat listed above, and because of the extensive restrictions on their use for development, sites with substantial amounts of existing wetlands should be handled carefully. If there is insufficient land available for development of the golf course (in addition to housing and other facilities) without damaging the wetlands, it would be wise to consider either a smaller scale of development (shorter course, less housing, etc.) or development of a different site altogether. Wetlands on site should be included in the plans as features and contiguous parts of the final landscape development.

**Constructed Ponds and Drainage Concerns**

The use of water as a hazard in golf course design has gained tremendous popularity in the United States, particularly following the invention of powered equipment that has made massive soil excavation possible. These ponds not only provide beauty to the golf course landscape and a hazard for the play of the game, they also help to control downstream flooding and make the storage of irrigation water for the course much more readily available. There are many important considerations in the location and design of constructed ponds and other drainage features of the course.

The use of constructed ponds within flowing streams should be avoided because of the thermal pollution and increased algae growth they cause (temperatures are raised in the captured waters) and because they act as barriers to fish migration (Klein, 1994). Instead, these ponds should be constructed away from other surface waters in their use as a source for irrigation. Ponds should be designed with some shallow areas to encourage growth of emergent plants (Ciekot, 1996). Not only does the emergent vegetation filter the water of nutrients from course runoff, these areas also provide habitat for birds that build nests that float or nests anchored to emergent vegetation. This shallow water vegetation area is the
most productive area of any water body, providing a majority of the habitat for aquatic invertebrates, a valuable food source for many species of wildlife (Thompson, 1992).

Figure 2.1 shows a typical concept section for the hydrologic cycle of a golf course where surface drainage is diverted to retention ponds. The contouring of fairways and rough with a one foot slope away from adjacent surface waters will keep the systems from interacting (Smart et al., 1993). The use of these vegetative berms and mounds will make it possible to contain and redirect surface runoff away from sensitive environments. These waters can then be filtered by the turfgrass or collected in stormwater management ponds which will reduce suspended nutrients and sediment in drainage water (Muirhead and Rando, 1994). Runoff from parking lots, buildings, and other impervious areas should also be collected and filtered in retention ponds. The biologically filtered water can then be pumped onto the golf course by the irrigation system.

The use of vegetative filtering systems contained in swales and infiltration trenches throughout the course (see Figure 2.2) can be another very effective way of treating irrigation runoff on site (Schueler, 1994b). This is particularly important for the treatment of water collected from sand-based areas such as greens and tees which are designed to have higher infiltration rates to increase drainage effectiveness.

Streams, Rivers, and Lakes

The design of the course should seek to minimize the occurrence of water crossings. If the crossing of a waterway cannot be avoided, cart paths should be perpendicular to the flow of the stream, less than eight feet wide, and elevated on pilings from the edges of the floodplain. This would avoid the use of culverts, which tend to reduce the connectivity of habitat within the waterway (Klein, 1994).

Figure 2.2 shows a concept plan (Schueler, 1994b) for a stream crossing that minimizes impacts upon the stream. Note that all fairway crossings are perpendicular to the stream and that no more than two stream crossings are recommended per 1000 feet of stream length. Also notice that the surface runoff and leachate outflow from fairways, tees, and greens is treated by a combination of vegetative filtration areas (swales and wetlands), as mentioned in the previous section.
Figure 2.1: Illustration of the golf course hydrologic cycle and drainage solutions (adapted from Muirhead and Rando, 1994)

Figure 2.2: Concept plan for a stream crossing that minimizes impacts upon the stream and vegetative filtration of collected runoff (adapted from Schueler, 1994b)
Stream channelization (straightening of flow channels for maximization of runoff and drainage) should be avoided because increased stormflow velocities tend to cause erosion and sedimentation problems both on site and downstream. Lack of stormwater storage and higher levels of runoff associated with development and channelization also cause increased peak flows and create additional erosion and flooding problems downstream. Naturally meandering channels, on the other hand, make it possible to establish vegetation which provides soil protection and increased frictional surfaces for flood flows. Natural channels are longer than those that are channelized, and this provides additional storage capacity of surface runoff waters and valuable habitat for a variety of aquatic invertebrates that are intolerant of higher flow velocities.

Buffer Strips

One of the proposals that has been made for the protection of surface waters is the use of native vegetation, usually perennial grasses, in a buffer planting between developed areas and surface waters. According to Richard Klein (1994), the presence of buffer strips in these areas would help to retard flood flows, slow channel erosion, shade and cool the stream, filter sediments and chemicals from runoff, and would contribute organic matter to the system, thus improving the quality of the soil.

Though there seems to be a consensus in the research that buffer strips are important contributors to the health of surface waters, there are differing opinions as to the appropriate width of these areas. Klein (1994) recommends a buffer width of 75 to 150 feet along waterways. Doug Carrick (1994), on the other hand, described a golf course he designed in eastern Canada where a 30 meter (100 foot) buffer strip was used between turfgrass areas and a sensitive trout stream, and 15 meters (50 feet) in other areas (Carrick, 1994). Bruneau et al. (1996) agree on the use of a 50 foot buffer around wetlands, and recommend that golfers, irrigation water runoff, parking lot runoff, and maintenance vehicle wash be designed to avoid interaction with these systems.

Based on these research results, it appears that a minimum of 50 feet of native vegetation should be planted as a buffer to surface water areas. Widths closer to 100 feet will provide even more opportunities for wildlife habitat and ecological health for the site. If
widths less than this are required, steps should be taken to route storm water runoff away from the surface water bodies through the use of berms and swales.

**Wildlife Habitat: Creation and Conservation**

After assessing the quality of the habitat that exists on the site and identifying the impact (both positive and negative) that the development will have on the wildlife and vegetation already present on the site, it then becomes important to incorporate this information into the design of the course. This approach extends through the construction phase and ultimately into the management plan for the course and surrounding lands.

According to Bill Roberts, a past president of Golf Course Superintendents Association of America (GCSAA), “Early golf course architecture traditionally tried to work with the shape of the land. Then, beginning in the 1960’s, builders and architects began moving a lot of dirt, trying to create some different looks. And that had an impact on habitat” (Frye, 1994). During the routing phase of the golf course design, the information gathered in the site analysis will be vital in minimizing environmental impacts and avoiding areas where it will be most difficult to mitigate damage. One of the keys of creating wildlife habitat and overall health in the ecosystem is the retention of contiguous connections and wildlife corridors. Preservation of these connections during the design and construction of the course will make it possible for wildlife to travel through the site and will encourage the health and growth of a wider range of animals, thereby promoting the biodiversity of the site. This work should be done in collaboration with ecologists and botanists in order to determine the configurations of contiguous habitats required to support and protect specific species types (Muirhead and Rando, 1994).

Qualified professionals should be on site during staking and clearing to identify (tag) endangered and sensitive flora. A very effective method for protecting these areas is by fencing off areas that will remain undisturbed and avoiding them during construction. If these areas cannot be avoided, any endangered species should be transplanted to other undisturbed areas on the site. Endangered or sensitive species and habitat that are identified should be noted in construction documents with photographs and drawings, and clear and detailed specifications should be provided for the transplanting of sensitive flora during construction. The specifications should also include locations and recommendations...
for the care and monitoring of endangered or sensitive species (or those relocated) for inclusion in golf course management and operating plans (Muirhead and Rando, 1994).

Throughout the development and management of the site, an effort should be made to use plant species that are native to the area. One effective method for determining plant quantities needed for planting is to take into account the survival rate of the species. For example, if 50% are expected to survive, then two should be planted to compensate (Klein, 1994). According to Powell and Jollie (1993), no more than 25% of the pre-existing forest cover should be removed in the watershed (Schueler, 1994). An effort should also be made to create and maintain snags (piles of brush and dead vegetation) of various sizes and ages in out-of-play areas, unless they are a safety hazard, since they provide valuable food and shelter for wildlife.

Additional information concerning the use of native vegetation on golf courses can be found in the management section of this chapter. Chapter III will extend the benefits of native vegetation to an economic comparison of its use to turfgrass. The management section also describes the Audubon Cooperative Sanctuary Program and the positive impacts that it has had upon golf course developments and their implementation of ecological principles.

Because of the size of this topic and the availability of quality sources of information, further discussion of design principles related to biodiversity, connectivity, wildlife habitat, and ecological restoration will be limited. For more information on these topics, the reader is referred to works such as *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning* (Dramstad, Olson, and Forman, 1996), *Landscape Restoration Handbook* (Harker et. al, 1993), *Ecology of Greenways* (Smith and Hellmund, 1993), and *Prairies, Forests, and Wetlands* (Thompson, 1992).

**Soils and Topography**

No other factor influences the health of turfgrass and affects future maintenance concerns as much as proper soil preparation. In addition to the methods outlined for the site analysis of the proposed development such as avoiding steep slopes (greater than fifteen percent) and highly erodible soils, there are additional concerns that should be dealt with during the design of the golf course.
One of the first tasks is to identify and, if necessary, change soil that is inappropriate for turfgrass growth. Because of the perennial nature of turfgrass systems, it is wisest to amend the soil as needed prior to planting in order to avoid future problems. Cation exchange capacity (CEC) is an important indicator of soil fertility. If it is too low (as is the case with highly sandy soils), it may be beneficial to add organic matter to the soil, which would raise the CEC levels. Another important factor related to soil health is pH, which reveals whether the soil is acidic (pH less than seven) or alkaline (pH greater than seven). If soil tests reveal a pH level that is too high or too low (six to seven is optimal for nutrient availability for turfgrass plants) it may be necessary to add lime (CaCO$_3$) to the soil (to raise a low pH). If high levels of sodium are present in the soil, gypsum may be added in order to improve soil structure and infiltration capacity. Calcareous soils (containing high levels of lime) create problems for management that will need to be considered as well. These concerns are discussed in more detail in the management section of this paper.

Methods of analysis should be in place to ensure that the growing medium of the course has enough depth and porosity, and that the subsurface and surface drainage are sufficient (Poellot, 1992). An underdrain system should be installed for all fairways, greens, and tees located on coarse-textured soils (such as sand susceptible to leaching) or anywhere the depth to bedrock or the water table is less than four feet. Another alternative would be the use of clay soils (to eliminate infiltration) or low maintenance vegetation (to avoid chemical usage) in these areas (Klein, 1994).

John Roedall, head superintendent at Chesapeake Bay Golf Course in the village of Northeast, Maryland, has found that improving the soil is the most important step toward the elimination of most maintenance problems. He also states that minimizing contour changes during design and construction is wise because, “You never know what you'll find once you start digging, and microclimate changes can be created by changing the topography.” His course uses organic conditioners to improve poor native soils (a kelp-concentrate biostimulant and fish emulsion product), in addition to a 100% silicon wetting agent that helps irrigation water penetrate the soils. Both of these practices reduce the nitrogen requirement for turfgrass maintenance (Roedall, 1996).

For cases where an existing golf course is undergoing renovation, it is important to know the age of the course and the management practices that have been applied to it. If
the golf course existed prior to 1980, the greens, tees, and fairways should be analyzed for organochlorine and metallic pesticide residues. If residues are found, measures should be taken to minimize their movement into surface and groundwater. Some methods for doing this would be the collection and treatment of water percolating out of these root systems, or through an increase in the organic matter content of the soil (Klein, 1994).

Soils and topography will also affect the costs for construction and management of golf courses. In general, golf courses developed on sites with a slightly rolling topography and sandy loam soils will require less earthwork and soil modification during construction, and therefore will have lower construction costs. Future management of such sites will also be more efficient because there is more likely to be proper drainage for the turfgrass areas and there will tend to be less compaction and better nutrient availability for turfgrasses in these types of soils. Whenever possible, earthwork should be kept to a minimum in order to protect existing soils from potential erosion during construction and to keep construction costs down, thereby providing cost savings to golfers that will play the course in the future.

**Design and Construction of Greens**

The designs of golf course greens have undergone a great deal of change over the past 50 years. In the early 1900's, the slopes of greens usually ranged from 5-8%, which is quite steep compared to the slopes of 1-4% used on today's greens. This disparity can be attributed to changes in grass varieties used on greens, lower mowing heights with new mowers, and softer greens from higher amounts of irrigation required to grow grass at the low mowing heights. Another important factor is that modern golf clubs hit the ball higher and with more spin, so that the ball goes farther (eight to twelve yards longer than in 1960) and spins more than ever before (3). This makes it possible for players to land approach shots on the green and stop the quickly, even on the flatter putting surfaces.

One factor that has influenced this trend toward flatter and more closely mowed greens is the Stimpmeter. A golf ball is placed in a grooved hole on this device and one end is lifted until gravity causes the ball to roll down its length and across the green. The length of the ball roll is measured in feet, and this value can then be compared with other greens. A number less than five is considered slow. Average speeds are six through eight, and a number of ten or above is considered fast ("Golf impact report," 1996). Putting greens for
most PGA golf tournaments measure eleven or more. Originally, this device was helpful to golf course superintendents because it made it possible to check the greens on their course for consistency. Now, however, it has become a problem because golfers continue to desire higher Stimpmeter readings for their greens. Turfgrasses maintained at such low mowing heights require more frequent and higher amounts of water and chemical applications (they are less disease and drought resistant because they are less able to tolerate additional stress).

The evolution of the golf green continues as more research is conducted on root zone mixes and new varieties of turfgrasses are discovered and tested. Because sand has a very low cation exchange capacity (CEC, or the ability of a soil to accommodate positively charged ions), nutrients are less available for turfgrasses in this type of rooting medium. However, sand is required for high traffic areas such as tees and greens because it has excellent drainage characteristics and is able to withstand compaction where normal soils (with higher CECs) perform poorly. It has been found that mixing peat moss with sand in putting green construction reduces nitrogen leaching because of the higher CEC which these organic materials possess (Snow, 1996). This presents problems, however, since peat moss is a resource that is being used at a tremendous rate, and the peat bogs that are being destroyed for this purpose are not being replaced. Because of this, alternatives for peat moss need to be found for use as organic soil amendments.

The two most widely recognized methods of green construction using sand-based media are the USGA Method and the California Method. The USGA Method uses a four inch base layer of small gravel, overlain with two to four inches of course sand (optional), followed by twelve inches of laboratory-tested sand blended with a small amount of organic matter (USGA Green Section Staff, 1960). Water is conserved in the root zone by the creation of a perched water table (water held in sand root zone because of the particle size transition between layers), making it more available to the turfgrass. The California Method also has twelve inches of carefully selected sand, but removes the gravel layer in the interest of rapid drainage.

Prior to the use of sand-based media, greens were built with native soil which became known as “push-up” green construction. This type of green is still very common throughout the U.S., particularly where native soils have a higher sand content. Though this
method can still be effective and is much less expensive to implement than the other two types, these greens tend to develop problems with compaction and drainage under heavy traffic. Use of one of the other methods is usually better in the long run unless the soils on the site have a high sand content and can support the expected traffic.

Tim Hiers, head superintendent at Collier’s Reserve in Naples, Florida, recommends the USGA Green construction method because he says it is better for controlling the leaching of chemicals. Although this method may have a higher up-front cost than other methods, it saves money in the long term by reducing water demand, the frequency of chemical application, avoiding soil compaction, and increasing the health of the turfgrass (Goldsby, 1991). The USGA specifications are continually being tested in the interest of promoting turfgrass health and course playability while decreasing water and chemical usage. They are currently enlisting golf courses from different areas throughout the country to implement experimental practice greens which will make it possible to test different green construction methods under normal golf course maintenance and traffic conditions.

Golf course superintendents are leaders in experimentation with golf course maintenance strategies. John Roedall and his crew at Chesapeake Bay Golf Course used the USGA construction method with calcified diatomaceous earth (DE) soil amendment at ten percent by volume in the top six inches of the root zone mix. This DE balances the air content in the soil, helping to control fungal development. It promotes the development of strong, deep roots, and it lowers the bulk density and helps prevent compaction (Roedall, 1996). At Squaw Creek Resort in Olympic Valley, California, head superintendent Carl Rygg has been operating a no-spray program since 1988. In other words, no pesticides, fertilizers, or fungicides are used on the course, and only limited nitrogen usage is allowed because of the location of the course over a major groundwater source. Part of that program has involved the use of charcoal filters in the greens to keep nitrogen out of water table (Jewell, 1994). These and other strategies will be discussed in more detail in the management section of this paper.

One environmental concern regarding the USGA method is that the water collected from the sand and gravel layers below turf is not given an outlet in the USGA specifications. These specifications show a four inch drain for collecting the percolate but they don’t describe how this water should be treated beyond saying that, “...considerations should be
given to disposal of drainage waters away from play areas, and to the laws regulating drainage water disposal" (USGA, 1997). Treatment of drainage water is also a concern for other methods of green construction and for water collected from other areas of the course, whether they are fairway depressions or teeing areas. Tom Schueler recommends that the collected infiltration should drain to a depression area with an organic layer, sand layer, and stone layer that will filter it, as was shown in Figure 2. He also recommends that the green be constructed more than four feet above the water table or bedrock layers in order to avoid possible groundwater contamination (Schueler, 1994).

Much of the traffic damage and maintenance problems encountered on golf greens can be avoided by properly designing the green to accommodate the expected amount of traffic for the course. According to Muirhead and Rando (1994), greens should have an area of at least 6500 square feet on high traffic courses, with six or more pin placements that are at least fifteen feet from the edges of the green. Hurdzan (1996) recommends a minimum of fourteen pin placements on each green. An effort should also be made to avoid draining the green to the front, which would result in a soggy approach susceptible to damage from foot traffic. The use of alternate greens (one with cool season grasses, one with warm) can be an effective solution for limiting year around traffic on greens in southern climates (Muirhead and Rando, 1994).

In addition to these design strategies, efforts should be made to raise mowing heights and lower green speeds in the interest of increased turfgrass health and decreased water and chemical usage. This will mean the return of increased slopes to golf greens in order to maintain the same level of playability. Continued research may reveal better methods of green construction, better rootzone mixes, and better varieties of turfgrasses for use at low mowing heights. Based on a review of the literature, the USGA method of green construction seems to be the best available based on the research results related to water conservation and improved turfgrass health. For areas with higher amounts of precipitation, the California method may be a better solution because of its drainage characteristics, but the same principles of proper treatment of collected drainage water should be used no matter which construction method is chosen.
Considerations for the Golfer

It is important to pause here and consider for whom these principles are written. Minimizing the impacts of golf course design, construction, and management is important for the future health of our ecosystem. It is important for the preservation of precious resources such as air, water, soil, fossil fuels, and the biodiversity of developed land. And, ultimately, it is good for the game of golf. Ethical land use in golf course development will mean the preservation of vital open spaces for the enjoyment of golfers and non-golfers alike. As more and more people enjoy the game, it becomes increasingly important to understand how the development will impact the land and the natural systems on which it depends. It is also vital that changes made to golf course design, construction, and management take the needs of those who play the game into consideration. The following are some of the issues related to the golfer that must be dealt with in order to create the best balance of golfer needs and environmental considerations.

Scoring System

Some of the interest that has been generated about golf has been through its expanded television coverage over the years. Originally, golfers were much more concerned about playing one-on-one against an opponent. This type of play, known as match play, was much more conducive to conservation, since the use of natural areas meant difficult play for both competitors, and there was less pressure to score well for the round. Most professional tournaments, however, have scoring based on a comparison with par for the course. Par is the score that an expert player is expected to make on a given hole, and seventy-two strokes is usually par for eighteen holes. Because of this, stroke play is now the most common way golfers evaluate their performance on the course. Since golfers have become so concerned about their scores compared to par, this has caused courses to be maintained for speed of play and keeping balls in play rather than for conservation.

Point-to-Point Golf™ is another approach to producing a scoring system that will reward accuracy and finesse rather than distance (Muirhead and Rando, 1994). This type of target scoring system could make it possible for smaller land areas to be developed for
the game of golf and still provide the rewards for playing with higher levels of accuracy. This concept will be discussed further in the section on Innovations in Golf Course Design.

**Golfer Expectations**

One of the key points raised throughout the literature reviewed for this study has been the influence of the golfer upon the design and maintenance of the golf course. Perhaps no other single factor has more of an impact upon golf course development than the expectations of the golfer. Many golfers demand emerald green turf areas without signs of wear or disease throughout the course. They expect lightning quick and very smooth greens, fairways without a bad lie, and out-of-play areas where they can still find their ball and play it easily. They also desire longer golf ball flights and purchase clubs and balls that will optimize their distance for each shot.

These demands have had a profound effect upon golf course development over the past thirty years. Perhaps golfer expectations have been influenced by the popularity of golf on television. Many have come to expect superintendents at their courses to maintain the perfected conditions they have observed on the courses which professional players compete upon each week. They fail to realize that these perfected conditions can only be maintained through the use of increased amounts of irrigation water, pesticides, and fertilizer. This is particularly true for the lower mowing heights that are also being demanded, especially on greens. The shorter the mowing height, the more difficult it becomes for the turfgrass plant to live. Because they no longer have the leaf surface required to conduct normal photosynthesis, the plants must increase the shoot density below the mowing height and therefore uses up energy that would normally be used for root growth. The result is reduced drought and stress tolerance. More water and nutrients must be applied because there is inadequate root growth, and more chemical pesticides must be applied because the plants are no longer as resistant to diseases and pests.

The longer golf ball flights desired by golfers have produced an expanding length of contemporary golf courses that will be discussed in the following section on equipment regulation. By changing golfer expectations about equipment and maintenance standards, less water and chemicals would be required and the firmer conditions would produce more shotmaking skill in golfers because they would be required to think more about how to
approach each hole (Doak, 1992). Shorter courses with healthier turfgrasses could be developed for the benefit of the environment and the game of golf.

**Playability Concerns**

The National Golf Foundation estimates that at least one course needs to be built per day up to the year 2000 in order to keep up with golfer demand (Hannigan, 1989). If this estimate is accurate, there is a need for more playable and less expensive courses as a wider range in playing ability develops among golfers. However, choosing an acceptable level of playability is not an easy task when considerations for the environment are added to the equation.

As discussed previously, the expanded use of target course design would reduce construction and maintenance costs, lower water consumption, and be a return to the original concepts of golf courses. However, the inclusion of more native vegetation in the areas adjacent to the course will mean that more golf balls will be out-of-play compared to existing turfgrass uses. This may result in fewer golfers playing the game because of the difficulty, and there may be fewer courses in the long run because of increased economic pressure (increasing land and resource prices and decreased demand for golf).

Because of the increased difficulty, the extensive use of native vegetation may be best suited to semi-private and private courses, which tend to have better golfers and less traffic (Seaberg, 1992). A decrease in maintained turf may require the construction of additional forward tees for playability. Also, by allowing golfers a free drop (a provisional ball without penalty) when their ball enters these natural areas, slow play (from looking for lost balls) can be avoided and the native vegetation can be protected from foot traffic. Because golf courses need to be developed and maintained that use less water and chemicals and provide more opportunities for wildlife habitat, serious considerations need to be made with regard to playability impacts through the conversion of turfgrass areas to native vegetation.

Should all golf courses be playable by all levels of golfers? This would be an unrealistic goal, especially considering the mounting costs of maintaining the large areas of turfgrass required for this level of playability. Perhaps there are some courses that could be designed and maintained for the needs of the beginning golfer, such as short courses that
require less land area. Most courses, however, should be developed with the goal of integrating the game with the land through maximization of wildlife habitat and native vegetation. Golfers will then be required to demonstrate skill in playing the course with rougher out-of-play areas and narrower turf areas. They may need to spend more time developing their swings on practice tees, but this will be best in the long run both for the game of golf and for the environment.

Alternative grasses such as mixtures of fescues can also be effectively used to balance playability and environmental concerns. They form an excellent and lower maintenance turf when mowed short, but can also be allowed to grow out and form maintenance-free zones. Courses can then maintain flexible boundaries between the primary and secondary rough areas depending upon where golfers tend to hit the ball on any particular hole. An example of this is the Devil’s Paintbrush course in Caledon, Ontario, where fescues have been allowed to grow out or have been mowed short depending upon playability and maintenance considerations. As golfers have become more familiar with this course, superintendents have been able to allow more of these areas to grow out because golfers are no longer hitting into them (Wright, 1997).

Safety Concerns

Because of the size, composition, and speed of travel of the golf ball, it is capable of causing damage to property and injury to people while in flight. Courses therefore need to be designed with considerations for the safety of both people and property. This relates to environmental impacts in that longer golf ball travel translates into increasing amounts of land required for golf course developments. Fairways need to become wider and holes become longer through the continued improvements in golf ball and club technology, again demonstrating the need for limits in this area.

As in the previous discussion on land usage, core golf courses tend to have fewer safety concerns than single fairway development, since the holes are adjacent to each other and homes aren't being built within range of most of the holes. An increasing amount of litigation has occurred over the past ten years related to golf ball damage to homes on golf courses. This has mainly been a problem in residential developments where homes are being placed directly adjacent to fairways, often on both sides of each hole. “If people are
willing to live on a golf course, they should know the dangers and design their homes accordingly," says golf course architect Desmond Muirhead (1996). This can be done through the use of things like hooded windows, blank walls facing drives and approach shots, and lakes and tree groupings to protect the properties.

By limiting the flight of the golf ball, safety concerns and hole lengths can be decreased, thereby making it possible for golf courses to be developed on less land. This applies particularly to the amount of turfgrass required on the course, and the land not required can be planted with native vegetation for all of the benefits of its use. Equipment and rules changes will be discussed in more detail in the following section.

Innovations in Golf Course Design

"Golf course architects must resist the myopic vision of current golf courses and expand the envelope of accepted standards," according to Donald Knott (1994, p. 500), a golf course architect with Robert Trent Jones II International. Knott believes that there are some unhealthy parameters that exist concerning contemporary golf course development, including fairways with perfect lies, trees on all sides of holes, fairways always well defined, greens puttable and fair at high Stimpmeter readings, greens always visible from the fairway, fairness value of courses measured by stroke-minded pros, and the limit of always having a 7000 yard course length and nine or eighteen holes (Knott, 1994). He also questioned whether some environmental impacts might be reduced by not always smashing eighteen holes into a piece of land, and whether fewer (but better quality) holes result in better quality natural areas.

It is quite possible that water scarcity, increased restrictions on chemical usage, and land use regulations may dictate a scruffier, lay-of-the-land style for course design in the near future (Whitten, 1993). These restrictions may also require renovation of existing courses in order to decrease water and chemical usage and maximize the use of the land for the benefit of the environment. For this reason, and because of the positive impacts that golf courses can have for both golfers and for the environment, it would be wise to consider some additional alternatives to traditional golf course design.
Changes to the Rules of Golf

The USGA recently amended the Rules of Golf to protect recognized environmental areas. Golf balls entering them cannot be retrieved; the golfer is allowed a free drop without penalty for hitting into these areas which are designated by an appropriate authority (Fuller, 1996). According to Trey Holland, USGA Rules of Golf Committee Chairman, “It was necessary to find a way for players to be able to continue to play the game when an environmentally sensitive area affected their play. We want the Rules of Golf to reflect that golf courses and nature reserves can be blended together. And they can” (Ryan, 1996).

This rule change makes it possible for sensitive areas on golf courses to be designated as out-of-play, no traffic zones for golfers while maintaining speed of play by not penalizing shots that enter these areas. Identification of these out-of-play areas might involve simply posting signs in rough areas which read, “Environmentally sensitive area: do not retrieve balls,” although it may be more beneficial to describe the reasons for this area to be set aside. For example, if there is a community of sensitive wetland plants present, this may represent an excellent opportunity to have interpretive signage that describes the plant communities and types of animals that utilize that area. It may be necessary to enforce a penalty for entering into these areas. One course enforced this rule by ejecting those that entered sensitive areas from the course (Osmun, 1992), but it may only be necessary to warn golfers as their appreciation for these natural areas begins to grow.

Artificial Playing Surfaces

While golfing purists are appalled with the thought of artificial surfaces for playing golf, there has been extensive progress made in this area of research. Artificial turf has been used extensively on practice ranges for more than fifteen years, but rarely are they used on golf courses. The use of mats on golf course tees would eliminate the extensive maintenance they require, especially on par three holes where more divots are taken by iron shots (Fream, 1978). Some golf courses in the deserts of Saudi Arabia take the use of mats to an extreme by having golfers carry them for the entire round and play each shot from them. Poles mark the boundaries for fairways and hazards, and the greens are made by sprinkling oil over the sand (Helphand, 1992). The arid conditions of the course dictate
this type of solution, and players accept it because it is their only opportunity to play golf in that area.

Another opportunity for the future may be the use of synthetic materials on golf course greens. Since these areas of the course require the highest amounts of maintenance in terms of mowing, fertilization, irrigation, and chemical treatment, this may indeed represent some beneficial alternatives. “Tour True” synthetic putting greens are currently being built for use at a par three course in New Hampshire. This is the first time that they have been used in a northern climate, but these types of greens have been implemented successfully at the Callaway Test Site in Carlsbad, California, and at the homes of several professional golfers (Labbance, 1996).

According to Pete and Mark Johnson, owners of “Tour True”, these greens have some great advantages as an alternative for normal greens. For example, the permitting process for courses is shorter and the environmental impact of greens is much less. Synthetic greens are faster to install and establish than natural turfgrass greens. Though they are more expensive to install, synthetic greens can provide a huge savings in chemicals and maintenance expense. They also make it possible to open the course six weeks earlier in the spring and close later in the fall, since synthetic greens are always playable and don’t require the same amount of protection from the elements.

Though synthetic greens may never gain acceptance for widespread use, they may be an excellent alternative where environmental impacts (particularly from chemical leaching and runoff) are a concern. Other problem areas include those where there is inadequate soil or insufficient sunlight, drainage, and air circulation. The traffic tolerance on these synthetic greens has been reasonable thus far. A 3000 square foot green was installed at the Mission Hill Golf Center (the busiest practice facility in the San Francisco Bay area) where it has seen 200-500 golfers per day for the past four years, and it has held up very well (Labbance, 1996).

Construction procedures for synthetic golf greens start with basic site preparation and grading similar to normal natural green construction. Surface drainage is a very important consideration in this process. Ground-up rubber from recycled tires is then applied as a subsurface layer (absorbs shock), followed by another shock-absorbing layer (non-compactable natural and artificial aggregates). Open tufted synthetic turf is spread out
over the surface and tied down in place. Maintenance of synthetic greens simply involves applying a sand topdressing in order to give the green its speed, and daily brooming keeps the putting surface uniform. As more research is conducted in this area, we may see further developments of synthetic turf that more closely resembles natural turfgrass, which would be ideal for use in high traffic areas such as tees and greens that are the most difficult to maintain.

Changes in Golf Equipment

According to the Rules of Golf published by the USGA (1997, p. 117), the Overall Distance Standard states that golf balls, "...when tested on apparatus approved by the USGA...shall not cover an average distance in carry and roll exceeding 280 yards (256 m) plus a tolerance of six percent." This standard, however, does not account for the advances that have been made in clubhead and shaft technology, and many professional golfers are now able to drive the ball longer than 300 yards with a great deal of frequency. According to Desmond Muirhead (1996), "Consistently longer drives and approaches obtained by new equipment demands increasingly longer courses. Clearly, the equipment requires regulation standards much more than golf courses."

There is a need to throttle back the liveliness of the golf ball in order to decrease the length of golf courses and the land area which they require. There may be a danger from lawsuits by ball manufacturers and touring pros, but if the ball isn't standardized, then tournament courses will continue to get longer, and existing classic designs will no longer be appropriate (3). Increasing amounts of land will be required by golf developments to account for the added length and safety concerns from longer golf ball flights. By limiting the length of the golf ball flight, golf courses will no longer need to add new tees and redesign fairways and hazard locations in order to accommodate the golf ball. Classic designs will again be viable alternatives for golf tournaments as they were intended to be and will again be the challenge for contemporary golfers that they were for past players.

Consider what would happen if new technologies were applied to baseballs and baseball bats. The ball would continue to fly farther and travel faster, creating safety problems for players and fans and requiring continual enlargements of baseball stadiums to
accommodate play. Just as equipment standardization makes sense for the game of baseball, it also makes sense for the game of golf.

**Target Course Design**

Target (also referred to as “natural”) golf course design incorporates forced carries off the tee and between predetermined landing areas throughout the course in an effort to limit the amount of turfgrass area that will need to be maintained (see Figures 2.3 and 2.4). Although some of the most recognized designs of this type have been developed in arid regions because of irrigation restrictions (including many courses in the southwestern U.S.), this type of design is not a new concept. Many of the oldest golf courses in the world (particularly the links courses discussed previously) have forced carries and fairways bordered closely by native vegetation. This was how the game of golf developed, in a close relationship with its surroundings and with minimal disturbance of out-of-play areas.

According to golf course architect Ronald Fream (1982), the design of a golf course should concentrate on providing the finest possible teeing surfaces, green sites, and interconnecting fairways, but beyond that, should also make the best possible use of the natural environment. The use of target style golf course design would have many of the same benefits for non-arid regions as it has had on desert courses. Because of the smaller areas dedicated to maintained turf, the out-of-play areas on the course could be protected during the development of the site. This would be especially beneficial for those developments taking place on previously undisturbed sites. Existing natural areas could be preserved and the golf course would have less of an impact upon the land. Also, because of the enlarged areas devoted to native vegetation, more habitat and travel corridors would be provided for wildlife, enhancing the suitability of the site for more diverse species types. This has value for both previously undeveloped sites and for courses built on highly modified landscapes.

Target course design makes it possible to build shorter courses which will rely more on accuracy and finesse than on distance (Wyllie, 1983). This type of development would reduce construction and maintenance costs since courses would be shorter and only the greens, tees, and fairways would be need to be developed and maintained. Lower water consumption, because of the decreased amount of maintained turf, reduces water use and
Figure 2.3: Plan view of a typical golf hole

Figure 2.4: Concept plan for the same hole with target course design principles
lowers water costs by requiring less water and smaller pumps and irrigation lines. Maintenance is thereby reduced up to 35% and water use by 30-50% (Borland, 1988). This will not only reduce irrigation costs, it will also decrease public concerns related to golf course water use and environmental impacts. Decreased amounts of fertilizers and pesticides will mean additional maintenance cost savings and reduced environment impacts. The native plantings will form natural buffers to nutrient and chemical movement away from the turf areas and will provide storage of excess rainfall, reducing flood flows on site and downstream. The benefits of this type of minimal golf course design are many, and the expansion of this concept would represent a return to the original concepts of golf courses and their relationships with the land (Graves, 1982).

Another issue related to this concept is actually a management practice currently used on many courses. Target area mowing, also called contour mowing, creates strategic landing areas on each golf hole and encourages better shot making from the player. It results in multiple fairway landing areas, offering progressively smaller target areas and requiring greater accuracy further from the tee (Silva, 1982). The use of contour mowing adds challenge to the game, increases the opportunities for the use of native vegetation in the roughs, and is more aesthetically appealing than straight fairway edges. The establishment of native vegetation on existing golf courses through the use of this target concept would be an excellent way for golf courses to provide habitat for wildlife and decrease maintenance costs.

A model for expected maintenance cost savings through the use of native vegetation versus turfgrass is outlined in Chapter III. Information related to the benefits of native vegetation and steps in establishment can be found in the management section of this chapter. Also, because of the severity of hazards and natural areas on target style golf courses, they can be frustrating and difficult for the average player to play (Hannigan, 1989). The issue of playability is addressed in more detail in the section related to considerations for the golfer.

**Point-to-Point Golf™**

This concept was created by Desmond Muirhead and Guy Rando (1994) in response to the problems caused by the drive for distance in golf course design: longer
courses mean more land area is converted during development, courses are more expensive to build and maintain, there is less safety because of the longer golf ball flights, and the old and classic designs are becoming outdated. The idea of Point-to-Point Golf™ is to land each consecutive shot within a point zone identified on the course, as close to a designated “hot point” as possible. The closer the ball is to that point, the more points that are awarded for the shot. Scoring is cumulative throughout the course, and the highest score wins.

This playing concept was designed to reward finesse and accuracy rather than distance. It can be played from existing tees and greens and therefore requires very little investment from golf courses. It produces challenging play on both short and long courses alike, is a challenge for all skill levels, and the course can be played with or without the system once it is in place. Because this playing system rewards accuracy rather than distance, it may be an excellent method for use with a target style golf course. It may also create a great deal more interest in shorter courses without par fives and decrease the amount of land required for golf developments.

Wastewater Use for Irrigation

Effluent water (treated wastewater) has been used for irrigation purposes for about thirty years in some areas of the country. It has been implemented successfully on many golf courses in the U.S. (Frye, 1994; Salvesen, 1996; Poellot, 1992) and may provide promise for future golf course irrigation and water treatment needs in this country. Effluent irrigation works especially well in arid regions such as the southwestern U.S., where more than twenty percent of the public golf courses use effluent as the primary source of irrigation water (Bishop, 1990). Because it is possible to grow turf throughout the year, waste continues to be utilized and there are no long periods of dormancy.

There are many advantages to the use of effluent for irrigation. Wastewater is available at a constant rate, and turfgrass plants require many of the nutrients already present in the effluent (nitrogen, phosphorus, potassium, and others), so additional fertilizer inputs can be reduced (Hayes et al., 1990). The cost of effluent water is significantly less than potable municipal water supplies (in some cases, the water itself may be free).
Turfgrass has the ability to use large quantities of organic waste that many other plants cannot withstand, and can therefore utilize effluent water that might otherwise be wasted.

One of the primary advantages to the use of effluent is that it creates another use for that land area devoted to golf course development. The course becomes not only a recreational area, it also preserves a community open space, provides habitat for wildlife, and acts as a wastewater treatment plant. For example, sewer pipes can collect waste from buildings into a lagoon near the course, where air is pumped up from the bottom in order to aerate the sewage. The resulting settling then creates sludge on the bottom which can be collected once every twenty years and composted for other uses. The water stays in the lagoon for about 36 days, then is pumped to another reservoir to go through sand filtration. After being treated with chlorine to kill bacteria, the treated water can then be used for irrigation of the golf course. The turfgrass and soil combine to act as a living filter for the reused wastewater, actually exceeding the benefits of traditional sewage treatment (Muirhead and Rando, 1994).

There are also disadvantages to the use of effluent that must be considered. For instance, there are usually restrictions on where and when wastewater can be applied, and requirements for monitoring of potable and wastewater for problems is costly. Effluent water often contains materials that can cause problems in turfgrass maintenance. Some of the water quality concerns related to turfgrass irrigation include suspended solids, pH levels, total soluble salts, leaching requirements, sodium absorption ratio, biological or chemical oxygen demand, toxic materials, and total or fecal coliforms. Because of the lack of purity of effluent water, there are also problems related to corrosion and plugging of the irrigation system, accumulation of suspended solids in storage ponds, chlorine toxicity to plants, and the interaction of many of these factors together (Peacock, 1994). Effluent irrigation may cause a reduction in the emergence of turfgrass seedlings during establishment. The turf may also experience heat stress due to excess nitrogen in the effluent or chloride toxicity, which is the most common problem encountered (Mancino, 1994).

A comparison of the costs and benefits of using effluent is an important step in determining the feasibility of its use for golf course irrigation. Some of the costs include the use of additional soil amendments to mitigate problematic salt and sodium levels, higher costs for the use of fresh water leaching systems for greens, higher water quality
management costs (as listed above), and poorer turf quality means the requirement of more fertilizer, herbicides, fungicides (Gill and Rainville, 1994). In spite of these costs, the use of effluent can be up to ten times less expensive than normal irrigation practices. One reason for this is that the cost of pumping effluent water is four to five times less (Peacock, 1994).

In some cases, golf courses have obtained additional funding from public or federal agencies for development with wastewater irrigation capabilities. For example, Meadow Lakes Golf Course in Prinville, Oregon received $5 million from the Environmental Protection Agency for the construction of their irrigation system, ten storage ponds, and a sewage treatment system. Because of this development, the annual city discharge of wastewater was reduced by 130 million gallons, a third of its normal output (Salvesen, 1996). This type of financial incentive may contribute to a growth in the use of wastewater effluent throughout the country.

A vital question concerning effluent water usage is whether those that generate the waste (industrial users, commercial users, and homeowners) or the recycled water users (in this case, the golf course) should pay for wastewater treatment (Rodie, 1994). Some courses have been given free access to irrigation water in exchange for acting as a wastewater treatment area for the municipality. An excellent example of this type of multiple use can be seen at Gainey Ranch in Scottsdale, Arizona. This golf course is designed around an effluent recycling system; the city pipes waste to the course for treatment at a tertiary treatment plant, where the effluent is stored in a pond and used for irrigation. The development saves $150,000-200,000 per year in water costs, and supplies the city with free wastewater treatment. Interconnected drainage systems recycle the water back to lakes for use in irrigation (Poellot, 1992). Ideally, people would see the benefit of the creation of this type of multiple use for that land area and be willing to subsidize the costs of this type of water treatment.

There are also maintenance concerns associated with effluent water usage. Superintendents will need to take into account the nutrients in the water so that they are not over-applied. Baseline levels for water monitoring are necessary for future testing of contamination and management effects to water quality (Smart et al., 1993). In particular, water high in salinates, sodium, boron, and chlorine should be avoided, or they should be mixed with higher quality water to dilute the effects of these impurities (Mancino, 1994).
Irrigation with effluent may also require higher rates of leaching to control salinity levels, more frequent applications of water amendments (gypsum and sulfur), more frequent soil aerification, adjustment of fertilizer application based on effluent levels, and higher seeding rates to make up for reduced seed emergence (Smart et al., 1993).

Hayes et al. (1990) tested the impacts of effluent irrigation upon Bermuda and Perennial Rye grasses for a 64 week test period. They found that effluent irrigation had lower seed emergence but improved seed establishment, and that it also showed signs of overfertilization, greater heat stress, and chlorosis (especially the Perennial Rye). They were able to produce a high quality turf, but higher soluble salt and nutrient contents require special consideration with wastewater use. It was recommended that, because of the lower emergence of Bermuda from the increased salinity and ammonium content in the water, potable water should be used during germination, or else higher seeding rates should be used if good sources of water are not available (Hayes et al., 1990).

From a turfgrass management perspective, the use of effluent water for irrigation is not desirable if there is an abundance of high quality surface or groundwater nearby (Peacock, 1994). However, because of the importance of maintaining water quality and creating opportunities for multiple uses for the land, it would be wise for communities to consider the use of wastewater irrigation for golf courses. This is particularly true in those regions that have very few times of freezing temperatures throughout the year, thereby making continual operation of the wastewater facility a possibility. Wastewater Reuse for Golf Course Irrigation (1994) is an excellent source of information related to this topic.

**Development on Marginal Lands**

As mentioned previously, golf course developments can improve the quality of degraded sites such as landfills, industrial waste dumps, abandoned sand and gravel mines, rock quarries, coal mines, and flood plains (Duthie, 1996). The funds generated by golf (from green fees on the course and from the increased value of the land after its conversion) make it economically feasible to convert these abandoned lands when nothing else will work (Osmun, 1992). This is probably one of the main arguments for the benefits of the use of golf courses as quality land uses.
Landfills offer one of the best opportunities for multiple use of abandoned lands. Golf courses can be built on these areas without significant problems because few structures are required that will need support. This makes it possible to provide storage for solid wastes (a growing problem in this country and in other areas throughout the world) and provide a community recreation open space rather than an eye sore. Another alternative to building on the landfill could be to use the golf course as a greenbelt around the landfill to buffer adjacent land uses (Muirhead and Rando, 1994).

One of the problems associated with the construction of golf courses on landfills is the development of gases (especially methane) which come up and are toxic to plants, smell bad, and create problems because they are combustible. Another area of concern is that uneven settling of the constituents of the landfill can cause surface drainage problems. Use of heavy equipment on the surface should be limited because of compaction and settling concerns, and special haul roads must be made to allow access of equipment to the site. The poor structural integrity also limits the locations on which golf course buildings can be built, usually requiring their location on areas exterior to the landfill.

Since the clay cap must be kept intact in order to eliminate downward migration of water, it then becomes necessary to use fill on top of this cap to shape golf course features. Enough room must be made that will allow for an appropriate gas barrier and space for irrigation and drainage lines. It is best to develop the design of the golf course and the landfill together, so that the fill locations and the shape of the clay cap can blend into the desired final contours of the course. The best landfill conditions for this type of development include those with low fill heights (20-35 feet) and those that have been closed less than 20 years (Muirhead and Rando, 1994).

There are many examples of the successful use of abandoned lands for golf course development. Harborside International Golf Course is a 425 acre landfill course in South Chicago, Illinois. In this design, Nugent Associates Design of Long Grove, Illinois utilized biosolids as a topsoil and growing medium over a cap of clay soil (although the greens and tees were planted with sand because of their special maintenance needs). The use of biosolids for topsoil may represent opportunities for golf courses to provide treatment of waste products, even those not constructed on landfills, and particularly for those that may have other types of soil problems. These biosolids, however, contain high levels of salts,
and poor drainage has been a problem at Harborside that will need to be addressed. Runoff from the course drains to seven inlets that retain water and feed it to a wastewater facility for treatment. Willow Hill, another Nugent design in Winnetka, Illinois, was also built over a landfill, and this course has a system for the collection of methane gas that makes it possible for it to be converted to electricity (Thompson, 1996). This again demonstrates the opportunities that exist for golf course developments with multiple uses of the land.

Widow's Walk, a Michael Hurdzan design set to open in 1997 in Scituate, Massachusetts, was built on a sand and gravel quarry and dump site. Hurdzan said of the project, "Local officials wanted to improve property but insisted that the development be self supportive, create value for the town, and provide public recreational value...only a golf course can do that" (Whitten, 1996). The course will also use recycled asphalt cartpaths, pulverized coconut for organic material (instead of peat moss), and drought tolerant fescue grasses (the turf in the fairways and rough will be allowed to turn brown in drought conditions). The course anticipates a cut in water, fertilizer, pesticide, and fossil fuel use of 50%. Irrigation water will be pumped from non-potable wells for use on the course and recycled via a tiling system.

Widow's Walk represents a different approach to golf course construction in that it has been developed with the goal of gathering scientific data related to the environmental impacts of golf courses. Experiments will be conducted with the greens at Widow's Walk in order to determine which construction method and drainage system will work best. Six of the greens will be constructed according to USGA specifications, six will use the California (pure sand) method, and six will be built with existing soil. Three types of subsurface drainage will be used for each type of green construction. Computer sensors in these drainage systems will measure and record percolate data like soil temperature, moisture, and fertility, and the greens will be built with drainage chambers from which samples can be removed and tested (Duthie, 1996).

Golf courses are even being built on EPA Superfund sites. Community leaders, the EPA, ARCO (Atlantic Richfield Company), and course designer Jack Nicklaus have partnered to produce Old Works Golf Course in Anaconda, Montana. Industrial waste (high in copper and zinc) left over from years of copper smelting on the site were capped with two inches of limestone, a twelve to fifteen inch layer of clay, and four to six inches of mixed
topsoil. Underground pipes collect and recycle excess water to prevent leaching from the site and make this water available for the irrigation needs of the course (Duthie, 1996). The EPA supervision increased the cost of the course to an estimated $11 million and the cleanup to about $30 million. Still, ARCO saved millions. Company officials estimate removing the waste could have cost as much as $65 million (Hanley, 1997). The course was turned over to the community when it opened and are able to reap the benefits of a high-end public golf course, such as increased tourism, land that creates revenue and jobs, and increased property values throughout the area. This again demonstrates the value that golf courses can have in the reclamation of damaged lands.

Much of the land relegated to golf course development occurs after a developer has selected the optimum ground for housing. This means that many courses have been built in floodplain areas. Examples such as The Village Links of Glen Ellyn (Illinois) have demonstrated that properly designed golf courses are able to utilize floodplain lands with minimal effects from flooding, even from some of the most severe events ever recorded. This is accomplished through the use of interconnected irrigation and retention ponds, contours that conduct floodwaters through areas resistant to damage, and elevation of higher maintenance areas such as tees and greens far above flood stages (Dodson, 1996). This type of development shows promise as we reconsider how floodplains have been developed in the past and look for new solutions for avoiding flood damage.

Golf Course Construction Principles

Introduction

Information gathered during the site analysis phase can be used by the golf course architect to develop plans for the construction of the golf course and surrounding property. Plans prepared by the architect usually include a golf course master plan, staking and clearing plans, grading and drainage plans, green detail plans, irrigation plans, turfgrass planting plans, and a landscape planting plan (Beard, 1982). Additional visits to the site and meetings with community officials and the client will help the architect in this process by continuing to provide information relevant to the project. If residential development will accompany the golf course, it will usually be done in conjunction with different phases of the
construction process for the course and will influence many of the final layout decisions, utility connections, and other factors in the development.

As mentioned previously, it is vital to the success of any development project to include a multidisciplinary team during the design of the course. As construction of the course begins, the course architect, construction contractor, the owner, and the superintendent take on the most important roles. By taking part in the design and construction process, the superintendent will be able to understand how the course has been built and will know how to best care for the course once it is completed. When minor modifications need to be done to the course in the future, they can then be done in a manner that is efficient and in keeping with the original concept of the intended design.

Construction methods used for golf course development can have both short and long term effects upon the success of the golf course. These methods have a great impact upon whether the course will be built on time and on budget, which are important considerations for the economic success of the development as well as making play more affordable for golfers. They will also greatly influence the environmental impact of the development, as will be discussed in the following paragraphs. Each of the steps encountered in the construction process are described, and then the discussion is expanded as to the opportunities some of these practices will provide for protecting and enhancing the developed lands.

The Construction Process

The process of the construction of a golf course involves a great deal of expense and complexity. Though there are some variations on how and when some of these tasks are accomplished, there is a general progression that occurs in construction that is followed by contractors in order to operate in an efficient manner. The following is a brief outline of the construction process as outlined by some of the contemporaries in the golf course construction field (Hurdzan, 1996; Muirhead and Rando, 1994; Beard, 1982).

Pre-construction Meeting

Conducted on site, this meeting includes the golf course architect, construction contractor, subcontractors, the client, representatives of any utility with existing or planned
installations, course superintendents, and other personnel involved in the planning of the
course such as engineers, other architects, and land planners. This meeting establishes
lines of communication between parties, schedules and deadlines for work, construction
sequences, site data that may have changed, and any other areas of concern that may exist
prior to construction (Hurdzan, 1996). It is at this meeting that the importance of
environmental stewardship can be established for all the parties involved, and the
development can take place with the optimization of environmental benefits in mind.

Erosion Control and Environmental Protection

This is done throughout the construction process and involves the use of methods
that will identify areas of concern on the site, such as erosion-prone soils and sensitive
vegetation and will provide means of protection for these areas. This is discussed in greater
detail below because of its importance in minimizing the environmental impact of golf course
construction.

Staking and Clearing

The architect and contractor identify the locations of key golf course elements such
as tees, greens, fairways, and water features by using stakes and flagging. Preliminary
staking usually involves a stake for the back tee, for the center of the landing zone(s) or
dogleg(s), and in the center of the green (Hurdzan, 1996). Once the centerlines of the golf
holes are identified with stakes according to the plans, these centerlines are then cleared for
twenty five feet on both sides so that final verification of the golf course routing can be
completed. Care must be taken during this process that sensitive environmental elements
are not damaged. Qualified professionals should be on site during staking and clearing to
identify (tag) endangered and sensitive flora. By physically delineating (fencing off) these
sensitive areas, contractors will be able to avoid compaction or destruction of elements that
can be incorporated into the golf course landscape. It may also be possible to transplant
sensitive or endangered species from these areas until construction of the course has been
completed (Muirhead and Rando, 1994). Selective clearing can take place once the routing
of the course is finalized and all sensitive areas have been identified. The most important
aspect of this process is the protection of sensitive vegetation and the disturbance of as little of the land as possible for construction of the course.

Disposal of Cleared Debris

An effort is usually made to salvage many of the stones and timber removed during clearing for use on the course or for sale to lumber companies. The remaining roots, stumps, vegetation, rubbish, and other debris are then pushed into burning piles or pits, hauled away (very expensive), buried in pre-selected out-of-play areas, or shoved up into large piles for wildlife habitat (Hurdzan, 1996). Care must be taken that the debris is not buried under structures or course elements where it may become a problem for stability, irrigation and utility lines, or other earthwork and long term maintenance operations. The topsoil is usually removed and stockpiled during the early stages of the project in order to protect it and make it available for re-application after rough grading is completed.

Drainage

After clearing and disposal have been completed, the major drainage structures that will be necessary on the course are installed. This will include catch basins, culverts, ditches, dry wells, and subsurface drain lines. An effort should be made to use as few of these structures as possible, and instead rely upon natural drainage systems for the handling of water on the developed site. The extent to which this can be accomplished depends greatly upon adjacent land uses, since high amounts of runoff occur from more heavily developed sites and will need to be accounted for in the design of the course. Ideally, stream reaches, springs, wetlands, and natural lakes can be avoided during construction in order to protect water resources and provide wildlife corridors and minimal disturbance to natural water systems. The utilization of drainage trenches with native vegetation rather than piping underground will produce much better results in terms of on-site storage and filtering of surface waters.

Earthwork

After the topsoil has been stockpiled for later use, some of the larger scale earthwork will take place. Some of the major elements that require the largest amount of
earthwork are water impoundments and structures, drainage ways, and large cuts and fills. The contractor uses the construction plans to establish the site and extent of cuts and fills, using grade stakes to identify existing and proposed elevations in these areas. Rough grading involves working the subgrade of the course to within approximately six to twelve inches of the final desired elevations, and is followed by feature shaping, which will begin to establish many of the design features for the course. Greens and tees will begin to take shape in this process, but they require different construction procedures than do the other areas on the course. Topsoil is then added once the subgrade is worked and graded to conform to the required grades on the project plans. Final shaping should produce a minimum depth of six inches of topsoil over fairways, mounds, and the slopes around tees and greens, and four inches over rough areas (although six inches is more desirable). Additional modifications to the topsoil may be needed such as pH adjustment, preplant fertilization, or the addition of other soil amendments that will prepare the soil for the establishment of turfgrass. Drainage is one of the most important considerations in the shaping of the course to the final elevations, since there needs to be a minimum of two to three percent of pitch to allow water to surface drain across turfgrass (Hurdzan, 1996). Since there are limitations to the amount of detail that can be achieved with construction plans, it is vital that the course be built in such a way that poor drainage and ongoing maintenance problems can be avoided.

Construction of Greens, Tees, and Bunkers

The construction of greens and some of the environmental implications of them were discussed in the design section of this paper. Tees also have special considerations in that they are high traffic areas that usually require the use of a sand or soil mixture that will accommodate compaction and higher maintenance needs. Tees are usually surface drained at a three-quarter to one percent slope. The turfgrass will be able to filter and use the chemicals that exist in the water in an efficient manner. Bunkers usually have little environmental impact related to drainage water collected from within them, since it is filtered by the sand and contains none of the chemicals applied to turfgrass areas. It is important that the final grades of these elements be established before the installation of irrigation begins so that major changes will not need to be made and the irrigation system can be
protected from damage. Sand is usually added to the bunkers during the landscaping phase of the process.

**Irrigation Installation**

Systems that will provide for the long-term water management needs on the course are added as the earthwork process is drawing to a close. This usually involves the installation of a pump house, pumps, pipes, and programming systems. Selection and implementation of these systems has a huge impact upon the maintenance and environmental impacts of the golf course. Irrigation efficiency and timing are key factors in the design, and often an irrigation specialist is employed by the golf course architect in order to lay out the design of the irrigation system. Water conservation practices such as the use of recycled irrigation water from retention ponds and irrigation with effluent water are valuable methods that were discussed in the design section of this paper. Soil moisture sensors, weather stations, computer application systems, and low-volume, low-pressure heads will also become more valuable as the costs of irrigation of courses continues to rise. These and other topics will be discussed in greater detail in the management section of this paper.

**Seedbed Preparation and Planting**

This is usually accomplished by plowing the area intended for turfgrass planting to allow growth without competition from weeds. Corrective applications of fertilizer, lime, and other soil amendments can then be applied as needed, based on soil test results from each area. These amendments are spread onto the finished grade of the soil and lightly tilled into the top two to three inches of topsoil to aid the establishment of turfgrass. The architect then performs an inspection of the site to ensure low spots have been filled, the soil is not overly compacted and has the proper moisture content, the irrigation system is in working order (it will be necessary during the establishment of the turfgrass), and proper erosion control procedures have been established. Green and tee complexes are usually established first, then fairways, then rough areas. The turfgrass can be seeded, sprigged, or sodded, with sod being the most expensive but also the most efficient method of establishment. The planted seedbed is lightly rolled to establish plant and soil contact, and
then mulch is added to moderate soil temperatures and retain moisture. The irrigation system is then used to assure proper moisture levels for the germinating plants (Hurdzan, 1996). From an environmental standpoint, the keys to this process are protection of soil from erosion, avoidance of areas not intended for development, and proper soil preparation that will maximize the efficiency of future turfgrass needs for water and chemical applications.

**General Construction and Final Inspection**

As the construction process draws to a close, many other tasks may need to be performed before the course is opened for play. Construction of cartpaths, bridges, shelters, rest rooms, and water fountains are often elements that will need to be included, depending upon the individual needs of each course. As the golf course superintendent manages the grow-in stage of the turfgrass, they will also take part in any final landscaping needs on the course such as trees and shrubs around the clubhouse or planting beds on the course. Final inspection will include all aspects of the development. It will pay particular attention to the course itself, establishing its readiness for golfer traffic based on the health of the turfgrass and proper functioning of other golf course elements. The course is then declared open for play, and ready to function as a source of enjoyment and recreation for golfers and as a healthy part of the surrounding landscape.

**Minimizing Site Disturbance**

The construction of the golf course lasts only a short time compared to the long-term maintenance of the facility once it is completed. However, much of what occurs during construction has ongoing impacts upon the wildlife, vegetation, water quality, and future maintenance concerns of the course.

**Water Quality Concerns**

Water quality is one of the most important factors to consider during the construction of the course. As stated previously, respect should be given to unique wetlands and other sensitive areas, avoiding their disturbance and incorporating them into the design of the course. This can be done by providing and maintaining a vegetative buffer zone of at least
50 feet next to all water courses, as discussed in the design section of this paper. Manipulation of streams and other water courses should be avoided, and operation of heavy construction equipment should be limited near these surface water areas. It is also important to monitor groundwater quality before, during, and after construction of the course, which will make it possible to compare these results and determine whether any changes occur in water quality.

Construction Scheduling

One of the primary considerations in scheduling for construction is efficiency. It is important that the various activities be coordinated and timed properly in order to avoid the possibility of one task damaging the finished work of another, which makes it possible for the project to proceed on time and on budget. In addition to these economic considerations, construction scheduling plays a key role in limiting the impacts of golf course construction upon the environment. For example, during the development of Belfair (Hilton Head, South Carolina), construction times were coordinated around site nesting seasons, and home site construction was designed to allow birds time to acclimate to new (post-construction) surroundings (Duthie, 1996). Doug Carrick, a golf course architect that has done extensive work with natural areas in Canada, recommends scheduling work adjacent to rivers after September and before June to protect spawning fish (Carrick, 1994). These are good examples of the type of thinking that will make a great difference in the amount of impact that the construction process will have upon wildlife.

Construction scheduling should also protect soils by minimizing the exposed area and the amount of time the ground is left without cover. This means planning for the completion of final grading to coincide with the best time for turfgrass establishment. It also means paying attention to the weather and avoiding the exposure of soils to potentially heavy rainfall events. A good rule of thumb is that disturbed areas should be made non-erosive and stable within thirty working days after completion of work in that area (Bruneau et al., 1996). Additional soil concerns are addressed in the following section.
Erosion and Sediment Control

Soil erosion is one of the most important concerns related to the impacts of construction upon the environment. Once the golf course has been established and the turfgrasses and other vegetation have matured, very little if any soil erosion will take place from a golf course. It is during the construction phase, however, where extensive erosion control measures must be in place to prevent sediment from leaving the site through surface runoff.

There are many methods by which erosion and sediment control can be accomplished, but the best one is disturbance of as little of the site as possible. No other erosion control method will work as well or provide the same number of benefits for the developed site in terms of wildlife habitat and water quality preservation. This is particularly the case for golf courses developed on previously undisturbed sites. For highly disturbed sites, however, it may be beneficial to replant an area that is dominated by weedy volunteer vegetation. Either way, exposure of these soils should be limited to the minimum necessary amount of time.

Disturbance of steeply sloped terrain (especially those exceeding fifteen percent) should be avoided if possible due to the difficulty of machinery operation and erosion control in these areas. For any areas that will be disturbed during construction, dikes, diversions, and waterways should be established before clearing and grading takes place. This will divert runoff waters from disturbed areas and greatly decrease the threat of erosion (Bruneau et al., 1996). Silt fencing should be erected in all work areas adjacent to river and stream corridors, especially in adjoining drainage swales (Carrick, 1994). Vegetative buffers should be preserved around sensitive areas, particularly surface water bodies on the site. Vegetation can be selected that will rapidly re-vegetate exposed soils and hold them in place (Muirhead and Rando, 1994).

Exposed soils can also be protected during construction through hydroseeding, sodding, or using mulch (“Environmentally responsible,” 1993). Hydroseeding is a method of applying seed in a mixture with water for the establishment of turfgrass or other types of seed on a prepared soil. This can be an effective method for applying seed to slopes where equipment may cause erosion and accessibility is a problem. Whether for seeding from a drop spreader or from hydroseeding, the application of a straw mulch with asphalt or
similar-type binder is an effective way to prevent soil erosion and provide moisture for germinating turfgrass seed, particularly on sloping sites. According to Beard (1982), "Jute net and excelsior mat mulching or sodding are quite effective in waterway erosion control where high-velocity water flow is probable during rainstorms." The use of sod rather than establishing areas with seed adds greatly to the expense of the construction, but the benefits that the quickly establish sod will have in terms of soil protection often outweigh these costs. This is particularly true in situations where construction is taking place on sloping lands or on highly erodible soils.

Rebuilding and Modifying Existing Courses

In addition to the high rates of golf course development discussed in Chapter I, there has been a substantial growth in the number of courses that have been rebuilt or modified over the past twenty years. According to the National Golf Foundation, there were 174 course expansions that opened in 1996, and an additional 272 were under construction. About 80 percent of these expansions were nine-hole additions to an existing course, a trend that has been consistent for the past five years ("U.S. golf," 1997).

There are various reasons to rebuild or expand existing facilities, including the following identified by Beard (1982):

1. Lengthen the Course--this could be due to equipment modifications that allow longer ball flights, a desire to increase playing difficulty, or to add a second nine holes to an existing nine-hole course

2. Improve Strategy--usually through reshaping or rebuilding greens, bunkers, and tees or changing the hazards on the course

3. Improve Flexibility--by adding tees for different handicap levels and allowing more versatility of play for the course

4. Improve Speed of Play--this may involve removing blind shots and unnecessary hazards

5. Improve Safety--reduction of the number of blind shots, planting of screening vegetation, and providing proper spacing between holes

6. Correction of Design and Construction Flaws--includes surface and subsurface drainage and compaction problems and blind or unfair hazards
7. **Minimize Traffic Effects**—reducing compaction and wear by providing larger greens and tees and altering the placement of elements that create concentrated traffic patterns.

In addition to these concerns, there are also environmental considerations that may cause renovation of existing golf courses such as:

8. **Endangered Flora and Fauna**—the course may have opportunities to provide habitat areas for sensitive species, or may need to be reconfigured in order to protect their habitat

9. **Water Quality**—it may be necessary to provide more vegetative buffer plantings near surface water areas or to avoid maintenance practices on areas that are sensitive to groundwater impacts from pesticides and fertilizer applications such as in karst (fractured limestone) topography or on shallow water table areas where infiltration is a concern

10. **Water Conservation and Reduced Maintenance Expense**—construction of larger tees and greens that can handle more traffic, installation of a more efficient irrigation system, promotion of functionality and accessibility of maintenance equipment, improving seedbed preparation, and conversion of unnecessary turfgrass areas to native vegetation.

Any of these alternatives may be necessary for existing courses as they continue to age, particularly those that were built more than twenty years ago. The methods used by the architect and builder have a tremendous influence on the durability and continued functionality of the course. Courses designed and built with features that cause traffic concentrations in tight areas, safety concerns, or improper construction methods that cause recurring maintenance problems will require attention that much more quickly than those that are properly designed and built. Maintenance costs for courses are heavily affected by construction practices such as seedbed preparation, size and layout of greens, tees, and hazards, and the amount of turfgrass area that needs to be maintained.

The same can be said for the environmental considerations of the developed course. Those that are designed and built with a vision for the needs of providing habitat for wildlife, function as multiple users of the land (landfills, wastewater irrigation, flood storage, etc.), and minimize water and chemical usage will be far more likely to have continued success as
the rising costs of water and chemical usage drive up the costs of building courses and playing the game.

**Golf Course Management Principles**

**Introduction**

Once the golf course has been designed and built, management becomes the key issue in the relationship of the golf course with the environment. Golf course superintendents are given the primary responsibility for the care of the course, which includes a very broad range of activities. In managing the turfgrasses on the course, the superintendent accounts for applications of irrigation water, fertilizer, and pesticides as well as cultural practices such as mowing, aerification, thatch removal, and assessment of turfgrass conditions. The superintendent is often involved in water quality monitoring and the care of other native vegetation and wildlife on site. Most of the smaller scale renovations that are frequently made to golf courses (tee and green reconstructions, bunker modifications, additional plantings of trees and shrubs, etc.) are supervised by superintendents. They also bear the responsibility for the day-to-day appearance of the course and therefore are often under pressure to maintain "tournament conditions" on their courses.

Because of the importance of their role in the operation and management of the golf course, superintendents need to be involved in the construction of new courses before they are completed. They need to know the intent of the design, the construction materials that were used, and the techniques necessary for best management of the course (Poellot, 1992). Superintendents also need to stay abreast of current research related to golf course management and understand their role in minimizing the environmental impacts of golf courses.

**Current Research on Turfgrass Establishment and Management**

A substantial body of recently published research on turfgrass has greatly expanded the understanding of the effects of establishment and management practices on turfgrass health and water quality. Collectively, they point to three major factors which must be well understood if risk of water contamination is to be avoided: specific site and soil conditions,