**Summary of Athletic Field Options:
A Decision-Making Guide for Native-Grass,
Modified and Engineered, and Synthetic Turf Fields**

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I. Executive Summary

Playing field surfaces have become a controversial topic, sparking regulations from local governments and protests from upset constituents. This controversy has created a difficult decision for universities, recreation centers, and other municipalities in regard to what playing surface type should be installed for field renovations and developments. As many stakeholders, ranging from athletic teams to homeowners, are impacted by field constructions and renovations, it is important to consider all possible field options that will best serve the community. This project investigates the advantages and disadvantages of artificial turf, modified-engineered soils, and native grass fields from multiple perspectives, using Duvall Field as a case study.

The goals of the project are to provide a guide and succinct discussion of field types to aid stakeholders in their decision making process of determining which field surface type would best suit their needs. The specific objectives of the project are to: 1) provide the City of College Park with a literature review on field surface options that encompasses the history of natural and turf fields, player safety, and the environmental concerns with each field type, 2) develop a matrix that summarizes the relative strengths and drawbacks for each field type for each of the topics that are reviewed in objective 1) and 3) create a brochure that informs the public of the advantages and drawbacks inherent in the selection of a specific field type.

The research on the development, environmental concerns, player risks, and costs associated with each field option are supported by peer-reviewed literature from databases (Google Scholar, Web of Science, Academic Search Complete), typical field maintenance regimen, industry professional and trade-specific publications, budget analyses of current field owners, and interviews with field experts.

Synthesis of the research on the examined topics indicate that even though native grassed fields may be financially appealing as they hold the lowest construction and maintenance costs, they still bear major disadvantages. Native grassed fields typically suffer from poor drainage, leading to less field use and resorting to major drainage installations to compensate. In contrast, artificial turf fields have made major improvements since they were first introduced in the 1960’s that are conducive for player safety, player performance, and maximum field use. These major improvements, such as cushioning, softer grass blades, and an efficient drainage system, come with high construction and maintenance costs as well as their own unique set of athletic injuries that only stem from playing on artificial turf fields. Modified/engineered fields are also a viable option as they serve as a compromise between the two previous field options, with moderate construction and maintenance costs. This field option appeases institutions who are deterred from artificial fields and their associated toxicology concerns, while still optimizing field use with drainage systems and modifications. Based on the findings, it is suggested for institutions to use this comparison and review of the field options to guide their decision-making process and determine which field type best suits their intended field use, priorities, and budgets.

II. Introduction

Increased demands being placed on recreational fields has resulted in many natural grass fields being replaced with artificial turf fields. Artificial turf is thought to provide the durability and strength to maintain integrity that allows for more games played per day and more hours of gameplay. With this, there have been two main schools of thought arising: those who prefer natural grass fields and those who prefer artificial fields. Those who prefer natural grass tend to be parents (Barton Straus, 2019). Parents worry about the heat hazard, possible chemical hazards, and injury risk. Those who prefer artificial turf tend to be school districts and sports organizations. For them, the reduced maintenance and durability of the artificial turf make it worth the installation (Putterman, 2017). The issue at hand is to determine whether natural grass, natural grass with modified soil, or artificial turf would be the best option for a sports field. The options for artificial turf are constantly changing so it is necessary to have an updated review of all options available, both natural and artificial, for a field renovation. The decision must be based on the sports played on the field, the age of those using the field, the climate patterns of the location of the field, and how often the field is in use (Putterman, 2017). The sports being played on the field will determine the wear and tear that the field will undergo and determine the durability that the playing surface must provide. The climate pattern of where the field is will factor into the concern about heat and if the field can be used during rainy weather. The age of those playing on the field determines the need for durability a well just as how often the field is in use will. The research done for this paper addresses the previously mentioned concerns about both artificial turf and natural grass with and without modifications. The research done also analyzes the most cost-effective decision, exploring not only pricing but the overall safety and environmental cost of each choice. Pricing, safety, and environmental effects are valid concerns for various stakeholders including municipalities, school districts, and parents. The final results are relevant to Duvall Field in College Park, and can ultimately be applied to any play field surface for any recreational sports field in the greater Maryland area.

III. Goals and Objectives

The goal of this report is to provide necessary background information on three play field types to serve as a resource in the decision-making process for field installation and renovation. Attainment of the goal was reliant on achieving three specific objectives. These were to 1) complete a literature review on field surface options encompassing the history of natural and turf fields, player safety, environmental concerns associated with each field type; 2) to conduct or perform a cost comparison and impact scores for the three field types assessing the benefits and drawbacks of each; and 3) to develop a concise, graphic summary in brochure form that can be directed toward the general public.

IV. Methodology and Research Approach

Literature Review: A review of literature pertaining to the history of play field construction, player safety, and environmental concerns associated with three field types was conducted utilizing search engines such as Google Scholar, Web of Science, Academic Search Complete, and other databases. Key terms are identified and defined in the Glossary of Terms for clarity and concision. Additional information from general media and/or industry-specific publications was examined as relevant. The City of College Park Duvall Field renovation project website and the existing conceptual design and recommendations provided to the City of College Park by their previous consultant were also considered. An interview with Mr. P.J Ellis, Assistant Athletic Director at the University of Maryland and head of maintenance of athletic fields, provided more information about management and maintenance of similar fields in proximity to Duvall Field.

Cost Comparisons: Information from field owners, managers, and sport fields manuals support the costs listed in the report. This information included an interview conducted with the head of maintenance for athletic fields at the University of Maryland. This interview provided information of the ins and outs of natural and synthetic fields located in the same geographical area as Duvall field. Information from the Montgomery County Parks Service, and regional institutions also provided information on managing sports fields in the area. The maintenance costs of the different field types vary based on usage, location, and many other factors. The data produced for the replacement cost of each field type is based on a ten-year lifecycle (that being the average year that artificial fields must be replaced.) Aside from installation and maintenance, recycling, and disposal costs are also considered in the report. The potential revenue generated from the use of each field type is also considered in the findings. The various dollar amounts presented in the cost comparison were adjusted to best reflect the needs of Duvall field. The installation costs were adjusted to reflect the standard football field size of 57,600 square feet. The maintenance costs were adjusted to reflect the estimated 770 hours of use for Duvall Field per year.

Score Matrix: A score matrix supports the research and findings related to each play field type. This matrix allows for a visualization of the findings in the report. Native grass, modified, and synthetic surface fields are all evaluated. The categories within the matrix include: risk of player injury, contaminant exposure to players, soil properties and drainage, chemical treatments, wildlife impacts, disposal methods, land disturbance, weather adaptability, installation and maintenance costs, and durability and longevity. This allows for a quick comparison of the three field types in comparison to one another.

Each field type was ranked from 1 to 3 for each category, where 1 represents the best score, while 3 is the worst. An additional 10-point matrix was added at the request of the client and City Council. Each of the categories above was given a score from 1 to 10, with 1 being the worst and 10 being the best were given for each category. Each team member provided a score based on research and knowledge of each category. Scores were compiled and the average value for each category is presented (see Appendix ii).

Brochure: The brochure is a concise summary of the findings, including images and graphics from key findings, cost comparison and score matrix. It was designed snapshot of the overall field type selection process, to be used as a quick reference guide for the general public and anyone unfamiliar with play field surfaces for recreational sports fields.

V. Glossary of Terms

Artificial or Synthetic Turf - a manufactured material, similar to carpet, that is used to simulate grass; this is used in conjunction with engineered sub-surfaces in the design of artificial or synthetic fields.

Crumb Rubber – a granular product made from recycled, shredded tires, with steel and tire cord material removed; often used as infill in synthetic turf fields.

Crown Design – a field design in which the center of the field is slightly elevated or domed to facilitate rain and run-off to flow away from the play area.

Modified & Engineered Soil Field – natural grass fields that have had their sub-surface altered or constructed, usually to facilitate rapid drainage, appropriate elevation grade, and soil type and composition; there are many degrees by which a field may be modified and/or engineered.

Native Soil Fields – natural grass fields that have not had their sub-surface built or altered from their natural or original state. Duvall Field is currently a native soil field.

Natural Grass Fields – fields that feature real, living grass as a play surface; this term includes native soil, modified and engineered solid designs.

Polycyclic Aromatic Hydrocarbons (PAHs) - naturally occurring chemicals found in rubber that are released when heated.

Shoe-Surface Interface: a catchall term that describes the interactions between the athlete's cleat and the playing surface.

Synthetic Infill – crushed or ground particulate material, often crumb rubber, used between blades of artificial grass in artificial or synthetic turf fields.

Volatile and Semi-volatile Organic Compounds (VOCs, SVOCs) – carbon-based chemicals that are released into the air at room temperature from various manufactured products

VI. Findings/Results

A. History and Evolution of Natural Grass, Modified & Engineered, and Synthetic Fields

Natural Grass Sports and Recreational Fields

For centuries, natural grass has served as the playing surface for numerous outdoor sporting activities. The documented history of turf grass as the playing surface for sports goes back to at least the 13th century with historical reporting of lawn bowling in the 1200s (Squires, 2009).

Around 1880, the investigation of grasses exhibiting quick recovery from damage due to sports traffic began in the USA. By 1930, the USDA had delineated several grass species that would perform best in the different climate zones of the USA. In the warmer areas of the country, such as the deep south, Bermuda grass (*Cynodon dactylon*) was found to perform best as a sports turf. In cooler regions of the county, such as upper Midwest and New England, Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*) were found to be well suited for use on sports fields. Kentucky bluegrass forms a dense turf and can recuperate from wear damage. Perennial grass has excellent wear tolerance, but does not recuperate in the same manner Kentucky bluegrass, resulting in the need to constantly reseed this species in high trafficked areas. Many northern recreational fields are planted with a mixture of Kentucky bluegrass and perennial ryegrass. The mixture helps make the turf less susceptible to damage from pests, and more able to persist when subjected to environmental or mechanical stresses.

Healthy plant growth is dependent on proper soil conditions. The ideal soil for growing turf grass has relatively good drainage and a ready supply of nutrients that will support plant growth. Sports field soils undergo compaction when subjected to constant play. Compaction is detrimental to turf grass growth because drainage and gas exchange (namely oxygen) between atmosphere and turf root system are both severely reduced. Additionally, compaction stunts the growth of roots, which results in reduced water and nutrient uptake by the turf. Compacted surface soil conditions can be alleviated for short periods of time (usually a few weeks) by cultivating the soil with hollow tines that remove plugs of soil, which are either removed, or broken up and returned to the soil. This practice, which is called aeration, needs to be done numerous times over the course of the year on high trafficked sports fields to maintain soil conditions that will support turf grass growth. The practice of aeration became prevalent on sports fields after the development of the first commercial aeration machine, the West Point Aerifier, in 1945 (Harper, 1991). In the decades following, aerating equipment has evolved and improved to help maintain a healthy turf efficiently.

Figure 1: soil cores are being removed from a core aerator to alleviate compaction (Gordon, 2019)

Good drainage is critical to the playability of natural grass fields. Natural grass fields are unusable when pools of water sit on top of them after it rains. This is a common occurrence when the field is sited directly on the native soil that exists at the site. A crowned field will promote runoff of water from the field, lessening the ponding of surface water. However, drainage of water that has entered the soil is dependent on the texture of the soil and presence or absence of tile drains beneath the root zone of the turf.

Based on the percentages of clay and silt in soil layers, some fields may have low water movement due to smaller pore sizes (Cheng, 2014). For the case of Duvall Field, its natural soils are heavily compacted from consistent foot traffic from the sport games held. Compacted soils constrict soil pores, reducing water percolation and increasing risks of flooding (Weil, 2016). Furthermore, its soils have a ~30% clay content and hydraulic conductivity value of 8 mm per hour, indicating geologic restrictions of water flow (Web Soil Survey, 2019). Brenda Alexander, the Assistant Director of Public Works for the City of College Park, corroborates this by reporting a fragipan boundary in the field, a brittle soil layer notoriously known for restricting water flow and root penetration (Weil, 2016). Additionally, the field's poor drainage capacity is also evident from the constructed drainage grates that are in place to compensate for the soil's inability to facilitate water flow.

Drainage in native fields can be enhanced through multiple mechanisms and approaches. French drains are an inexpensive and easy approach to help saturation prone soils. After surveying the geology of the field, trenches are dug typically 5-6 inches wide and 8-12 inches deep along the perimeter of the field to receive the flowing water from its slopes (Liskey, 2019). If the field is not sloped to this approach's advantage, grading is a necessary method to create subtle slopes in the field that will then allow water to effortlessly move into the trenches (Liskey, 2019). The trenches are filled with gravel and topped off with sand to allow the water to permeate deeper into the soil. To make the trenches inconspicuous, turf can be seeded that will grow on top of the ditches.

Another popular approach is topdressing. Topdressing is the application of a thin uniform layer of sand or finely milled organic materials over natural grass (Cornell University, 2019). Repeated long-term topdressing with sand alters soil physical properties by allowing water to infiltrate. Though typically routinely practiced 1-2 times a year, frequent applications over years will modify the soil profile to improve soil physical characteristics and eventually create a sand cap field in the long run (Cornell University, 2019).

A sand cap field can be constructed over time with topdressing, or it can be deliberately constructed (Sprecher, 2014). A sand cap field is created when 2-6 inches of topsoil is removed and replaced with sand (Sprecher, 2014). This is a less intrusive method than a modified and engineered soil field, as it only requires a small excavation of a few inches of soil rather than a completely re-engineering the soil profile (Sprecher, 2014).

Modified and Engineered Sports Fields

The terms *modified soil* and *engineered soil* are sometimes used interchangeably, but in the context of sports fields, the two terms are respectively used when referring to the renovation of an existing native soil natural grass field, and to the creation and placement of one or more precisely specified soil textures into an artificially created soil profile. Modified soils are natural soils that have been amended, while engineered soils are those associated with construction of an athletic field soil profile.

Modified soils are mixed with another material along with the natural soil, that material being sand. Usually, the mixture must be at least 80% of the other material in order to create the most significant impact on the overall outcome of the playing field quality (Landschoot, 2019). A big issue with natural grass fields is soil compaction, which makes it hard for water to drain and thus creates pools of water on the surface of the field, essentially making it unusable until the water drains. Adding material such as sand to the soil mixture improves internal drainage and significantly decreases soil compaction. Different particle sizes for sand are used for different purposes depending on the use and wear of the field and the type of activity the field is intended for. One of the most important things to consider is the size and shape of the sand particle, as different sizes come with their own benefits and drawbacks. In addition to sand, other materials include pea gravel or coarse sand, and organic material such as well-composted organic matter or fibrous sphagnum peat moss can be added into the mixture of sand and soil to maximize the benefits of a modified field (Kowalewski, 2015).

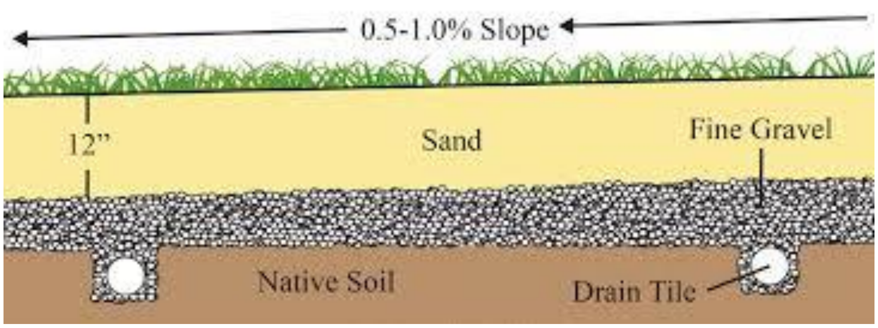

Figure 2: Drainage design of an engineered athletic field (Kowalewski, 2015)

In order to install a field with modified soils, crowning may be necessary, as well as drainage lines and an irrigation system in order to optimize playing conditions (Landschoot, 2019). Drainage lines are only necessary if the subsoil is impermeable, and the irrigation systems are necessary in order to keep fields from getting too dry. Getting a uniform mixture is also important in the design of the field; in terms of construction, most soil is mixed with sand off site and then transported to the location where it will be used, meaning that native soil will be removed and replaced by the mixture (Kowalewski, 2015).

By the late 1940s and 1950s, sports fields were seeing increasingly intense traffic. Combined with the high clay content soils that were being used in sports fields at that time, public demand for higher quality sports fields rose as problems such as soil compaction and limited turf grass growth emerged (Schmidt, 1990). Thus, the high sand content root zones evolved. Sand-based playing fields became popular because natural grass fields were not sustainable in allowing for high-use playing because of the compaction and drainage issues. With sand-based playing fields, players could keep using fields during and after rain events, as they provide efficient draining and improved filtration; this allows for higher use of the playing field.

Coarser textured soils provided drainage of excess water as well as provide aeration for the root systems, promoting healthy turf grass growth. This type of engineered sports fields were first pioneered in 1960 in the United States, developed by the U.S. Golf Association (USGA) Green Section Method of root zone construction, which has seen many revisions since the first publication (Schmidt, 1990). Various modifications to the USGA Green Section Method have been proposed, and construction plans include The Prescription Athletic Turf (PAT) System, the Sportsturf All Weather Field, the H-Play System, and the Cambridge System (Kowalewski, 2015). With the exception of the Cambridge System, all of the following methods are alternative ways to construct a sports field that does not involve amending the native soil (engineered as opposed to modified).

- USGA Green Section Method: recommendations for specifications on top-mix soil; particle size distribution, infiltration rate, porosity, bulk density, and a pea gravel layer below the sand root zone
- The PAT system: a sand root zone with a plastic liner and suction pumps- removes excess surface moisture and prevents the vertical movement of water out of the system
- Sportsturf All Weather Field: almost identical to the PAT system- both emphasize flat playing surfaces free of the crowns used in other fields
- H-Play system: drainage tubes, an automatic irrigation system, as well as a fertilizer injection system are installed
- The Cambridge System: a system of renovating and improving drainage on existing fields (founded in Europe)

Problems in the past with modified soils included figuring out how to solve the problem of poor drainage as well as the lack of aeration. Now, modified fields look to solving issues of severe divoting (in the case of a sports field primarily used for golf; divoting is when a piece or chunk of turf gets cut out from the ground and leaves a hole) and turf grass wear of above ground shoots due to intense traffic, although this is a problem found more at the professional level as opposed to the recreational level.

Synthetic Turf Fields

Synthetic Turf was first introduced in 1966 as AstroTurf and was installed in the Astrodome. The stadium was originally built on top of an old baseball field with a transparent roof to provide sunshine. The glinting of the sun was affecting games so the owner of the stadium decided to paint over the roof. This prevented the natural grass from getting enough sunlight to grow properly. This forced the owner of the AstroDome to resort to using an artificial playing surface. The first field to use what later became known as AstroTurf was Moses Brown School in Rhode Island in 1964. The artificial field concept turned out to be a huge success and has spread throughout the world. By the start of the early 1970s, AstroTurf became so popular that it helped spark the desire to build indoor sports stadiums. To keep up with the demand the nylon fibers of the original AstroTurf were replaced by polypropylene. The new material was cheaper and posed less of a threat for injury.

The artificial field surfaces in use back then are now referred to as first generation synthetic turf. First generation turf began as a tightly curled nylon fiber that was woven into a foam backing. It had loosely packed tufts and was also quite abrasive. The field was essentially a grass carpet over concrete. Due to this, the artificial fields became known for being unforgiving and led to more joint injuries than grass fields. To list a few of the issues: Athletes and doctors blamed the fields for friction burns, balls bounced harder and rolled faster, the turf wore at the seams and fell apart, and surface temperatures got very hot due to lack of transpiration cooling at the surface of the field.

In response to these issues, the manufacturers of synthetic turf released a second generation of turf. It had longer tufts and sand was placed between fibers for an increase in firmness. A shock-absorbing pad was installed underneath the turf to ease player impact. The carpet pile was filled with silica sand to within several millimeters of the top of the fibers, allowing them to stand upright. Thus provided a flatter playing surface and gave the players an increase in ball control. Even though strides were made, the field still could not compete with natural grass. It was very suitable for sports such as field hockey, but not football nor baseball. If a player fell, there would be painful abrasions caused by the sand. In order to improve player safety several professional fields went back to natural grass during the 1990s. The problems with natural turf fields (difficult maintenance, need for abundant sunlight, risk of deterioration in adverse weather conditions), however, remained. While second-generation playing surfaces were not widely adopted within the United States, they did pave the way for the modern, third-generation systems now commonly used.

The third generation underwent the most modifications. The grass “blades” are longer and are spaced far apart in the backing – this allows cleats to sink well into the surface (much like they do with natural grass) which results in less stress on the players’ joints and lets the foot easily get under the ball. The fibers are no longer made of polypropylene but of polyethylene, which is much softer and kinder to the skin, so that sliding tackles are not a problem. The turf systems feature mixtures of sand and rubber granules – when spread between the grass blades, this infill provides stability for the players, gives better ball control, and creates cushioning for the athletes which helps prevent injuries. These recent improvements have increased the popularity of synthetic fields. Unlike natural grass fields, it offers a surface that is easy to maintain, and does not require sunlight, and has a drainage system.

Third generation fields have evolved to different forms, such as slit filament and monofilament, and are marketed for different uses, therefore the selection of the correct filament type is essential for efficient maintenance. Slit filament is necessary for high use fields, and monofilament for lower trafficked fields —so choosing accordingly for the anticipated field traffic will keep maintenance requirements at a minimum, while being the most cost efficient.

Despite its preferred aesthetic value, monofilaments may incur higher maintenance costs if improperly chosen for a high-use field. Because monofilaments are designed to stand straight up, a large portion of infill is exposed. With most exposure, infill is more likely to be loss from field use, requiring frequent replenishment and redistribution of infill (McKenzie, 2017). On the other hand, silt filaments are more conducive to higher use fields. As the filaments are further worn down from play, they from a cross-hatch design that encapsulate the infill, preventing infill loss (McKenzie, 2017). Additionally, these fibers are created to endure and sustain significant activity, whereas monofilaments would split faster and flatten under high field use (McKenzie, 2017).

The most notable feature of third generation artificial fields is that it is designed purposefully to drain water quickly, circumventing rainstorm effects that would typically inhibit field use for natural grass fields. To accomplish this, turf fields are first constructed with a perforated carpet to allow vertical infiltration of rainwater (Cheng, 2014). Underlain the carpet, are layers of geotextiles, permeable fabrics, and coarse aggregates, that allow excess water to quickly flow away from the surface (Cheng, 2014). Coarse aggregates like sand and gravel are utilized for their large pores that can facilitate water flow (Jastifer, 2019). To satisfy artificial field requirements, the stones must have a minimum permeability of 14 inches per hour (Strohman, 2018). Additionally, a perforated pipe is installed below the multi-layered system, collecting and transporting the drained water to collectors installed around the perimeter of the field (Cheng, 2014). The water in the collectors can then either discharge into storm drains or be treated and reused for irrigation or cooling the turf field down for hot summers (Risse, 2010). Collectively, this closed-system design optimizes field use by limiting chances of flooding.

Figure 3: Drainage design of a typical third generation artificial turf field (Donaghy, 2019)

B. Player Safety

Injury Risk

Player safety is a priority, since recreational fields are used primarily for organized sporting activities. Injury risks from artificial turf and natural grass surfaces have been extensively researched. In the 1970s, when AstroTurf was widely used, it was found that players on this surface encountered a higher rate of lower body injuries than players on natural grass. As improvements to artificial turf have been made, the types of injuries occurring on artificial surfaces have changed. On Generation 3 turf, it was found that out of 2253 injuries occurring in both high school athletes and athletes of a professional caliber, 46% happened on the artificial turf and 54% happened on the natural grass surface (Taylor 2012). As described previously, the most recent development of turf was designed to reduce injury risk to players.

Despite advancements in artificial turf, one type of injury that is pervasive on artificial turf surfaces is "turf toe". Turf toe is when the joint of the big toe hyperflexes. Since players' cleats often get caught on the "blades" of the turf, the risk factor of this injury is higher than on natural grass. The main cause of this injury are inappropriate shoe-surface interface interactions in which the player's shoe is getting hooked on the turf, or the turf is not providing enough give or shock absorption when a player's foot comes in contact with its surface. Natural grass does not have the tensile strength to get caught in shoes. Ankle injuries are the most common injury that occur to athletes and the inappropriate shoe-surface interference is often to blame. Artificial turf does not always allow for a cleat to completely lift from its surface. This causes a build-up in torque not allowing for the rotation needed for a player to move. In a comparison between European soccer players on turf and Swedish soccer players on natural grass (Taylor 2012) failed to find a relationship between injury occurrence and the playing surface, but did find that ankle sprain injuries happen more often on the turf surface.

Artificial turf is sometimes considered to be a harder surface than natural grass. Most modern natural grass fields do have a shock absorption element. The soil/sand layer of natural grass fields provides cushioning. Aside from player-player contact, in high school athletes, falling onto a hard surface is one of the major reasons that players get concussions (Jastifer, 2018). Because artificial turf has the ability to allow players to reach a higher peak acceleration, a head will hit it with higher force and less shock absorption as it decelerates. A study comparing natural grass to third generation crumb-rubber infill turf found that players were more likely to lose consciousness after falling on artificial turf (Jastifer, 2019). Though the construction of artificial turf surfaces has evolved with player safety in mind, this playing surface continues to have a higher risk for certain types of injuries than natural grass.

Direct Material Contact

The temperature, texture, and chemical composition of the surface materials all have important impacts on player safety. The temperatures of artificial turf can be up to 50 degrees Celsius (122 degrees Fahrenheit) higher than natural grass (Buskirk, 1971). The temperature of natural grass tends to match that of the ambient temperature. This means that on an 80-degree Fahrenheit day, the natural grass will be around 80 degrees whereas an artificial turf field would be around 168-degrees Fahrenheit. The minimum temperature to burn skin is 104.9 degrees Fahrenheit. The Synthetic Turf Council has stated for the safety of players, they do not suggest playing on an 160-degree turf surface. TCool antimicrobial turf cooling infill©, is a recent synthetic turf infill that was created to address this issue. The company that created TCool© states that it keeps an artificial surface down by 50-degrees Fahrenheit (Global Syn-Turf, 2019). However, due to it being so recent, there is no other data from outside of the company to determine that this turf infill is efficient in staying cool.

Blade texture imparts friction. Natural grass poses the risk of grass rash, which occurs from direct skin contact with the grass (contact dermatitis) or when the skin quickly rubs against the grass. Grass tends to have microscopic serrations that cause micro-cuts on the skin. The rash can also occur from an allergy to grass, one of the most common allergies in the U.S. This allergic reaction can also be caused by the fertilizers used on natural grass (Cornell University, 2019). Sulfur based fertilizer can irritate the skin and mucous membranes, like the inner nostrils and eyes. Artificial turf poses a lesser risk of contact dermatitis since the blades are smooth and there are no fertilizers used. However, artificial turf does pose a risk for turf burn. Turf burn is a friction-caused abrasion of the skin. Compared to each other, artificial turf has a lower coefficient of friction, so an athlete will slide further generating a larger burn (Basler, 2004). It is important to note that it was found in non-professional football players, there was no difference in the occurrence or severity of friction-caused injuries when comparing artificial turf to a natural grass surface (Fuller, 2007). Friction-caused abrasions have been thought to be one route of MRSA (Methicillin-resistant *Staphylococcus aureus*) or Staph infections in football players. In lab settings, Staph bacteria can survive on artificial turf in an indoor setting for up to a week (Waninger, 2011). In outdoor settings, ultra violet (UV) rays from sunlight kill bacteria present on the surface of the turf within two hours of inoculation (Penn State Extension, 2016).

Contaminant Exposure

A concern in selecting artificial turf is exposure to carcinogens. Players inhale polycyclic aromatic hydrocarbons (PAHs) and other metals while playing on artificial fields (Mechini, 2011), but in negligible amounts (less than .01 mg/m^3). In addition, heavy metal exposure from crumb rubber infill has been reported to present no greater risk to cancer than playing on a natural grass field (Peterson, 2018; Pavilonis, 2013). In youth sports, players in California had a higher incidence of lymphoma in areas with more artificial turf fields (Bleyer, 2018). This data is incorrectly cited by anti-artificial turf advocates to imply that artificial turf causes cancer in youth players (Ropiek, 2018). The actual correlation between the two factors is that in areas of higher socioeconomic status, there is a higher occurrence of lymphoma cases. Areas of higher socioeconomic status are able to install more artificial turf fields in their areas thus the link between artificial turf and cancer in places like California. On natural grass, it is suspected that fertilizers could pose a cancer risk. Nitrogen fertilizer is legal in use for turf grass management (USDA, 2013). Nitrates, compounds formed from nitrogen, do cause cancer in individuals (NIH, 2019). With this in mind, there are no known links between the incidence of cancer and occurrence of playing on turf grass in youth athletes (Bramlet 2016). As for air quality, artificial fields have been shown to have elevated levels of volatile organic contaminants and other suspected carcinogens in indoor settings (Cheng, 2014). For outdoor settings, research has proven that artificial fields did not produce hazardous constituents above background levels and were not at levels to cause adverse health effects to breathing zones of communities around the field (Vetrano, 2009). Additionally, a common confounding variable in the research is that none of the research can determine that turf fields are the definitive source of some of the air constituents (Ginsberg, 2010). The most recent research suggests outdoor artificial fields do not produce enough hazardous air constituents to pose as a health risk for communities.

Laboratory Studies on Field Components

The National Toxicology Program (NTP) is an interagency program housed within the National Institute of Environmental Health Sciences (NIEHS), which is part of the National Institutes of Health under the umbrella of the US Department of Health and Human Services. NTP began a large research project in 2015 to understand potential health risks associated with synthetic turf with the objective to investigate exposure conditions that could have biological effects. This project was initiated by request of the California Office of Environmental Health Hazard Assessment (OEHHA) to broaden the scope of research of potential human health effects associated with the use of recycled waste tires, also known as crumb rubber, in playground and other synthetic turf products. The NTP was engaged to assist with the objectives of hazard identification, exposure scenario development, sampling and analysis of new and in-field synthetic turf, and bio-monitoring study protocol development. Research that was part of this initiative included in vivo (live animal) and in vitro (human cell line) studies designed to characterize systemic exposure and bio-accessibility of synthetic turf constituents. The results of the NTP studies published in July 2019 are available through the National Center of Biotechnology Information and the National Library of Medicine in a series of Research Reports. It is important to emphasize that the primary objective of the NTP reports is to provide empirical data and identify causal relationships between synthetic play field components and biological response. The findings of our report are synthesized here, bridging the report research objectives of Player Safety and Environmental Concerns.

Constituents identified in crumb rubber included zinc, aluminum, cobalt, and other metals and metalloids totaling ~2.9% by weight; volatile organic compounds (VOCs) and inorganics totaling ~8% by weight; and 33 other compounds totaling ~0.0007% by weight. Approximately 200 other compounds previously reported in crumb rubber samples were investigated but were not detected. Data from these analyses demonstrate that VOCs, semi-volatile organic compounds (SVOCs), and metals constitute a very small fraction of the crumb rubber and chemical profiles are fairly similar between different particle size fractions. VOCs and SVOCs are most relevant to inhalation exposure. However "dust" of a breathable particle size could reach the moist surface of the respiratory tract if inhaled.

In Vitro Studies: The aim of the in vitro studies was to determine the cytotoxicity to cultured human skin-derived keratinocytes (skin cells), peripheral lung cells, and intestinal cells and hepatic (liver) cells exposed to crumb rubber extractions as proxies for potential routes of toxicity from dermal, inhalation, and ingestion exposure. Cytotoxicity was observed in skin, lung and intestinal cells at 60°C (140°F) and 37°C (98.6º F, average body temperature) and ambient temperatures. The higher temperature is not physiologically viable temperature, has been reported on synthetic turf play fields. Liver cells did not show cytotoxicity.

In Vivo Studies: The aim of the in vivo studies was to determine if systemic exposure is evident after exposure to crumb rubber in experimental animals. Fourteen-day studies were conducted with female mice by oral gavage, dosed feed, or by housing on crumb rubber mixed bedding. Hematology, bone marrow cytology, urinalysis, and histopathology were used to assess systemic exposure and biological effects. Analysis of urine and plasma showed no significant difference in chemical profiles between experimental and control groups for any route of exposure. Minor hematological changes were observed in experimental groups, but none of these changes was considered biologically relevant. No effects were observed on survival, food consumption, body weight, or organ weights following crumb rubber exposure by any route tested. No histo-pathological lesions were observed.

In summary, the four NTP studies collectively demonstrate that cultured cells that are directly exposed to crumb rubber extracts experience toxic effects, and that live animals that are exposed to crumb rubber in their bedding and food experienced no effects. Sensitivity to toxic effects in cultured human cell lines may be influenced by their origin (fetal or adult) and may not be relevant to actual exposure in the field. This work is intended as a contribution to what is known about potential human exposure and biological effects resulting from contact with constituents of synthetic turf.

C. Environmental Concerns

Native Soil Fields

Environmental concerns, like water use, runoff, and pollution attenuation, for natural fields are case by case. Depending on their climate, native fields may require large quantities of water for irrigation in order to maintain a healthy field of grass (Government of Australia, 2019). Another important factor is soil permeability and porosity as they determine runoff rates and transportation of contaminants (Weil, 2016). If a soil has a porous texture, run off will be limited, but leaching of pollutants from fertilizers and pesticides may be a concern.

Currently, Duvall Field is a minimally maintained native soil field that does not include either of the previously stated drainage enhancement mechanisms. Since there is an impermeable layer, there will be greater runoff rates that mobilize contaminants and nutrients into streams, degrading its water quality. However, as it is a minimally maintained field limited to receiving fertilizer amounts in compliance with Maryland's turf grass fertilizer law, runoff of pollutants from field is not an ongoing concern. Pollutant loading origination from this field is.

Engineered & Modified Soils

As an alternative to using natural grass, though not submitting to the use of artificial turf, modified or engineered soil turf grass becomes a viable option. Modified soil turf involves the use of real grass, though the soil structure is engineered to achieve certain desired effects—such as increased resistance to compaction, which in turn increases drainage and soil aeration (DePew & Guise, 2001). This type of turf selection is often chosen for specialized applications that require enhanced structural stability and durability (Sloan, Ampim, Basta & Scott, 2012).

To maintain this type of field, irrigation and fertilizer regimens are still a necessity. Though, proper and optimal field designs are the core purpose of modified soil fields as to reduce maintenance needs over the lifespan of the field. Reviewed above, were the necessities of proper sand selection (size, shape, etc.) to ensure proper drainage and aeration—this also reduces the ability for anaerobic areas to form in the field, which compromises grass plant growth (Hummel & Petrovic, 2006). The use of gravel or stone carpeting between the subsoil and root zone, with the addition of organic materials like peat, ensures some water and nutrient retention for plant growth requirements (Hummel

& Petrovic, 2006). Overall, irrigation requirements for a modified soil fields are higher than that of a native soil field because of the enhanced drainage properties, which reduce water retention within the field. Additionally, fertilizers need to be applied more frequently due to the low nutrient content and holding capacity of sand. Other maintenance requirements include aerating the field, seeding, and topdressing it with sand to keep the sand infill ratio in the needed range. Mowing should be performed at least once a week during the growing season. To reduce mowing requirements, certain chemicals can be applied to the grass to stunt growth.

According to PJ Ellis, who oversees the management of all Department of Athletics sports fields at the University of Maryland, a single trained individual working 40 hours a week, can maintain a sand based Bermuda grass sports field up to the size of about 1.5 acres. Less time would likely be required to maintain the same size field with a cool season grass because the mowing frequency for Bermuda grass is higher than that for the cool season turf grasses. On a longer time scale, the field must be fully renovated approximately every 8 years.

Synthetic Surface Fields

The environmental implications that artificial turf fields have on water are multi-faceted. Because they are constructed with plastic fibers and do not require water to maintain its aesthetic value, one of the main benefits of artificial fields is that it conserves water (Cheng, 2014). Additionally, as artificial fields maximize infiltration rates and reduce runoff, research has shown that these fields may improve water quality as the rainwater that would typically transport nutrients and pollute streams is instead confined (Government of Western Australia, 2019).

However, artificial turf fields still can impair water quality by releasing hazardous contaminants from its turf materials (Cheng, 2014). If rainwater is uncollected and directly discharged to receiving bodies of water, the contaminants carried can severely endanger aquatic species and making drinking water treatments more difficult (Cheng, 2014). Crumb rubber, a typical in-fill material made of shredded tires, leaches toxic heavy metals and organic compounds after rainfall (Government of Western Australia, 2019). Though rock materials may filter out these hazardous substances like zinc, installing mixed sorbents underneath the field can ensure treatment of collected discharge by removing stubborn contaminants (Cheng, 2014). An alternative method is to avoid crumb rubber altogether and use non-hazardous cork and coconut fibers for turf in-fill (Shay, 2019). However, this approach may be counterproductive by increasing energy costs from extracting and processing the raw materials that could have been avoided by manufacturing crumb rubber out of recycled, repurposed tires (Cheng, 2014).

Not only does artificial turf play a role in water quality, but it also impacts surrounding wildlife. Replacing natural fields with artificial turf, displaces the soil that burrowing organisms depend on and the natural vegetation that wildlife feed on (Laville, 2016). Artificial field's carpet component poses as a barrier for burrowing animals like worms, which provide ecosystem services like soil enhancement. Though the turf carpeting has proven to be an issue for worms, research has shown that crumb rubber is non-lethal to earthworms (Pochron, 2017). This is a significant finding as earthworms are typically an indicator species, the "first" species to suggest if the environment is unsafe. It can be inferred from this research that if crumb rubber is not leaching hazardous toxins at a high enough level to harm earthworms, then they are benign to higher trophic animals. Additionally, by installing plastic grass, vegetative animals such as deer, rabbits, and geese are deterred from entering the field, shifting their common feeding habits (Laville, 2016).

Along with short-term impacts, artificial fields also have significant long term environmental concerns. As turf fields last around 10 years, it is important to consider the implications sustained during manufacturing, life span and after disposal (Cheng, 2014). Little energy is required in manufacturing crumb rubber as it is made of recycled tires that otherwise would have been placed in landfills. In the long term, the result of not processing raw materials saves 527-ton carbon dioxide equivalents of greenhouse gases from entering the atmosphere in its life span (Magnusson, 2017). If untreated over the course of ten years, crumb rubber can contaminate as much as 24,000 cubic meters of water to the secondary drinking water standard of (5 mg/L) and exceed the concentration maximum criteria for protection of freshwater aquatic animals (Cheng, 2014).

It was believed that infill materials could not be recycled, but emerging markets for cheap, spent, in-fill have proved otherwise. Companies have begun to recycle spent in-fill materials by reusing the crumb rubber in new installations of sports fields (Berger, 2016). As technology has enabled efficient cleaning and repurposing turf components, turf field materials are becoming less present in landfills. Grass portions and carpets of synthetic fields can be used in dog parks and landfill caps where low quality turf application is suitable (Berger, 2016). Although a new practice, the disposal of turf fields is taking steps towards a sustainable direction.

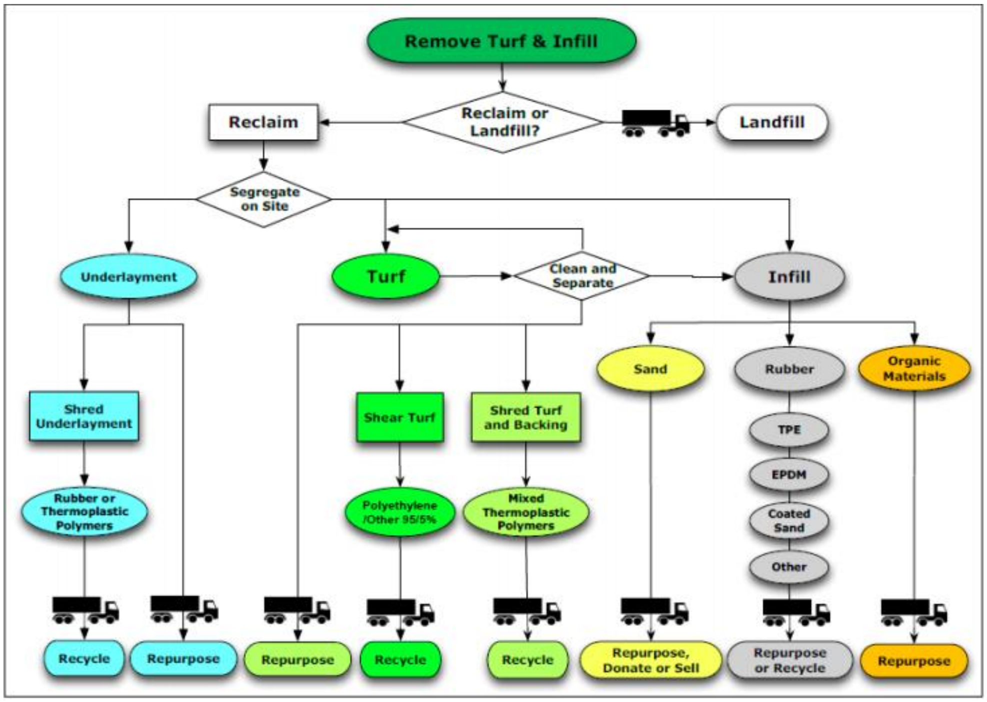

Figure 4: The turf components at the end of their life cycle are recycled, repurposed, or donated. (Berger, 2016).

D. Cost Comparisons

In order to compare the costs of natural, modified, and synthetic playing fields, several assumptions must be established. Firstly, the field will be used for recreational sports such as football, soccer, and baseball. It is also assumed that College Park community members, as well as local middle and high school teams will utilize the field. The field is also expected to hold a number of community events and gatherings. The renovation, and recurring costs will be based on a ten year lifecycle, which is the average amount of time that synthetic fields needs two carpet replacements, and natural fields require renovation. Lastly, it is assumed that the playing surfaces will endure up to 1,000 hours of use a year (MCPS, 2011).

When constructing or installing any of the three field types, the costs depend on several factors such as field size, location, labor costs, and usage. According to Sports Turf Managers Association, the cost to construct a synthetic turf field ranges from $6.00-$10.25 per square foot (STMA, 2019). The costs include field excavation, base materials, drainage, labor costs, and infill. Maintaining a synthetic field includes costs for infill, paint, disinfectants, as well as additional costs for the equipment needed to perform the maintenance. The average cost to maintain this field type ranges from $5,000-$8,000 per year (STMA,2019). A study conducted by Montgomery County Public Schools revealed that the initial cost for constructing synthetic fields is roughly $1,125,000. The report also indicates that the Maryland Soccer Plex spends roughly $10,000 a year in maintenance costs for their synthetic field (MCPS, 2011). The routine that goes into maintaining synthetic field types involves brooming to reduce matted-down fiber, replacing lost infill, topdressing, and increasing or reducing the amount of paint on the surface (Jastifer, 2019).

The installation costs of natural grass fields are typically lower than those of synthetic fields. The construction of natural grass fields using native soils can cost anywhere from $0.60-$3.00 per square foot (STMA, 2019). Tilling, fertilizer applications, topdressing, and irrigation are some of the factors that contribute to the cost. Modified soils with sand cap costs anywhere from $2,75-$4.00 per sq. foot (STMA, 2019). The MCPS report finds that the construction cost of native, natural grass fields can range from $75,000-$150,000. The report states that the cost of sand based or modified fields ranges from $530,000-$580,000 (MCPS, 2011).

The cost to maintain natural grass playing fields depends on a number of factors. Such factors that influence the cost include grass species, usage rate, and root zone type. A natural playing field that endures around 120 hours of play per year, cost roughly $6,500-$9,880 to maintain, with equipment costs of $1350-$1570. A sand-based field that experiences around 300 hours of play a year costs $20,000-$37,000 to maintain, with $5,000 on equipment (STMA, 2019). The staff of the Maryland Soccer Plex shared the annual maintenance costs of three natural field types they oversee. A cool season native soil field costs $25,000 per year, Bermuda grass native field costs $45,000, and the sand based field (Bermuda or Kentucky Blue Grass) costs $50,000 per year (MCPS, 2011).

Maintenance and replacement costs are two important factors to consider when deciding on a field's playing surface. These costs vary greatly amongst the different field types. Synthetic turf fields require a carpet replacement roughly every ten years. In a twenty-year lifecycle, accounting for two carpet replacements, synthetic fields costs about $1,280,000 to replace/rehab (MCPS, 2011). That is roughly $640,000 per carpet replacement. In the same twenty-year lifecycle, natural Bermuda grass fields cost $100,000 to rehab, while cool season native fields cost $60,000 (MCPS, 2011). Bermuda sand base fields cost around $150,000, and Kentucky Blue Grass and fields cost $175,000 (MCPS, 2011).

Durability and hours used of these field surfaces are also important to consider when evaluating overall cost. Although synthetic turf fields have higher upfront and rehab costs than the other field options, it is the most durable. Synthetic turf fields are flexible in the sense that they can be used regardless of certain climate and weather events. For example, rainfall is significantly less harmful to synthetic fields compared to natural fields where rain can lead to poor field conditions and damage (STMA, 2019). This leads to a higher usage of synthetic turf compared to the other options. The increased usage results in higher revenue for synthetic fields. MCPS found that when considering revenue generated by synthetic fields, the net costs for them are less than all the other filed options other than the cool season native field (MCPS, 2011).

The various dollar amounts presented in the cost comparison chart were adjusted to best reflect the needs of Duvall field. The installation costs were adjusted to reflect the standard football field size of 57,600 square feet. The square footage estimates provided above were multiplied by 57,600 square feet. The maintenance costs were adjusted to reflect the estimated 770 hours of use for Duvall Field per year.

Cost	**Natural**	**Modified**	**Synthetic**
Installation (STMA)	Low~ $34,560 High~ $172,800	Low~$158,400 High~ $230,400	Low~ $345,600 High~ $590,400
Maintenance (STMA) (Based on Duvall Field's estimated 770 hours of use per year)	Low~ $39,000 High~ $58,800	Low~ $50,000 High~ $92,500	Low~ $5,000 High~ $8,000
Replacement (MGPS) (Every 10 years)	~$50,000	~$80,000	~$640,000

VII. Discussion of Findings:

The information presented about the three options can be applied to any recreational sports field in the College Park region and beyond. As there were multiple factors to be considered and compared, this cost matrix comprehensively summarizes the findings on all three surfaces.

If a natural, non-modified field is selected, here is a summary of the benefits and costs. In terms of player safety, it provides the lowest risk of harmful direct material contact and contaminant risk. It provides the lowest environmental disturbance risk as very little modifications are made and it does not need to be disposed off over the years. It is also the cheapest option for both installation and renovation. Duvall Field has the highest amount of foot traffic in the spring, which is also when Maryland sees the most rain. If a non-modified natural field is used, during the rainy season, it will not be suitable for any type of play, as the drainage is poor. It also requires the most expensive maintenance costs and highest amount of chemical treatment needed, with fertilizer use.

An artificial turf field will provide the most opportunity to maximize field use, as it has the best durability and drainage. It is able to be used during rainy weather and can hold up to the action of multiple sports. It is the most expensive to install, but is the cheapest option to maintain as it does not require many additional treatments once in place. It ranks the lowest for player safety as it provides the highest risks for injury, direct material contact, and contamination risk. It is physically the hardest playing surface and reaches the highest surface temperature that puts players at risk.

A modified soil field falls right in the middle between the previous two options. It provides better drainage than the non-modified field and is a more durable. It also provides the lowest risk of injury due to its incorporation of sand under the grass, providing more cushion and give. It is the intermediate for both installation and maintenance costs. It does require the most chemical treatments out of the three options.

Currently Duvall Field is estimated to have 770 hours of recreational sports play and 250 hours of play from a local elementary school for recess, for a total of a little over 1,000 hours of use per year. These play hours are coming from mostly children, which impacts the wear and tear the field will face. A durable field is appropriate for 1,000 hours of play but it does not need to be of a professional sports grade. Due to the hours of play and the intensity of activity, the field will need consistent but not constant maintenance. Installation is also an important consideration, as Duvall Field is surrounded by homes. The actual installation of a modified or artificial field will take time to complete and could disturb various factors, like wildlife and surrounding homeowners. If Duvall Field is to maximize use, it should have great drainage as it is mostly used in the spring. College Park gets an average of 44.7 inches of rain per spring season (World Climate, 2019). High quality drainage will allow for the field to be used during rain, without putting players at risk. In the spring, Maryland averages at about 68 degrees Fahrenheit and in the summer temperatures average out at 78.7 degrees (Maryland State Archives, 2019). The natural grass surface types will match the ambient temperatures. An artificial surface could be up to 160 degrees on its surface, which is a dangerous condition for players.

Analyzing and considering the factors of player safety, environmental concerns, and practicality allow for the most efficient selection to be made for a playing surface for a recreational sports field. Each of those factors and its primary considerations are what the matrix aids in summarizing. The appropriate selection for a playing surface for Duvall Field ultimately should be made with these various factors in mind.

Score Matrix

Note: Total values are not used for this matrix, as the different factors are not meant to be weighted equally. It serves as a tool for stakeholders to determine which factors they prioritize and which are most are most suitable for their needs.

Factors	Native Soil	Modified Soil	Synthetic
Risk of Player Injury	2	1	3
Direct Material Contact to Players	1	2	3
Contaminant Exposure to Players	1	2	3
Chemical Treatments	2	3	1
Land Disturbance	1	2	3
Wildlife Impact	1	2	3
Disposal Method	1	2	3
Drainage	3	2	1
Adaptability	3	2	1
Installation Costs	1	2	3
Maintenance Costs	3	2	1
Durability/Longevity	3	2	1
Lifespan	1	2	3

Key: 1-Best rating 3-Worst rating
Red – Player Health Factors
Green – Environmental Factors
Blue – Practicality Factors

**Native rankings are based on the current state of Duvall Field (exception of costs, which were based on standard football field size and range values from MCPS fields)*

***Application of chemical treatments refer to the environmental risks resulting from the fertilizers and pesticides needed for maintenance*

VIII. Conclusion

In conclusion, a field that will be primarily used by children in a recreational manner should be one that is safe for athletes of all ages, durable enough to withstand many seasons of play, suitable for many types of weather, and must be cost-effective. These concerns must be considered when choosing between artificial turf, natural grass, or natural grass with modified soil for a recreational play field surface.

When compared to the other field types, natural grass fields with native soil are the most economical, have the lowest risk of harmful direct material contact and contaminant risk to players, and provide the lowest environmental disturbance risk. An artificial field provides the most durability and can be used in rainy weather. Despite being the most expensive to install, having the highest risk of harmful direct material contact and contaminant risk to players, artificial turf has the lowest ongoing maintenance cost of the three options. Natural grass fields with modified soil have the lowest risk of injury for athletes, but require the most maintenance in terms of irrigation and chemical treatments due to their enhanced drainage.

This guide and the score matrix developed from the findings of the different field types summarize the strengths and drawbacks of each field surface options for each factor of concern. This report, the score matrix, and the cost comparison chart can be used by the City of College Park to assess options for Duval Field, and by other municipalities in the decision-making process when determining which field type best fits their planned field use, stakeholder priorities, and budgets.

Appendix i

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Appendix ii

10-point Score Matrix

At the request of City Council Members present at the December 2019 City Council meeting in which this report was presented, this additional 10-point matrix is provided to offer a slightly more comprehensive evaluation of the play filed options discussed. Each category was given a score from 1 to 10, with 1 being the worst and 10 being the best. Each team member provided a score for each category based on research and knowledge gained during this project. Scores were compiled and the average value for each category is presented.

Factors	Native Soil	Modified Soil	Synthetic
Risk of Player Injury	5	6	4
Direct Material Contact to Players	6	6	3
Contaminant Exposure to Players	7	7	4
Chemical Treatments	4	3	9
Land Disturbance	9	5	3
Wildlife Impact	9	7	4
Disposal Method	10	9	6
Drainage	2	7	9
Adaptability	2	7	9
Installation Costs	8	5	2
Maintenance Costs	6	4	8
Replacement	6	4	8
Durability	3	6	9
Lifespan	9	4	5

Key: 10-Best rating 1-Worst rating
Red – Player Health Factors
Green – Environmental Factors
Blue – Practicality Factors

**Native rankings are based on the current state of Duvall Field (exception of costs, which were based on standard football field size and range values from MCPS fields)*

***Application of chemical treatments refer to the environmental risks resulting from the fertilizers and pesticides needed for maintenance*