PLANNING COMMISSION REPORT
Regular Agenda -- Public Hearing Item

PC Staff Report
6/22/11

ITEM NO. 11 TEXT AMENDMENT TO CITY OF LAWRENCE DEVELOPMENT CODE; CHP 20; SYNTHETIC TURF AS LANDSCAPING MATERIAL (MKM)

TA-4-6-11: Consider Text Amendments to the City of Lawrence Land Development Code, Chapter 20, Articles 10 and 17, regarding synthetic turf as landscaping material. *Initiated by City Commission on 5/3/11.*

RECOMMENDATION:
Staff recommends denial of the amendments to Articles 10 and 17 of the Land Development Code to add synthetic turf as landscaping material based on the analysis provided in the Staff Report.

Reason for Request: *"To allow synthetic turf landscaping recently applied to an apartment development to remain".*

RELEVANT FACTOR:
- Conformance with the Comprehensive Plan.

PUBLIC COMMENT RECEIVED PRIOR TO PRINTING
- None to date.

ATTACHMENTS
A. Initiation staff memo
B. LEED 2009 for New Construction and Major Renovations
C. State of New York Health Fact Sheet, including referenced studies
D. 2008 Center for Disease Control and Prevention Health Advisory
E. Connecticut Department of Environmental Protection Report
F. Natural Landscaping and Artificial Turf: Achieving Water Use and Pesticide Reduction
G. Low Maintenance Landscaping, K-State Experiment and Extension Office Report
H. Punta Gorda, FL Application

OVERVIEW OF PROPOSED AMENDMENT
The City Commission initiated consideration of a request to allow the use of synthetic turf as landscaping material at their May 3, 2011 meeting at the request of Paul Werner Architects. The request is being made in order to maintain recently installed synthetic turf at the apartment complex being constructed at the intersection of Trail and Frontier, formerly known as the Boardwalk Apartments. While the site plan was approved with code compliant landscape materials (sod, seed), a routine inspection of the site yielded the installation of the synthetic turf. The owner was informed of the non-compliant installation and was provided options to conform to the code, including installing the approved plant material, seeking a variance, or requesting a text amendment to revise the applicable sections of the code.

The applicant would like the city to consider revising the Development Code to permit the use of synthetic turf in any landscape application.

A similar situation occurred previously with the Oread Inn development. Synthetic turf was installed in a small area, although the approved development plan [FDP-02-03-09] required code compliant landscape materials. The artificial turf was discovered during a site inspection prior to the release of occupancy permits. The Planning Director made the following statement when approving the use of this limited amount of artificial turf: "While artificial turf is not a normally accepted landscape material, it is appropriate in this specific situation in combination with the natural materials on site." It is possible that synthetic turf may be appropriate in some locations where traditional or low maintenance landscaping would be difficult to establish or maintain. In these cases, Alternative Compliance can be requested per the requirements in Section 20-1007. Section 20-1007(b) states that, "Alternative Compliance is limited to the specific site under consideration and does not establish precedent for acceptance of alternative compliance plans on other sites."

The amendment would include 'synthetic turf' in the definition of 'landscape materials'. Standards pertaining to the use of synthetic turf as landscaping material would likely need to be developed to support its use, if found to be appropriate, as discussed later in this report. The use of synthetic turf for athletic fields is not included in this amendment as the synthetic turf is being utilized in this situation as a 'surfacing' rather than 'landscaping' material.

CONFORMANCE WITH THE COMPREHENSIVE PLAN

A sustainable physical environment is a principal goal of *Horizon 2020.* Sustainable landscaping practices and materials comply with this goal. The comprehensive plan recommends the use of high quality materials in the construction of landscape areas and recognizes that natural vegetation adds greatly to the appearance of the community as a whole and should be maintained. *Horizon 2020* and the Land Development Code emphasize the use of natural and living plant materials. The proposed amendment to allow the use of synthetic landscaping materials is not in conformance with *Horizon 2020.*

CRITERIA FOR REVIEW AND DECISION-MAKING

Section 20-1302(f) provides review and decision-making criteria on proposed text amendments. It states that review bodies shall consider at least the following factors:

1) Whether the proposed text amendment corrects an error or inconsistency in the Development Code or meets the challenge of a changing condition; and

Applicant Response:

"The amendment does not correct an error or inconsistency but instead provides an alternative option to turf grass. Synthetic turf is a viable option for turf management in the right location. This text amendment would give the Planning Department the ability to approve it."

"With the increased awareness of providing green building options synthetic turf has its benefits which include using no irrigation, fertilizer or pesticides to maintain it. Synthetic turf also reduces emissions since it does not need mowed."

Staff Review:

The text amendment is intended to address a changing situation: the need for more sustainable development and greater environmental protection of our natural resources. The applicant indicated that, in the right location, synthetic turf is a viable option to natural turf because it does not require water, fertilizer, pesticide or mowing.

As a community, we are becoming more conscious of the environmental impacts of our actions and conservation of water is recognized as an important means to protect a non-renewable natural resource. Minimizing the use of fertilizers and pesticides are steps that could reduce negative impacts on our ground and surface waters. Mowing may result in emissions so reduced mowing could be a factor in sustainable landscaping. In order to reduce the negative impacts and conserve water, landscaping which addresses these concerns is more sustainable and should be encouraged.

This staff report reviews the impact of synthetic turf to determine if the use of synthetic turf meets the challenge of increased sustainability. **This review concludes that artificial turf is not a sustainable means of landscaping and does not meet the challenge of changing conditions but that low maintenance natural landscaping does. Staff concludes that there is no error in the Comprehensive Plan or Development Code to correct and that the use of living and natural landscape materials is appropriate.**

2) Whether the proposed text amendment is consistent with the Comprehensive Plan and the stated purpose of this Development Code (Sec. 20-104).

Applicant Response:

"Horizon 2020 states on pages 5-22, 5-28, and 6-28, "Encourage the use of high quality materials in the construction of screening and landscape areas to decrease long-term maintenance costs." Synthetic turf falls into this category because it is a high quality material made of partly recycled materials and has no yearly maintenance cost such as irrigation systems, fertilizers or pesticides.

Staff Review:

As the applicant pointed out, *Horizon 2020* recommends the use of high quality materials in the construction of landscape areas to minimize maintenance costs. The comprehensive plan does not recommend the use or synthetic landscaping materials, but in several places emphasizes the importance of natural features and natural vegetation.

- "The Plan proposes the development of neighborhoods in a range of densities to provide a sense of community and to complement and preserve natural features in the area." (Page 3-1, Background Studies)
- "Natural environmental features within residential areas should be preserved and protected. Natural vegetation and large mature trees in residential areas add greatly to the appearance of the community as a whole and should be maintained. Changes to the natural topography should be minimal." (Policy 5.1, page 5-19 Residential)
- "Promote the integration of mature trees, natural vegetation, natural and environmentally sensitive areas whenever possible to buffer low-density developments from more intensive land uses. (Policy 6.1(c)(2)(a), page 5-21, Residential)
- "Site design and building features shall be reflective of the quality and character of the overall community and incorporate elements familiar to the local landscape." (Page 6-2, Commercial)
- "Encourage the use of existing vegetation, such as stands of mature trees, and other natural site features into the landscape design as natural buffers or focal points." (Policy 3.1(d)(4)(c). Page 7-16 Industrial and Employment)

Horizon 2020 does not specifically address synthetic landscaping materials, but does in several instances recommend the use of natural landscaping materials. The plan states in the residential chapter that natural vegetation 'adds greatly to the appearance of the community as a whole'. When discussing commercial development it recommends that site design should be reflective of the quality and character of the overall community and should incorporate elements familiar to the local landscape. The type of landscaping material used has an impact on the character of the area.

Introducing synthetic turf into the landscape creates an artificial characteristic that is inconsistent with the natural look of Lawrence today. **The proposed text amendment is not in conformance with the comprehensive plan.**

GENERAL REVIEW

The purpose of landscaping, per Section 20-1001 of the Development Code, is to maintain the City's quality, heritage and character by enhancing its visual appearance, and to enhance environmental conditions by providing shade, air purification, oxygen regeneration, groundwater recharge filtering of stormwater runoff, abatement of noise, glare and heat. The review below analyzes synthetic turf in regards to these purposes:

- **to maintain the City's quality, heritage and character by enhancing its visual appearance**;

It may be a matter of opinion whether synthetic turf would enhance the visual appearance of the City; however, the addition of an artificial component into the landscape would not maintain the City's heritage and character. Figures 1-3 illustrate the installation process for the synthetic turf that was installed in Lawrence and the finished look.

- **to enhance environmental conditions by providing shade, air purification, oxygen regeneration, groundwater recharge filtering of stormwater runoff, abatement of noise, glare and heat;**

The applicant indicated that synthetic turf would be more environmentally friendly than natural turf because it would not need fertilizer, pesticide, mowing or watering as it is not a growing material. Synthetic turf does not require watering but does require washing, as organic matter does not decompose on synthetic turf and it may require water for cooling in hot temperatures, so the use of water may be reduced; however, it has not been eliminated.

The following information was taken from "Natural Landscaping and Artificial Turf: Achieving Water Use and Pesticide Reduction", an article written by Alex Wilson, Executive Editor of Environmental Building News:

> Kim Sorvig, research associate professor at the University of New Mexico, and co-author of *Sustainable Landscape Construction: A Guide to Green Building Outdoors*, is concerned about the soil conditions under artificial turf. "It blocks both water and sunlight either completely or in very large degree," he said, "and without that, you can't have a living system in the soil." Sorvig thinks it is ironic that artificial turf is heralded as a solution to water shortages, since it diminishes the health of the underlying soil, thereby decreasing its ability to hold water. "When you remove the vegetation from an area so completely," he said, "you're actually, in the long term, contributing to drought."

Synthetic landscaping materials would not contribute to air purification or oxygen regeneration. Landscaping materials are intended to provide abatement of heat; however, synthetic turf may contribute to the heat island effect.

Health and Environmental

The State of New York Health Department prepared a fact sheet on crumb-rubber infilled synthetic turf athletic fields in 2008. The items reviewed were: heat stress, injury, infection, latex allergy, chemical exposure.

HEAT STRESS: The fact sheet states that the average surface temperature on a synthetic turf field at Brigham Young University in June 2002 was reported to be 117°F while the average surface temperature on natural turf and asphalt were 78°F and 110°F respectively. The maximum temperature reported on the turf field was 200°F. Measurements taken at the University of Missouri field had a 138°F air temperature at 'head-level' height on a 98° F day. The surface temperature of the field was reported to be 178°F. A study at BYU found that watering synthetic turf reduced the surface temperature from 174°F to 85°F but the temperature rose to 120°F in five minutes and 164°F in twenty minutes.

INFECTION: The review concluded that synthetic turf surfaces are no more likely to harbor infectious agents than other surfaces.

LATEX ALLERGY: Tire rubber is used in many synthetic turf products as the infill material. Some people are allergic to 'latex allergens' which are substances within the latex in rubber tires. Tests did not find any relation between the crumb rubber used in synthetic turf and latex allergies.

CHEMICAL EXPOSURE: Studies have been conducted on the various chemicals used in synthetic turf and no negative results were obtained with the exception of 'lead'. Some types of synthetic turf fibers contain elevated levels of lead. Degradation of these fibers can form a dust that presents a potential source of lead exposure. The Centers for Disease Control and Prevention addressed the potential for lead exposure in a June 2008 Health Advisory, attached.

The Connecticut Department of Environmental Protection prepared an Artificial Turf Study in 2010 which looked specifically at health impacts and stormwater leaching. The study analyzed the runoff from turf fields and identified zinc as a potential risk to surface waters. Best Management Practices recommended for management of stormwater runoff from turf fields included wet ponds, infiltration structures, filters and bio-filtration structures.

Synthetic turf does not support soil organisms. The grass and these organisms play an ecological role by purifying water as it leaches into the earth.

Many developments in Lawrence are being constructed to LEED standards in order to obtain LEED certification. LEED, Leadership in Energy and Environmental Design, is an internationally recognized green building certification system. LEED offers credit for water efficient landscaping and recommends various options for reducing water requirements. (See pages 23-24 in attached LEED certification booklet.) LEED recommends installing landscaping that does not require permanent irrigation systems, but does not directly recommend synthetic turf or even infer its use. While synthetic turf may qualify for LEED points, it is not listed as a recommended landscaping option.

Some communities, particularly in areas with limited water sources such as California, have encouraged the use of artificial turf to conserve water. Glendale Arizona had once given rebates to residents for installing artificial turf but stopped giving rebates after the issuance of the Centers for Disease Control and Prevention 2008 health advisory.

To summarize, synthetic turf is not, in staff's opinion, an environmentally sustainable form of landscaping because it contributes to the heat island effect, diminishes the health of the underlying soil, has the potential to leach zinc into surface water through stormwater runoff and has potential health consequences related to the levels of lead in some types of synthetic turf fibers.

LOW MAINTENANCE LANDSCAPING: XERISCAPE:

Reducing the use of pesticides and fertilizer is a sound environmental concept and can be achieved with natural landscaping through the use of native species which are adapted to the climate and environment of the area. The following description of low maintenance landscaping was provided in the K-State Agricultural Experiment Station and Cooperative Extension Service Report: "It simply imitates nature's design: putting hardy, adapted plant materials in the places where they grow best. Once established, this kind of landscape requires little maintenance because it is designed to work in harmony with nature, not against it." (page 2) Savings will be realized due to reduced water, pesticide and herbicide usage.

This report stated that turfgrass areas usually require the most water and maintenance in a landscape and recommended that irrigated turfgrass areas be limited to places with high use. Low-maintenance and native grasses are recommended for other areas.

The K-State report also recommends that a development collect runoff and 'harvest' water by collecting or redirecting water from the downspouts to areas of the landscape that need it. Different types of irrigation systems, such as drip or trickle, in addition to traditional sprinklers could also help conserve water. Watering slowly, deeply and infrequently will help reduce water usage.

OTHER CONSIDERATIONS

UTILITIES:

- When providing locates for underground utilities the location will more than likely be painted on the turf as flags are difficult to push through the fabric.
- Identifying the responsible party for restoration of the artificial turf should excavation be required to perform repairs/maintenance on existing infrastructure below the artificial turf or on surface structures within the artificial turf area such as meters, manhole, lids, etc, as well as areas that may be damaged adjacent to the work area due to access or storing materials, spoils etc. The Utilities Department does not currently have the expertise or equipment to repair and replace the synthetic turf.
- Establishing the appropriate way to make an excavation; cut the turf or roll the turf back before beginning an excavation.

TURF MAINTENANCE:

- Would need to establish regulations for maintenance of turf and require replacement when it has aged. The City of Punta Gorda, FL included the following requirement in their requirements for synthetic turf: "Artificial turf shall be maintained in a green fadeless condition and shall be maintained free of dirt, mud, stains, weeds, debris, tears, holes and impressions. All edges of the artificial turf shall not be loose, and must be maintained with appropriate edging or stakes."

PRODUCT SPECIFICATIONS:

- Many companies produce various types of synthetic turf and the quality varies between different brands or types of turf. Standards regulating the quality of synthetic turf would be necessary. The City of Punta Gorda, FL permits the use of synthetic turf with a Special Exception. A copy of the application is included with this report. Features considered are the minimum tufted weight, minimum permeability, color, and warranty. In addition, information on the anchoring system is required to ensure the turf will withstand the effects of wind.

While there may be solutions to some of these concerns, the effort necessary to accommodate synthetic turf does not appear to be justified when natural alternatives exist and have been in practice for decades without major issue.

Staff Recommendation

Staff recommends denial of the requested amendment to Articles 10 and 17 of the Land Development Code to permit synthetic turf as a landscape material. 'Low maintenance' landscaping can and should be utilized to meet the need for more sustainable landscaping practices.

Figure 1. Prepared Base

Figure 2. Installation

Figure 3. Finished product

LANDSCAPING PRACTICES COMPARISON CHART:			
	Synthetic Turf	Low Maintenance Landscaping	Traditional Lawn
Low water usage	✓	✓	
No Pesticide usage	✓	✓	
No Fertilizer	✓	✓	
No mowing	✓	✓	
Pervious	✓	✓	✓
Filters pollutants		✓	✓
Provides Habitat		✓	✓
Provides Oxygen		✓	✓
Absorbs Carbon Dioxide		✓	✓
Reduces Heat Island		✓	✓
Adds to Heat Island	✓		

Attachment A-
Initiation Memo

Memorandum
City of Lawrence
Planning & Development Services

TO: **David L. Corliss, City Manager**

FROM: **Planning Staff**

CC: **Scott McCullough, Director of Planning and Development Services**
Sheila Stogsdill, Assistant Planning Director

Date: **For May 3, 2011 City Commission meeting**

RE: **Text Amendment Initiation to permit the use of synthetic turf to meet landscaping requirements in Article 10 of the Development Code**

A request was made by Paul Werner Architects to initiate a text amendment to the *Land Development Code* to include 'synthetic turf' in the list of landscape materials that may be used to meet the landscape requirements in Article 10 and to revise the definition of 'Landscaping' in Article 17 to include 'synthetic turf'. The request is being made in order to maintain recently installed synthetic turf at the apartment complex being constructed at the intersection of Trail and Frontier, formerly known as the Boardwalk Apartments. While the site plan was approved with code compliant landscape materials (sod, seed), a routine inspection of the site yielded the installation of the synthetic turf. The owner was informed of the non-compliant installation and was provided options to conform to the code, including installing the approved plant material, seeking a variance, or requesting a text amendment to revise the applicable sections of the code. The applicant would like the city to consider revising the Development Code to permit the use of synthetic turf for this and potentially future projects.

The code emphasizes the use of living landscape materials and states the following about landscaping (non-exclusive list):

Section 20-1009 Landscape Material Standards – (b) Artificial Plants – No artificial plants or vegetation may be used to meet any standards of this section.

Section 20-1009 Landscape Material Standards – (e) Grass Seed and Sod – Turf areas shall be planted with species suitable as permanent lawns in Lawrence. Turf areas may be sodded or seeded.

Section 20-1010(a)(2) – All Landscape Material, including trees, plant material and structural elements, shall be in place and healthy prior to issuance of a final Certificate of Occupancy. The Planning Director may authorize issuance of a temporary Certificate of Occupancy prior to installation of required Landscaping, when seasonal conditions render installation impractical…

Section 20-1701 Definitions

Landscape Material – Such living material such as trees, Shrubs, Ground Cover/vines, turf grasses, and non-living material such as: ricks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), and/or other items of a decorative or embellishing nature such as: fountains, pools, walls, fencing, sculpture, etc.

Landscaping – Any combination of living plants such as trees, Shrubs, plants, vegetative Ground Cover or turf grasses…

Ground Cover – Living Landscape Materials or living low-growing plants other than turf grasses, installed in such a manner so as to provide a continuous cover of the ground surface and which, upon maturity, normally reach an average maximum Height of not greater than 24 inches.

The application noted that synthetic turf is low maintenance and may be appropriate in some locations. The application also identified synthetic turf as a ‘green building option’ as it does not require watering, mowing, or the use of fertilizers or pesticides. The application is attached for your reference.

If the text amendment is approved, it will be necessary to revise the Community Design Manual as well for landscaping requirements within the Commercial and Industrial Zoning Districts for consistency.

Staff recommends that the Commission initiate the amendment so that careful consideration can be given to the request and so that the pros and cons of using synthetic turf to meet the values of landscaping requirements can be discussed by the community stakeholders.

Action requested: Initiate a text amendment to Article 10 and Article 17 of the Land Development Code – Code of the City of Lawrence, Kansas regarding landscaping and landscape materials and associated revisions to the Community Design Manual, if appropriate.

City *of* Lawrence
Douglas County
PLANNING & DEVELOPMENT SERVICES

Lawrence Douglas County
Metropolitan Planning Office
6 East 6th Street, P.O. Box 708, Lawrence, KS 66044
(785) 832-3150 Fax (785) 832-3160
http://www.lawrenceplanning.org

REQUEST FOR INITIATION of a TEXT AMENDMENT

APPLICATION FORM

APPLICANT/AGENT INFORMATION

Contact Joy Rhea

Company Paul Werner Architects

Address 1918 Edgelea Road

City Lawrence State KS ZIP 66044

Phone (785) 832-0804 Fax (785) 832-0890

E-mail joyr@paulwernerarchitects.com Mobile/Pager (___) ______

Pre-Application Meeting Date 4-1-11 Planner Scott McCullough

Are you submitting any other applications? If so, please state which one(s).

Please identify the section of the Development Code or Subdivision Regulations proposed to be amended. 20-1003(e) , 20-1009 (b), 20-1009(e)(4), 20-1701

Please provide proposed amendment. (Attach additional sheets if needed)

20-1003(e) In addition to required Shade Trees and Shrubs, landscape areas within the interior of off-street Parking Areas shall be planted with turf which can be synthetic or natural, Ground Cover, Ornamental Trees, or Shrubs.

20-1009(b) No artificial plants or vegetation other than synthetic turf may be used to meet any standards of this section.

ADD TO DEV CODE 20-1009(e)(4) Synthetic turf areas shall be installed per the manufactures specification as permanent lawns in Lawrence.

20-1701 - Landscaping: Such living material as trees, Shrubs, Ground Cover/vines, turf grasses, and non-living material suchas: rocks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), synthetic turf and/or other items of a decorative or embellishing nature such as: fountains, pools, walls, fencing, sculpture, etc.

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Please respond to the following questions to the best of your knowledge. In reviewing and making decisions on proposed text amendments review bodies shall consider the following factors. (Attach additional sheets if needed.)

1. **Does the proposed text amendment correct an error or inconsistency in the Development Code or Subdivision Regulations?** If so, please provide the specific error found and/or reference the specific section of the Development Code that is inconsistent with the section identified to be amended above.
   The amendment does not correct an error or inconsistency but instead provides an alternative option to turf grass. Synthetic turf is a viable option for turf management in the right location. This text amendment would give the Planning Department the ability to approve it.

2. **Does the proposed amendment meet the challenge of a changing condition? If so, please explain.**
   With the increased awareness of providing green building options synthetic turf has its benefits which include using no irrigation, fertilizer or pesticides to maintain it. Synthetic turf also reduces emissions since it does not need mowed.

3. **Is the proposed amendment consistent with Horizon 2020? Please explain.**
   Horizon 2020 states on pages 5-22, 5-28 and 6-28, "Encourage the use of high quality materials in the construction of screening and landscape areas to decrease long-term maintenance costs." Synthetic turf falls into this category because it is a high quality material made of partly recycled materials and has no yearly maintenance cost such as irrigation systems, fertilizers or pesticides.

4. **Is the proposed amendment consistent with the stated purpose of the Development Code? See Sec. 20-104 of the Development Code for the stated purpose.**
   This amendment in no way endangers the health, safety and welfare of the public.

City of Lawrence
Douglas County
PLANNING & DEVELOPMENT SERVICES

Lawrence Douglas County
Metropolitan Planning Office
6 East 6th Street, P.O. Box 708, Lawrence, KS 66044
(785) 832-3150 Fax (785) 832-3160
http://www.lawrenceplanning.org

SIGNATURE

By execution of my/our signature, I/we do hereby officially apply to request initiation of the proposed text amendment as indicated above.

Signature(s): Jay Rhea Date 4-18-11

____________ Date ________

____________ Date ________

STAFF USE ONLY

Application No. ________

Date Received ________

Planning Commission Date ________

Fee $________

Date Fee Paid ________

paulwerner
ARCHITECTS

LETTER OF TRANSMITTAL

RECEIVED
APR 18 2011
City County Planning Office
Lawrence, Kansas

FROM : Joy Rhea
TO : Scott McCullough
DATE : **April 18, 2011**
RE : Text Amendment for synthetic turf

We are Sending :

_X_ Attached ____ Per your request ____ For your files

Items Transmitted Via :

____ US Mail ____ Overnight ____ Courier X Other

Items Transmitted are For Your :

____ Information ____ Use ____ Approval _X_ Review

Items Transmitted are :

_X_ Originals ____ Disk (s) ____ Shop Drawings ____ Blueprints

____ Specifications ____ Samples ____ Other ____________.

COPIES/ SETS:	DESCRIPTION:
1	Text Amendment Application

REMARKS :

Office : 123 W. 8th Suite B2 : Lawrence, Kansas : 66044
Mail : PO BOX 1536 : Lawrence, Kansas : 66044-8536
PHONE: 785.832.0804 FAX: 785.832.0890

Attachment B- LEED (pg 23-24)

LEED 2009 FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS

For Public Use and Display

LEED 2009 for New Construction and Major Renovations Rating System

USGBC Member Approved November 2008 (Updated May 2011)

U.S. GREEN BUILDING COUNCIL LEED USGBC ®

PREFACE FROM USGBC

The built environment has a profound impact on our natural environment, economy, health, and productivity. Breakthroughs in building science, technology, and operations are now available to designers, builders, operators, and owners who want to build green and maximize both economic and environmental performance.

Through the LEED® green building certification program, the U.S. Green Building Council (USGBC) is transforming the built environment. The green building movement offers an unprecedented opportunity to respond to the most important challenges of our time, including global climate change, dependence on non sustainable and expensive sources of energy, and threats to human health. The work of innovative building professionals is a fundamental driving force in the green building moment. Such leadership is a critical component to achieving USGBC's mission of a sustainable built environment for all within a generation.

USGBC MEMBERSHIP

USGBC's greatest strength is the diversity of our membership. USGBC is a balanced, consensus based nonprofit with more than 18,000 member companies and organizations representing the entire building industry. Since its inception in 1993, USGBC has played a vital role in providing a leadership forum and a unique, integrating force for the building industry. USGBC's programs have three distinguishing characteristics:

Committee-based

The heart of this effective coalition is our committee structure, in which volunteer members design strategies that are implemented by staff and expert consultants. Our committees provide a forum for members to resolve differences, build alliances, and forge cooperative solutions for influencing change in all sectors of the building industry.

Member-driven

Membership is open and balanced and provides a comprehensive platform for carrying out important programs and activities. We target the issues identified by our members as the highest priority. We conduct an annual review of achievements that allows us to set policy, revise strategies, and devise work plans based on members' needs.

Consensus-focused

We work together to promote green buildings, and in doing so, we help foster greater economic vitality and environmental health at lower costs. We work to bridge ideological gaps between industry segments and develop balanced policies that benefit the entire industry.

Contact the U.S. Green Building Council
2101 L Street, NW
Suite 500
Washington, DC 20037
(800) 795-1747 Office
(202) 828-5110 Fax
www.usgbc.org

DISCLAIMER

None of the parties involved in the funding or creation of the LEED Rating System, including the USGBC, its members, its members, volunteers, or contractors, assume any liability or responsibility to the user or any third parties for the accuracy, completeness, or use of or reliance on any information contained in the LEED Rating System, or for any injuries, losses, or damages (including, without limitation, equitable relief) arising from such use or reliance. Although the information contained in the LEED Rating System is believed to be reliable and accurate, all materials set forth within are provided without warranties of any kind, either express or implied, including but not limited to warranties of the accuracy or completeness of information or the suitability of the information for any particular purpose.

As a condition of use, the user covenants not to sue and agrees to waive and release the U.S. Green Building Council, its members, volunteers, and contractors from any and all claims, demands, and causes of action for any injuries, losses, or damages (including, without limitation, equitable relief) that the user may now or hereafter have a right to assert against such parties as a result of the use of, or reliance on, the LEED Rating System.

U.S. Green Building Council
2101 L Street, NW
Suite 500
Washington, DC 20037

TRADEMARKS

ACKNOWLEDGMENTS

The LEED 2009 Rating System has been made possible only through the efforts of many dedicated volunteers, staff members, and others in the USGBC community. The Rating System improvement work was managed and implemented by USGBC staff and included review and input by many Technical Advisory Group (TAG) members with oversight by the LEED Steering Committee. We extend our deepest gratitude to all of our LEED committee members who participated in the development of this rating system, for their tireless volunteer efforts and constant support of USGBC's mission:

LEED Steering Committee

Scot Horst, Chair, LSC	Horst, Inc
Joel Ann Todd, Vice-Chair, LSC	Joel Ann Todd
Muscoe Martin	M2 Architecture
Stuart Carron	JohnsonDiversey, Inc.
Holley Henderson	H2 Ecodesign, LLC
Christine Magar	Greenform
Kristin Shewfelt	Architectural Energy Corporation
Jessica Millman	Agora DC
Bryna Dunn	Moseley Architects
Neal Billetdeaux	JJR
Greg Kats	Managing Good Energies
Mark Webster	Simpson Gumpertz & Heger
Bob Thompson	EPA Indoor Environment Management Branch
Malcolm Lewis	Constructive Technologies Group, Inc.
John Boecker	7Group
Sara O'Mara	Choate Construction Company
Alex Zimmerman	Rep Canada Green Building Council
Ian Theaker	Rep Canada Green Building Council

Sustainable Sites TAG

Bryna Dunn, Chair	Moseley Architects
Stewart Comstock, Vice-Chair	Maryland Department of the Environment
Michele Adams	Cahill Associates
Gina Baker	Burt Hill
Ted Bardacke	Global Green USA
Stephen Benz	Sasaki
Mark Brumbaugh	Brumbaugh & Associates
Laura Case	Emory University Campus Services
Zach Christeson	the HOK Planning Group
Jay Enck	Commissioning & Green Building Services
Ron Hand	E/FECT. Sustainable Design Solutions
Richard Heinisch	Acuity Lighting Group
Michael Lane	Lighting Design Lab
Marita Roos	HNTB
Zolna Russell	Hord Coplan Macht, Inc.
Alfred Vick	Ecos Environmental Design, Inc.

Water Efficiency TAG

Neal Billetdeaux, Chair	JJR
John Koeller, Vice-Chair	Alliance for Water Efficiency
David Carlson	Columbia University
Bill Hoffman	H.W. Hoffman and Associates, LLC
Geoff Nara	Civil & Environmental Consultants
Stephanie Tanner	U.S. Environmental Protection Agency
Daniel Yeh	University of South Florida
David Bracciano	Tampa Bay Water
Robert Rubin	NCSU-BAE and McKim & Creed
Winston Huff	SSR Engineers
Robert Benazzi	Jaros Baum & Bolles
Gunnar Baldwin	TOTO USA, INC
Heather Kinkade	Forgotten Rain, LLC
Shabbir Rawalpindiwala	Kohler Company
Bill Wall	Clivus New England, Inc.

Energy & Atmosphere TAG

Greg Kats, Chair	GoodEnergies
Marcus Sheffer, Vice-Chair	7group
Drury Crawley	US Department of Energy
Jay Enck	Commissioning & Green Building Solutions, Inc.
Ellen Franconi	IPMVP and AEC
Mark Frankel	New Buildings Institute
Nathan Gauthier	Harvard Green Campus Initiative
Rusty Hodapp	Dallas/Fort Worth, Energy & Transportation Management
John Hogan	City of Seattle Department of Planning & Development
Bion Howard	Building Environmental Science and Technology
Dan Katzenberger	Engineering, Energy, and the Environment
Bob Maddox	Sterling Planet
Brenda Morawa	BVM Engineering, Inc.
Erik Ring	LPA, Inc.
Michael Rosenberg	Oregon Department of Energy
Mick Schwedler	Trane
Gord Shymko	IPMVP and G.F. Shymko & Associates
Gail Stranske	CTG Energetics
Michael Zimmer	Thompson Hine LLP

Materials & Resources TAG

Mark Webster, Chair	Simpson Gumpertz & Heger
Steven Baer, Vice Chair	Five Winds International
Paul Bertram	NAIMA
Chris Dixon	NBBJ
Ann Edminster	Design AVEnues
Lee Gros	Lee Gros Architect and Artisan, Inc
Theresa Hogerheide-Reusch	Reusch Design Services
Nadav Malin	BuildingGreen, LLC.

Nancy Malone	Siegel & Strain Architects
Kirsten Ritchie	Gensler
Wayne Trusty	Athena Sustainable Materials Institute
Denise Van Valkenburg	MASCO Retail Cabinet Group
Gabe Wing	Herman Miller, Inc.

Indoor Environmental Quality TAG

Bob Thompson, Chair	EPA Indoor Environment Management Branch
Steve Taylor, Vice-Chair	Taylor Engineering
Nancy Clanton	Clanton and Associates
Alexis Kurtz	Ove Arup &Partners
George Loisos	Loisos+ Ubelohde
Prasad Vaidya	The Weidt Group
Daniel Bruck	BRC Acoustics & Tech.
David Lubman	David Lubman & Associates
Charles Salter	Salter Associates
Ozgem Ornektekin	DMJM Harris
Jude Anders	Shoreline Concepts, LLC
Brian Cloward	Mithun Architects+Designers+Planners
Larry Dykhuis	Herman Miller, Inc
Francis (Bud) Offerman	Indoor Environmental Engineering
Christopher Schaffner	The Green Engineer
Dennis Stanke	Trane Company

The LEED 2009 for New Construction Rating System builds on the work of those who helped create previous versions:

LEED for New Construction Version 2.2 Core Committee

James H. Goldman, Chair	Turner Construction
Tom Scarola, Vice-Chair	Tishman Speyer Properties
Lee Burgett	Trane Company
Craig Kneeland	NYSERDA
Joe Higgins	Fidelity Real Estate Company
Harry Gordon	Burt Hill Kosar Rittelmann Associates
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Chris Dixon	Mithun
Bill Odell	HOK Architects
Chris Schaffner	The Green Engineer
Wayne Trusty	Athena Sustainable Materials Institute
Jerry Yudelson	Greenway Consulting Group, LLC
Charlotte Matthews	Bovis Lend Lease
John McFarland	WorkingBuildings LLC
Prasad Vaidya	The Weidt Group
Aalok Deshmuk	The Rocky Mountain Institute

LEED 2009 FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS PROJECT CHECKLIST

Sustainable Sites			**26 Possible Points**
☑	Prerequisite 1	Construction Activity Pollution Prevention	Required
☐	Credit 1	Site Selection	1
☐	Credit 2	Development Density and Community Connectivity	5
☐	Credit 3	Brownfield Redevelopment	1
☐	Credit 4.1	Alternative Transportation—Public Transportation Access	6
☐	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
☐	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
☐	Credit 4.4	Alternative Transportation—Parking Capacity	2
☐	Credit 5.1	Site Development—Protect or Restore Habitat	1
☐	Credit 5.2	Site Development—Maximize Open Space	1
☐	Credit 6.1	Stormwater Design—Quantity Control	1
☐	Credit 6.2	Stormwater Design—Quality Control	1
☐	Credit 7.1	Heat Island Effect—Nonroof	1
☐	Credit 7.2	Heat Island Effect—Roof	1
☐	Credit 8	Light Pollution Reduction	1

Water Efficiency			**10 Possible Points**
☑	Prerequisite 1	Water Use Reduction	Required
☐	Credit 1	Water Efficient Landscaping	2-4
☐	Credit 2	Innovative Wastewater Technologies	2
☐	Credit 3	Water Use Reduction	2-4

Energy and Atmosphere			**35 Possible Points**
☑	Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required
☑	Prerequisite 2	Minimum Energy Performance	Required
☑	Prerequisite 3	Fundamental Refrigerant Management	Required
☐	Credit 1	Optimize Energy Performance	1–19
☐	Credit 2	On-site Renewable Energy	1–7
☐	Credit 3	Enhanced Commissioning	2
☐	Credit 4	Enhanced Refrigerant Management	2
☐	Credit 5	Measurement and Verification	3
☐	Credit 6	Green Power	2

Materials and Resources			**14 Possible Points**
☑	Prerequisite 1	Storage and Collection of Recyclables	Required
☐	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors and Roof	1-3
☐	Credit 1.2	Building Reuse—Maintain Existing Interior Nonstructural Elements	1
☐	Credit 2	Construction Waste Management	1-2
☐	Credit 3	Materials Reuse	1-2
☐	Credit 4	Recycled Content	1-2

☐	Credit 5	Regional Materials	1-2
☐	Credit 6	Rapidly Renewable Materials	1
☐	Credit 7	Certified Wood	1

Indoor Environmental Quality — 15 Possible Points

☑	Prerequisite 1	Minimum Indoor Air Quality Performance	Required
☑	Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required
☐	Credit 1	Outdoor Air Delivery Monitoring	1
☐	Credit 2	Increased Ventilation	1
☐	Credit 3.1	Construction Indoor Air Quality Management Plan—During Construction	1
☐	Credit 3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	1
☐	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
☐	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
☐	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
☐	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
☐	Credit 5	Indoor Chemical and Pollutant Source Control	1
☐	Credit 6.1	Controllability of Systems—Lighting	1
☐	Credit 6.2	Controllability of Systems—Thermal Comfort	1
☐	Credit 7.1	Thermal Comfort—Design	1
☐	Credit 7.2	Thermal Comfort—Verification	1
☐	Credit 8.1	Daylight and Views—Daylight	1
☐	Credit 8.2	Daylight and Views—Views	1

Innovation in Design — 6 Possible Points

☐	Credit 1	Innovation in Design	1-5
☐	Credit 2	LEED Accredited Professional	1

Regional Priority — 4 Possible Points

☐	Credit 1	Regional Priority	1-4

LEED 2009 for New Construction and Major Renovations

100 base points; 6 possible Innovation in Design and 4 Regional Priority points

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

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INTRODUCTION

I. LEED® GREEN BUILDING RATING SYSTEM

Background on LEED®

Following the formation of the U.S. Green Building Council (USGBC) in 1993, the organization's members quickly realized that the sustainable building industry needed a system to define and measure "green buildings." USGBC began to research existing green building metrics and rating systems. Less than a year after formation, the members acted on the initial findings by establishing a committee to focus solely on this topic. The composition of the committee was diverse; it included architects, real estate agents, a building owner, a lawyer, an environmentalist, and industry representatives. This cross section of people and professions added a richness and depth both to the process and to the ultimate product.

The first LEED Pilot Project Program, also referred to as LEED Version 1.0, was launched at the USGBC Membership Summit in August 1998. After extensive modifications, LEED Green Building Rating System Version 2.0 was released in March 2000, with LEED Version 2.1 following in 2002 and LEED Version 2.2 following in 2005.

As LEED has evolved and matured, the program has undertaken new initiatives. In addition to a rating system specifically devoted to building operational and maintenance issues (LEED for Existing Buildings: Operations & Maintenance), LEED addresses the different project development and delivery processes that exist in the U.S. building design and construction market, through rating systems for specific building typologies, sectors, and project scopes: LEED for Core & Shell, LEED for New Construction, LEED for Schools, LEED for Neighborhood Development, LEED for Retail, LEED for Healthcare, LEED for Homes, and LEED for Commercial Interiors.

Project teams interact with the Green Building Certification Institute (GBCI) for project registration

and certification. GBCI was established in 2008 as a separately incorporated entity with the support of the U.S. Green Building Council. GBCI administers credentialing and certification programs related to green building practice. These programs support the application of proven strategies for increasing and measuring the performance of buildings and communities as defined by industry systems such as LEED.

The green building field is growing and changing daily. New technologies and products are being introduced into the marketplace, and innovative designs and practices are proving their effectiveness. The LEED rating systems and reference guides will evolve as well. Project teams must comply with the version of the rating system that is current at the time of their registration.

USGBC will highlight new developments on its website on a continual basis at www.usgbc.org.

Features of LEED®

The LEED Green Building Rating Systems are voluntary, consensus-based, and market-driven. Based on existing and proven technology, they evaluate environmental performance from a whole building perspective over a building's life cycle, providing a definitive standard for what constitutes a green building in design, construction, and operation.

The LEED rating systems are designed for rating new and existing commercial, institutional, and residential buildings. They are based on accepted energy and environmental principles and strike a balance between known, established practices and emerging concepts. Each rating system is organized into 5 environmental categories:

Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality. An additional category, Innovation in Design, addresses sustainable building expertise as well as design measures not covered under the 5 environmental categories. Regional bonus points are another feature of LEED and acknowledge the importance of local conditions in determining best environmental design and construction practices.

The LEED Credit Weightings

In LEED 2009, the allocation of points between credits is based on the potential environmental impacts and human benefits of each credit with respect to a set of impact categories. The impacts are defined as the environmental or human effect of the design, construction, operation, and maintenance of the building, such as greenhouse gas emissions, fossil fuel use, toxins and carcinogens, air and water pollutants, indoor environmental conditions. A combination of approaches, including energy modeling, life-cycle assessment, and transportation analysis, is used to quantify each type of impact. The resulting allocation of points among credits is called credit weighting.

LEED 2009 uses the U.S. Environmental Protection Agency's TRACI[1] environmental impact categories as the basis for weighting each credit. TRACI was developed to assist with impact evaluation for life-cycle assessment, industrial ecology, process design, and pollution prevention.

LEED 2009 also takes into consideration the weightings developed by the National Institute of Standards and Technology (NIST); these compare impact categories with one another and assign a relative weight to each. Together, the 2 approaches provide a solid foundation for determining the point value of each credit in LEED 2009.

The LEED 2009 credit weightings process is based on the following parameters, which maintain consistency and usability across rating systems:

- All LEED credits are worth a minimum of 1 point.
- All LEED credits are positive, whole numbers; there are no fractions or negative values.
- All LEED credits receive a single, static weight in each rating system; there are no individualized scorecards based on project location.
- All LEED rating systems have 100 base points; Innovation in Design (or Operations) and Regional Priority credits provide opportunities for up to 10 bonus points.

Given the above criteria, the LEED 2009 credit weightings process involves 3 steps:

1. A reference building is used to estimate the environmental impacts in 13 categories associated with a typical building pursuing LEED certification.
2. The relative importance of building impacts in each category are set to reflect values based on the NIST weightings.[2]
3. Data that quantify building impacts on environmental and human health are used to assign points to individual credits.

Each credit is allocated points based on the relative importance of the building-related impacts that it addresses. The result is a weighted average that combines building impacts and the relative value of the impact categories. Credits that most directly address the most important impacts are given the greatest weight, subject to the system design parameters described above. Credit weights also reflect a decision by LEED to recognize the market implications of point allocation. The result is a significant change in allocation of points compared with previous LEED rating systems. Overall, the changes increase the relative emphasis on the reduction of energy consumption and greenhouse gas emissions associated with building systems, transportation, the embodied energy of water, the embodied energy of materials, and where applicable, solid waste.

The details of the weightings process vary slightly among individual rating systems. For example, LEED for Existing Buildings: Operations & Maintenance includes credits related to solid waste management but LEED for New Construction does not. This results in a difference in the portion of the environmental footprint addressed by each rating system and the relative allocation of points. The weightings process for each rating system is fully documented in a weightings workbook.

The credit weightings process will be reevaluated over time to incorporate changes in values ascribed to different building impacts and building types, based on both market reality and evolving scientific knowledge related to buildings. A complete explanation of the LEED credit weightings system is available on the USGBC website, at www.usgbc.org.

Regional Priority Credits

To provide incentive to address geographically specific environmental issues, USGBC regional councils and chapters have identified 6 credits per rating system that are of particular importance to specific areas. Each regional priority credit is worth an additional 1 point, and a total of 4 regional priority points may be earned. Upon project registration, LEED Online automatically determines a project's regional priority credits based on its zip code. If the project achieves more than 4 regional priority credits, the team can choose the credits for which these points will apply. The USGBC website also contains a searchable database of regional priority credits.

II. OVERVIEW AND PROCESS

The LEED 2009 Green Building Rating System for New Construction and Major Renovations is a set of performance standards for certifying the design and construction of commercial or institutional buildings and high-rise residential buildings of all sizes, both public and private. The intent is to promote healthful, durable, affordable, and environmentally sound practices in building design and construction.

Prerequisites and credits in the LEED 2009 for New Construction and Major Renovations addresses 7 topics:

- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy and Atmosphere (EA)
- Materials and Resources (MR)
- Indoor Environmental Quality (IEQ)
- Innovation in Design (ID)
- Regional Priority (RP)

LEED 2009 for New Construction and Major Renovations certifications are awarded according to the following scale:

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

GBCI will recognize buildings that achieve 1 of these rating levels with a formal letter of certification.

When to Use LEED 2009 for New Construction

LEED for New Construction was designed primarily for new commercial office buildings, but it has been applied to many other building types by LEED practitioners. All commercial buildings, as defined by standard building codes, are eligible for certification as LEED for New Construction buildings. Examples of commercial occupancies include offices, institutional buildings (libraries, museums, churches, etc.), hotels, and residential buildings of 4 or more habitable stories.

LEED for New Construction addresses design and construction activities for both new buildings and major renovations of existing buildings. If the project scope does not involve significant design and construction activities and focuses more on operations and maintenance activities, LEED for Existing Buildings: Operations & Maintenance is more appropriate because it addresses operational and maintenance issues of working buildings.

Please see the Rating System Selection Policy, located in the LEED resources section of www.usgbc.org, for more information about choosing a rating system.

Registration

Project teams interested in earning LEED certification for their buildings must first register the project with GBCI. Projects can be registered on the GBCI website (www.gbci.org). The website also has information on registration costs for USGBC national members as well as nonmembers. Registration is an important step that establishes contact with GBCI and provides access to software tools, errata, critical communications, and other essential information.

Certification

To earn LEED certification, the applicant project must satisfy all the prerequisites and qualify for a minimum number of points to attain the established project ratings as listed below. Having satisfied the basic prerequisites of the program, applicant projects are then rated according to their degree of compliance within the rating system.

LEED 2009 for New Construction provides the option of splitting a certification application into two phases: design and construction. Documentation for design phase credits, identified in LEED-Online, can be submitted for review at the end of the design phase; the submittals for these credits can be fully evaluated based on documentation available during this phase of the project. For example, if a project site meets the requirements of LEED for New Construction SS Credit 3, Brownfield Redevelopment, the likelihood of credit achievement can be assessed before construction is complete. The LEED credit itself, however, is not awarded at the design review stage.

For more information on the LEED certification process including LEED-Online, Credit Interpretation Requests and Rulings, Appeals, and Fees please see the LEED Reference Guide for Green Building Design and Construction, 2009 Edition and visit www.usgbc.org or www.gbci.org.

III. MINIMUM PROGRAM REQUIREMENTS

The LEED 2009 Minimum Program Requirements (MPRs) define the minimum characteristics that a project must possess in order to be eligible for certification under LEED 2009. These requirements define the categories of buildings that the LEED rating systems were designed to evaluate, and taken together serve three goals: to give clear guidance to customers, to protect the integrity of the LEED program, and to reduce challenges that occur during the LEED certification process. It is expected that MPRs will evolve over time along with LEED rating system improvements. The requirements will apply only to those projects registering under LEED 2009.

To view the MPRs and the MPR Supplemental Guidance, visit the LEED Resources and Tools section of www.usgbc.org/projecttools.

IV. EXEMPLARY PERFORMANCE STRATEGIES

Exemplary performance strategies result in performance that greatly exceeds the performance level or expands the scope required by an existing LEED 2009 for New Construction credit. To earn exemplary performance credits, teams must meet the performance level defined by the next step in the threshold progression. For credits with more than 1 compliance path, an Innovation in Design point can be earned by satisfying more than 1 compliance path if their benefits are additive.

The credits for which exemplary performance points are available through expanded performance or scope are noted in the LEED Reference Guide for Green Design & Construction, 2009 Edition and in LEED Online.

Endnotes

1 Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). U.S. Environmental Protection Agency, Office of Research and Development. http://www.epa.gov/nrmrl/std/sab/traci/.

2 Relative impact category weights based on an exercise undertaken by NIST (National Institute of Standards and Technology) for the BEES program. http://www.bfrl.nist.gov/oae/software/bees/.

SS Prerequisite 1: Construction Activity Pollution Prevention

Required

Intent
To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation.

Requirements
Create and implement an erosion and sedimentation control plan for all construction activities associated with the project. The plan must conform to the erosion and sedimentation requirements of the 2003 EPA Construction General Permit OR local standards and codes, whichever is more stringent. The plan must describe the measures implemented to accomplish the following objectives:

- To prevent loss of soil during construction by stormwater runoff and/or wind erosion, including protecting topsoil by stockpiling for reuse.
- To prevent sedimentation of storm sewers or receiving streams.
- To prevent pollution of the air with dust and particulate matter.

The EPA's construction general permit outlines the provisions necessary to comply with Phase I and Phase II of the National Pollutant Discharge Elimination System (NPDES) program. While the permit only applies to construction sites greater than 1 acre, the requirements are applied to all projects for the purposes of this prerequisite. Information on the EPA construction general permit is available at http://cfpub.epa.gov/npdes/stormwater/cgp.cfm.

Potential Technologies & Strategies
Create an erosion and sedimentation control plan during the design phase of the project. Consider employing strategies such as temporary and permanent seeding, mulching, earthen dikes, silt fencing, sediment traps and sediment basins.

SS Credit 1: Site Selection

1 Point

Intent

To avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site.

Requirements

Do not develop buildings, hardscape, roads or parking areas on portions of sites that meet any of the following criteria:

- Prime farmland as defined by the U.S. Department of Agriculture in the United States Code of Federal Regulations, Title 7, Volume 6, Parts 400 to 699, Section 657.5 (citation 7CFR657.5)
- Previously undeveloped land whose elevation is lower than 5 feet above the elevation of the 100-year flood as defined by the Federal Emergency Management Agency (FEMA)
- Land specifically identified as habitat for any species on federal or state threatened or endangered lists
- Land within 100 feet of any wetlands as defined by the U.S. Code of Federal Regulations 40 CFR, Parts 230-233 and Part 22, and isolated wetlands or areas of special concern identified by state or local rule, OR within setback distances from wetlands prescribed in state or local regulations, as defined by local or state rule or law, whichever is more stringent
- Previously undeveloped land that is within 50 feet of a water body, defined as seas, lakes, rivers, streams and tributaries that support or could support fish, recreation or industrial use, consistent with the terminology of the Clean Water Act
- Land that prior to acquisition for the project was public parkland, unless land of equal or greater value as parkland is accepted in trade by the public landowner (park authority projects are exempt).

Potential Technologies & Strategies

During the site selection process, give preference to sites that do not include sensitive elements or restrictive land types. Select a suitable building location and design the building with a minimal footprint to minimize disruption of the environmentally sensitive areas identified above.

SS Credit 2: Development Density and Community Connectivity

5 Points

Intent

To channel development to urban areas with existing infrastructure, protect greenfields, and preserve habitat and natural resources.

Requirements

OPTION 1. Development Density

Construct or renovate a building on a previously developed site AND in a community with a minimum density of 60,000 square feet per acre net. The density calculation is based on a typical two-story downtown development and must include the area of the project being built.

OR

OPTION 2. Community Connectivity

Construct or renovate a building on a site that meets the following criteria:

- Is located on a previously developed site
- Is within 1/2 mile of a residential area or neighborhood with an average density of 10 units per acre net
- Is within 1/2 mile of at least 10 basic services
- Has pedestrian access between the building and the services

For mixed-use projects, no more than 1 service within the project boundary may be counted as 1 of the 10 basic services, provided it is open to the public. No more than 2 of the 10 services required may be anticipated (i.e., at least 8 must be existing and operational). In addition, the anticipated services must demonstrate that they will be operational in the locations indicated within 1 year of occupation of the applicant project.

Examples of basic services include the following:

- Bank
- Place of Worship
- Convenience Grocery
- Day Care Center
- Cleaners
- Fire Station
- Beauty Salon
- Hardware
- Laundry
- Library
- Medical or Dental Office
- Senior Care Facility
- Park
- Pharmacy
- Post Office
- Restaurant
- School
- Supermarket
- Theater
- Community Center
- Fitness Center
- Museum

Proximity is determined by drawing a 1/2-mile radius around a main building entrance on a site map and counting the services within that radius.

Potential Technologies & Strategies

During the site selection process, give preference to urban sites with pedestrian access to a variety of services.

SS Credit 3: Brownfield Redevelopment

1 Point

Intent

To rehabilitate damaged sites where development is complicated by environmental contamination and to reduce pressure on undeveloped land.

Requirements

OPTION 1

Develop on a site documented as contaminated (by means of an ASTM E1903-97 Phase II Environmental Site Assessment or a local voluntary cleanup program).

OR

OPTION 2

Develop on a site defined as a brownfield by a local, state, or federal government agency.

For projects where asbestos is found and remediated also earn this credit. Testing should be done in accordance with EPA Reg 40CFR part 763, when applicable.

Potential Technologies & Strategies

During the site selection process, give preference to brownfield sites. Identify tax incentives and property cost savings. Coordinate site development plans with remediation activity, as appropriate.

SS Credit 4.1: Alternative Transportation—Public Transportation Access

6 Points

Intent

To reduce pollution and land development impacts from automobile use.

Requirements

OPTION 1. Rail Station Proximity

Locate the project within 1/2-mile walking distance (measured from a main building entrance) of an existing or planned and funded commuter rail, light rail or subway station.

OR

OPTION 2. Bus Stop Proximity

Locate the project within 1/4-mile walking distance (measured from a main building entrance) of 1 or more stops for 2 or more public, campus, or private bus lines usable by building occupants.

Potential Technologies & Strategies

Perform a transportation survey of future building occupants to identify transportation needs. Locate the building near mass transit.

SS Credit 4.2: Alternative Transportation—Bicycle Storage and Changing Rooms

1 Point

Intent

To reduce pollution and land development impacts from automobile use.

Requirements

CASE 1. Commercial or Institutional Projects

Provide secure bicycle racks and/or storage within 200 yards of a building entrance for 5% or more of all building users (measured at peak periods)

Provide shower and changing facilities in the building, or within 200 yards of a building entrance, for 0.5% of full-time equivalent (FTE) occupants.

CASE 2. Residential Projects

Provide covered storage facilities for securing bicycles for 15% or more of building occupants.

Potential Technologies & Strategies

Design the building with transportation amenities such as bicycle racks and shower/changing facilities.

SS Credit 4.3: Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles

3 Points

Intent

To reduce pollution and land development impacts from automobile use.

Requirements

OPTION 1

Provide preferred parking[1] for low-emitting and fuel-efficient vehicles[2] for 5% of the total vehicle parking capacity of the site. Providing a discounted parking rate is an acceptable substitute for preferred parking for low-emitting/ fuel-efficient vehicles. To establish a meaningful incentive in all potential markets, the parking rate must be discounted at least 20%. The discounted rate must be available to all customers (i.e., not limited to the number of customers equal to 5% of the vehicle parking capacity), publicly posted at the entrance of the parking area and available for a minimum of 2 years.

OR

OPTION 2

Install alternative-fuel fueling stations for 3% of the total vehicle parking capacity of the site. Liquid or gaseous fueling facilities must be separately ventilated or located outdoors.

OR

OPTION 3

Provide low-emitting and fuel-efficient vehicles[2] for 3% of full-time equivalent (FTE) occupants.

Provide preferred parking[1] for these vehicles.

OR

OPTION 4

Provide building occupants access to a low-emitting or fuel-efficient vehicle-sharing program. The following requirements must be met:

- One low-emitting or fuel-efficient vehicle must be provided per 3% of FTE occupants, assuming that 1 shared vehicle can carry 8 persons (i.e., 1 vehicle per 267 FTE occupants). For buildings with fewer than 267 FTE occupants, at least 1 low emitting or fuel-efficient vehicle must be provided.
- A vehicle-sharing contract must be provided that has an agreement of at least 2 years.

1 For the purposes of this credit "preferred parking" refers to the parking spots that are closest to the main entrance of the project (exclusive of spaces designated for handicapped persons) or parking passes provided at a discounted price.

2 For the purposes of this credit, low-emitting and fuel-efficient vehicles are defined as vehicles that are either classified as Zero Emission Vehicles (ZEV) by the California Air Resources Board or have achieved a minimum green score of 40 on the American Council for an Energy Efficient Economy (ACEEE) annual vehicle rating guide.

- The estimated number of customers served per vehicle must be supported by documentation.
- A narrative explaining the vehicle-sharing program and its administration must be submitted.
- Parking for low-emitting and fuel-efficient vehicles must be located in the nearest available spaces in the nearest available parking area. Provide a site plan or area map clearly highlighting the walking path from the parking area to the project site and noting the distance.

Potential Technologies & Strategies

Provide transportation amenities such as alternative-fuel refueling stations. Consider sharing the costs and benefits of refueling stations with neighbors.

SS Credit 4.4: Alternative Transportation—Parking Capacity

2 Points

Intent

To reduce pollution and land development impacts from automobile use.

Requirements

CASE 1. Non-Residential Projects

OPTION 1

Size parking capacity to meet but not exceed minimum local zoning requirements.

Provide preferred parking for carpools or vanpools for 5% of the total parking spaces.

OR

OPTION 2

For projects that provide parking for less than 5% of full-time equivalent (FTE) building occupants:

Provide preferred parking[1] for carpools or vanpools, marked as such, for 5% of total parking spaces. Providing a discounted parking rate is an acceptable substitute for preferred parking for carpool or vanpool vehicles. To establish a meaningful incentive in all potential markets, the parking rate must be discounted at least 20%. The discounted rate must be available to all customers (i.e., not limited to the number of customers equal to 5% of the vehicle parking capacity), publicly posted at the entrance of the parking area, and available for a minimum of 2 years.

OR

OPTION 3

Provide no new parking.

OR

OPTION 4

For projects that have no minimum local zoning requirements, provide 25% fewer parking spaces than the applicable standard listed in the 2003 Institute of Transportation Engineers (ITE) "Parking Generation" study at http://www.ite.org.

CASE 2. Residential Projects

OPTION 1

Size parking capacity to meet but not exceed minimum local zoning requirements

Provide infrastructure and support programs to facilitate shared vehicle use such as carpool drop-off areas, designated parking for vanpools, car-share services, ride boards and shuttle services to mass transit.

1 For the purposes of this credit "preferred parking" refers to the parking spots that are closest to the main entrance of the project (exclusive of spaces designated for handicapped persons) or parking passes provided at a discounted price.

OR

OPTION 2

Provide no new parking.

CASE 3. Mixed Use (Residential with Commercial/Retail) Projects

OPTION 1

Mixed-use buildings with less than 10% commercial area must be considered residential and adhere to the residential requirements in Case 2. For mixed-use buildings with more than 10% commercial area, the commercial space must adhere to non-residential requirements in Case 1 and the residential component must adhere to residential requirements in Case 2.

OR

OPTION 2

Provide no new parking.

Potential Technologies & Strategies

Minimize parking lot/garage size. Consider sharing parking facilities with adjacent buildings. Consider alternatives that will limit the use of single occupancy vehicles.

SS Credit 5.1: Site Development—Protect or Restore Habitat

1 Point

Intent

To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

Requirements

CASE 1. Greenfield Sites[1]

Limit all site disturbance to the following parameters:

- 40 feet beyond the building perimeter;
- 10 feet beyond surface walkways, patios, surface parking and utilities less than 12 inches in diameter;
- 15 feet beyond primary roadway curbs and main utility branch trenches;
- 25 feet beyond constructed areas with permeable surfaces (such as pervious paving areas, stormwater detention facilities and playing fields) that require additional staging areas to limit compaction in the constructed area.

CASE 2. Previously Developed[2] Areas or Graded Sites

Restore or protect a minimum of 50% of the site (excluding the building footprint) or 20% of the total site area (including building footprint), whichever is greater, with native or adapted vegetation[3]. Projects earning SS Credit 2: Development Density and Community Connectivity may include vegetated roof surface in this calculation if the plants are native or adapted, provide habitat, and promote biodiversity.

Projects with limited landscape opportunities may also donate offsite land in perpetuity, equal to 60% of the previously developed area (including the building footprint), to a land trust within the same EPA Level III Ecoregion identified for the project site. The land trust must adhere to the Land Trust Alliance 'Land Trust Standards and Practices' 2004 Revision.

Potential Technologies & Strategies

Survey greenfield sites to identify site elements and adopt a master plan for developing the project site. Carefully site the building to minimize disruption to existing ecosystems and design the building to minimize its footprint. Strategies include stacking the building program, tuck-under parking and sharing parking facilities with neighbors. Establish clearly-marked construction boundaries to minimize disturbance of the existing site and restore previously degraded areas to their natural state. For previously developed sites, use local and regional governmental agencies, consultants, educational facilities and native plant societies as resources for the selection of appropriate native or adapted plants. Prohibit plants listed as invasive or noxious weed species. Once established, native/adapted plants require minimal or no irrigation; do not require active maintenance such as mowing or chemical inputs such as fertilizers, pesticides or herbicides; and provide habitat value and promote biodiversity through avoidance of monoculture plantings.

1 Greenfield sites are those that are not previously developed or graded and remain in a natural state.
2 Previously developed areas are those that previously contained buildings, roadways, parking lots or were graded or altered by direct human activities.
3 Native or adapted plants are plants indigenous to a locality or cultivars of native plants that are adapted to the local climate and are not considered invasive species or noxious weeds.

SS Credit 5.2: Site Development—Maximize Open Space

1 Point

Intent

To promote biodiversity by providing a high ratio of open space to development footprint.

Requirements

CASE 1. Sites with Local Zoning Open Space Requirements

Reduce the development footprint[1] and/or provide vegetated open space within the project boundary such that the amount of open space exceeds local zoning requirements by 25%.

CASE 2. Sites with No Local Zoning Requirements (e.g. some university campuses, military bases)

Provide a vegetated open space area adjacent to the building that is equal in area to the building footprint.

CASE 3. Sites with Zoning Ordinances but No Open Space Requirements

Provide vegetated open space equal to 20% of the project site area.

ALL CASES

For projects in urban areas that earn SS Credit 2: Development Density and Community Connectivity, vegetated roof areas can contribute to credit compliance.

For projects in urban areas that earn SS Credit 2: Development Density and Community Connectivity, pedestrian-oriented hardscape areas can contribute to credit compliance. For such projects, a minimum of 25% of the open space counted must be vegetated.

Wetlands or naturally designed ponds may count as open space and the side slope gradients average 1:4 (vertical: horizontal) or less and are vegetated.

Potential Technologies & Strategies

Perform a site survey to identify site elements and adopt a master plan for developing the project site. Select a suitable building location and design the building footprint to minimize site disruption. Strategies include stacking the building program, tuck-under parking and sharing parking facilities with neighbors to maximize the amount of open space on the site.

1 Development footprint is defined as the total area of the building footprint, hardscape, access roads and parking.

SS Credit 6.1: Stormwater Design—Quantity Control

1 Point

Intent

To limit disruption of natural hydrology by reducing impervious cover, increasing on-site infiltration, reducing or eliminating pollution from stormwater runoff and eliminating contaminants.

Requirements

CASE 1. Sites with Existing Imperviousness 50% or Less

OPTION 1

Implement a stormwater management plan that prevents the postdevelopment peak discharge rate and quantity from exceeding the predevelopment peak discharge rate and quantity for the 1- and 2-year 24-hour design storms.

OR

OPTION 2

Implement a stormwater management plan that protects receiving stream channels from excessive erosion. The stormwater management plan must include stream channel protection and quantity control strategies.

CASE 2. Sites with Existing Imperviousness Greater Than 50%

Implement a stormwater management plan that results in a 25% decrease in the volume of stormwater runoff from the 2-year 24-hour design storm.

Potential Technologies & Strategies

Design the project site to maintain natural stormwater flows by promoting infiltration. Specify vegetated roofs, pervious paving and other measures to minimize impervious surfaces. Reuse stormwater for non-potable uses such as landscape irrigation, toilet and urinal flushing, and custodial uses.

SS Credit 6.2: Stormwater Design—Quality Control

1 Point

Intent

To limit disruption and pollution of natural water flows by managing stormwater runoff.

Requirements

Implement a stormwater management plan that reduces impervious cover, promotes infiltration and captures and treats the stormwater runoff from 90% of the average annual rainfall[1] using acceptable best management practices (BMPs).

BMPs used to treat runoff must be capable of removing 80% of the average annual postdevelopment total suspended solids (TSS) load based on existing monitoring reports. BMPs are considered to meet these criteria if:

- They are designed in accordance with standards and specifications from a state or local program that has adopted these performance standards,

OR

- There exists infield performance monitoring data demonstrating compliance with the criteria. Data must conform to accepted protocol (e.g., Technology Acceptance Reciprocity Partnership [TARP], Washington State Department of Ecology) for BMP monitoring.

Potential Technologies & Strategies

Use alternative surfaces (e.g., vegetated roofs, pervious pavement, grid pavers) and nonstructural techniques (e.g., rain gardens, vegetated swales, disconnection of imperviousness, rainwater recycling) to reduce imperviousness and promote infiltration and thereby reduce pollutant loadings.

Use sustainable design strategies (e.g., low-impact development, environmentally sensitive design) to create integrated natural and mechanical treatment systems such as constructed wetlands, vegetated filters and open channels to treat stormwater runoff.

1 There are 3 distinct climates in the United States that influence the nature and amount of annual rainfall. Humid watersheds are defined as those that receive at least 40 inches of rainfall each year. Semiarid watersheds receive between 20 and 40 inches of rainfall per year, and arid watersheds receive less than 20 inches of rainfall per year. For this credit, 90% of the average annual rainfall is equivalent to treating the runoff from the following (based on climate):
- Humid Watersheds — 1 inch of rainfall
- Semiarid Watersheds — 0.75 inches of rainfall
- Arid Watersheds — 0.5 inches of rainfall

SS Credit 7.1: Heat Island Effect—Nonroof

1 Point

Intent

To reduce heat islands[1] to minimize impacts on microclimates and human and wildlife habitats.

Requirements

OPTION 1

Use any combination of the following strategies for 50% of the site hardscape (including roads, sidewalks, courtyards and parking lots):

- Provide shade from the existing tree canopy or within 5 years of landscape installation. Landscaping (trees) must be in place at the time of occupancy.
- Provide shade from structures covered by solar panels that produce energy used to offset some nonrenewable resource use.
- Provide shade from architectural devices or structures that have a solar reflectance index[2] (SRI) of at least 29.
- Use hardscape materials with an SRI of at least 29.
- Use an open-grid pavement system (at least 50% pervious).

OR

OPTION 2

Place a minimum of 50% of parking spaces under cover[3]. Any roof used to shade or cover parking must have an SRI of at least 29, be a vegetated green roof or be covered by solar panels that produce energy used to offset some nonrenewable resource use.

Potential Technologies & Strategies

Employ strategies, materials and landscaping techniques that reduce the heat absorption of exterior materials. Use shade (calculated on June 21, noon solar time) from native or adapted trees and large shrubs, vegetated trellises or other exterior structures supporting vegetation. Consider using new coatings and integral colorants for asphalt to achieve light-colored surfaces instead of blacktop. Position photovoltaic cells to shade impervious surfaces.

Consider replacing constructed surfaces (e.g., roof, roads, sidewalks, etc.) with vegetated surfaces such as vegetated roofs and open grid paving or specify high-albedo materials, such as concrete, to reduce heat absorption.

1 Heat islands are defined as thermal gradient differences between developed and undeveloped areas.
2 The solar reflectance index (SRI) is a measure of the constructed surface's ability to reflect solar heat, as shown by a small temperature rise. It is defined so that a standard black surface (reflectance 0.05, emittance 0.90) is 0 and a standard white surface (reflectance 0.80, emittance 0.90) is 100. To calculate the SRI for a given material, obtain the reflectance value and emittance value for the material. SRI is calculated according to ASTM E 1980. Reflectance is measured according to ASTM E 903, ASTM E 1918, or ASTM C 1549. Emittance is measured according to ASTM E 408 or ASTM C 1371.
3 For the purposes of this credit, under cover parking is defined as parking underground, under deck, under roof, or under a building.

SS Credit 7.2: Heat Island Effect—Roof

1 Point

Intent

To reduce heat islands[1] to minimize impacts on microclimates and human and wildlife habitats.

Requirements

OPTION 1

Use roofing materials with a solar reflectance index[2] (SRI) equal to or greater than the values in the table below for a minimum of 75% of the roof surface.

Roofing materials having a lower SRI value than those listed below may be used if the weighted rooftop SRI average meets the following criteria:

$$\frac{\text{Area Roof Meeting Minimum SRI}}{\text{Total Roof Area}} \times \frac{\text{SRI of Installed Roof}}{\text{Required SRI}} \geq 75\%$$

Roof Type	Slope	SRI
Low-sloped roof	≤ 2:12	78
Steep-sloped roof	> 2:12	29

OR

OPTION 2

Install a vegetated roof that covers at least 50% of the roof area.

OR

OPTION 3

Install high-albedo and vegetated roof surfaces that, in combination, meet the following criteria:

$$\frac{\text{Area Roof Meeting Minimum SRI}}{0.75} + \frac{\text{Area of Vegetated Roof}}{0.5} \geq \text{Total Roof Area}$$

Roof Type	Slope	SRI
Low-sloped roof	≤ 2:12	78
Steep-sloped roof	> 2:12	29

1 Heat islands are defined as thermal gradient differences between developed and undeveloped areas.

2 The solar reflectance index (SRI) is a measure of the constructed surface's ability to reflect solar heat, as shown by a small temperature rise. It is defined so that a standard black surface (reflectance 0.05, emittance 0.90) is 0 and a standard white surface (reflectance 0.80, emittance 0.90) is 100. To calculate the SRI for a given material, obtain the reflectance value and emittance value for the material. SRI is calculated according to ASTM E 1980. Reflectance is measured according to ASTM E 903, ASTM E 1918 or ASTM C 1549. Emittance is measured according to ASTM E 408 or ASTM C 1371.

Potential Technologies & Strategies

Consider installing high-albedo and vegetated roofs to reduce heat absorption. Default values will be available in the LEED Reference Guide for Green Building Design and Construction, 2009 Edition. Product information is available from the Cool Roof Rating Council Web site at http://www.coolroofs.org/ and the ENERGY STAR® Web site at http://www.energystar.gov/.

SS Credit 8: Light Pollution Reduction

1 Point

Intent

To minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve nighttime visibility through glare reduction and reduce development impact from lighting on nocturnal environments.

Requirements

Project teams must comply with 1 of the 2 options for interior lighting AND the requirement for exterior lighting.

For Interior Lighting

OPTION 1

Reduce the input power (by automatic device) of all nonemergency interior luminaires with a direct line of sight to any openings in the envelope (translucent or transparent) by at least 50% between 11 p.m. and 5 a.m. After-hours override may be provided by a manual or occupant-sensing device provided the override lasts no more than 30 minutes.

OR

OPTION 2

All openings in the envelope (translucent or transparent) with a direct line of sight to any nonemergency luminaires must have shielding (controlled/closed by automatic device for a resultant transmittance of less than 10% between 11 p.m. and 5 a.m.).

For Exterior Lighting

Light areas only as required for safety and comfort. Exterior lighting power densities shall not exceed those specified in ANSI/ASHRAE/IESNA Standard 90.1-2007 with Addenda 1 for the documented lighting zone. Justification shall be provided for the selected lighting zone. Lighting controls for all exterior lighting shall comply with section 9.4.1.3 of ANSI/ASHRAE/IESNA Standard 90.1- 2007, without amendments[1].

Classify the project under 1 of the following zones, as defined in IESNA RP-33, and follow all the requirements for that zone:

LZ1: Dark (**developed areas within national parks, state parks, forest land and rural areas**)
Design exterior lighting so that all site and building-mounted luminaires produce a maximum initial illuminance value no greater than 0.01 horizontal and vertical footcandles at the site boundary and beyond. Document that 0% of the total initial designed fixture lumens (sum total of all fixtures on site) are emitted at an angle of 90 degrees or higher from nadir (straight down).

1 The requirement to use ASHRAE Addenda I is unique to this credit and does not obligate Project teams to use ASHRAE approved addenda for other credits.

LZ2: Low (primarily residential zones, neighborhood business districts, light industrial areas with limited nighttime use and residential mixed-use areas)
Design exterior lighting so that all site and building-mounted luminaires produce a maximum initial illuminance value no greater than 0.10 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 10 feet beyond the site boundary. Document that no more than 2% of the total initial designed fixture lumens (sum total of all fixtures on site) are emitted at an angle of 90 degrees or higher from nadir (straight down).

LZ3: Medium (all other areas not included in LZ1, LZ2 or LZ4, such as commercial/ industrial, and high-density residential)
Design exterior lighting so that all site and building-mounted luminaires produce a maximum initial illuminance value no greater than 0.20 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 15 feet beyond the site. Document that no more than 5% of the total initial designed fixture lumens (sum total of all fixtures on site) are emitted at an angle of 90 degrees or higher from nadir (straight down).

LZ4: High[2] (high-activity commercial districts in major metropolitan areas)
Design exterior lighting so that all site and building-mounted luminaires produce a maximum initial illuminance value no greater than 0.60 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 15 feet beyond the site. Document that no more than 10% of the total initial designed fixture lumens (sum total of all fixtures on site) are emitted at an angle of 90 degrees or higher from nadir (straight down).

LZ2, LZ3 and LZ4 - For site boundaries that abut public rights-of-way, light trespass requirements may be met relative to the curb line instead of the site boundary.

For All Zones
Illuminance generated from a single luminaire placed at the intersection of a private vehicular driveway and public roadway accessing the site is allowed to use the centerline of the public roadway as the site boundary for a length of 2 times the driveway width centered at the centerline of the driveway.

Potential Technologies & Strategies

Adopt site lighting criteria to maintain safe light levels while avoiding off-site lighting and night sky pollution. Minimize site lighting where possible, and use computer software to model the site lighting. Technologies to reduce light pollution include full cutoff luminaires, low-reflectance surfaces and low-angle spotlights.

2 To be LZ4, the area must be so designated by an organization with local jurisdiction, such as the local zoning authority.

WATER EFFICIENCY

WE Prerequisite 1: Water Use Reduction

Required

Intent

To increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

Requirements

Employ strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation).

Calculate the baseline according to the commercial and/or residential baselines outlined below.[1] Calculations are based on estimated occupant usage and must include only the following fixtures and fixture fittings (as applicable to the project scope): water closets, urinals, lavatory faucets, showers, kitchen sink faucets and prerinse spray valves.

Commercial Fixtures, Fittings, and Appliances	Current Baseline
Commercial toilets	1.6 gallons per flush (gpf)* Except blow-out fixtures: 3.5 (gpf)
Commercial urinals	1.0 (gpf)
Commercial lavatory (restroom) faucets	2.2 gallons per minute (gpm) at 60 pounds per square inch (psi), private applications only (hotel or motel guest rooms, hospital patient rooms) 0.5 (gpm) at 60 (psi)** all others except private applications 0.25 gallons per cycle for metering faucets
Commercial prerinse spray valves (for food service applications)	Flow rate ≤ 1.6 (gpm) (no pressure specified; no performance requirement)

Residential Fixtures, Fittings, and Appliances	Current Baseline
Residential toilets	1.6 (gpf)***
Residential lavatory (bathroom) faucets	2.2 (gpm) at 60 psi
Residential kitchen faucet	
Residential showerheads	2.5 (gpm) at 80 (psi) per shower stall****

* EPAct 1992 standard for toilets applies to both commercial and residential models.
** In addition to EPAct requirements, the American Society of Mechanical Engineers standard for public lavatory faucets is 0.5 gpm at 60 psi (ASME A112.18.1-2005). This maximum has been incorporated into the national Uniform Plumbing Code and the International Plumbing Code.
*** EPAct 1992 standard for toilets applies to both commercial and residential models.
**** Residential shower compartment (stall) in dwelling units: The total allowable flow rate from all flowing showerheads at any given time, including rain systems, waterfalls, bodysprays, bodyspas and jets, must be limited to the allowable showerhead flow rate as specified above (2.5 gpm) per shower compartment, where the floor area of the shower compartment is less than 2,500 square inches. For each increment of 2,500 square inches of floor area thereafter or part thereof, an additional showerhead with total allowable flow rate from all flowing devices equal to or less than the allowable flow rate as specified above must be allowed. Exception: Showers that emit recirculated nonpotable water originating from within the shower compartment while operating are allowed to exceed the maximum as long as the total potable water flow does not exceed the flow rate as specified above.

1 Tables adapted from information developed and summarized by the U.S. Environmental Protection Agency (EPA) Office of Water based on requirements of the Energy Policy Act (EPAct) of 1992 and subsequent rulings by the Department of Energy, requirements of the EPAct of 2005, and the plumbing code requirements as stated in the 2006 editions of the Uniform Plumbing Code or International Plumbing Code pertaining to fixture performance.

The following fixtures, fittings and appliances are outside the scope of the water use reduction calculation:

- Commercial Steam Cookers
- Commercial Dishwashers
- Automatic Commercial Ice Makers
- Commercial (family sized) Clothes Washers
- Residential Clothes Washers
- Standard and Compact Residential Dishwashers

Potential Technologies & Strategies

WaterSense-certified fixtures and fixture fittings should be used where available. Use high-efficiency fixtures (e.g., water closets and urinals) and dry fixtures, such as toilets attached to composting systems, to reduce potable water demand. Consider using alternative on-site sources of water (e.g., rainwater, stormwater, and air conditioner condensate) and graywater for nonpotable applications such as custodial uses and toilet and urinal flushing. The quality of any alternative source of water used must be taken into consideration based on its application or use.

WE Credit 1: Water Efficient Landscaping

2–4 Points

Intent

To limit or eliminate the use of potable water or other natural surface or subsurface water resources available on or near the project site for landscape irrigation.

Requirements

OPTION 1. Reduce by 50% (2 points)

Reduce potable water consumption for irrigation by 50% from a calculated midsummer baseline case.

Reductions must be attributed to any combination of the following items:

- Plant species, density and microclimate factor
- Irrigation efficiency
- Use of captured rainwater
- Use of recycled wastewater
- Use of water treated and conveyed by a public agency specifically for nonpotable uses

Groundwater seepage that is pumped away from the immediate vicinity of building slabs and foundations may be used for landscape irrigation to meet the intent of this credit. However, the project team must demonstrate that doing so does not affect site stormwater management systems.

OR

OPTION 2. No Potable Water Use or Irrigation[1] (4 points)

Meet the requirements for Option 1.

AND

PATH 1

Use only captured rainwater, recycled wastewater, recycled graywater or water treated and conveyed by a public agency specifically for nonpotable uses for irrigation.

OR

PATH 2

Install landscaping that does not require permanent irrigation systems. Temporary irrigation systems used for plant establishment are allowed only if removed within a period not to exceed 18 months of installation.

1 If the percent reduction of potable water is 100% AND the percent reduction of total water is equal to or greater than 50%, then Option 2 is earned, for a total of 4 points.

Potential Technologies & Strategies

Perform a soil/climate analysis to determine appropriate plant material and design the landscape with native or adapted plants to reduce or eliminate irrigation requirements. Where irrigation is required, use high-efficiency equipment and/or climate-based controllers.

WE Credit 2: Innovative Wastewater Technologies

2 Points

Intent

To reduce wastewater generation and potable water demand while increasing the local aquifer recharge.

Requirements

OPTION 1

Reduce potable water use for building sewage conveyance by 50% through the use of water-conserving fixtures (e.g., water closets, urinals) or nonpotable water (e.g., captured rainwater, recycled graywater, on-site or municipally treated wastewater).

OR

OPTION 2

Treat 50% of wastewater on-site to tertiary standards. Treated water must be infiltrated or used on-site.

Potential Technologies & Strategies

Specify high-efficiency fixtures and dry fixtures (e.g., composting toilet systems, nonwater-using urinals) to reduce wastewater volumes. Consider reusing stormwater or graywater for sewage conveyance or on-site mechanical and/or natural wastewater treatment systems. Options for on-site wastewater treatment include packaged biological nutrient removal systems, constructed wetlands and high-efficiency filtration systems.

WE Credit 3: Water Use Reduction

2–4 Points

Intent

To further increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

Requirements

Employ strategies that in aggregate use less water than the water use baseline calculated for the building (not including irrigation). The minimum water savings percentage for each point threshold is as follows:

Percentage Reduction	Points
30%	2
35%	3
40%	4

Calculate the baseline according to the commercial and/or residential baselines outlined below.[1] Calculations are based on estimated occupant usage and must include only the following fixtures and fixture fittings (as applicable to the project scope): water closets, urinals, lavatory faucets, showers, kitchen sink faucets and pre-rinse spray valves.

Commercial Fixtures, Fittings, and Appliances	Current Baseline
Commercial toilets	1.6 gallons per flush (gpf)* Except blow-out fixtures: 3.5 (gpf)
Commercial urinals	1.0 (gpf)
Commercial lavatory (restroom) faucets	2.2 gallons per minute (gpm) at 60 pounds per square inch (psi), private applications only (hotel or motel guest rooms, hospital patient rooms) 0.5 (gpm) at 60 (psi)** all others except private applications 0.25 gallons per cycle for metering faucets
Commercial prerinse spray valves (for food service applications)	Flow rate ≤ 1.6 (gpm) (no pressure specified; no performance requirement)

Residential Fixtures, Fittings, and Appliances	Current Baseline
Residential toilets	1.6 (gpf)***
Residential lavatory (bathroom) faucets	2.2 (gpm) at 60 psi
Residential kitchen faucet	
Residential showerheads	2.5 (gpm) at 80 (psi) per shower stall****

* EPAct 1992 standard for toilets applies to both commercial and residential models.
** In addition to EPAct requirements, the American Society of Mechanical Engineers standard for public lavatory faucets is 0.5 gpm at 60 psi (ASME A112.18.1-2005). This maximum has been incorporated into the national Uniform Plumbing Code and the International Plumbing Code.
*** EPAct 1992 standard for toilets applies to both commercial and residential models.
**** Residential shower compartment (stall) in dwelling units: The total allowable flow rate from all flowing showerheads at any given time, including rain systems, waterfalls, bodysprays, bodyspas and jets, must be limited to the allowable showerhead flow rate as specified above (2.5 gpm) per shower compartment, where the floor area of the shower compartment is less than 2,500 square inches. For each increment of 2,500 square inches of floor area thereafter or part thereof, an additional showerhead with total allowable flow rate from all flowing devices equal to or less than the allowable flow rate as specified above must be allowed. Exception: Showers that emit recirculated nonpotable water originating from within the shower compartment while operating are allowed to exceed the maximum as long as the total potable water flow does not exceed the flow rate as specified above.

1 Tables adapted from information developed and summarized by the U.S. Environmental Protection Agency (EPA) Office of Water based on requirements of the Energy Policy Act (EPAct) of 1992 and subsequent rulings by the Department of Energy, requirements of the EPAct of 2005, and the plumbing code requirements as stated in the 2006 editions of the Uniform Plumbing Code or International Plumbing Code pertaining to fixture performance.

The following fixtures, fittings and appliances are outside the scope of the water use reduction calculation:

- Commercial Steam Cookers
- Commercial Dishwashers
- Automatic Commercial Ice Makers
- Commercial (family-sized) Clothes Washers
- Residential Clothes Washers
- Standard and Compact Residential Dishwashers

Potential Technologies & Strategies

Use WaterSense-certified fixtures and fixture fittings where available. Use high-efficiency fixtures (e.g., water closets and urinals) and dry fixtures, such as toilets attached to composting systems, to reduce the potable water demand. Consider using alternative on-site sources of water (e.g., rainwater, stormwater, and air conditioner condensate, graywater) for nonpotable applications (e.g., toilet and urinal flushing, custodial uses). The quality of any alternative source of water being used must be taken into consideration based on its application or use.

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems

Required

Intent

To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents.

Benefits of commissioning include reduced energy use, lower operating costs, fewer contractor callbacks, better building documentation, improved occupant productivity and verification that the systems perform in accordance with the owner's project requirements.

Requirements

The following commissioning process activities must be completed by the project team:

- Designate an individual as the commissioning authority (CxA) to lead, review and oversee the completion of the commissioning process activities.
  - The CxA must have documented commissioning authority experience in at least 2 building projects.
  - The individual serving as the CxA must be independent of the project design and construction management, though the CxA may be an employee of any firm providing those services. The CxA may be a qualified employee or consultant of the owner.
  - The CxA must report results, findings and recommendations directly to the owner.
  - For projects smaller than 50,000 gross square feet, the CxA may be a qualified person on the design or construction team who has the required experience.
- The owner must document the owner's project requirements. The design team must develop the basis of design. The CxA must review these documents for clarity and completeness. The owner and design team must be responsible for updates to their respective documents.
- Develop and incorporate commissioning requirements into the construction documents.
- Develop and implement a commissioning plan.
- Verify the installation and performance of the systems to be commissioned.
- Complete a summary commissioning report.

Commissioned Systems

Commissioning process activities must be completed for the following energy-related systems, at a minimum:

- Heating, ventilating, air conditioning and refrigeration (HVAC&R) systems (mechanical and passive) and associated controls
- Lighting and daylighting controls
- Domestic hot water systems
- Renewable energy systems (e.g., wind, solar)

Potential Technologies & Strategies

Engage a CxA as early as possible in the design process. Determine the owner's project requirements, develop and maintain a commissioning plan for use during design and construction and incorporate commissioning requirements in bid documents. Assemble the commissioning team, and prior to occupancy verify the performance of energy consuming systems. Complete the commissioning reports with recommendations prior to accepting the commissioned systems.

Owners are encouraged to seek out qualified individuals to lead the commissioning process. Qualified individuals are identified as those who possess a high level of experience in the following areas:

- Energy systems design, installation and operation
- Commissioning planning and process management
- Hands-on field experience with energy systems performance, interaction, start-up, balancing, testing, troubleshooting, operation and maintenance procedures
- Energy systems automation control knowledge

Owners are encouraged to consider including water-using systems, building envelope systems, and other systems in the scope of the commissioning plan as appropriate. The building envelope is an important component of a facility that impacts energy consumption, occupant comfort and indoor air quality. While this prerequisite does not require building envelope commissioning, an owner can achieve significant financial savings and reduce risk of poor indoor air quality by including it in the commissioning process.

The LEED Reference Guide for Green Building Design and Construction, 2009 Edition provides guidance on the rigor expected for this prerequisite for the following:

- Owner's project requirements
- Basis of design
- Commissioning plan
- Commissioning specification
- Performance verification documentation
- Commissioning report

EA Prerequisite 2: Minimum Energy Performance

Required

Intent

To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.

Requirements

OPTION 1. Whole Building Energy Simulation

Demonstrate a 10% improvement in the proposed building performance rating for new buildings, or a 5% improvement in the proposed building performance rating for major renovations to existing buildings, compared with the baseline building performance rating.

Calculate the baseline building performance rating according to the building performance rating method in Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 (with errata but without addenda[1]) using a computer simulation model for the whole building project.

Appendix G of Standard 90.1-2007 requires that the energy analysis done for the building performance rating method include all energy costs associated with the building project. To achieve points using this credit, the proposed design must meet the following criteria:

- Comply with the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) in Standard 90.1-2007 (with errata but without addenda[1]).
- Include all energy costs associated with the building project.
- Compare against a baseline building that complies with Appendix G of Standard 90.1-2007 (with errata but without addenda[1]). The default process energy cost is 25% of the total energy cost for the baseline building. If the building's process energy cost is less than 25% of the baseline building energy cost, the LEED submittal must include documentation substantiating that process energy inputs are appropriate.

For the purpose of this analysis, process energy is considered to include, but is not limited to, office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from the lighting power allowance (e.g., lighting integral to medical equipment) and other (e.g., waterfall pumps).

Regulated (non-process) energy includes lighting (for the interior, parking garage, surface parking, façade, or building grounds, etc. except as noted above), heating, ventilation and air conditioning (HVAC) (for space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, kitchen hood exhaust, etc.), and service water heating for domestic or space heating purposes.

Process loads must be identical for both the baseline building performance rating and the proposed building performance rating. However, project teams may follow the exceptional calculation method (ANSI/ASHRAE/IESNA Standard 90.1-2007 G2.5) to document measures that reduce process loads. Documentation of process

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

load energy savings must include a list of the assumptions made for both the base and the proposed design, and theoretical or empirical information supporting these assumptions.

Projects in California may use Title 24-2005, Part 6 in place of ANSI/ASHRAE/IESNA Standard 90.1-2007 for Option 1.

OR

OPTION 2. Prescriptive Compliance Path: ASHRAE Advanced Energy Design Guide

Comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide appropriate to the project scope, outlined below. Project teams must comply with all applicable criteria as established in the Advanced Energy Design Guide for the climate zone in which the building is located.

PATH 1. ASHRAE Advanced Energy Design Guide for Small Office Buildings 2004

The building must meet the following requirements:

- Less than 20,000 square feet.
- Office occupancy.

PATH 2. ASHRAE Advanced Energy Design Guide for Small Retail Buildings 2006

The building must meet the following requirements:

- Less than 20,000 square feet.
- Retail occupancy.

PATH 3. ASHRAE Advanced Energy Design Guide for Small Warehouses and Self Storage Buildings 2008

The building must meet the following requirements:

- Less than 50,000 square feet.
- Warehouse or self-storage occupancy.

OR

OPTION 3. Prescriptive Compliance Path: Advanced Buildings™ Core Performance™ Guide

Comply with the prescriptive measures identified in the Advanced Buildings™ Core Performance™ Guide developed by the New Buildings Institute. The building must meet the following requirements:

- Less than 100,000 square feet.
- Comply with Section 1: Design Process Strategies, and Section 2: Core Performance Requirements.
- Health care, warehouse and laboratory projects are ineligible for this path.

Potential Technologies & Strategies

Design the building envelope and systems to meet baseline requirements. Use a computer simulation model to assess the energy performance and identify the most cost-effective energy efficiency measures. Quantify energy performance compared with a baseline building.

If local code has demonstrated quantitative and textual equivalence following, at a minimum, the U.S. Department of Energy (DOE) standard process for commercial energy code determination, then the results of that analysis may be used to correlate local code performance with ANSI/ASHRAE/IESNA Standard 90.1-2007. Details on the DOE process for commercial energy code determination can be found at http://www.energycodes.gov/implement/determinations_com.stm.

EA Prerequisite 3: Fundamental Refrigerant Management

Required

Intent

To reduce stratospheric ozone depletion.

Requirements

Zero use of chlorofluorocarbon (CFC)-based refrigerants in new base building heating, ventilating, air conditioning and refrigeration (HVAC&R) systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phase-out conversion prior to project completion. Phase-out plans extending beyond the project completion date will be considered on their merits.

Existing small HVAC units (defined as containing less than 0.5 pounds of refrigerant) and other equipment, such as standard refrigerators, small water coolers and any other equipment that contains less than 0.5 pounds of refrigerant, are not considered part of the base building system and are not subject to the requirements of this prerequisite.

Potential Technologies & Strategies

When reusing existing HVAC systems, conduct an inventory to identify equipment that uses CFC-based refrigerants and provide a replacement schedule for these refrigerants. For new buildings, specify new HVAC equipment in the base building that uses no CFC-based refrigerants.

EA Credit 1: Optimize Energy Performance

1–19 Points

Intent

To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

Requirements

Select 1 of the 3 compliance path options described below. Project teams documenting achievement using any of the 3 options are assumed to be in compliance with EA Prerequisite 2: Minimum Energy Performance.

OPTION 1. Whole Building Energy Simulation (1–19 points)

Demonstrate a percentage improvement in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 (with errata but without addenda[1]) using a computer simulation model for the whole building project. The minimum energy cost savings percentage for each point threshold is as follows:

New Buildings	Existing Building Renovations	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

Appendix G of Standard 90.1-2007 requires that the energy analysis done for the building performance rating method include all the energy costs associated with the building project. To achieve points under this credit, the proposed design must meet the following criteria:

- Compliance with the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) in Standard 90.1-2007 (with errata but without addenda).
- Inclusion of all the energy costs within and associated with the building project.
- Comparison against a baseline building that complies with Appendix G of Standard 90.1-2007 (with errata but without addenda). The default process energy cost is 25% of the total energy cost for the baseline building. If the building's process energy cost is less than 25% of the baseline building energy cost, the LEED submittal must include documentation substantiating that process energy inputs are appropriate.

For the purpose of this analysis, process energy is considered to include, but is not limited to, office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from the lighting power allowance (e.g., lighting integral to medical equipment) and other (e.g., waterfall pumps).

Regulated (non-process) energy includes lighting (e.g., for the interior, parking garage, surface parking, façade, or building grounds, etc. except as noted above), heating, ventilating, and air conditioning (HVAC) (e.g., for space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, kitchen hood exhaust, etc.), and service water heating for domestic or space heating purposes.

For this credit, process loads must be identical for both the baseline building performance rating and the proposed building performance rating. However, project teams may follow the exceptional calculation method (ANSI/ASHRAE/IESNA Standard 90.1-2007 G2.5) to document measures that reduce process loads. Documentation of process load energy savings must include a list of the assumptions made for both the base and proposed design, and theoretical or empirical information supporting these assumptions.

Projects in California may use Title 24-2005, Part 6 in place of ANSI/ASHRAE/IESNA Standard 90.1-2007 for Option 1.

OR

OPTION 2. Prescriptive Compliance Path: ASHRAE Advanced Energy Design Guide (1 point)

Comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide appropriate to the project scope, outlined below. Project teams must comply with all applicable criteria as established in the Advanced Energy Design Guide for the climate zone in which the building is located.

PATH 1. ASHRAE Advanced Energy Design Guide for Small Office Buildings 2004

The building must meet the following requirements:

- Less than 20,000 square feet.
- Office occupancy.

PATH 2. ASHRAE Advanced Energy Design Guide for Small Retail Buildings 2006

The building must meet the following requirements:

- Less than 20,000 square feet.
- Retail occupancy.

PATH 3. ASHRAE Advanced Energy Design Guide for Small Warehouses and Self Storage Buildings 2008

The building must meet the following requirements:

- Less than 50,000 square feet.
- Warehouse or self-storage occupancy.

OR

OPTION 3. Prescriptive Compliance Path: Advanced Buildings™ Core Performance™ Guide (1–3 points)

Comply with the prescriptive measures identified in the Advanced Buildings™ Core Performance™ Guide developed by the New Buildings Institute. The building must meet the following requirements:

- Less than 100,000 square feet.
- Comply with Section 1: Design Process Strategies, and Section 2: Core Performance Requirements.
- Health care, warehouse or laboratory projects are ineligible for this path.

Points achieved under Option 3 (1 point):

- 1 point is available for all projects (office, school, public assembly, and retail projects) less than 100,000 square feet that comply with Sections 1 and 2 of the Core Performance Guide.
- Up to 2 additional points are available to projects that implement performance strategies listed in Section 3, Enhanced Performance. For every 3 strategies implemented from this section, 1 point is available.
- The following strategies are addressed by other aspects of LEED and are not eligible for additional points under EA Credit 1:
  - 3.1 — Cool Roofs
  - 3.8 — Night Venting
  - 3.13 — Additional Commissioning

Potential Technologies & Strategies

Design the building envelope and systems to maximize energy performance. Use a computer simulation model to assess the energy performance and identify the most cost-effective energy efficiency measures. Quantify energy performance compared with a baseline building.

If local code has demonstrated quantitative and textual equivalence following, at a minimum, the U.S. Department of Energy (DOE) standard process for commercial energy code determination, the results of that analysis may be used to correlate local code performance with ANSI/ASHRAE/IESNA Standard 90.1-2007. Details on the DOE process for commercial energy code determination can be found at http://www.energycodes.gov/implement/determinations_com.stm.

EA Credit 2: On-site Renewable Energy

1–7 Points

Intent

To encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use.

Requirements

Use on-site renewable energy systems to offset building energy costs. Calculate project performance by expressing the energy produced by the renewable systems as a percentage of the building's annual energy cost and use the table below to determine the number of points achieved.

Use the building annual energy cost calculated in EA Credit 1: Optimize Energy Performance or the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey database to determine the estimated electricity use.

The minimum renewable energy percentage for each point threshold is as follows:

Percentage Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

Potential Technologies & Strategies

Assess the project for nonpolluting and renewable energy potential including solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, take advantage of net metering with the local utility.

EA Credit 3: Enhanced Commissioning

2 Points

Intent

To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.

Requirements

Implement, or have a contract in place to implement, the following additional commissioning process activities in addition to the requirements of EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems and in accordance with the LEED Reference Guide for Green Building Design and Construction, 2009 Edition:

- Prior to the start of the construction documents phase, designate an independent commissioning authority (CxA) to lead, review and oversee the completion of all commissioning process activities.
  - The CxA must have documented commissioning authority experience in at least 2 building projects.
  - The individual serving as the CxA:
    - Must be independent of the work of design and construction.
    - Must not be an employee of the design firm, though he or she may be contracted through them.
    - Must not be an employee of, or contracted through, a contractor or construction manager holding construction contracts.
    - May be a qualified employee or consultant of the owner.
  - The CxA must report results, findings and recommendations directly to the owner.
- The CxA must conduct, at a minimum, 1 commissioning design review of the owner's project requirements basis of design, and design documents prior to the mid-construction documents phase and back-check the review comments in the subsequent design submission.
- The CxA must review contractor submittals applicable to systems being commissioned for compliance with the owner's project requirements and basis of design. This review must be concurrent with the review of the architect or engineer of record and submitted to the design team and the owner.
- The CxA or other project team members must develop a systems manual that gives future operating staff the information needed to understand and optimally operate the commissioned systems.
- The CxA or other project team members must verify that the requirements for training operating personnel and building occupants have been completed.
- The CxA must be involved in reviewing the operation of the building with operations and maintenance (O&M) staff and occupants within 10 months after substantial completion. A plan for resolving outstanding commissioning-related issues must be included.

Potential Technologies & Strategies

Although it is preferable that the CxA be contracted by the owner, for the enhanced commissioning credit the CxA may also be contracted through the design firms or construction management firms not holding construction contracts.

The LEED Reference Guide for Green Building Design and Construction, 2009 Edition provides detailed guidance on the rigor expected for the following process activities:

- Commissioning design review
- Commissioning submittal review
- Systems manual.

EA Credit 4: Enhanced Refrigerant Management

2 Points

Intent

To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.

Requirements

OPTION 1

Do not use refrigerants.

OR

OPTION 2

Select refrigerants and heating, ventilation, air conditioning and refrigeration (HVAC&R) equipment that minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. The base building HVAC&R equipment must comply with the following formula, which sets a maximum threshold for the combined contributions to ozone depletion and global warming potential:

$$LCGWP + LCODP \times 10^5 \leq 100$$

Calculation definitions for LCGWP + LCODP x $10^5 \leq 100$
LCODP = [ODPr x (Lr x Life +Mr) x Rc]/Life
LCGWP = [GWPr x (Lr x Life +Mr) x Rc]/Life
LCODP: Lifecycle Ozone Depletion Potential (lb CFC 11/Ton-Year)
LCGWP: Lifecycle Direct Global Warming Potential (lb CO_2/Ton-Year)
GWPr: Global Warming Potential of Refrigerant (0 to 12,000 lb CO_2/lbr)
ODPr: Ozone Depletion Potential of Refrigerant (0 to 0.2 lb CFC 11/lbr)
Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 2% unless otherwise demonstrated)
Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated)
Rc: Refrigerant Charge (0.5 to 5.0 lbs of refrigerant per ton of gross ARI rated cooling capacity)
Life: Equipment Life (10 years; default based on equipment type, unless otherwise demonstrated)

For multiple types of equipment, a weighted average of all base building HVAC&R equipment must be calculated using the following formula:

$$\frac{\sum \left(LCGWP + LCODP \times 10^5 \right) \times Qunit}{Qtotal} \leq 100$$

Calculation definitions for [$\sum$ (LCGWP + LCODP x 10^5) x Qunit] / Qtotal ≤ 100
Qunit = Gross ARI rated cooling capacity of an individual HVAC or refrigeration unit (Tons)
Qtotal = Total gross ARI rated cooling capacity of all HVAC or refrigeration

Small HVAC units (defined as containing less than 0.5 pounds of refrigerant) and other equipment, such as standard refrigerators, small water coolers and any other cooling equipment that contains less than 0.5 pounds of refrigerant, are not considered part of the base building system and are not subject to the requirements of this credit.

Do not operate or install fire suppression systems that contain ozone-depleting substances such as CFCs, hydrochlorofluorocarbons (HCFCs) or halons.

Potential Technologies & Strategies

Design and operate the facility without mechanical cooling and refrigeration equipment. Where mechanical cooling is used, utilize base building HVAC&R systems for the refrigeration cycle that minimize direct impact on ozone depletion and global climate change. Select HVAC&R equipment with reduced refrigerant charge and increased equipment life. Maintain equipment to prevent leakage of refrigerant to the atmosphere. Use fire suppression systems that do not contain HCFCs or halons.

EA Credit 5: Measurement and Verification

3 Points

Intent

To provide for the ongoing accountability of building energy consumption over time.

Requirements

OPTION 1

Develop and implement a measurement and verification (M&V) plan consistent with Option D: Calibrated Simulation (Savings Estimation Method 2) as specified in the International Performance Measurement & Verification Protocol (IPMVP) Volume III: Concepts and Options for Determining Energy Savings in New Construction, April 2003.

The M&V period must cover at least 1 year of post-construction occupancy.

Provide a process for corrective action if the results of the M&V plan indicate that energy savings are not being achieved.

OR

OPTION 2

Develop and implement a measurement and verification (M&V) plan consistent with Option B: Energy Conservation Measure Isolation, as specified in the International Performance Measurement & Verification Protocol (IPMVP) Volume III: Concepts and Options for Determining Energy Savings in New Construction, April 2003.

The M&V period must cover at least 1 year of post-construction occupancy.

Provide a process for corrective action if the results of the M&V plan indicate that energy savings are not being achieved.

OR

OPTION 3 (1 point)

Meet MPR 6 through compliance Opttion1: Energy and Water Data Release Form. Projects must register an account in ENERGY STAR's Portfolio Manager tool and share the project file with the USGBC master account.

Potential Technologies & Strategies

Develop an M&V plan to evaluate building and/or energy system performance. Characterize the building and/or energy systems through energy simulation or engineering analysis. Install the necessary metering equipment to measure energy use. Track performance by comparing predicted performance to actual performance, broken down by component or system as appropriate. Evaluate energy efficiency by comparing actual performance to baseline performance.

While the IPMVP describes specific actions for verifying savings associated with energy conservation measures (ECMs) and strategies, this LEED credit expands upon typical IPMVP M&V objectives. Measurement & verification activities should not necessarily be confined to energy systems where ECMs or energy conservation strategies have been implemented. The IPMVP provides guidance on M&V strategies and their appropriate applications for various situations. These strategies should be used in conjunction with monitoring and trend logging of significant energy systems to provide for the ongoing accountability of building energy performance.

For the corrective action process, consider installing diagnostics within the control system to alert the staff when equipment is not being optimally operated. Conditions that might warrant alarms to alert staff could include:

- Leaking valves in the cooling and heating coils within air handling units;
- Missed economizer opportunities (e.g., faulty economizer damper controls) ;
- Software and manual overrides allowing equipment to operate 24 hours a day/7 days a week;
- Equipment operation during unusual circumstances (e.g., boiler on when outside air temperature is above 65 °F).

Besides control diagnostics, consider employing retro-commissioning services or dedicating staff to investigate increases in energy usage (such a staff member is usually a resource conservation manager — see http://www.energy.state.or.us/rcm/rcmhm.htm for additional information).

EA Credit 6: Green Power

2 Points

Intent

To encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis.

Requirements

Engage in at least a 2-year renewable energy contract to provide at least 35% of the building's electricity from renewable sources, as defined by the Center for Resource Solutions' Green-e Energy product certification requirements.

All purchases of green power shall be based on the quantity of energy consumed, not the cost.

OPTION 1. Determine Baseline Electricity Use

Use the annual electricity consumption from the results of EA Credit 1: Optimize Energy Performance.

OR

OPTION 2. Estimate Baseline Electricity Use

Use the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey database to determine the estimated electricity use.

Potential Technologies & Strategies

Determine the energy needs of the building and investigate opportunities to engage in a green power contract. Green power is derived from solar, wind, geothermal, biomass or low-impact hydro sources. Visit http://www.green-e.org/energy for details about the Green-e Energy program. The green power product purchased to comply with credit requirements need not be Green-e Energy certified. Other sources of green power are eligible if they satisfy the Green-e Energy program's technical requirements. Renewable energy certificates (RECs), tradable renewable certificates (TRCs), green tags and other forms of green power that comply with the technical requirements of the Green-e Energy program may be used to document compliance with this credit.

MR Prerequisite 1: Storage and Collection of Recyclables

Required

Intent

To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.

Requirements

Provide an easily-accessible dedicated area or areas for the collection and storage of materials for recycling for the entire building. Materials must include, at a minimum: paper, corrugated cardboard, glass, plastics and metals.

Potential Technologies & Strategies

Designate an area for recyclable collection and storage that is appropriately sized and located in a convenient area. Identify local waste handlers and buyers for glass, plastic, metals, office paper, newspaper, cardboard and organic wastes. Instruct occupants on recycling procedures. Consider employing cardboard balers, aluminum can crushers, recycling chutes and other waste management strategies to further enhance the recycling program.

MR Credit 1.1: Building Reuse—Maintain Existing Walls, Floors and Roof

1–3 Points

Intent

To extend the lifecycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Maintain the existing building structure (including structural floor and roof decking) and envelope (the exterior skin and framing, excluding window assemblies and non-structural roofing material). The minimum percentage building reuse for each point threshold is as follows:

Building Reuse	Points
55%	1
75%	2
95%	3

Hazardous materials that are remediated as a part of the project must be excluded from the calculation of the percentage maintained. If the project includes an addition that is more than 2 times the square footage of the existing building, this credit is not applicable.

Potential Technologies & Strategies

Consider reusing existing, previously-occupied building structures, envelopes and elements. Remove elements that pose a contamination risk to building occupants and upgrade components that would improve energy and water efficiency such as windows, mechanical systems and plumbing fixtures.

MR Credit 1.2: Building Reuse—Maintain Interior Nonstructural Elements

1 Point

Intent

To extend the lifecycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Use existing interior nonstructural elements (e.g., interior walls, doors, floor coverings and ceiling systems) in at least 50% (by area) of the completed building, including additions. If the project includes an addition with square footage more than 2 times the square footage of the existing building, this credit is not applicable.

Potential Technologies & Strategies

Consider reusing existing building structures, envelopes and interior nonstructural elements. Remove elements that pose a contamination risk to building occupants, and upgrade components that would improve energy and water efficiency such as mechanical systems and plumbing fixtures. Quantify the extent of building reuse.

MR Credit 2: Construction Waste Management

1–2 Points

Intent
To divert construction and demolition debris from disposal in landfills and incineration facilities. Redirect recyclable recovered resources back to the manufacturing process and reusable materials to appropriate sites.

Requirements
Recycle and/or salvage nonhazardous construction and demolition debris. Develop and implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on-site or comingled. Excavated soil and land-clearing debris do not contribute to this credit. Calculations can be done by weight or volume, but must be consistent throughout. The minimum percentage debris to be recycled or salvaged for each point threshold is as follows:

Recycled or Salvaged	Points
50%	1
75%	2

Potential Technologies & Strategies
Establish goals for diversion from disposal in landfills and incineration facilities and adopt a construction waste management plan to achieve these goals. Consider recycling cardboard, metal, brick, mineral fiber panel, concrete, plastic, clean wood, glass, gypsum wallboard, carpet and insulation. Construction debris processed into a recycled content commodity that has an open market value (e.g., wood derived fuel [WDF], alternative daily cover material, etc.) may be applied to the construction waste calculation. Designate a specific area(s) on the construction site for segregated or comingled collection of recyclable materials, and track recycling efforts throughout the construction process. Identify construction haulers and recyclers to handle the designated materials. Note that diversion may include donation of materials to charitable organizations and salvage of materials on-site.

MR Credit 3: Materials Reuse

1–2 Points

Intent
To reuse building materials and products to reduce demand for virgin materials and reduce waste, thereby lessening impacts associated with the extraction and processing of virgin resources.

Requirements
Use salvaged, refurbished or reused materials, the sum of which constitutes at least 5% or 10%, based on cost, of the total value of materials on the project. The minimum percentage materials reused for each point threshold is as follows:

Reused Materials	Points
5%	1
10%	2

Mechanical, electrical and plumbing components and specialty items such as elevators and equipment cannot be included in this calculation. Include only materials permanently installed in the project. Furniture may be included if it is included consistently in MR Credit 3: Materials Reuse through MR Credit 7: Certified Wood.

Potential Technologies & Strategies
Identify opportunities to incorporate salvaged materials into the building design, and research potential material suppliers. Consider salvaged materials such as beams and posts, flooring, paneling, doors and frames, cabinetry and furniture, brick, and decorative items.

MR Credit 4: Recycled Content

1–2 Points

Intent

To increase demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials.

Requirements

Use materials with recycled content[1] such that the sum of postconsumer[2] recycled content plus 1/2 of the preconsumer[3] content constitutes at least 10% or 20%, based on cost, of the total value of the materials in the project. The minimum percentage materials recycled for each point threshold is as follows:

Recycled Content	Points
10%	1
20%	2

The recycled content value of a material assembly is determined by weight. The recycled fraction of the assembly is then multiplied by the cost of assembly to determine the recycled content value.

Mechanical, electrical and plumbing components and specialty items such as elevators cannot be included in this calculation. Include only materials permanently installed in the project. Furniture may be included if it is included consistently in MR Credit 3: Materials Reuse through MR Credit 7: Certified Wood.

Potential Technologies & Strategies

Establish a project goal for recycled content materials, and identify material suppliers that can achieve this goal. During construction, ensure that the specified recycled content materials are installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.

1 Recycled content is defined in accordance with the International Organization of Standards document, ISO 14021 — Environmental labels and declarations — Self-declared environmental claims (Type II environmental labeling).

2 Postconsumer material is defined as waste material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product, which can no longer be used for its intended purpose.

3 Preconsumer material is defined as material diverted from the waste stream during the manufacturing process. Reutilization of materials (i.e., rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it) is excluded.

MR Credit 5: Regional Materials

1–2 Points

Intent

To increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation.

Requirements

Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site for a minimum of 10% or 20%, based on cost, of the total materials value. If only a fraction of a product or material is extracted, harvested, or recovered and manufactured locally, then only that percentage (by weight) can contribute to the regional value. The minimum percentage regional materials for each point threshold is as follows:

Regional Materials	Points
10%	1
20%	2

Mechanical, electrical and plumbing components and specialty items such as elevators and equipment must not be included in this calculation. Include only materials permanently installed in the project. Furniture may be included if it is included consistently in MR Credit 3: Materials Reuse through MR Credit 7: Certified Wood.

Potential Technologies & Strategies

Establish a project goal for locally sourced materials, and identify materials and material suppliers that can achieve this goal. During construction, ensure that the specified local materials are installed, and quantify the total percentage of local materials installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.

MR Credit 6: Rapidly Renewable Materials

1 Point

Intent

To reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials.

Requirements

Use rapidly renewable building materials and products for 2.5% of the total value of all building materials and products used in the project, based on cost. Rapidly renewable building materials and products are made from plants that are typically harvested within a 10-year or shorter cycle.

Potential Technologies & Strategies

Establish a project goal for rapidly renewable materials, and identify products and suppliers that can support achievement of this goal. Consider materials such as bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard and cork. During construction, ensure that the specified renewable materials are installed.

MR Credit 7: Certified Wood

1 Point

Intent

To encourage environmentally responsible forest management.

Requirements

Use a minimum of 50% (based on cost) of wood-based materials and products that are certified in accordance with the Forest Stewardship Council's principles and criteria, for wood building components. These components include at a minimum, structural framing and general dimensional framing, flooring, sub-flooring, wood doors and finishes.

Include only materials permanently installed in the project. Wood products purchased for temporary use on the project (e.g., formwork, bracing, scaffolding, sidewalk protection, and guard rails) may be included in the calculation at the project team's discretion. If any such materials are included, all such materials must be included in the calculation. If such materials are purchased for use on multiple projects, the applicant may include these materials for only one project, at its discretion. Furniture may be included if it is included consistently in MR Credits 3, Materials Reuse, through MR Credit 7, Certified Wood.

Potential Technologies & Strategies

Establish a project goal for FSC-certified wood products and identify suppliers that can achieve this goal. During construction, ensure that the FSC-certified wood products are installed and quantify the total percentage of FSC-certified wood products installed.

INDOOR ENVIRONMENTAL QUALITY

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance

Required

Intent

To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.

Requirements

Meet the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality (with errata but without addenda[1]).

AND

CASE 1. Mechanically Ventilated Spaces

Mechanical ventilation systems must be designed using the ventilation rate procedure or the applicable local code, whichever is more stringent.

CASE 2. Naturally Ventilated Spaces

Naturally ventilated buildings must comply with ASHRAE Standard 62.1-2007, Paragraph 5.1 (with errata but without addenda[1]).

Potential Technologies & Strategies

Design ventilation systems to meet or exceed the minimum outdoor air ventilation rates as described in the ASHRAE standard. Balance the impacts of ventilation rates on energy use and indoor air quality to optimize for energy efficiency and occupant comfort. Use the ASHRAE Standard 62.1-2007 Users Manual (with errata but without addenda[1]) for detailed guidance on meeting the referenced requirements.

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this prerequisite may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Required

Intent

To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS).

Requirements

OPTION 1

Prohibit smoking in the building.

Prohibit on-property smoking within 25 feet of entries, outdoor air intakes and operable windows. Provide signage to allow smoking in designated areas, prohibit smoking in designated areas or prohibit smoking on the entire property.

OR

OPTION 2

CASE 1. Non-Residential Projects

Prohibit smoking in the building except in designated smoking areas.

Prohibit on-property smoking within 25 feet of entries, outdoor air intakes and operable windows. Provide signage to allow smoking in designated areas, prohibit smoking in designated areas or prohibit smoking on the entire property.

Provide designated smoking rooms designed to contain, capture and remove ETS from the building. At a minimum, the smoking room must be directly exhausted to the outdoors, away from air intakes and building entry paths, with no recirculation of ETS-containing air to nonsmoking areas and enclosed with impermeable deck-to-deck partitions. Operate exhaust sufficient to create a negative pressure differential with the surrounding spaces of at least an average of 5 Pascals (Pa) (0.02 inches of water gauge) and a minimum of 1 Pa (0.004 inches of water gauge) when the doors to the smoking rooms are closed.

Verify performance of the smoking rooms' differential air pressures by conducting 15 minutes of measurement, with a minimum of 1 measurement every 10 seconds, of the differential pressure in the smoking room with respect to each adjacent area and in each adjacent vertical chase with the doors to the smoking room closed. Conduct the testing with each space configured for worst-case conditions of transport of air from the smoking rooms (with closed doors) to adjacent spaces.

CASE 2. Residential and Hospitality Projects

Prohibit smoking in all common areas of the building.

Locate any exterior designated smoking areas, including balconies where smoking is permitted, at least 25 feet from entries, outdoor air intakes and operable windows opening to common areas.

Prohibit on-property smoking within 25 feet of entries, outdoor air intakes and operable windows. Provide signage to allow smoking in designated areas, prohibit smoking in designated areas or prohibit smoking on the entire property.

Weather-strip all exterior doors and operable windows in the residential units to minimize leakage from outdoors.

Minimize uncontrolled pathways for ETS transfer between individual residential units by sealing penetrations in walls, ceilings and floors in the residential units and by sealing vertical chases adjacent to the units.

Weather-strip all doors in the residential units leading to common hallways to minimize air leakage into the hallway[1].

Demonstrate acceptable sealing of residential units by a blower door test conducted in accordance with ANSI/ASTM-E779-03, Standard Test Method for Determining Air Leakage Rate By Fan Pressurization.

Use the progressive sampling methodology defined in Chapter 4 (Compliance Through Quality Construction) of the Residential Manual for Compliance with California's 2001 Energy Efficiency Standards. Residential units must demonstrate less than 1.25 square inches leakage area per 100 square feet of enclosure area (i.e., sum of all wall, ceiling and floor areas).

Potential Technologies & Strategies

Prohibit smoking in commercial buildings or effectively control the ventilation air in smoking rooms. For residential buildings, prohibit smoking in common areas and design building envelope and systems to minimize ETS transfer among dwelling units.

1 If the common hallways are pressurized with respect to the residential units then doors in the residential units leading to the common hallways need not be weather-stripped provided that the positive differential pressure is demonstrated as in Option 2, Case 1 above, considering the residential unit as the smoking room.

IEQ Credit 1: Outdoor Air Delivery Monitoring

1 Point

Intent

To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.

Requirements

Install permanent monitoring systems to ensure that ventilation systems maintain design minimum requirements. Configure all monitoring equipment to generate an alarm when airflow values or carbon dioxide (CO_2) levels vary by 10% or more from the design values via either a building automation system alarm to the building operator or a visual or audible alert to the building occupants

AND

CASE 1. Mechanically Ventilated Spaces

Monitor CO_2 concentrations within all densely occupied spaces (those with a design occupant density of 25 people or more per 1,000 square feet). CO_2 monitors must be between 3 and 6 feet above the floor.

Provide a direct outdoor airflow measurement device capable of measuring the minimum outdoor air intake flow with an accuracy of plus or minus 15% of the design minimum outdoor air rate, as defined by ASHRAE 62.1-2007 (with errata but without addenda[1]) for mechanical ventilation systems where 20% or more of the design supply airflow serves nondensely occupied spaces.

CASE 2. Naturally Ventilated Spaces

Monitor CO_2 concentrations within all naturally ventilated spaces. CO_2 monitors must be between 3 and 6 feet above the floor. One CO_2 sensor may be used to monitor multiple nondensely occupied spaces if the natural ventilation design uses passive stack(s) or other means to induce airflow through those spaces equally and simultaneously without intervention by building occupants.

Potential Technologies & Strategies

Install CO_2 and airflow measurement equipment and feed the information to the heating, ventilating and air conditioning (HVAC) system and/or building automation system (BAS) to trigger corrective action, if applicable. If such automatic controls are not feasible with the building systems, use the measurement equipment to trigger alarms that inform building operators or occupants of a possible deficiency in outdoor air delivery.

1 Project teams wishing to use addenda approved by ASHRAE for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Credit 2: Increased Ventilation

1 Point

Intent

To provide additional outdoor air ventilation to improve indoor air quality (IAQ) and promote occupant comfort, well-being and productivity.

Requirements

CASE 1. Mechanically Ventilated Spaces

Increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates required by ASHRAE Standard 62.1-2007 (with errata but without addenda[1]) as determined by IEQ Prerequisite 1: Minimum Indoor Air Quality Performance.

CASE 2. Naturally Ventilated Spaces

Determine that natural ventilation is an effective strategy for the project by following the flow diagram process shown in Figure 2.8 of the CIBSE Applications Manual 10: 2005, Natural Ventilation in Non-domestic Buildings.

AND

OPTION 1

Show that the natural ventilation systems design meets the recommendations set forth in the CIBSE manuals appropriate to the project space.

PATH 1. CIBSE Applications Manual 10: 2005, Natural Ventilation in Non-domestic Buildings

PATH 2. CIBSE AM 13:2000, Mixed Mode Ventilation

OR

OPTION 2

Use a macroscopic, multizone, analytic model to predict that room-by-room airflows will effectively naturally ventilate, defined as providing the minimum ventilation rates required by ASHRAE 62.1-2007 Chapter 6 (with errata but without addenda[1]), for at least 90% of occupied spaces.

Potential Technologies & Strategies

For mechanically ventilated spaces: Use heat recovery, where appropriate, to minimize the additional energy consumption associated with higher ventilation rates.

For naturally ventilated spaces, follow the 8 design steps described in the Carbon Trust Good Practice Guide 237:

- Develop design requirements.
- Plan airflow paths.

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

- Identify building uses and features that might require special attention.
- Determine ventilation requirements.
- Estimate external driving pressures.
- Select types of ventilation devices.
- Size ventilation devices.
- Analyze the design.

Use public domain software such as NIST's CONTAM, Multizone Modeling Software, along with LoopDA, Natural Ventilation Sizing Tool, to analytically predict room-by-room airflows.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan—During Construction

1 Point

Intent

To reduce indoor air quality (IAQ) problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants.

Requirements

Develop and implement an IAQ management plan for the construction and preoccupancy phases of the building as follows:

- During construction, meet or exceed the recommended control measures of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines For Occupied Buildings Under Construction, 2nd Edition 2007, ANSI/SMACNA 008-2008 (Chapter 3).
- Protect stored on-site and installed absorptive materials from moisture damage.
- If permanently installed air handlers are used during construction, filtration media with a minimum efficiency reporting value (MERV) of 8 must be used at each return air grille, as determined by ASHRAE Standard 52.2-1999 (with errata but without addenda[1]). Replace all filtration media immediately prior to occupancy.

Potential Technologies & Strategies

Adopt an IAQ management plan to protect the heating, ventilating and air conditioning (HVAC) system during construction, control pollutant sources and interrupt contamination pathways. Sequence the installation of materials to avoid contamination of absorptive materials, such as insulation, carpeting, ceiling tile and gypsum wallboard. Coordinate with IEQ Credit 3.2: Construction IAQ Management Plan — Before Occupancy and IEQ Credit 5: Indoor Chemical & Pollutant Source Control to determine the appropriate specifications and schedules for filtration media.

If possible, avoid using permanently installed air handlers for temporary heating/cooling during construction. Consult the LEED Reference Guide for Green Building Design and Construction, 2009 Edition for more detailed information on how to ensure the well-being of construction workers and building occupants if permanently installed air handlers must be used during construction.

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Credit 3.2: Construction Indoor Air Quality Management Plan—Before Occupancy

1 Point

Intent

To reduce indoor air quality (IAQ) problems resulting from construction or renovation to promote the comfort and well-being of construction workers and building occupants.

Requirements

Develop an IAQ management plan and implement it after all finishes have been installed and the building has been completely cleaned before occupancy.

OPTION 1. Flush-Out[1]

PATH 1

After construction ends, prior to occupancy and with all interior finishes installed, install new filtration media and , perform a building flush-out by supplying a total air volume of 14,000 cubic feet of outdoor air per square foot of floor area while maintaining an internal temperature of at least 60° F and relative humidity no higher than 60%.

OR

PATH 2

If occupancy is desired prior to completion of the flush-out, the space may be occupied following delivery of a minimum of 3,500 cubic feet of outdoor air per square foot of floor area. Once the space is occupied, it must be ventilated at a minimum rate of 0.30 cubic feet per minute (cfm) per square foot of outside air or the design minimum outside air rate determined in IEQ Prerequisite 1: Minimum Indoor Air Quality Performance, whichever is greater. During each day of the flush-out period, ventilation must begin a minimum of 3 hours prior to occupancy and continue during occupancy. These conditions must be maintained until a total of 14,000 cubic feet per square foot of outside air has been delivered to the space.

OR

OPTION 2. Air Testing

Conduct baseline IAQ testing after construction ends and prior to occupancy using testing protocols consistent with the EPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air or the ISO method listed in the table below. Testing must be done in accordance with one standard; project teams may not mix requirements from the EPA Compendium of Methods with ISO.

1 All finishes must be installed prior to flush-out.

Demonstrate that the contaminant maximum concentration levels listed below are not exceeded:

Contaminant	Maximum Concentration	EPA Compendium method	ISO method
Formaldehyde	27 parts per billion	IP-6	ISO 16000-3
Particulates (PM10)	50 micrograms per cubic meter	IP-10	ISO 7708
Total volatile organic compounds (TVOCs)	500 micrograms per cubic meter	IP-1	ISO 16000-6
4-Phenylcyclohexene (4-PCH) *	6.5 micrograms per cubic meter	IP-1	ISO 16000-6
Carbon monoxide (CO)	9 parts per million and no greater than 2 parts per million above outdoor levels	IP-3	ISO 4224
*This test is required only if carpets and fabrics with styrene butadiene rubber (SBR) latex backing are installed as part of the base building systems.			

For each sampling point where the maximum concentration limits are exceeded, conduct an additional flush-out with outside air and retest the noncompliant concentrations. Repeat until all requirements are met. When retesting noncompliant building areas, take samples from the same locations as in the first test, although it is not required.

Conduct the air sample testing as follows:

- All measurements must be conducted prior to occupancy, but during normal occupied hours with the building ventilation system started at the normal daily start time and operated at the minimum outside air flow rate for the occupied mode throughout the test.
- All interior finishes must be installed, including but not limited to millwork, doors, paint, carpet and acoustic tiles. Movable furnishings such as workstations and partitions should be in place for the testing, although it is not required.
- The number of sampling locations will depend on the size of the building and number of ventilation systems. The number of sampling locations must include the entire building and all representative situations. Include areas with the least ventilation and greatest presumed source strength.
- Air samples must be collected between 3 and 6 feet from the floor to represent the breathing zone of occupants, and over a minimum 4-hour period.

Potential Technologies & Strategies

Prior to occupancy, perform a building flush-out or test the air contaminant levels in the building. The flush-out is often used where occupancy is not required immediately upon substantial completion of construction. IAQ testing can minimize schedule impacts but may be more costly. Coordinate with IEQ Credit 3.1: Construction IAQ Management Plan — During Construction and IEQ Credit 5: Indoor Chemical & Pollutant Source Control to determine the appropriate specifications and schedules for filtration media.

The intent of this credit is to eliminate IAQ problems that occur as a result of construction. Architectural finishes used in tenant build-outs constitute a significant source of air pollutants and must be addressed to qualify for this credit.

IEQ Credit 4.1: Low-Emitting Materials—Adhesives and Sealants

1 Point

Intent

To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

All adhesives and sealants used on the interior of the building (i.e., inside of the weatherproofing system and applied on-site) must comply with the following requirements as applicable to the project scope[1]:

- Adhesives, Sealants and Sealant Primers must comply with South Coast Air Quality Management District (SCAQMD) Rule #1168. Volatile organic compound (VOC) limits listed in the table below correspond to an effective date of July 1, 2005 and rule amendment date of January 7, 2005.

Architectural Applications	VOC Limit (g/L less water)	Specialty Applications	VOC Limit (g/L less water)
Indoor carpet adhesives	50	PVC welding	510
Carpet pad adhesives	50	CPVC welding	490
Wood flooring adhesives	100	ABS welding	325
Rubber floor adhesives	60	Plastic cement welding	250
Subfloor adhesives	50	Adhesive primer for plastic	550
Ceramic tile adhesives	65	Contact adhesive	80
VCT and asphalt adhesives	50	Special purpose contact adhesive	250
Drywall and panel adhesives	50	Structural wood member adhesive	140
Cove base adhesives	50	Sheet applied rubber lining operations	850
Multipurpose construction adhesives	70	Top and trim adhesive	250
Structural glazing adhesives	100		
Substrate Specific Applications	**VOC Limit (g/L less water)**	**Sealants**	**VOC Limit (g/L less water)**
Metal to metal	30	Architectural	250
Plastic foams	50	Roadway	250
Porous material (except wood)	50	Other	420
Wood	30		
Fiberglass	80		
Sealant Primers	**VOC Limit (g/L less water)**		
Architectural, nonporous	250		
Architectural, porous	775		
Other	750		
This table excludes adhesives and sealants integral to the water-proofing system or that are not building related.			

1 The use of a VOC budget is permissible for compliance with this credit.

- Aerosol Adhesives must comply with Green Seal Standard for Commercial Adhesives GS-36 requirements in effect on October 19, 2000.

Aerosol Adhesives	VOC Limit
General purpose mist spray	65% VOCs by weight
General purpose web spray	55% VOCs by weight
Special purpose aerosol adhesives (all types)	70% VOCs by weight

Potential Technologies & Strategies

Specify low-VOC materials in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where adhesives and sealants are addressed. Common products to evaluate include general construction adhesives, flooring adhesives, fire-stopping sealants, caulking, duct sealants, plumbing adhesives and cove base adhesives. Review product cut sheets, material safety data (MSD) sheets, signed attestations or other official literature from the manufacturer clearly identifying the VOC contents or compliance with referenced standards.

IEQ Credit 4.2: Low-Emitting Materials—Paints and Coatings

1 Point

Intent

To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Paints and coatings used on the interior of the building (i.e., inside of the weatherproofing system and applied on-site) must comply with the following criteria as applicable to the project scope[1]:

- Architectural paints and coatings applied to interior walls and ceilings must not exceed the volatile organic compound (VOC) content limits established in Green Seal Standard GS-11, Paints, 1st Edition, May 20, 1993.
- Anti-corrosive and anti-rust paints applied to interior ferrous metal substrates must not exceed the VOC content limit of 250 g/L established in Green Seal Standard GC-03, Anti-Corrosive Paints, 2nd Edition, January 7, 1997.
- Clear wood finishes, floor coatings, stains, primers, sealers, and shellacs applied to interior elements must not exceed the VOC content limits established in South Coast Air Quality Management District (SCAQMD) Rule 1113, Architectural Coatings, rules in effect on January 1, 2004.

Potential Technologies & Strategies

Specify low-VOC paints and coatings in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where paints and coatings are addressed. Track the VOC content of all interior paints and coatings during construction.

1 The use of a VOC budget is permissible for compliance with this credit.

IEQ Credit 4.3: Low-Emitting Materials—Flooring Systems

1 Point

Intent

To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

OPTION 1

All flooring must comply with the following as applicable to the project scope:

- All carpet installed in the building interior must meet the testing and product requirements of the Carpet and Rug Institute Green Label Plus[1] program.
- All carpet cushion installed in the building interior must meet the requirements of the Carpet and Rug Institute Green Label program.
- All carpet adhesive must meet the requirements of IEQ Credit 4.1: Adhesives and Sealants, which includes a volatile organic compound (VOC) limit of 50 g/L.
- All hard surface flooring must meet the requirements of the FloorScore[2] standard (current as of the date of this rating system, or more stringent version) as shown with testing by an independent third-party. Mineral-based finish flooring products such as tile, masonry, terrazzo, and cut stone without integral organic-based coatings and sealants and unfinished/untreated solid wood flooring qualify for credit without any IAQ testing requirements. However, associated site-applied adhesives, grouts, finishes and sealers must be compliant for a mineral-based or unfinished/untreated solid wood flooring system to qualify for credit.
- Concrete, wood, bamboo and cork floor finishes such as sealer, stain and finish must meet the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1113, Architectural Coatings, rules in effect on January 1, 2004.
- Tile setting adhesives and grout must meet South Coast Air Quality Management District (SCAQMD) Rule 1168. VOC limits correspond to an effective date of July 1, 2005 and rule amendment date of January 7, 2005.

OR

OPTION 2

All flooring elements installed in the building interior must meet the testing and product requirements of the California Department of Health Services Standard Practice for the Testing of Volatile Organic Emissions

1 The Green Label Plus program for carpets and its associated VOC emission criteria in micrograms per square meter per hour, along with information on testing method and sample collection developed by the Carpet & Rug Institute (CRI) in coordination with California's Sustainable Building Task Force and the California Department of Public Health, are described in Section 9, Acceptable Emissions Testing for Carpet, DHS Standard Practice CA/DHS/EHLB/R-174, dated 07/15/04. This document is available at http://www.dhs.ca.gov/ps/deodc/ehlb/iaq/ VOCS/Section01350_7_15_2004_FINAL_PLUS_ADDENDUM-2004-01.pdf (also published as Section 01350 Section 9 [dated 2004] by the Collaborative for High Performance Schools [http://www.chps.net]).

2 FloorScore is a voluntary, independent certification program that tests and certifies hard surface flooring and associated products for compliance with criteria adopted in California for indoor air emissions of VOCs with potential health effects. The program uses a small-scale chamber test protocol and incorporates VOC emissions criteria, which are widely known as Section 1350, developed by the California Department of Health Services.

from Various Sources Using Small-Scale Environmental Chambers, including 2004 Addenda. Mineral-based finish flooring products such as tile, masonry, terrazzo, and cut stone without integral organic-based coatings and sealants and unfinished/untreated solid wood flooring qualify for credit without any IAQ testing requirements. However, associated site-applied adhesives, grouts, finishes and sealers must be compliant for a mineral-based or unfinished/untreated solid wood flooring system to qualify for credit.

Potential Technologies & Strategies

Clearly specify requirements for product testing and/or certification in the construction documents. Select products that are either certified under the Green Label Plus program or for which testing has been done by qualified independent laboratories in accordance with the appropriate requirements.

IEQ Credit 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products

1 Point

Intent

To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Composite wood and agrifiber products used on the interior of the building (i.e., inside the weatherproofing system) must contain no added urea-formaldehyde resins. Laminating adhesives used to fabricate on-site and shop-applied composite wood and agrifiber assemblies must not contain added urea-formaldehyde resins.

Composite wood and agrifiber products are defined as particleboard, medium density fiberboard (MDF), plywood, wheatboard, strawboard, panel substrates and door cores. Materials considered fixtures, furniture and equipment (FF&E) are not considered base building elements and are not included.

Potential Technologies & Strategies

Specify wood and agrifiber products that contain no added urea-formaldehyde resins. Specify laminating adhesives for field and shop-applied assemblies that contain no added urea-formaldehyde resins. Review product cut sheets, material safety data (MSD) sheets, signed attestations or other official literature from the manufacturer.

IEQ Credit 5: Indoor Chemical and Pollutant Source Control

1 Point

Intent

To minimize building occupant exposure to potentially hazardous particulates and chemical pollutants.

Requirements

Design to minimize and control the entry of pollutants into buildings and later cross-contamination of regularly occupied areas through the following strategies:

- Employ permanent entryway systems at least 10 feet long in the primary direction of travel to capture dirt and particulates entering the building at regularly used exterior entrances. Acceptable entryway systems include permanently installed grates, grill s and slotted systems that allow for cleaning underneath. Roll-out mats are acceptable only when maintained on a weekly basis by a contracted service organization.
- Sufficiently exhaust each space where hazardous gases or chemicals may be present or used (e.g., garages, housekeeping and laundry areas, copying and printing rooms) to create negative pressure with respect to adjacent spaces when the doors to the room are closed. For each of these spaces, provide self-closing doors and deck-to-deck partitions or a hard-lid ceiling. The exhaust rate must be at least 0.50 cubic feet per minute (cfm) per square foot with no air recirculation. The pressure differential with the surrounding spaces must be at least 5 Pascals (Pa) (0.02 inches of water gauge) on average and 1 Pa (0.004 inches of water) at a minimum when the doors to the rooms are closed.
- In mechanically ventilated buildings, each ventilation system that supplies outdoor air shall comply with the following:
  - Particle filters or air cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces.
  - These filters or devices shall be rated a minimum efficiency reporting value (MERV) of 13 or higher in accordance with ASHRAE Standard 52.2.
  - Clean air Filtration media shall be installed in all air systems after completion of construction and prior to occupancy.

Potential Technologies & Strategies

Design facility cleaning and maintenance areas with isolated exhaust systems for contaminants. Maintain physical isolation from the rest of the regularly occupied areas of the building. Install permanent architectural entryway systems such as grills or grates to prevent occupant-borne contaminants from entering the building. Install high-level filtration systems in air handling units processing outside supply air. Ensure that air handling units can accommodate required filter sizes and pressure drops.

IEQ Credit 6.1: Controllability of Systems—Lighting

1 Point

Intent
To provide a high level of lighting system control by individual occupants or groups in multi-occupant spaces (e.g., classrooms and conference areas) and promote their productivity, comfort and well-being.

Requirements
Provide individual lighting controls for 90% (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences

Provide lighting system controls for all shared multi-occupant spaces to enable adjustments that meet group needs and preferences.

Potential Technologies & Strategies
Design the building with occupant controls for lighting. Strategies to consider include lighting controls and task lighting. Integrate lighting systems controllability into the overall lighting design, providing ambient and task lighting while managing the overall energy use of the building.

IEQ Credit 6.2: Controllability of Systems—Thermal Comfort

1 Point

Intent

To provide a high level of thermal comfort system control[1] by individual occupants or groups in multi-occupant spaces (e.g., classrooms or conference areas) and promote their productivity, comfort and well-being.

Requirements

Provide individual comfort controls for 50% (minimum) of the building occupants to enable adjustments to meet individual needs and preferences. Operable windows may be used in lieu of controls for occupants located 20 feet inside and 10 feet to either side of the operable part of a window. The areas of operable window must meet the requirements of ASHRAE Standard 62.1-2007 paragraph 5.1 Natural Ventilation (with errata but without addenda[2]).

Provide comfort system controls for all shared multi-occupant spaces to enable adjustments that meet group needs and preferences.

Conditions for thermal comfort are described in ASHRAE Standard 55-2004 (with errata but without addenda[2]) and include the primary factors of air temperature, radiant temperature, air speed and humidity.

Potential Technologies & Strategies

Design the building and systems with comfort controls to allow adjustments to suit individual needs or those of groups in shared spaces. ASHRAE Standard 55-2004 (with errata but without addenda[2]) identifies the factors of thermal comfort and a process for developing comfort criteria for building spaces that suit the needs of the occupants involved in their daily activities. Control strategies can be developed to expand on the comfort criteria and enable individuals to make adjustments to suit their needs and preferences. These strategies may involve system designs incorporating operable windows, hybrid systems integrating operable windows and mechanical systems, or mechanical systems alone. Individual adjustments may involve individual thermostat controls, local diffusers at floor, desk or overhead levels, control of individual radiant panels or other means integrated into the overall building, thermal comfort systems and energy systems design. Designers should evaluate the closely tied interactions between thermal comfort as required by ASHRAE Standard 55-2004 (with errata but without addenda[2]) and acceptable indoor air quality as required by ASHRAE Standard 62.1-2007 (with errata but without addenda[2]), whether natural or mechanical ventilation.

1 For the purposes of this credit, comfort system control is defined as control over at least 1 of the following primary factors in the occupant's vicinity: air temperature, radiant temperature, air speed and humidity.
2 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Credit 7.1: Thermal Comfort—Design

1 Point

Intent

To provide a comfortable thermal environment that promotes occupant productivity and well-being.

Requirements

Design heating, ventilating and air conditioning (HVAC) systems and the building envelope to meet the requirements of ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy (with errata but without addenda[1]). Demonstrate design compliance in accordance with the Section 6.1.1 documentation.

Potential Technologies & Strategies

Establish comfort criteria according to ASHRAE 55-2004 (with errata but without addenda) that support the desired quality and occupant satisfaction with building performance. Design the building envelope and systems with the capability to meet the comfort criteria under expected environmental and use conditions. Evaluate air temperature, radiant temperature, air speed and relative humidity in an integrated fashion, and coordinate these criteria with IEQ Prerequisite 1: Minimum IAQ Performance, IEQ Credit 1: Outdoor Air Delivery Monitoring, and IEQ Credit 2: Increased Ventilation.

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Credit 7.2: Thermal Comfort—Verification

1 point in addition to IEQ credit 7.1

Intent

To provide for the assessment of building occupant thermal comfort over time.

Requirements

Achieve IEQ Credit 7.1: Thermal Comfort—Design

Provide a permanent monitoring system to ensure that building performance meets the desired comfort criteria as determined by IEQ Credit 7.1: Thermal Comfort—Design.

Agree to conduct a thermal comfort survey of building occupants within 6 to 18 months after occupancy. This survey should collect anonymous responses about thermal comfort in the building, including an assessment of overall satisfaction with thermal performance and identification of thermal comfort-related problems. Agree to develop a plan for corrective action if the survey results indicate that more than 20% of occupants are dissatisfied with thermal comfort in the building. This plan should include measurement of relevant environmental variables in problem areas in accordance with ASHRAE Standard 55-2004 (with errata but without addenda[1]).

Residential projects are not eligible for this credit.

Potential Technologies & Strategies

ASHRAE 55-2004 provides guidance for establishing thermal comfort criteria and documenting and validating building performance to the criteria. While the standard is not intended for purposes of continuous monitoring and maintenance of the thermal environment, the principles expressed in the standard provide a basis for the design of monitoring and corrective action systems.

1 Project teams wishing to use ASHRAE approved addenda for the purposes of this credit may do so at their discretion. Addenda must be applied consistently across all LEED credits.

IEQ Credit 8.1: Daylight and Views—Daylight

1 Point

Intent

To provide for the building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Through 1 of the 4 options, achieve daylighting in at least the following spaces[1]:

Regularly Occupied Spaces	Points
75%	1

OPTION 1. Simulation

Demonstrate through computer simulations that the applicable spaces achieve daylight illuminance levels of a minimum of 10 footcandles (fc) and a maximum of 500 fc in a clear sky condition on September 21 at 9 a.m. and 3 p.m.

Provide glare control devices to avoid high-contrast situations that could impede visual tasks. However, designs that incorporate view-preserving automated shades for glare control may demonstrate compliance for only the minimum 10 fc illuminance level.

OR

OPTION 2. Prescriptive

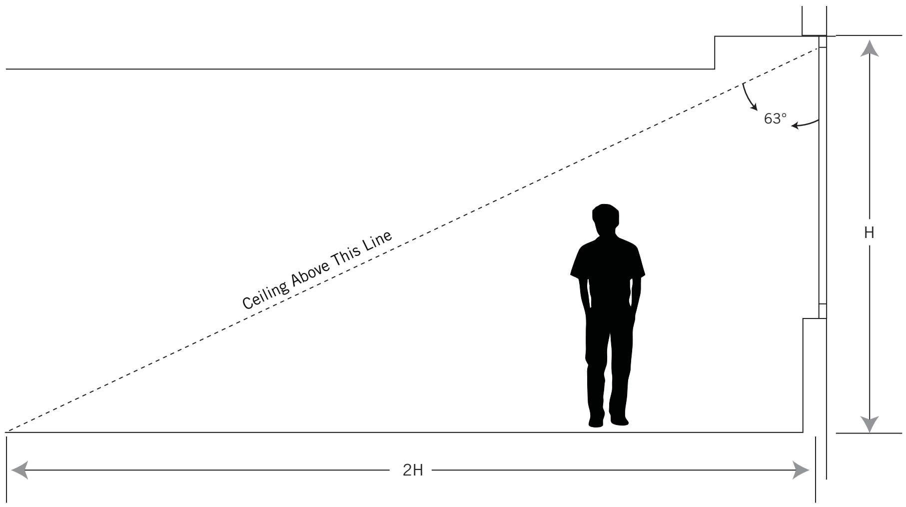
For side-lighting zones:

- Achieve a value, calculated as the product of the visible light transmittance (VLT) and window-to-floor area ratio (WFR) between 0.150 and 0.180.

$$0.150 < VLT \times WFR < 0.180$$

- The window area included in the calculation must be at least 30 inches above the floor.
- In section, the ceiling must not obstruct a line that extends from the window-head to a point on the floor that is located twice the height of the window-head from the exterior wall as measured perpendicular to the glass (see diagram on next page).

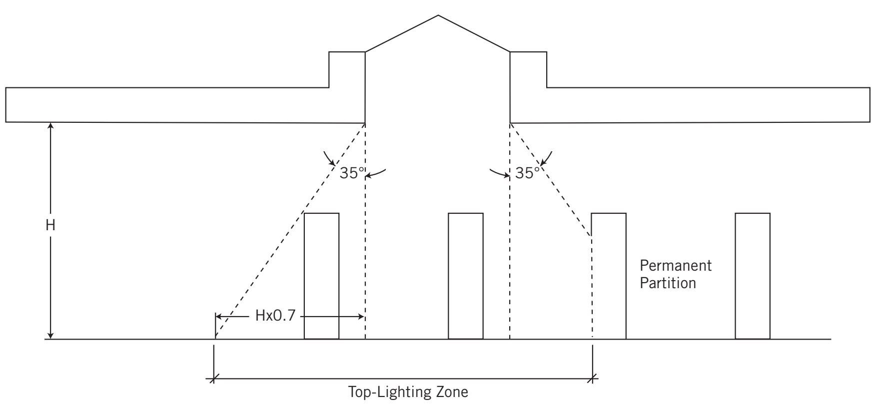
1 Exceptions for areas where tasks would be hindered by the use of daylight will be considered on their merits.



- Provide glare control devices to avoid high-contrast situations that could impede visual tasks. However, designs that incorporate view-preserving automated shades for glare control may demonstrate compliance for only the minimum 0.150 value.

For top-lighting zones:

- The top-lighting zone under a skylight is the outline of the opening beneath the skylight, plus in each direction the lesser of (see diagram below):
  - 70% of the ceiling height,
  - 1/2 the distance to the edge of the nearest skylight,
  - The distance to any permanent partition that is closer than 70% of the distance between the top of the partition and the ceiling.



- Achieve skylight coverage for the applicable space (containing the top-lighting zone) between 3% and 6% of the total floor area.
- The skylight must have a minimum 0.5 VLT.
- A skylight diffuser, if used, must have a measured haze value of greater than 90% when tested according to ASTM D1003.

OR

OPTION 3. Measurement

Demonstrate through records of indoor light measurements that a minimum daylight illumination level of 10 fc and a maximum of 500 fc has been achieved in the applicable spaces. Measurements must be taken on a 10-foot grid and shall be recorded on building floor plans.

Provide glare control devices to avoid high-contrast situations that could impede visual tasks. However, designs that incorporate view-preserving automated shades for glare control may demonstrate compliance for only the minimum 10 fc illuminance level.

OR

OPTION 4. Combination

Any of the above calculation methods may be combined to document the minimum daylight illumination in the applicable spaces.

Potential Technologies & Strategies

Design the building to maximize interior daylighting. Strategies to consider include building orientation, shallow floor plates, increased building perimeter, exterior and interior permanent shading devices, high-performance glazing, and high-ceiling reflectance values; ly, additionally, automatic photocell-based controls can help to reduce energy use. Predict daylight factors via manual calculations or model daylighting strategies with a physical or computer model to assess footcandle levels and daylight factors achieved.

IEQ Credit 8.2: Daylight and Views—Views

1 Point

Intent

To provide building occupants a connection to the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Achieve a direct line of sight to the outdoor environment via vision glazing between 30 inches and 90 inches above the finish floor for building occupants in 90% of all regularly occupied areas. Determine the area with a direct line of sight by totaling the regularly occupied square footage that meets the following criteria:

- In plan view, the area is within sight lines drawn from perimeter vision glazing.
- In section view, a direct sight line can be drawn from the area to perimeter vision glazing.

The line of sight may be drawn through interior glazing. For private offices, the entire square footage of the office may be counted if 75% or more of the area has a direct line of sight to perimeter vision glazing. For multi-occupant spaces, the actual square footage with a direct line of sight to perimeter vision glazing is counted.

Potential Technologies & Strategies

Design the space to maximize daylighting and view opportunities. Strategies to consider include lower partitions, interior shading devices, interior glazing and automatic photocell-based controls.

INNOVATION IN DESIGN

ID Credit 1: Innovation in Design

1–5 Points

Intent

To provide design teams and projects the opportunity to achieve exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.

Requirements

Credit can be achieved through any combination of the Innovation in Design and Exemplary Performance paths as described below:

PATH 1. Innovation in Design (1-5 points)

Achieve significant, measurable environmental performance using a strategy not addressed in the LEED 2009 for New Construction and Major Renovations Rating System.

One point is awarded for each innovation achieved. No more than 5 points under IDc1 may be earned through PATH 1—Innovation in Design.

Identify the following in writing:

- The intent of the proposed innovation credit.
- The proposed requirement for compliance.
- The proposed submittals to demonstrate compliance.
- The design approach (strategies) used to meet the requirements.

PATH 2. Exemplary Performance (1-3 points)

Achieve exemplary performance in an existing LEED 2009 for New Construction and Major Renovations prerequisite or credit that allows exemplary performance as specified in the LEED Reference Guide for Green Building Design & Construction, 2009 Edition. An exemplary performance point may be earned for achieving double the credit requirements and/or achieving the next incremental percentage threshold of an existing credit in LEED.

One point is awarded for each exemplary performance achieved. No more than 3 points under IDc1 may be earned through PATH 2— Exemplary Performance.

PATH 3. Pilot Credit (1-5 points)

Attempt a pilot credit available in the Pilot Credit Library at www.usgbc.org/pilotcreditlibrary. Register as a pilot credit participant and complete the required documentation. Projects may pursue up to 5 Pilot Credits total.

Potential Technologies & Strategies

Substantially exceed a LEED 2009 for New Construction and Major Renovations performance credit such as energy performance or water efficiency. Apply strategies or measures that demonstrate a comprehensive approach and quantifiable environment and/or health benefits.

ID Credit 2: LEED Accredited Professional

1 Point

Intent
To support and encourage the design integration required by LEED to streamline the application and certification process.

Requirements
At least 1 principal participant of the project team shall be a LEED Accredited Professional (AP).

Potential Technologies & Strategies
Educate the project team members about green building design and construction, the LEED requirements and application process early in the life of the project. Consider assigning integrated design and construction process facilitation to the LEED AP.

REGIONAL PRIORITY

RP Credit 1: Regional Priority

1–4 Points

Intent

To provide an incentive for the achievement of credits that address geographically-specific environmental priorities.

Requirements

Earn 1-4 of the 6 Regional Priority credits identified by the USGBC regional councils and chapters as having environmental importance for a project's region. A database of Regional Priority credits and their geographic applicability is available on the USGBC website, http://www.usgbc.org.

One point is awarded for each Regional Priority credit achieved; no more than 4 credits identified as Regional Priority credits may be earned. The USGBC has prioritized credits for projects located in the U.S., Puerto Rico, the U.S. Virgin Islands, and Guam. All other international projects should check the database for eligible Regional Priority credits.

Potential Technologies & Strategies

Determine and pursue the prioritized credits for the project location.

Attachment C-
NY Fact Sheet and Brigham
Young and MU reports

STATE OF NEW YORK
DEPARTMENT OF HEALTH

Flanigan Square 547 River Street Troy, New York 12180-2216

Richard F. Daines, M.D.
Commissioner

Wendy E. Saunders
Chief of Staff

FACT SHEET
Crumb-Rubber Infilled Synthetic Turf Athletic Fields
August 2008

PURPOSE

There are several kinds of synthetic turf surfaces (*e.g.*, surfaces that use a fill material ("infill") between the blades of artificial grass and those that do not), and synthetic turf may be installed for different uses (*e.g.*, single or multiple sport athletic fields, landscaping, golf applications). The focus of this fact sheet is athletic fields with crumb rubber infilled synthetic turf. This fact sheet was developed to assist people in making decisions about installing or using this kind of synthetic turf athletic field. Considerations related to other kinds of synthetic turf fields are not addressed in this fact sheet.

BACKGROUND

The first well-publicized use of AstroTurf, a synthetic turf for athletic fields, was at the Houston Astrodome in 1966. This first generation of synthetic turf was essentially a short pile carpet with a foam backing. Since then, design changes have resulted in a greater variety of synthetic turf athletic fields. One type of synthetic turf is fabricated using synthetic fibers, manufactured to resemble natural grass, and a base material that stabilizes and cushions the playing surface. The fibers are typically made from nylon, polypropylene or polyethylene and are connected to a backing material. The base material, also called infill, consists of one or more granular materials that are worked in between the fibers during the installation process. Commonly used base materials are granulated crumb rubber (usually from used tires), flexible plastic pellets, sand, and rubber-coated sand. A combination of sand and crumb rubber is often used.

Crumb rubber is produced by grinding used tires. Steel and fiber tire components are removed during the process and the rubber pellets are sorted by size. Pellet sizes ranging from about one-sixteenth to one-quarter inch in diameter are used on synthetic turf. Crumb rubber is typically applied at a rate of two to three pounds per square foot of field surface.

HEALTH AND SAFETY CONSIDERATIONS

Some potential health and safety considerations related to synthetic turf have generated public concern. These include:

- Heat stress
- Injury
- Infection
- Latex allergy
- Chemical exposure

Heat Stress

Synthetic turf fields absorb heat, resulting in surface temperatures that are much higher than the temperatures of the surrounding air. In June 2002 at Brigham Young University (BYU) in Utah, the average surface temperature on a synthetic turf field was reported to be 117°F while the average surface temperatures on natural turf and asphalt were 78°F and 110°F, respectively. A maximum surface temperature of 200°F on the BYU synthetic turf field was reported. A turfgrass specialist at the University of Missouri reported measuring an air temperature of 138°F at "head-level" height on the university's synthetic turf field on a sunny 98°F day. The surface temperature of the field was reported to be 178°F. A study conducted at Penn State University measured surface temperatures on experimental plots of nine different types of infilled turf. Temperature measurements were made on three occasions. The average air temperatures reported were 79°, 78°, and 85°F. The corresponding average surface temperatures reported for the synthetic turf plots are 120°, 130° and 146°F.

Water can be applied to synthetic turf to reduce the surface temperatures on warm days. A study at BYU found that watering synthetic turf lowered the surface temperature from 174°F to 85°F, but the temperature rose to 120°F in five minutes and to 164°F in twenty minutes. A study conducted by Penn State University on experimental synthetic turf plots examined the effect of watering synthetic turf on surface temperature. Measurements were made on three occasions. For one monitoring period, surface temperatures ranging from about 130° to 160°F were lowered initially to about 75°F, but increased within 30 minutes to temperatures ranging from about 90° to 120°F, where they remained fairly stable for the three-hour monitoring period.

The surface temperatures reported on synthetic turf fields can get high enough to reach levels of discomfort and may contribute to heat stress among users of the fields. While watering synthetic turf may reduce surface temperatures, other factors are likely to influence its effectiveness. At the present time, NYSDOH is unaware of any studies that have examined the role of synthetic turf in contributing to heat stress or that have compared the occurrence of heat stress among athletes playing on natural turf and synthetic turf.

Because of the potential for high temperatures on infilled synthetic turf fields, it is important that people who play or work on the fields be provided with adequate warnings regarding the potential for heat stress. People should also be advised to remain hydrated and to seek relief from the heat in shaded areas. The potential for and frequency of high surface temperatures warrant consideration when making decisions about installing and using a synthetic turf field.

Injury

There is a common perception that there are more sports injuries on synthetic than on natural turf athletic fields. Many factors influence the rate of sports injuries, including the type of playing surface. The many kinds of synthetic turf surfaces and changes in the turf products over the years complicate the assessment of how the playing surface affects injury rates. Other risk factors have been implicated in injury rates among athletes, in addition to the type of playing surface. These risk factors include level of competition, skill level, age, shoe type, previous injury and rehabilitation, and a number of individual physical characteristics. We identified five studies that compared injury (*e.g.,* sprains, lacerations, fractures) rates among athletes when playing on infilled synthetic turf and natural turf fields. Although the ability of the studies to detect differences in the injury rates was limited by the small number of injuries reported, the studies concluded that there were no major differences in overall injury rates between natural and infilled synthetic turf. Although each study found some differences in specific injury types, there was no consistent pattern across the studies.

The potential for head injuries from contact with the surfaces has been assessed by determining the ability of the surfaces to absorb impacts. Tests have shown that the force of impact on asphalt surfaces is much higher than the level generally accepted to be associated with serious head injury. The force of impact on many types of natural turf and all types of synthetic turf tested are below this level. The force of impact on frozen natural turf is typically above the acceptable level. No data are available for the force of impact on frozen synthetic turf.

The abrasiveness of synthetic turf fibers may contribute to the injury risk among athletes, particularly for abrasions or "turf burns." The degree of abrasiveness appears to be dependent on the composition and shape of the turf fibers. A study conducted at Penn State University suggests that synthetic turf with nylon fibers is more abrasive than synthetic turf with other types of fibers.

Infection Risk

Some people have expressed concern that infections, including methicillin-resistant *Staphylococcus aureus* (MRSA), may be more common among users of synthetic turf fields than users of natural turf fields. This possibility has not been studied systematically, and no definitive statements can be made about differences in risk between the two surfaces.

At least two questions are important in evaluating the risk of infection. Does skin damage occur more frequently on synthetic turf than natural turf, thus providing a place where infections are more likely to occur? Are there more germs on synthetic turf than natural turf?

While injury studies have not consistently identified differences in abrasion and laceration risks between natural and infilled synthetic turf, some types of synthetic turf may result in more skin abrasions. Although very few tests have been performed, the available data do not suggest the widespread presence of infectious agents, such as MRSA, on synthetic turf fields. Also, the available information indicates that outdoor or indoor synthetic turf surfaces are no more likely to harbor infectious agents than other surfaces in those same environments. Disease outbreak investigations conducted in response to illnesses caused by a variety of germs (*e.g.*, MRSA, *Campylobacter*, meningococcus, echovirus, herpes simplex virus, hepatitis virus, coxsackie virus) have not identified playing fields, either natural or synthetic, as likely to increase the risk of transmitting infections.

Skin cuts and abrasions that may result from contact with athletic fields, including both natural and synthetic fields, are susceptible to infection. Athletes and others developing skin abrasions should clean the wounds and seek prompt medical attention. Athletes should avoid sharing towels (on and off the field), equipment, razors, soap and other objects with others, because sharing these items can spread germs.

Latex Allergy

Latex, a substance found in natural rubber, contains substances called "latex allergens," which can cause an allergic response in some people. About 6 percent of the general population is allergic to the substances in latex. Tire rubber contains the latex allergen, although at much lower levels than in latex gloves and other consumer products. People playing on synthetic turf may be exposed to latex allergens through direct contact with the skin (dermal exposure) and inhalation of small rubber particles suspended in the air.

A study conducted for the California Environmental Protection Agency tested samples of tire rubber on the skin of guinea pigs. None of the animals developed any rashes or allergic reactions from contact with the rubber.

Whether crumb rubber can cause an allergic response in people is not known. NYSDOH is unaware of any occurrences of latex allergy associated with contact with crumb rubber or synthetic turf fields.

Chemical Exposure

Exposure to a chemical requires contact with it. Contact with a chemical occurs in three ways: swallowing it (ingestion exposure), breathing it (inhalation exposure), and having it come in contact with the skin (dermal exposure) or eyes (ocular exposure). The potential for harmful effects from exposure to a chemical depends on the amount of the chemical a person contacts, how the chemical enters the body (ingestion, inhalation, dermal, or ocular), how often contact occurs, and the toxic properties of the chemical. The ability of a chemical to be released from a substance (*e.g.*, crumb rubber) is an important factor in determining how much exposure actually occurs. Other factors that can influence a person’s risk for adverse health effects from environmental chemicals include age, gender, general health, genetic differences, exposure to other chemicals and lifestyle choices.

Tires are manufactured from natural and synthetic rubbers along with numerous chemical additives, including zinc, sulfur, carbon black, and oils that contain polyaromatic hydrocarbons (PAHs) and volatile organic chemicals. Because crumb rubber is manufactured from used tires, it probably contains the same chemicals as tire rubber.

Studies have been conducted by the California Environmental Protection Agency Office of Environmental Health Hazard Assessment and the Norwegian Institute of Public Health to assess the potential for ingestion exposure to the chemicals in crumb rubber by children playing on synthetic turf. Both studies concluded that health risks to children resulting from the ingestion of crumb rubber are low.

The Norwegian Institute of Public Health also collected data to assess potential health risks resulting from dermal and inhalation exposures to chemicals contained in synthetic turf fields. Health assessments were conducted for adults and children. The researchers concluded that adverse health effects resulting dermal exposures to crumb rubber or from inhalation exposures to organic chemicals released from the fields are unlikely. No health assessment of the concentrations of rubber particles in the air was made.

A French study measured the concentrations of organic chemicals emitted as gases (known as volatile organic compounds or VOCs) from crumb rubber under laboratory conditions. The data were used by the French National Institute for Industrial Environment and Risks to evaluate possible health effects from inhaling VOCs released from synthetic turf. The study authors concluded that the concentrations of organic compounds emitted did not pose a health concern for athletes, officials or spectators.

Some types of synthetic turf fibers contain elevated levels of lead (*e.g.*, in the range of about 2,000 to 9,000 parts per million). Degradation of these fibers can form a dust that presents a potential source of lead exposure to users of the fields. The Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry addressed the potential for lead exposures from synthetic turf fibers in a June 2008 Health Advisory (http://www.cdc.gov/nceh/lead/artificialturf.htm). For new or replacement installations, select synthetic turf products that do not have elevated lead levels.

Our review of the available information on crumb rubber and crumb rubber infilled turf fields indicates that ingestion, dermal or inhalation exposures to chemicals in or released from crumb rubber do not pose a significant public health concern.

OTHER CONSIDERATIONS

A number of other factors may need to be considered when installing and using synthetic turf.

Use: Synthetic turf is more durable than natural turf and can be used without the rest periods that natural turf requires to keep the turf healthy. The New York City Department of Parks and Recreation (NYCDPR) estimates that on an annual basis, permitted use (hours per year) for synthetic turf athletic fields is 28 percent higher than for natural grass fields.

Installation: Installation costs of synthetic turf vary depending on the amount of site preparation required and the specific field design. The installation costs of synthetic turf are generally much higher than the installation costs of natural turf.

Maintenance: The maintenance costs of synthetic turf will vary depending on the field's use and design, but are typically estimated to be lower than the maintenance costs of natural turf. Natural turf requires regular mowing, fertilizer application, pest control and possibly watering. Synthetic turf requires replacing infill materials, repairing seams and removing weeds and moss. Specialized equipment, which may or may not be included in the field's purchase price, is required for these activities.

Lifetime: NYCDPR estimates that the lifetime of a natural turf field is on the order of five years. The synthetic turf industry estimates that the lifetime of an infilled synthetic turf athletic field is eight to ten years, depending on care during installation and use. NYCDPR and other New York entities have seen similar lifetimes.

SUMMARY OF INFORMATION FOR CRUMB-RUBBER INFILLED SYNTHETIC TURF ATHLETIC FIELDS

Heat stress	Surface temperatures on crumb-rubber infilled synthetic turf fields can reach levels of discomfort and may contribute to heat stress. This warrants consideration when making decisions about installing and using a synthetic turf field. While watering synthetic turf may briefly reduce surface temperatures, a number of factors may influence its effectiveness. People using these fields should be advised to remain hydrated and to seek relief from the heat in shaded areas.
Injury	Overall, studies have found no consistent differences in injury rates between natural and crumb-rubber infilled synthetic turf.
Infection	Skin cuts and abrasions that may result from contact with athletic fields (natural and synthetic turf) are susceptible to infection. Athletes and others developing skin abrasions should clean the wounds and seek prompt medical attention. Athletes should avoid sharing equipment, razors, towels, soap and other objects with others, because these items can spread germs.
Latex allergy	At the present time, NYSDOH is unaware of any occurrences of latex allergy resulting from contact with crumb rubber or synthetic turf fields.
Chemical exposures	Based on the available information, chemical exposures from crumb rubber in synthetic turf do not pose a public health hazard.

WHERE CAN I GET MORE INFORMATION?

If you have any questions about the information in this fact sheet or would like to know more about in-filled synthetic turf athletic fields, please call the NYSDOH at 1-800-458-1158 or write to the following address:

New York State Department of Health
Bureau of Toxic Substance Assessment
Flanigan Square, 547 River St.
Troy, NY 12180-2216

SOME RELEVANT REFERENCES

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Brigham Young University Study

"Synthetic Surface Heat Studies"

C. Frank Williams and Gilbert E. Pulley
Brigham Young University

Synthetic turf surfaces have long been regarded as a lower maintenance alternative to natural turf. However, synthetic surfaces like natural turf have their shortcomings. In the spring of 2002 a Field Turf synthetic surface was installed on one half of Brigham Young University's Football Practice Field. The other half of the installation is a sand-based natural turf field. Shortly after the Field Turf was installed football camps were started. The coaches noticed the surface of the synthetic turf was very hot. One of the coaches got blisters on the bottom of his feet through his tennis shoes. An investigation was launched to determine the range of the temperatures, the effect water for cooling of the surfaces, and how the temperatures compared to other surfaces.

On June of 2002 preliminary temperatures were taken at five feet and six inches above the surface and at the surface with an infrared thermometer of the synthetic turf, natural turf, bare soil, asphalt and concrete. A soil thermometer was used to measure the temperature at two inches below the surface of the synthetic turf. Also, water was used to cool the surface of the natural and artificial turf. It was determined that the natural turf did not heat up very quickly after the irrigation so only the artificial turf was tracked at five and twenty minutes after wetting. The results of the preliminary study are shocking. The surface temperature of the synthetic turf was 37º F higher than asphalt and 86.5º F hotter than natural turf. Two inches below the synthetic turf surface was 28.5º F hotter than natural turf at the surface. Irrigation of the synthetic turf had a significant result cooling the surface from 174º F to 85º F but after five minutes the temperature rebounded to 120º F. The temperature rebuilt to 164º F after only twenty minutes. These preliminary findings led to a more comprehensive look at the factors involved in heating of the artificial turf.

Three aspects of light were measured along with relative humidity. The synthetic surface was treated as two areas, the soccer field and the football field and the natural turf was one area. Four randomly selected sampling spots were marked with a measuring tape from reference points on the fields so it could be accessed for subsequent data collection. Bare soil, concrete, and asphalt sampling areas were selected and marked in a similar manner. The results are shown in table form below:

Table 1.

Surface	**Average Surface Temperature between 7:00 AM and 7:00 PM**	
Soccer	117.38º F	high 157º F
Football	117.04º F	high 156º F
Natural Turf	78.19º F	high 88.5º F
Concrete	94.08º F	
Asphalt	109.62º F	
Bare Soil	98.23º F	

Table 2.

Two inch depth	**Average Soil Temperature between 7:00 AM and 7:00 PM**	
Soccer	95.33º F	high 116º F
Football	96.48º F	high 116.75º F
Natural Turf	80.42º F	high 90.75º F
Bare Soil	90.08º F	

Table 3.

Shade	**Average Temperature between 9:00 AM and 2:00 PM**	
Surface Temperature of Natural Turf	66.35º F	high 75º F
Surface Temperature of Artificial Turf	75.89º F	high 99º F
Average Air Temperature	81.42º F	

Surface Temperature of A.T. (Artificial Turf) is significantly higher than air or soil temperature of A.T. The amount of light (electromagnetic radiation) has a greater impact on temperature of A.T. than air temperature. The hottest surface temperature recorded was 200º F on a 98º F day. Even in October the surface temperature reached 112.4º F. This is 32.4º F higher than the air temperature. White lines and shaded areas are less affected because of reflection and intensity of light. Natural grass areas have the lowest surface and subsurface temperatures than other surfaces measured. Cooling with water could be a good strategy but the volume of water needed to dissipate the heat is greatly lessened by poor engineering (infiltration and percolation).

Average air temperature over natural turf in the late afternoon is lower than other surfaces. Soil temperature of A.T. is greater than bare soil and natural turf. Humidity appears to be inversely related to surface and soil temperature. It is likely that energy is absorbed from the sunlight by the water vapor.

The heating characteristics of the A.T. make cooling during events a priority. The Safety Office at B.Y.U. set 120º F as the maximum temperature that the surface could reach. When temperature reaches 122º F it takes less than 10 minutes to cause injury to skin. At this temperature the surface had to be cooled before play was allowed to continue on the surface. The surface is monitored constantly and watered when temperatures reach the maximum. The heat control adds many maintenance dollars to the maintenance budget.

A budget comparison was made using actual dollars spent and for every dollar spent on the A.T. maintenance one dollar and thirty cents was spent on the natural turf (N.T.) practice field. While construction costs are very unbalanced, for every dollar spent on the N.T. eleven dollars and seventy-seven dollars were spent on the A.T.

The area under the carpet of BYU’s installation is designed to move water from the surface and into an extensive drain mat system. This part of the installation is two thirds of the overall cost of the A.T. Thus, for a 2.5 million dollars installation approximately 1.7 million dollars go for the subsurface and drainage. The most interesting thing about this is that the drain mat probably sees little or nº water. The surface is hydrophobic and the undersurface is poorly engineered to favor water retention rather than drainage. That seems like a high price to pay for something that does not work!

Artificial turf surfaces have their place in the turf industry. They can work in environments where grass will not grow and are marginal. However, they are costly and not maintenance free. It is important to take all the factors in to consideration before making a large investment. Don’t take the manufacture’s word for the factors of concern i.e. don’t let the fox guard the hen house. The propaganda on BYU’s installation is charts with surface temperatures less than the air temperature and claims for drainage of 60 inches per hour. The question still remains is A.T. 11.47 times better than natural turf?

University of Missouri Report

Revised: July 21 2006

Published by **CAFNR Communications**

Feature Research

Synthetic Turf Playing Fields Present Unique Dangers

By Chuck Adamson

Brad Fresenburg made a disturbing discovery when he took surface temperatures of artificial playing turf on a summer afternoon.

The University of Missouri turfgrass expert found that on a 98-degree day at MU's Faurot Field the surface temperature on the synthetic grass was 173 degrees. Nearby natural grass showed a temperature of just 105 degrees.

When Fresenburg took the temperature at head-level height over the faux turf, the thermometer registered 138 degrees.

Fresenburg said there's a national trend toward high schools and municipal recreation departments replacing grass with artificial turf – once the almost exclusive purview of college and professional sports teams – and he wants coaches and parents to know how to keep players safe.

"If they are going to have artificial fields, we need coaches, parents and players to know that temperatures on these fields are going to be anywhere from 150 to 170 degrees on some days," Fresenburg said. "You might as well be sitting in an oven somewhere."

Brad Fresenburg takes the temperature at head-level height over the faux turf at Faurot Field; the thermometer registered 138 degrees. *Photo by Jim Curley*

Turfgrass Debate (WMV)

Brad Fresenburg on MU's football playing surface. *Photo by Adam Masloski*

Natural Grass Systems (Flash)

Related Article: Synthetic Turfgrass Costs Far Exceed Natural Grass Playing Fields

The new generation of synthetic turfs are as safe, even safer in some ways, as natural grass, concluded Michael Meyers, a professor at West Texas A&M University. He has tracked playing field injuries in Texas high schools for eight years now.

Athletes tend to suffer injuries at roughly the same frequency on natural and synthetic turfs, but different surfaces tend to result in different types of injuries, he said.

"There is more torque, more velocity and more traction" on artificial turf, Meyers said

"There is more torque, more velocity and more traction" on artificial turf, Meyers said.

That can lead to more muscle strains and spasms.

But natural grass has its own hazards, such as slippery mud or unseen potholes, and possibly in arid areas, harder surfaces. More concussions per games played occurred on natural grass fields.

The newer generation of synthetic turfs is "far superior," said Meyers, to previous types like the former industry standard Astroturf, which he described as basically a carpet and carpet pad laid over concrete. Now fields are built over surfaces in-filled with recycled rubber pellets and other materials that make for softer falls, mimicking natural grass and soil playing conditions.

The drawback, said Fresenburg, is that all those rubber and plastic materials amplify sunlight to cause near unbearable temperatures at certain times of the day.

Rex Sharp, MU's head athletic trainer, said he believes synthetic turf to be just as safe as grass. But he agrees that outdoor fields will get hotter under certain conditions. In his experience the artificial fields get at least 10 to 15 degrees hotter under the afternoon sun, he said.

University staff constantly monitors field temperatures during practices, Sharp said.

Fresenburg suggested that sports teams schedule morning and evening practices, times when playing surfaces are cool. In the hot afternoon hours of August and September he said teams should seek out natural grass alternatives.

Under any workout conditions, hydration of athletes should be closely monitored, he said.

MU has two artificial turf fields, the indoor field in the Devine Pavilion and the outdoor Faurot Field in Memorial Stadium.

The older-generation turf used at Devine Pavilion is more tacky and prone to cause twisting-related injuries, Sharp said. The football players wear special cleats when practicing there. Faurot Field has the newer-generation FieldTurf brand surface. He said players can wear regular grass cleats there, and he believes that the surface is just as safe as natural grass.

Fresenburg is not so sure.

Tests Fresenburg has done show increased potential pressure on joints and bones from the inability of a fully planted cleat-wearing foot to divot or twist out, an action that releases force.

The traction on synthetic turf is much greater, he said.

"Grounds managers prefer artificial turf over natural because when teams play on grass, they leave divots and rip out grass," Fresenburg said. "Most people see those areas as damaged turf. I like to say those divots are a sign that the field is doing its job – yielding to the athletes' cleats."

Fresenburg tested four turf types, three natural grasses and MU's Faurot Field using a contraption of cleats, weights to simulate an athlete's weight and a torque wrench-like tool. When a cleat was completely planted in Faurot Field, it needed an average of 110 foot-pounds – a foot-pound is a measured unit of applied force – of torque to twist free. That was compared to 81 to 85 foot-pounds needed on the natural surfaces.

"In some areas of Faurot Field, we maxed out the instrument at 120 foot-pounds," Fresenburg said. "The cleated foot simply wouldn't shear. That's not good."

The good news is that the difference only occurred when a cleat was fully planted in the field. When only a portion of the cleat simulating the ball of a foot was planted, the force needed to twist free was the about the same on all surfaces.

The hidden danger on an artificial field is the threat of bacterial infections, Fresenburg said. He said disinfectant should be sprayed as needed if there's a known infection risk, but Fresenburg said he doesn't know what procedures are necessary to prevent bacterial contamination in the first place.

"Natural grass has a microbial system. It's self-cleaning. These synthetic fields don't have that," Fresenburg said. "There's warmth. There's moisture. Bacteria can thrive in there. There's sweat, spit and blood."

Sharp said players need to immediately report any "turf-burns," abrasions so named for their similarity to rug burns. Turf burns are common on certain types of synthetic turf. They must be immediately washed with soap and water to prevent infection, Sharp said.

Often young athletes are inclined to ignore seemingly minor injuries, Sharp said.

"We have done a good job of educating our students on turf burns," Sharp said. "We've had to educate our kids to let us clean and treat those."

Anyone interested in more tips on turfgrass safety can contact Fresenburg at 573-442-4893.

"Many schools or communities may only look at the maintenance chores of natural grass when deciding to switch to artificial turf," Fresenburg said. "They should look beyond that. They need to look at all the differences between the two surfaces."

Attachment D-CDC

Centers for Disease Control and Prevention
Your Online Source for Credible Health Information

Artificial Turf

Recent tests by the New Jersey Department of Health and Senior Services (NJDHSS) of artificial turf playing fields in that state have found these fields contain potentially unhealthy levels of lead dust. The initial tests were conducted on a limited number of playing fields. NJDHSS sampling of additional athletic fields and other related commercial products indicates that artificial turf made of nylon or nylon/polyethylene blend fibers contains levels of lead that pose a potential public health concern. Tests of artificial turf fields made with only polyethylene fibers showed that these fields contained very low levels of lead.

Information provided by NJDHSS to CDC and ATSDR indicates that some of the fields with elevated lead in either dust and/or turf fiber samples were weathered and visibly dusty. Fields that are old, that are used frequently, and that are exposed to the weather break down into dust as the turf fibers are worn or demonstrate progressive signs of weathering, including fibers that are abraded, faded or broken. These factors should be considered when evaluating the potential for harmful lead exposures from a given field.

The risk for harmful lead exposure is low from new fields with elevated lead levels in their turf fibers because the turf fibers are still intact and the lead is unlikely to be available for harmful exposures to occur. As the turf ages and weathers, lead is released in dust that could then be ingested or inhaled, and the risk for harmful exposure increases. If exposures do occur, CDC currently does not know how much lead the body will absorb; however, if enough lead is absorbed, it can cause neurological development symptoms (e.g. deficits in IQ). Additional tests are being performed by NJDHSS to help us better understand the absorption of lead from these products.

Learn About Lead Contamination in Artificial Turf

Potential Exposure to Lead in Artificial Turf
CDC Health Alert Network (HAN) Advisory from June 18, 2008, 16:10 EDT.

New Jersey Artificial Turf Investigation
Additional information about testing, dust suppression measures, and other topics related to New Jersey's artificial turf investigation.

Learn About Lead

CDC's Lead Poisoning Prevention Program
Learn more about the CDC's efforts to eliminate childhood lead poisoning in the United States.

ToxFAQs™
Frequently asked questions from the Agency for Toxic Substances & Disease Registry (ATSDR).

Toxicological Profile

Toxicologic & adverse health effects information from the Agency for Toxic Substances & Disease Registry (ATSDR).

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Centers for Disease Control and Prevention 1600 Clifton Rd. Atlanta, GA 30333, USA
800-CDC-INFO (800-232-4636) TTY: (888) 232-6348, 24 Hours/Every Day - cdcinfo@cdc.gov

Attachment E
Connecticut Report

Artificial Turf Field Investigation in Connecticut
Final Report

Prepared By

Nancy Simcox, MS
Anne Bracker, MPH, CIH

John Meyer, MD, MPH
Section of Occupational and Environmental Medicine
University of Connecticut Heath Center

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1.0 Executive Summary

The primary purpose of this project was to characterize the concentrations of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), rubber-related chemicals (e.g. benzothiazole), and particulate matter less than 10 micron (PM_{10}) and its constituents in ambient air at selected crumb rubber fields in Connecticut under conditions of active field use.

This project employed a cross-sectional environmental sampling strategy of synthetic crumb rubber turf fields to capture a range of chemical exposures during the summer season when ambient air temperatures are above 75-80^{o}F. Three general types of fields were targeted: outdoor crumb rubber fields, indoor facilities with crumb rubber turf, and an outdoor grass field in a suburban area. Sampling goals were to collect air samples on old and new turf fields during active field use and to collect air samples at background sites upwind and off of each field. A special focus of the design study included personal air sampling of many of the chemicals reported in previous studies (e.g. VOCs and benzothiazole), and other chemicals of potential concern, such as a volatile nitrosamine reported to be part of rubber manufacture. The sampling strategy also included the collection of area air samples for chemicals at different heights on the turf to assess a vertical profile of release. These air samples were collected in areas on the turf field near active play and areas on the turf away from active play. Because crumb rubber includes some amount of dusts and small particles, particulate matter air monitoring was incorporated into the stationary sampling plan (using sampling at a single height only). Bulk samples of turf grass and crumb rubber were also collected, and meteorological data (e.g. air direction, wind speed and ambient air temperature) were recorded.

Industrial hygienists from the Section of Occupational and Environmental Medicine at the University of Connecticut Health Center (OEM UCHC) conducted the field sampling and managed the analytical components of this exposure investigation. This report summarizes the data collected by OEM UCHC. This report identifies and measures chemicals across several synthetic crumb rubber turf fields and background locations. The measurements collected from background locations are necessary to better understand the data because many of these chemicals are present in ambient air as a result of general air pollution.

CT DEP recruited six fields: 4 outdoor turf fields (Fields A-D), 1 indoor turf field (Field K) and 1 outdoor suburban grass area (Field L). Six additional fields were recruited to collect crumb rubber bulk samples only (Fields E-J). Air sampling occurred during July 2009 on crumb rubber fields with polyethylene fibers that were both new (<2 years) and old (>3years). Algorithms were developed to identify chemicals possibly related to turf. Of the 60 VOCs tested in air, 4 VOCs appear to be associated with turf. Of 22 PAHs, 6 were found in the air on the turf at 2 fold greater concentrations than in background locations on at least two fields. Of the five targeted SVOCs, benzothiazole and butylated hydroxytoluene were the only chemicals detected in the personal and area air samples from outdoor turf fields ranging from <80-1200 ng/m^3 and <80-130 ng/m^3, respectively. Nitrosamine air levels were below reporting levels. PM_{10} air concentrations were greater in background locations than on the turf at all fields with the exception of Field B. However, the PM_{10} air concentration on turf at Field B, 5.89 ug/m^3, was within the range of other PM_{10} background concentrations. All of the composite samples of turf fibers and crumb rubber were below the level EPA considers as presenting a “soil-lead hazard” in play areas (400ppm).

The airborne concentrations of VOCs, targeted SVOCs (e.g. benzothiazole) and miscellaneous SVOCs were highest at the indoor field. These data were collected from only one indoor facility. Higher concentrations of these chemicals at the indoor field likely reflects the lack of air movement relative to outdoor fields. In addition, the air in the indoor field was not influenced by outdoor factors that may degrade and off-gas chemicals, such as sunlight, rain, and other weather conditions. Furthermore, potential point sources were identified in the facility, (electric carts, portable chargers, and maintenance supplies) and the indoor facility did not have its exhaust system operating on the day samples were collected. More research is needed to better understand chemical exposures in indoor facilities.

2.0 Introduction

2.1 Purpose

Crumb rubber fields have been installed or are being proposed in many towns throughout Connecticut, and elsewhere in the United States. Crumb rubber consists of recycled, chipped/pulverized, used automobile tires. The tire crumbs are roughly the size of grains of course sand and generally are spread two to three inches thick over the field surface and packed between ribbons of green plastic used to simulate grass. Crumb rubber granules may release a variety of chemicals typical in rubber, including polycyclic aromatic hydrocarbons (PAHs) and volatile organic chemicals (VOCs). In addition, crumb rubber includes some amount of dusts and small particles, which may be further increased by mechanical abrasion and wear that comes with use of the fields [1]. Health questions continue to arise because exposures and risks to playing on these fields have not been fully characterized [2, 3, 4].

The primary purpose of this project was to characterize the concentrations of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), rubber-related chemicals (e.g. benzothiazole), and particulate matter less than 10 micron concentrations (PM_{10}) and its constituents in ambient air at selected crumb rubber fields in Connecticut under conditions of active field use. Air monitoring data is needed to characterize exposure patterns of targeted compounds in the breathing zone of children using artificial turf fields. In addition, there is insufficient data on how relevant variables, such as weather conditions, age of field, nature of sporting activities and type of infill, affect exposure to chemical constituents and particulate matter.

In Connecticut, we know of at least 85 crumb rubber fields already in use, and another 30 that have been proposed or are being constructed. Air data collected at selected crumb rubber fields are needed to begin the characterization of potential exposures that could be used in a companion risk assessment of the data generated from this work.

Data from the Connecticut Agricultural Experiment Station (CAES) laboratory head space analyses on manufacturers' crumb rubber infill were used to guide aspects of the design of this field investigation [5]. We also established collaborative relationships with those doing similar research in New Jersey, New York State, New York City and U.S. EPA to learn of parallel activities and results as this project proceeded [6, 7]. For example, a recent study conducted in New York found that rubber dust was not found in the respirable range, and therefore, PM_{10} was selected for this study [6].

2.2 Field Investigation Objectives

This exposure characterization had the following objectives.

1. Collect personal measurements in the breathing zone of the target population - young children who play on crumb rubber athletic fields.
2. Characterize the concentrations of VOCs, SVOCs, and particulate matter (PM) (and constituents on PM) in air at selected crumb rubber fields in Connecticut under conditions involving active field use in warm weather.
3. Assess airborne concentrations of the targeted chemicals and particulates in areas surrounding and away from the crumb rubber fields. The collection of background samples is a key component as exposure to airborne rubber particles and component gases is not unique to turf fields.

2.3 Sampling Plan

Industrial hygienists from the Section of Occupational and Environmental Medicine at the University of Connecticut Health Center (OEM UCHC) conducted the field sampling and managed the analytical components of this exposure investigation. OEM UCHC provides research, educational programs and training, industrial hygiene consulting, prevention guidance, risk communication and clinical care for occupational and environmental illnesses and problems. Specifically, OEM UCHC personnel performed the collection of air samples, contracted with laboratories for analyses, provided quality control /quality assurance, and reviewed and compiled the data. OEM UCHC sub-contracted laboratory analyses to three AIHA accredited laboratories: Wisconsin Occupational Health Laboratory (WOHL), the Wisconsin State Laboratory of Hygiene (WSLH) and the ESIS Environmental Health Laboratory (EHL) in Cromwell, Connecticut. WOHL is a full service industrial hygiene chemistry laboratory that is part of the Wisconsin State Laboratory of Hygiene (WSLH) at the University of Wisconsin-Madison. WSLH analyzed air samples for VOCs, SVOCs and PM_{10}. WOHL analyzed bulk crumb rubber head space for VOCs and targeted SVOCs (e.g. benzothiazole), and air samples for nitrosamines and targeted SVOCs. Additional bulk samples were analyzed for lead by the ESIS Environmental Health Laboratory (EHL). The EHL has been accredited by the American Industrial Hygiene Association (AIHA) for both industrial hygiene and environmental lead. This report summarizes the data collected by OEM UCHC.

This project employed a cross-sectional environmental sampling strategy of synthetic crumb rubber turf fields to capture a range of chemical exposures during the summer season when ambient air temperatures are above 75-80^{o}F. Three general types of sites were targeted: outdoor crumb rubber fields, indoor facilities with crumb rubber turf, and an outdoor grass field in a suburban area. Sampling goals were to collect air samples on old and new turf fields during active field use and to collect air samples at an upwind site of each field. A special focus of the design included personal air sampling of many of the chemicals reported in previous studies (e.g. VOCs and benzothiazole), and other chemicals of potential concern, such as a nitrosamine. The sampling strategy also included the collection of area air samples for chemicals at different heights on the turf to assess a vertical profile of release. These air samples were collected in areas on the turf field near active play and areas on the turf away from active play. Because crumb rubber includes some amount of dusts and small particles, particulate matter air monitoring was incorporated into the stationary sampling plan (using sampling at a single height only). Bulk samples of turf grass and crumb rubber were also collected, and meteorological data (e.g. air direction, wind speed and ambient air temperature) were recorded.

Bulk Samples: Composite bulk samples of green artificial turf fibers and composite bulk samples of crumb rubber were collected from 5 locations on each study field. These samples were analyzed for lead by EHL in Connecticut. Additional bulk samples of crumb rubber were collected at eleven fields. These samples were analyzed for targeted SVOCs, VOCs and other chemicals in a 340 milliliter large volume sample headspace unit (LVSH) by WOHL. CAES collected and analyzed samples of crumb rubber material supplied by several manufacturers [5]. Their crumb rubber samples included material from only two of our outdoor fields (A and D). These two crumb rubber fields were manufactured by two different companies. The results are difficult to compare between the two laboratories (WOHL and CAES) because they used different analytical methods.

Personal Sampling: Study team members from the Connecticut Department of Public Health (CT DPH), Connecticut Department of Environmental Protection (CT DEP), and OEM-UCHC simulated a soccer game for the collection of the personal airborne chemicals. Active play among 3-4 players consisted of running and kicking the ball on the turf field, one on one soccer drills and “keep away” soccer games. Duration of play was two hours with one break. Personal air samples were collected at waist height, approximately 3-feet, with sampling equipment worn by 3 players during active play on the field. Personal measurements for nitrosamine, benzothiazole, and VOC were collected from players at each field. Two personal samples were collected for each of the types of measurements. Evacuated 1.4 liter SUMMA canisters were worn by players at hip height to collect VOC samples. Personal sampling pumps fit with absorptive media were worn by players at hip height to collect samples for benzothiazole, nitrosamine, 4-Tert (octyl) phenol, 2-mercaptobenzothiazole, Butylated hydroxyanisole (BHA) and Butylated hydroxytoluene (BHT).

Area Sampling:
Area samples were collected for 2 hours to measure VOCs, SVOCs, benzothiazole, and ambient PM_{10} concentrations during active play. Samplers were located at various heights on the field in the immediate vicinity of the simulated soccer game and in an off-turf upwind area to represent background locations. Additional background samples were collected in one suburban community location (non-turf grass field) to help put the field-related results into a larger exposure context. VOCs were measured with 6-liter SUMMA canisters according to EPA Method TO-15 [8]. SVOCs in ambient air were measured with PS-1 Samplers according to EPA Method TO-13A [9]. An additional day of sampling for 6 hours was conducted with the PS-1 Samplers on one field without active play. Specific chemicals (e.g. benzothiazole and nitrosamines) were separately measured using sampling pumps and sorptive media to trap those chemicals according to NIOSH methods [10, 11]. PM_{10} concentrations were measured using Harvard Impactors (Air Diagnostics and Engineering, Inc., Harrison, ME) [12, 13]. OEM-UCHC collected all samples and shipped sampling media to WOHL for analysis. Table 1 provides a general description of the targeted analytes, air sampling and analytical methods for each set of analytes. Appendix A provides a sampling map.

3.0 Methods and Results

3.1 Field Recruitment

CT DEP recruited six fields: 4 outdoor turf fields (Fields A-D), 1 indoor turf field (Field K) and 1 outdoor suburban grass area (Field L). Six additional fields were recruited to collect crumb rubber bulk samples only (Fields E-J). As shown in Table 2, air sampling occurred during July 2009 on crumb rubber fields with polyethylene fibers that were both new (<2 years) and old (>3years). Fields B, C, and J contained silica sand in the crumb rubber. Sampling dates were chosen to coordinate several factors: sunny and no wind days, rental sampling equipment costs/availability, field accessibility due to school summer programs, and staff availability. Table 2 provides the total number of air samples collected at each field.

Fields A-B and K were in located in rural areas and fields C, D and L were in suburban communities with nearby roads with high traffic volume. Field D was also near an interstate highway. Field K, the indoor turf facility, had four exhaust fans at each end of the building. These fans were not operating during sampling. There was an equipment room located inside the facility containing small electric motorized carts (these carts were driven out of the facility minutes before the sampling began). In addition, the room had a portable charger, an ice machine, maintenance supplies (e.g. cans of paints) and other gym equipment.

3.2 Meteorological Sampling

Meteorological conditions for each sampling day were collected by a subcontactor (Air Quality Research and Logistics, LLC) with a Davis Vantage Pro 2 weather station by Air Quality Research and Logistics, Inc. Meteorological parameters included: wind speed, wind direction and air temperature at different heights (near ground level and 3 feet above the ground). Thermometers were enclosed in naturally aspirated radiation shields (Davis Part. No. 7714). Measurement of continuous (15 minute average) ambient air temperature, wind direction and speed were collected. Table 3 provides a summary of the meteorological conditions at each field. Appendix B provides a report by Air Quality Research and Logistics, Inc. On July 28, 2009, meteorological data was not collected during the 6 hour sampling at Field D. Temperature and wind direction data were obtained from Weather Underground (www.wunderground.com).

Table 1. Target Analytes, Air Sampling Equipment and Analytical Methods

Compounds	Type	N	Sampling Equipment and Media	Analytical Method
Volatile Organic Compounds (VOCs)	Personal Area	10 16	1.4 L SUMMA 6.0 L SUMMA	EPA TO-15 (GC/MS)
General Semi-Volatile Organic Compounds (SVOCs) scan	Area	12	PS-1 Sampler PUF and XAD-2	EPA TO-13A (modified) GC/MS
Targeted SVOCs Benzothiazole 2-mercaptobenzothiazole 4-Tert (octyl)phenol Butylated hydroxyanisole Butylated hydroxytoluene	Personal Area	10 35	Personal Pump Gilair®, SKC Airlite® XAD-2 37mm, 2 µm PTFE pre-filter	WOHL Method LC-100 (based upon NIOSH 2550)
Nitrosamines	Personal Area	10 23	Personal Pump Gilair®, SKC Airlite® Thermosorb/N™	WOHL Method LC-96 (based upon NIOSH 2522)
Particulate Matter (PM_{10})	Area	12	MS&T Area Sampler 20 L sampling pump 37 mm Teflon Filter 2 µm pore size	CFR Title 40 Part 50 (Appendix L) WP001-03 Gravimetric Analysis

Table 2. Total number of air samples collected at each field

Compounds/ Methods	Location	N	Fields A	B	C	D	K	L	Sampling Comments
VOCs EPA TO-15	Personal On Turf Area Background Area	10 10 6	2 2 1	2 2 1	2 2 1	2 2 1	2 2 1	0 0 1	At Field A, no data at 6" on turf AFAP At Field C, pesticide application occurred adjacent to turf field
SVOCs scan EPA TO-13A	On Turf Area Background Area	6 6	1 1	1 0	1 0	2 2	1 1	0 2	At Fields B, C and L, no data at background locations
Targeted SVOCs NIOSH 2550 (modified)	Personal On Turf Area Background Area Field Blanks Field Spikes	10 23 12 7 6	2 4 2 1 1	2 4 2 1 2	2 4 2 1 0	2 6 2 2 1	2 4 2 1 2	0 1 2 1 0	At Field D during 6 hour sampling, no data at 6" or 3' on turf
Nitrosamines NIOSH 2522	Personal On Turf Area Background Area Field Blanks	10 12 11 7	2 2 2 1	2 2 2 1	2 2 2 1	2 4 2 2	2 2 2 1	0 0 1 1	None
PM_{10} CFR Title 40 Part 50	On Turf Area Background Area Field Blanks	5 7 6	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	0 2 1	At Field A, no data at 3' on turf or at background location

Table 3. Description of sampling fields and weather conditions during sampling day.

Field ID	Surface Age (location)	Sampling Date	Sampling Time of Day	Ambient Temperature On Surface (°Fahrenheit) 3 inches	36 inches	Wind Speed (mph)
A	2 years (outdoor)	7/27/09	12:15-2:15pm	79-89	76-83	0-6
B	2 years (outdoor)	7/15/09	11:30-1:30pm	83-89	77-80	4-8
C	5 years (outdoor)	7/20/09	11:30-1:45pm	85-88	81-82	1-2
D	2 years (outdoor)	7/14/09 7/28/09	12:35-2:40pm 9:30-3:30pm	80-88	76-86 68-87*	1-3 2-8
K	3 years (indoor)	7/22/09	3:50-5:50pm	77-79	78-80	1-2
L	Grass (outdoor)	7/12/09	11:48-1:48pm	NA [a]	78-80[b]	1-3

* Temperature not measured directly. Information collected from Weather Underground.
[a]NA=Not available. Temperature information was not collected 3 inches above the surface.

3.3 Bulk Samples

Crumb Rubber Bulk Sampling Methods for Head Space Analysis: Crumb rubber bulk samples were collected from 11 different fields in June 2009. Table 3 provides the turf surface age for fields A-D, K. The turf surface age of the other six fields were: E (3 yrs), F (9 yrs), G (4 yrs), H (6 yrs), I (1 yr), and J (1 yr). Bulk samples were collected from 5 locations on each field (see Figure 1). At each location, crumb rubber was placed in a pre-cleaned glass jar, covered with foil and placed in a brown paper bag. Five samples per field were collected and shipped to WOHL (n=55).

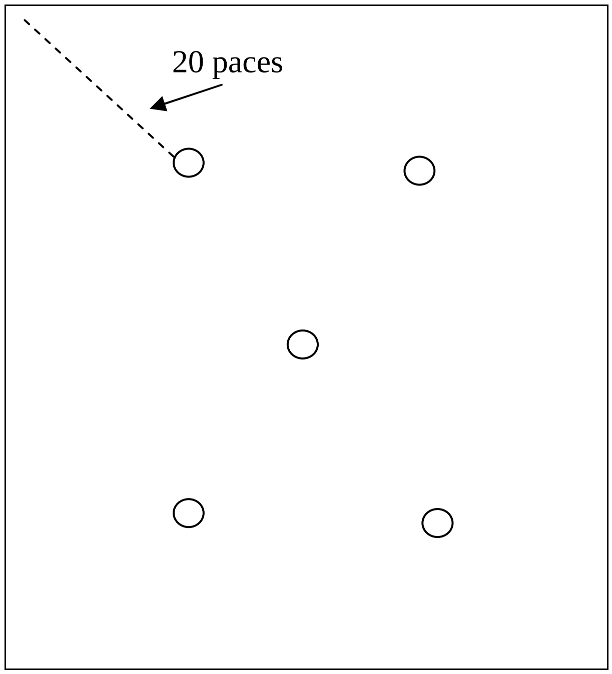

Figure 1. Sampling locations for bulk samples.

3.3.1 VOC Crumb Rubber Head Space Analysis: WOHL stored the samples in a refrigerator at 4^{o}C. Bulk samples were analyzed for VOCs by WOHL method WG086.2, a method based on OSHA PV2120 for the analysis of volatile organic compounds (VOCs) in air. The samples were analyzed in a 340 milliliter large volume sample headspace unit (LVSH) as follows: The cleaned LVSH was heated to 70^{o}C overnight and then brought to room temperature in a clean room. A 0.5 gram sample was placed in the LVSH and heated in an oven at 70^{o}C for at least 1 hour. Immediately after the LVSH was removed from the oven, a 100 ml sample volume from the LVHS was cryofocused and injected in a gas chromatograph equipped with a mass selective detector and a RTX-624 capillary column. The following precautions were taken for the bulk crumb rubber VOC analysis: 1)bulk crumb rubber samples were stored in teflon lined screw capped jars and were opened only when removing sample for analysis;2) the 340mL LVSH were baked at 70^{o}C overnight; and 3) one of the LVSH units was analyzed empty with each analytical run as a method blank, and any VOCs detected above reporting limit noted in the analytical report.

VOC identification was conducted by the National Institute of Standards and Technology Library (NIST) search. Laboratory blanks during analyses were below reporting limits for most compounds. Carbon disulfide, silyls, and siloxane-containing VOCs are common contaminants of the analytical system. Therefore, trace amounts of these VOCs reported may not be components of the samples. Trace levels of carbon disulfide were detected in laboratory blanks. All siloxane-containing VOCs were below reporting limits (<20ppb) in laboratory blanks. Because some of the VOC compounds detected in bulk crumb rubber off gassing experiments are commonly used laboratory solvents, a laboratory background VOC sample was also collected in the walk-in cooler/sample storage area and analyzed. The following VOC compounds were reported in the laboratory background sample: 2-methyl-butane (31ppb), acetone (830ppb), benzene (18ppb), methylene chloride (1030ppb), methyl alcohol (790ppb), and pentane (52ppb).

The head space methodology used by WOHL differed from CAES in several areas. WOHL used smaller amount of crumb rubber (0.5 vs.1 gram), a larger volume head space unit, and different analytical parameters (e.g. cryogenically concentrates head space injection vs. direct injection technique). Appendix C provides a description of the analytical method used by WOHL.

Results: Table 4 provides a list of VOCs identified in crumb rubber samples from the 11 different turf fields. The most commonly found VOCs (range of concentrations in parts per billion-ppbV) include: acetonitrile (60-300ppbV), methylene chloride (20-430ppbV), methyl alcohol (33-270ppbV), and methyl isobutyl ketone (21-150ppbV). Bulk crumb rubber from the newer fields (A, B and D) contained more than ten VOCs. Crumb rubber from other fields contained less than 5 VOCs. Carbon disulfide concentrations were found in the majority of field samples with estimates ranging from 41-141 ppb, and are considered a contaminant of the analytical system and not a turf related VOC. VOCs also found in the laboratory background sample are noted below with the asterisks “c”. Appendix C provides the WOHL analytical laboratory reports of the data.

Table 4. VOCs identified in bulk crumb rubber head space at 11 fields.

Volatile Organic Compounds (VOCs)	Fields A-D, K	Fields E-J
1,1,2-Trichloro-1,2,2-trifluoroethane	A	
2-methyl-Butane[c]	A, B, C	
3-methyl-Pentane	A[a], B, D[b]	
Acetone[c]	A[a], B[a]	I[a]
Acetonitrile	A, B, C, D	E
Benzene[c]	A, D	
Carbon Tetrachloride	A	
Cyclopentane, methyl-	A, B, D	
Ethanol	A	
Ethyl Benzene	D	
Hexane	B, C, D	
Isopropyl Alcohol	A, B	
Methyl Alcohol[c]	A, B, C, D, K	E
Methylene Chloride[c]	A, B, C, D	E, F, G, H, I
Methyl Isobutyl Ketone	A, B, D	E, G, H, I
Pentane[c]	A	
Styrene	A, B, D	
Toluene	A, B, D	

Reporting limit is <10 or 20 ppbV depending on the chemical.
[a]Indicates that the area summed includes an unresolved compound.
[b]Indicates that there is some question as to identity.
[c]Compound was also detected in the laboratory background sample.

3.3.2 Targeted SVOCs Bulk Crumb Rubber Head Space Analysis: In the crumb rubber bulk samples, five targeted SVOCs were analyzed: benzoathiazole, 2-mercaptobenzothiazole, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and 4-tert-(octyl)-phenol). Four chemicals, 2-mercaptobenzothiazole, BHA, BHT, and 4-tert-(octyl)-phenol) were added to the list of targeted SVOCs as a result of the findings reported by CAES in 2009. For targeted SVOCs, a Supelco Adsorbent Tube Injector System (ATIS) was utilized to thermally extract the bulk rubber infill samples. The off-gassed SVOCs were loaded onto sampling media and analyzed according to the various analytical methods used in the study. For benzothiazole/4-tert-(octyl)-phenol, the method is based upon National Institute for Occupational Safety and health (NIOSH) Method Number 2550 (Modified). In summary, SVOCs off gassed from bulk infill material collected on XAD filter air sampling devices were desorbed separately with 10 minutes of sonication performed 3 times with 3mL of methanol each. The combined methanol fractions were evaporated to approximately 0.5mL with nitrogen, and brought to a final volume of 1.0mL with methanol. Extracts were analyzed by reversed phase high-performance liquid chromatography employing a 0.1% formic acid:methanol linear gradient program. Detection was achieved by triple quadrupole mass spectrometry using multiple reaction monitoring (MRM).

SVOCs Bulk Crumb Rubber Results: Table 5 provides a list of SVOCs identified in crumb rubber samples from the 11 different turf field fields. Appendix D provides WOHL laboratory analytical reports.

Table 5. Identification of targeted SVOCs in bulk crumb rubber head space samples collected at 11 fields.

Semi-Volatile Organic Compounds (SVOCs)	Study Turf Fields A-K	Additional Turf Fields E -J
Benzothiazole	A, B, C, D and K	E, G, J
2-mercaptobenzothiazole	None	None
4-tert-(octyl)-phenol	A, B, C, D and K	E, F, G, H, I, J
Butylated hydroxyanisole (BHA)	None	None
Butylated hydroxytoluene (BHT)	A, K	G
Nitrosamine	None	None

3.3.3 Lead

Bulk Sampling Method: Composite bulk samples of green artificial turf fibers and composite bulk samples of crumb rubber were collected from 5 locations on each field (Figure 1) at study fields only. The bulk samples were placed in zip lock bags. Because lead was detected in the composite bulk sample from Field D, four additional crumb rubber composite bulk samples (two at 20 paces and two at 40 paces) and one additional composite fiber bulk sample were collected from Field D. The bulk samples were analyzed for environmental lead by the ESIS Environmental Health Laboratory (EHL) in Cromwell, Connecticut. The analytical method used by the laboratory was Modified EPA-SW-846-3050/ ICP, Modified OSHA ID 125. The sampling and analytical methods are similar to the methods used by New York City Department of Parks and Recreation during their study of 103 crumb rubber fields [14].

Results: Table 6 show that all of the composite samples were below the level EPA considers as presenting a "soil-lead hazard" in play areas (400ppm). This definition, however, applies to residential buildings and to soil rather than other surfaces [15]. Appendix E provides the EHL analytical laboratory reports.

Table 6. Concentrations of microgram lead/gram material (µg/g) in fibers and crumb rubber at study field fields.

Field	Fiber Concentration (µg/g)	Crumb Rubber Concentration (µg/g)
A	< 60.1	<71.4
B	<59.0	<68.9
C	<60.2	<70.4
D	<59.0 <76.5	271 (20 paces) <70.6 (20 paces) <78.5 (20 paces) <72.6 (40 paces) <78.7 (40 paces)
K	<60.8	<72.1

Limit of Detection: 7.5 µg/sample
Environmental Protection Agency (EPA) lead level for soil in children's play areas: 400 ppm (µg/g)

3.4 Air Samples

3.4.1 Volatile Organic Compounds (VOCs)

Personal Sampling: Personal air samples for VOCs were collected using evacuated 1.4 L silica-lined SUMMA Canisters with FSL QT MicroValve (Entech Instruments, California). Two study team members each wore a canister at waist-height during each sampling session. Each canister was placed inside a cotton "tool belt" and secured to a coated mesh waist belt with plastic ties. Study team members played soccer on the turf field with 2 other members for 120 minutes. One water/food break (5-10 minutes) was taken by the team members during the play period. At the beginning of each sampling event staff checked each canister's gauge and confirmed that the pressure was at the level noted in the laboratory's SOP. At the end of each sampling event, staff confirmed that the pressure gauge had reached "0". The majority of samples collected air for at least 60 minutes or greater. Two samples collected air for less than 25 minutes (collected at indoor field, Field K). Samples were sent to the WSLH laboratory (Madison, WI) by overnight mail on the day they were collected. All canisters were received by WSLH the next day. Ten samples were collected, two from each turf field field (Fields A, B, C, D, and K). All of the 1.4L cans were pressure checked upon return to the lab and prior to analysis. No data wereflagged to indicate problems.

Newly purchased items, such as apron belt, coated mesh belt, and plastic twist ties were used to hold the sampling equipment in place during personal sampling. Because several VOCs, such as acrolein, were present in personal samples and not in any area samples, a request was made to WOHL to analyze these extra items to determine if they released any VOC emissions. Therefore, seven months after sampling, a cloth apron, plastic twist tie, sampling pump, segment of the coated mesh waist belt and the belt buckle were analyzed for VOCs in the head space unit. This sampling was done because these items were in close contact to the sampling inlet of the 1.4L canisters that team members wore.

Area Sampling: Area air samples for VOCs were collected using evacuated 6 liter (L) silica-lined SUMMA Canisters with Nupro Valve (Entech Instruments, California). Canisters were placed at 6 inches and at 3 feet above the turf in an area away from active play of study team members (AFAP) during each sampling session. Another canister was placed upwind of the turf field on grass at 3 feet above the ground. At Field L (grass field), the canister was placed at 3 feet. At the beginning of each sampling event staff checked each canister's gauge and confirmed that the pressure was at the level noted in the laboratory's SOP. At the end of each sampling event, staff confirmed that the pressure gauge had reached "0". The majority of samples collected air for at least 60 minutes or greater. One sample collected air for less than 20 minutes (collected at outdoor background, Field K). Samples were sent to the WSLH (Madison, WI) by overnight mail on the day they were collected. All canisters were received by WSLH the next day. In total, sixteen samples were collected from the various fields. Samples were collected from the following fields: A (n=3), B (n=3), C (n=3), D (n=3), K (n=3) and L (n=1). The lab confirmed if the canister valve was closed and tight upon arrival. One 6 L canister valve was open upon arrival, and the sample was not analyzed (collected at Field A, 6 inches above the turf).

Sample Preparation and Analysis: All canisters (1.4L and 6L) were calibrated with a mass flow controller to collect air samples for up to 120 minutes by the ESS Organics WSHL. A modified version of Compendium EPA Method TO-15 by GC/MS was used to measure ambient-level concentrations for 60 VOC analytes. Briefly, this method incorporates a multi-stage concentration process using an Entech 7100A Preconcentrator. This removes carbon dioxide, nitrogen, and water with a series of traps. The sample (500ml) is injected on a glass bead trap at a temperature of -150°C. The trap is then heated to 10°C and purged gently with helium to transfer the VOCs and the carbon dioxide to a second trap. The second trap, which contains Tenax(tm), is then cooled to 10°C, allowing the carbon dioxide to pass through the trap while retaining the VOCs. The second trap is heated and back-flushed with helium, sending the sample to the focusing trap, which is cooled to -160°C. The focusing trap is then rapidly heated to 60°C and the sample is injected onto the Rxi-lm s (Restek U.S., 110 Benner Circle, Bellefonte, PA 16823), 60m capillary column and finally the mass spec detector. VOC concentrations were reported in ppbV and microgram per cubic meter ($\mu g/m^3$).

Each analytical run included one method blank per batch of samples. If an analyte in the method blank was greater than its limit of detection (LOD), the result for that analyte was flagged to indicate blank contamination. One set of samples contained acetone in the blank sample, and concentrations were corrected (samples collected at Field B). Duplicate analysis was performed on one sample per analytical batch. Duplicate analyses were always within 25% for each compound. Daily quality control checks were performed using a second source standard. Analytes in the quality control/QC check standard were always within 30% of the corresponding calibration standards.

Results: The EPA Method TO-15 is designed to scan for 60 VOCs, and the results provide a list of VOCs that are detected at least once on field or background locations. WSHL analytical laboratory reports for all 60 VOCs (in ppbV) in air per field are summarized in Appendix F. Tables 7-10 summarize the VOC concentrations in µg/m^3 at Fields A-D, all outdoor turf fields. Table 11 shows the VOC concentrations from Field K (an indoor field), and Table 12 presents data for Field L (the non-turf grass background suburban site). Table 13 provides an additional list of VOCs in the personal, on-turf, and background samples that were tentatively identified through the use of the National Institute of Standards and Technology (NIST) library. VOC concentrations are shown in bold for each VOC analyte if concentrations were two times higher than the background concentration. Total Volatile Organic Compound (TVOC) value is the sum of the all the concentrations that were detectable, and is not an approximate concentration based on toluene response. The airborne VOC concentrations reported at Field C should be reviewed with caution (Table 9). During the first ten minutes of sampling at Field C, a pesticide mixture was applied to the grass field adjacent to the synthetic turf field. Study coordinator asked the applicator to stop the application. Unfortunately, air sampling had already begun in the background location near the grass field when the application occurred. Three different pesticides (Merit 75 WSP Insecticide, Drive 75 DF Herbicide, and Cross Check Insecticide) were applied to the perimeter of the field with a Perma Green Ride-on Spreader.

Special Sampling Equipment Head Space Results: WOHL's VOC head space analyses of the plastic ties, cloth apron bag, mesh waist belt and buckle are summarized in Appendix G. The cloth apron contained detectable levels of acetaldehyde, propanal, hexanal, nonanal, and octanal and trace levels of acrolein. The mesh belt contained acetaldehyde, 2-butenal, pentanal, hexanal, heptanal, and nonanal and trace levels of acrolein. A peak with NIST mass spectral library match for acrolein was detected in the cloth apron and mesh belt sample. These peaks were below the reporting limit of 20ppb and additional mass spectral peaks were present, including possible co-eluting compounds. Detectable levels of nonanal, decanal, and octanal were found in the plastic ties.

Table 7. Volatile Organic Compound (VOC) Concentrations in µg/m^3 at Field A (personal and on-turf concentrations 2X higher than background are in bold)

	VOC Concentration (µg/m^3)			
Compound Name	**Personal**	**Personal**	**On Turf 3 AFAP 3 ft**	**Background 3 ft**
1,1,2,2-Tetrachloroethane	<0.68	<0.68	<0.68	1.02
1,2,4-Trichlorobenzene	<0.74	<0.74	<0.74	0.89
Acetone	**52.17**	**33.20**	12.33	12.33
Acrolein	**1.95**	**1.40**	<1.15	<1.15
Benzene	<0.32	<0.32	<0.32	0.41
Bromoform	<1.02	**2.35**	<1.022	<1.02
Carbon Tetrachloride	<0.62	<0.62	<0.62	0.93
Chloromethane	1.57	1.55	1.45	1.33
Dichlorodifluoromethane	2.42	2.47	2.28	2.23
Ethyl Acetate	**1.37**	**1.76**	<0.36	0.61
Halocarbon 11	1.85	1.79	1.74	1.96
Hexane	**24.61**	**8.79**	<0.35	3.30
Methyl Ethyl Ketone	2.94	2.53	1.35	1.74
Methylene Chloride	<0.34	<0.34	<0.34	0.69
Propene	<0.17	**0.38**	<0.17	<0.17
Toluene	**1.58**	**1.92**	<0.38	0.75
Vinyl Acetate	1.23	1.13	<0.35	1.02
Total VOCs*	91.69	59.27	19.15	29.21

A tentative ID match for four compounds was made using the NIST Library in personal samples. No tentative ID matches were found in other areas. See Table 13.
AFAP= away from active play of study team members.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 8. Volatile Organic Compound (VOC) Concentrations in µg/m^3 at Field B.
(personal and on-turf concentrations 2X higher than background are in bold)

	VOC Concentration (µg/m^3)				
Compound Name	**Personal**	**Personal**	**On Turf AFAP 6 inch**	**On Turf AFAP 3 ft**	**Background 3 ft**
1,2,4-Trimethyl Benzene	1.32	**2.16**	<0.49	<0.49	<0.49
1,2-Dichloropropane	<0.46	**1.14**	<0.46	<0.46	<0.46
1,3,5-Trimethyl Benzene	<0.49	**1.37**	<0.49	<0.49	<0.49
1-Ethyl-4-Methyl Benzene	<0.49	**1.86**	<0.49	<0.49	<0.49
Acetone[a]	**13.75**	**34.74**	3.93	3.65	4.01
Acrolein	**1.58**	**3.66**	<1.15	<1.15	<1.15
Benzene	< 0.32	**1.56**	<0.32	<0.32	<0.32
Carbon Disulfide	<0.31	**0.47**	<0.31	<0.31	<0.31
Carbon Tetrachloride	0.68	<0.68	0.75	0.81	0.75
Chlorobenzene	<0.46	**0.78**	<0.46	<0.46	<0.46
Chloromethane	1.25	1.70	1.19	1.14	1.04
Cyclohexane	**0.86**	**17.51**	**1.51**	<0.34	<0.34
Dichlorodifluoromethane	2.42	2.13	2.52	2.57	2.42
Ethyl Acetate	**1.30**	**11.87**	<0.36	<0.36	<0.36
Ethylbenzene	<0.43	**4.29**	<0.43	<0.43	<0.43
Halocarbon 11	1.46	1.40	1.51	1.51	1.51
Heptane	<0.41	**5.72**	<0.41	<0.41	<0.41
Hexane	<0.35	**31.29**	<0.35	<0.35	0.88
M/P-Xylene	<0.87	**10.83**	<0.87	<0.87	<0.87
Methyl Ethyl Ketone	<0.29	<0.23	1.41	1.21	1.30
Methyl Isobutyl Ketone	**2.33**	**3.39**	<2.04	<2.04	<2.04
Methylene Chloride	<0.34	**14.08**	<0.34	<0.34	<0.34
O-Xylene	<0.43	**3.90**	<0.43	<0.43	<0.43
Propene	**0.5**	**0.89**	<0.17	<0.17	<0.17
Styrene	<0.43	**1.96**	<0.43	<0.43	<0.43
Tetrachloroethylene	<0.67	**3.29**	<0.67	<0.67	<0.67
Tetrahydrofuran	<1.48	**2.47**	<1.5	<1.5	<1.5
Toluene	1.54	**52.66**	0.87	0.79	0.87
Trichloroethylene	<0.53	**23.39**	<0.53	<0.53	<0.53
Total VOCs*	28.99	240.51	13.69	11.68	12.78

A tentative ID match for 16 compounds was made using the NIST Library in personal samples. See Table 12. There was one tentative ID match in a background sample. See Table 13.
AFAP= away from active play of study team members.
[a]Acetone was detected in lab blank (1.5ppb) and all concentrations were corrected.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 9. Volatile Organic Compound (VOC) Concentrations in µg/m³ at Field C. (personal and on-turf concentrations 2X higher than background are in bold)

	VOC Concentration (µg/m³)				
Compound Name	**Personal**	**Personal**	**On Turf 6 inch AFAP**	**On Turf 3 ft AFAP**	**Background 3 ft**
1,1,2,2-Tetrachloroethane	<0.68	<0.68	<0.68	<0.68	1.09
1,1,2-Trichlorotrifluorethane	<0.78	<0.78	<0.78	0.76	1.99
1,1-Dichloroethane	<0.40	<0.40	<0.40	<0.40	0.80
1,1-Dichloroethene	<0.40	<0.40	<0.40	<0.40	0.63
1,2-Dibromoethane	<0.80	<0.80	<0.80	<0.80	1.84
1,3- Butadiene	<0.22	<0.22	<0.22	<0.22	0.38
1,2-Dichlorobenzene	<0.60	<0.60	<0.60	<0.60	1.37
1,3-Dichlorobenzene	<0.60	<0.60	<0.60	<0.60	1.13
1,4-Dichlobenzene	<0.60	<0.60	<0.60	<0.60	1.37
Acetone	**30.83**	**26.08**	**23.71**	10.67	11.14
Benzene	0.61	0.57	0.54	0.54	0.92
Bromoform	1.94	<1.02	<1.02	<1.02	1.74
Bromomethane	<0.38	<0.38	<0.38	<0.38	0.69
Carbon Disulfide	<0.31	0.50	<0.31	<0.31	0.62
Carbon Tetrachloride	0.68	<0.62	0.87	0.93	1.43
Chlorobenzene	<0.49	<0.49	<0.49	<0.49	1.10
Chloroethane	<0.26	<0.26	<0.26	<0.26	0.55
Chloromethane	0.70	0.63	1.00	1.06	1.02
Cis-1,3-Dichloropropene	<0.45	<0.45	<0.45	<0.45	0.99
Cyclohexane	0.62	<0.34	<0.34	<0.34	<0.34
Dibromochloromethane	<0.84	<0.84	<0.84	<0.84	1.85
Dichlorodifluoromethane	1.43	1.19	2.23	2.42	2.33
Ethyl Acetate	<0.36	0.61	<0.36	<0.36	<0.36
Ethylbenzene	<0.43	<0.43	<0.43	<0.43	1.21
Halocarbon 11	1.01	0.84	1.51	1.62	2.46
Heptane	**0.49**	<0.41	<0.41	<0.41	<0.41
Hexane	**3.48**	0.63	0.87	0.49	1.02
Methyl Ethyl Ketone	2.06	1.83	1.62	2.03	1.53
Methylene Chloride	1.20	<0.43	<0.43	<0.43	0.76
M/P-Xylene	1.56	<0.66	<0.66	<0.66	1.78
o-Xylene	<0.43	<0.43	<0.43	<0.43	0.91
Propene	**0.34**	**0.24**	<0.17	<0.17	<0.17
Styrene	<0.42	<0.42	<0.42	<0.42	0.94
Tetrachloroethylene	<0.67	<0.67	<0.67	<0.67	1.27
Toluene	**4.89**	1.77	1.13	1.13	1.54
Trans-1,2-Dichloroethylene	<0.39	<0.39	<0.39	<0.39	0.82
Vinyl Chloride	<0.25	<0.25	<0.25	<0.25	0.48
Total VOCs*	51.84	34.89	33.48	21.66	48.43

A tentative ID match for 5 compounds was made using the NIST Library in personal samples. No tentative ID matches for compounds were found in other areas. See Table 13.
AFAP= away from active play of study team members.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 10. Volatile Organic Compound (VOC) Concentrations in µg/m^3 at Field D.
(personal and on-turf concentrations 2X higher than background are in bold)

	VOC Concentration (µg/m^3)				
Compound Name	**Personal**	**Personal**	**On Turf 6 inch AFAP**	**On Turf 3 ft AFAP**	**Background 3 ft**
1,2,4-Trimethyl Benzene	1.37	<0.49	<0.49	<0.49	<0.49
Acetone	**28.45**	**23.71**	5.69	6.64	7.35
Bromoform	1.02	13.29	1.02	1.02	1.02
Chloromethane	0.98	1.06	1.10	1.08	1.06
Dichlorodifluoromethane	2.23	2.33	2.42	2.47	2.47
Ethyl Acetate	**1.15**	**1.22**	<0.36	<0.36	<0.36
Halocarbon 11	1.40	1.40	1.40	1.46	1.46
Heptane	**0.65**	**0.70**	<0.41	<0.41	<0.41
Hexane	0.77	0.77	<0.35	<0.35	1.05
Methyl Ethyl Ketone	1.59	1.44	1.09	1.12	1.06
Methyl Isobutyl Ketone	**2.66**	**2.29**	<2.04	<2.04	<2.04
Propene	**0.48**	**0.50**	<0.17	<0.17	<0.17
Toluene	**1.39**	**1.47**	**0.71**	<0.38	<0.38
Total VOCs*	44.14	50.18	13.43	13.79	15.47

A tentative ID match for 6 compounds was made using the NIST Library in personal samples. There were tentative ID matches 3 feet above the turf and in the background area. See Table 13.
AFAP= away from active play of study team members.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 11. Volatile Organic Compound (VOC) Concentrations in μg/m^3 at Field K.
(personal and on-turf concentrations 2X higher than background are in bold)

	VOC Concentration (μg/m^3)				
Compound Name	**Personal**	**Personal**	**On Turf 6 inch AFAP**	**On Turf 3 ft AFAP**	**Background 3 ft**
1,1,-2Trichlorotrifluoroethane	<0.54	<0.54	<0.54	<0.54	1.53
1,1,2-Trichloroethane	<0.54	<0.54	<0.54	<0.54	0.76
1,2-Dichloropropane	<0.45	<0.45	<0.45	<0.45	0.69
1,2,4-Trimethyl Benzene	**1.28**	**2.11**	<0.49	<0.49	<0.49
1,2-Dichloroethane	1.04	<0.40	<0.40	<0.40	0.68
1,3,5-Trimethyl Benzene	<0.49	**1.18**	<0.49	<0.49	<0.49
1-Ethyl-4-Methyl Benzene	<0.49	**1.37**	<0.49	<0.49	<0.49
Acetone	**92.48**	<1.19	17.01	12.33	9.25
Acrolein	**3.66**	**3.89**	<1.15	<1.15	<1.15
Benzene	1.15	1.18	<0.32	<0.32	0.64
Bromodichloromethane	**0.62**	<0.62	<0.66	<0.66	<0.66
Bromoform	**34.75**	<1.02	<1.02	<1.02	<1.02
Carbon Disulfide	**0.87**	**0.84**	**0.90**	**0.90**	<0.31
Carbon Tetrachloride	<0.62	<0.62	<0.62	<0.62	1.30
Chloroform	<0.48	<0.48	<0.48	<0.48	0.68
Chloromethane	1.57	1.45	1.17	1.23	1.21
Cyclohexane	**10.30**	**7.21**	**0.82**	**0.82**	<0.34
Dichlorodifluoromethane	3.02	2.87	2.77	2.87	2.72
Ethyl Acetate	**10.07**	**11.87**	<0.36	<0.36	<0.36
Ethylbenzene	**4.77**	**4.77**	**1.00**	**1.04**	<0.43
Halocarbon 11	2.07	1.96	1.90	2.02	2.41
Heptane	**10.22**	**7.36**	0.98	0.98	0.53
Hexane	11.25	10.90	7.38	7.38	9.4
M/P-Xylene	**12.13**	**11.70**	**2.17**	**2.17**	<0.87
Methyl Ethyl Ketone	**44.15**	**44.15**	2.09	2.00	1.83
Methyl Isobutyl Ketone	20.44	**22.08**	**35.98**	**35.98**	<0.29
Methylene Chloride	**10.30**	**9.96**	1.10	1.17	1.10
O-Xylene	**3.42**	**4.03**	**0.87**	**0.91**	<0.43
Propene	**0.76**	**0.72**	<0.17	<0.17	<0.17
Styrene	**1.45**	**3.53**	<0.43	<0.43	<0.43
Tetrachloroethylene	1.34	1.14	<0.67	<0.67	0.94
Tetrahydrofuran	**3.53**	**3.24**	<1.42	<1.42	<1.47
Toluene	**135.4**	**127.88**	**2.78**	**2.82**	1.09
Trichloroethylene	**2.23**	**2.13**	<0.53	<0.53	<0.53
Vinyl Acetate	<0.35	**2.95**	<0.35	<0.35	<0.35
Total VOCs*	424.27	292.47	78.92	71.80	36.76

A tentative ID match for 10 compounds was made using the NIST Library in personal samples. There were tentative ID matches for 5 compounds on turf and no matches were found in the background area. See Table 13.
[a]Concentration is an estimate. The value is above the upper calibration range.
AFAP= away from active play of study team members.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 12. Volatile Organic Compounds (VOC) Concentrations in μg/m^3 at Field L.

Compound Name	VOC Concentration (μg/m^3) 3 ft
Acetone	7.11
Carbon Tetrachloride	0.75
Chloromethane	1.19
Dichlorodifluoromethane	2.28
Halocarbon 11	1.46
Hexane	7.38
Methyl Ethyl Ketone	1.41
Methylene Chloride	0.48
Propene	0.48
Toluene	0.90
Total VOCs	23.44

No tentative ID matches for additional compounds were found using the NIST Library.
*Total VOCs is the sum of all the concentrations that were detectable (does not include values less than reporting limit).

Table 13. Tentative identification of VOCs in personal, on-turf and background areas matched with the NIST Library at all fields (A-D, K-L).

Chemicals	Fields Personal	Fields On-Turf (height of sample)	Fields (Background)
1-Bromo-propane	B, K		
1-Chloro-1,1-Difluoroethane	K	K (3')	
1,1-Difluorethane	B	B (6" and 3')	B (3')
1,2-diethylbenzene	D		
2-Methyl Butane	B, K	D, K (3')	
2-Methyl Pentane	B		
3-Methyl Hexane	B		
3-Methyl Pentane	B		
1,3-Pentadiene	A,		
1R-Alpha-Pinene	D		
Acetaldehyde	A, B, C		
Acetonitrile	B, K		
Beta-Pinene	D		
Butane		K (6" and 3')	
D-Limonen	B		
Ethanol	K	K (6")	
Ethyl Alcohol	B		
Fluorobenzene	D		
Hexanal	B, K		
Isobutane	B		
Isobutene	K		
Isopropyl Alcohol	A, B, C, D, K	K (6" and 3')	
Methyl-Cyclopentane	B		
Nonanal	C		
Octamethyl – Cyclotetrasiloxane	D	D (3')	D (3')
Octanal	A, B, C		
Pentane	B, C, K	K (6" and 3')	

3.4.2 Semi-Volatile Organic Compounds (SVOCs)

An SVOC is any organic compound having a vapor pressure of 1 mmHg or less at standard conditions (293 K and 760 mmHg). Three categories of SVOCs were included in this investigation:1) polyaromatic hydrocarbons (PAHs), 2) miscellaneous SVOCs associated with air pollution such as alkanoic acids (sources include road dust), hopanes/steranes (sources include diesel and gasoline vehicles), and other general compounds such as branched/n-alkanes [16] and 3) five targeted rubber-related SVOCs: benzothiazole, 2-mercaptobenzothiazole, 4-tert-(octyl-phenol, butylated hydroxanisole (BHA), and butylated hydroxytoluene (BHT).

PAHs and Miscellaneous SVOCs Area Sampling: PAHs and miscellaneous SVOCs associated with air pollution were collected with Polyurethane Foam Samplers (PS-1, Anderson Instruments, Inc., GA) according to EPA Method TO-13A. Air samples were collected for two hours at flow rates ranging from 207-237 liters per minute (lpm). At Field D, additional air sampling was conducted for 6 hours at flow rates ranging from 209-226 lpm. Samplers were placed on the turf near the middle of each field and in a location upwind and off the turf field (background). All of the samples were collected at a height of approximately 4 feet. The same sampler was used for each designated location (background or on-turf) at all fields. Several extension cords (100-150ft) were used to supply power to samplers from buildings near the sampling fields. The motor of each sampler was exhausted downwind and away from sampling equipment with a 15 foot flexible duct.

Sampler magnehelic gauges were calibrated for each sampling event using a calibrated critical orifice as a transfer standard. The orifices were connected to a slack tube manometer in the UCHC office in Farmington, CT. Manometer and magnehelic gauge readings were recorded, and flow rates were compared to the WOHL calibrations measurements recorded in the WOHL laboratory. Measurements were within $\pm$ 10% of one another. Calibration flow verifications were performed after use to ensure that the calculated magnehelic set point was accurate. Prior to each sampling event, sampling heads and samplers were cleaned with hexane.

Sampling heads were loaded with cylindrical glass PUF (polyurethane foam)/XAD-2 cartridge (PUF Plug Part #20038, Supelco, Bellefonte, PA) and filter (Whatman Quartz Microfiber Filters, 102 mm, NJ) in UCHC office. After loading, each head was placed in a ziplock bag, then placed in a travel bag, and transported to the field. In the field, samplers were turned on for five minutes. Leak checks were conducted on site prior to sampling. Sampling heads were placed in the PS-1 samplers and magnehelic gauge measurements were recorded on site at the beginning and end of sampling. Magnehelic gauge measurements were the same at the beginning and end of sampling at all fields. Sampling heads were transported to UCHC on ice. Media was processed out of the sampling heads and placed in glass jars at UCHC. All samples were shipped to WOHL/WSLH on ice on the same day as sampling.

During 2 hour sampling at Field D on July 14, 2009, the PS-1 Sampler was turned on for approximately ten minutes without the valve open (sample 217-background). Site coordinator corrected the problem, checked for air leaks, re-tightened seals, and re-checked for air leaks. During the 6-hour sampling session on July 28 at Field D, power was lost for approximately ten minutes (sample 221-background). The site coordinator reported the power problem, and facilities corrected it.

A total of 12 field samples were collected. The first set of samples collected from Field L (community) broke during shipment to WOHL/WSLH. Shipping procedures were modified to place the glass cartridges in foam and extra wrapping. Unfortunately, glass PUF/XAD cartridges broke during transportation of the media to UCHC and insufficient sampling media was available to collect samples from Fields B and C (upwind background location only). It was not possible to reschedule these sampling events to collect more data. Ten field samples were analyzed.

Sample Preparation and Analysis: Samples were prepared and analyzed according to EPA Method TO-13 by WSLH. All samples had all internal standards spiked pre-extraction. A rotovap was used in place of a K-D concentrator. Other parameters include: inlet temp 300 C, flow 1.0 ml/min, and average velocity 37cm/sec. Initial oven temperature 65C hold for 10 min, ramp up at 10 C/min until 300 C, then hold at 300 C for 26.50 minutes. Although laboratory spike recoveries of benzothiazole were acceptable on the PUF/XAD media, low levels of benzothiazole were observed in the high volume field samples in comparison to the personal sampler benzothiazole method. Since collection efficiency is unknown for benzothiazole on high volume sampler media, the high volume sampler results were determined to be non-reportable.

If an analyte in the method blank was greater than its reporting limit, the result for that analyte was flagged to indicate blank contamination. Concentrations were corrected for any blank contamination. Extraction of most chemicals was complete ranging from 75 to 125% as specified by the EPA Method TO-13A. Final concentrations were adjusted by extraction recoveries for analytes below 75% (Appendix H). Concentrations with recoveries exceeding 125% are not adjusted.

Results: Tables 1-6 in Appendix I provide the SVOC concentrations for Fields A-D and K. Final SVOC concentrations are reported as nanogram per cubic meter (ng/m^3). Analytes not detected are reported as nondetectable (ND). Target analytes positively detected but too far below the reporting limit are reported as DNQ. Values for analyte concentrations confirmed but measured below the reporting limit are reported with the footnote “a”. Values for analyte concentrations corrected by extraction recoveries are reported with the footnote “b”.

SVOCs Six Hour vs. Two Hour Sampling Method: Our sampling strategy included a 2 hour sampling time because it represents a typical activity period for athletes using turf fields. At Field D, an extra day of sampling was conducted for 6 hours using EPA Method TO-13A to increase the sensitivity (Tables 3 and 4 in Appendix I). The results suggest that the 2 hour sampling time period allowed for the collection of useful data. During both the 2 and 6 hour sampling periods, similar patterns were observed-nearly half of the SVOCs were either not detected or they were found in greater concentrations on turf than in background locations. Although additional PAHs were detected on turf during the 6 hour sampling (e.g. benz(a)anthracene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(GHI)perylene, benzo(k)fluroanthene), their concentrations on turf were similar to background concentrations. Eight miscellaneous SVOCs were not detected during the 2 hour sampling but were reported with two fold greater concentrations on the turf than in background during the 6 hour sampling period (e.g. decycloclohexane , dodecane, dotriacontane, octacosane, pristine, tetratriacontane, triacontane, tritriacontane).

Polyaromatic Hydrocarbons

The EPA Method TO-13A includes qualitative and quantitative analyses for certain categories of compounds, such as PAHs. The concentrations of PAHs are provided in Tables 14-16. Because PAHs may be found in crumb rubber made from tires, the following 22 were targeted:

Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(e)pyrene
Benzo(GHI)perylene
Benzo(k)fluoranthene
Benzo(b)fluoranthene
Chrysene
Coronene
Dibenz(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Perylene
1-Methylnaphthalene
2-Methylnaphthalene
2,6-Dimethylnaphthalene
Pyrene

Table 14. PAH concentrations in ng/m^3 at Fields A-C (ng/m^3).
(on-turf concentrations 2X higher than background are in bold for field A only)

	SVOC Concentrations ng/m^3			
PAHs	**Field A On Turf**	**Field A Background**	**Field B On Turf**	**Field C On Turf**
Acenaphthene	2.14	2.95	2.74 [b]	3.46 [b]
Benz(a)anthracene	ND <0.36	ND <0.41	0.11 [a]	ND <0.41
Benzo(a)pyrene	ND <0.20	ND <0.22	0.19 [a]	0.16 [a]
Benzo(b)fluoranthene	ND <0.65	ND <0.74	0.22 [a]	0.13 [a]
Benzo(e)pyrene	ND <0.21	ND <0.24	0.26	0.12 [a]
Benzo(GHI)fluoranthene	ND <0.35	ND <0.40	0.08 [a]	ND <0.39
Benzo(GHI)perylene	**0.14** [a]	ND <0.67	0.05 [a]	0.07 [a]
Benzo(k)fluoranthene	ND <0.32	ND <0.40	0.04 [a]	0.08 [a]
Chrysene	ND <0.26	ND <0.30	0.34	0.13 [a]
Fluoranthene	1.68	1.474	2.83	1.70
Fluorene	2.21 [b]	2.87 [b]	4.10 [b]	2.62 [b]
Naphthalene	5.99	7.72	6.17	12.51
Phenanthrene	5.07	6.35	10.46	7.27
Pyrene	1.70	1.01	2.66	0.97
1-Methylnaphthalene	3.96 [b]	6.34 [b]	3.72 [b]	5.67 [b]
2,6-Dimethylnaphthalene	2.83	4.47	ND <0.91	5.74

Abbreviations: ND= analytes not detected. DNQ= analytes positively detected but too far below the reporting limit.
[a]Values for analyte concentrations confirmed but measured below the reporting limit.
[b]Values for analyte concentrations corrected by extraction recoveries. See Appendix F.

Table 15. PAH concentrations in ng/m³ at Field D (2 and 6 hour sampling).
(on-turf concentrations 2X higher than background are in bold)

PAHs	Field D On Turf (2 hour)	Field D Background (2 hour)	Field D On Turf (6 hour)	Field D Background (6 hour)
Acenaphthene	3.38 [b]	2.95 [b]	**2.79** [b]	2.47 [b]
Acenaphthylene	**6.60** [b]	ND <3.74	ND <1.25	0.77
Anthracene	ND <0.22	ND <0.22	ND <0.07	0.02 [a]
Benz(a)anthracene	ND <0.42	ND <0.42	**0.04** [a]	0.03
Benzo(a)pyrene	ND <0.23	ND <0.23	**0.07** [a]	0.05 [a]
Benzo(b)fluoranthene	ND <0.75	ND <0.76	0.07 [a]	0.07 [a]
Benzo(e)pyrene	ND <0.24	ND <0.25	**0.07** [a]	0.06 [a]
Benzo(GHI)fluoranthene	DNQ	ND <0.41	**0.02** [a]	ND <0.13
Benzo(GHI)perylene	ND <0.67	ND <0.69	0.04 [a]	0.06 [a]
Benzo(k)fluoranthene	ND <0.37	ND <0.38	**0.05** [a]	0.04 [a]
Chrysene	**0.30**	0.07 [a]	**0.12**	0.08 [a]
Fluoranthene	**6.76**	1.19	2.26	3.96
Fluorene	3.65 [b]	3.59 [b]	**2.93** [b]	2.43 [b]
Naphthalene	6.32	4.51	14.57	16.94
Phenanthrene	**14.34**	6.11	11.48	13.05
Pyrene	**6.92**	0.47	2.42	3.16
1-Methylnaphthalene	**9.31** [b]	4.08 [b]	**8.31** [b]	6.91 [b]
2-Methylnaphthalene	**4.237** [b]	2.16 [b]	**3.76** [b]	3.31 [b]
2,6-Dimethylnaphthalene	ND <0.95	ND <0.97	**7.65**	6.13

Abbreviations: ND= analytes not detected. DNQ= analytes positively detected but too far below the reporting limit.
[a]Values for analyte concentrations confirmed but measured below the reporting limit.
[b]Values for analyte concentrations corrected by extraction recoveries. See Appendix F.

Table 16. PAH concentrations in ng/m³ at Field K.
(on-turf concentrations 2X higher than background are in bold)

PAHs	Field K On Turf	Field K Background
Acenaphthene	**17.37** [b]	3.99 [b]
Acenaphthylene	**6.79**	ND <3.20
Chrysene	ND <0.26	0.04 [a]
Fluoranthene	**5.55**	0.58
Fluorene	**53.70** [b]	3.42 [b]
Naphthalene	**112.99**	7.05
Phenanthrene	**32.26**	7.56
Pyrene	**11.84**	0.37
1-Methylnaphthalene	**114.20** [b]	6.16 [b]
2,6-Dimethylnaphthalene	**28.70**	10.37
2-Methylnaphthalene	**63.38** [b]	2.72 [b]

Abbreviations: ND= analytes not detected.
[a]Values for analyte concentrations confirmed but measured below the reporting limit.
[b]Values for analyte concentrations corrected by extraction recoveries. See Appendix F.
*Not in calibration standard mix but is quantitated.

3.4.2.3 Targeted Rubber-Related SVOCs

Air Sampling: Personal and area air samples were collected for the following five rubber-related SVOCs: benzothiazole, 2-mercaptobenzothiazole, 4-tert-(octyl-phenol, butylated hydroxanisole (BHA), and butylated hydroxytoluene (BHT). Air samples for these compounds were collected using sampling pumps fit with XAD-2 adsorbent media and 37mm, 2 micron PTFE pre filters. The pumps were pre and post calibrated for approximately 2 liters per minute (LPM). The samples were collected for two hours.

At Fields A-D and K, the personal samples were collected by placing the pumps at waist-height on two study team members involved in active play. Two area samples were collected at 6 inches and 3 feet above the ground at the following locations: on the field near active play (NAP), on the field away from active play (AFAP), and at the upwind background location. At Field L, an area sample was collected at 3 feet. At Field D during the six hour sampling event, two on field air samples were collected (6 inches and 3 feet). The two sampling pumps failed during the six hour sampling event. The data were considered unreliable and are not reported. A field blank was submitted for each field. Field spike samples were also submitted for Fields A, B, D (6 hr), and K. A total of 58 samples were collected including 7 field blanks and 6 field spikes.

Sample Analysis: All samples were analyzed by WOHL using NIOSH Method 2550 (modified). Bulk material or samples collected on XAD-2 (vapor) and/or PTFE pre-filter (particulate) filter air sampling devices were desorbed with 10 minutes of sonication performed with methanol. Desorption volumes were 2mL methanol for the particulate portion and 1mL methanol for vapor portion of each sample. Extracts were analyzed by reversed phase high-performance liquid chromatography employing a 0.1% formic acid:methanol linear gradient program. Detection was achieved by triple quadrupole mass spectrometry using multiple reaction monitoring (MRM). Quality control samples also included laboratory reagent blanks, laboratory method blanks, and laboratory control spikes. Calibration check standards were also analyzed after every 10 samples analyzed.

Results: Concentrations are reported in ng/m^3. Benzothiazole and 2-mercaptobenzothiazole recoveries were incomplete (below 75%). The field spike recovery for benzathiozole (vapor phase) was also incomplete (mean recovery = 72%). Therefore, results reported were corrected for incomplete recoveries. 4-tert-(octyl-phenol, Butylated hydroxanisole (BHA), and Butylated hydroxytoluene (BHT) recoveries were also adjusted when spike recoveries observed were below 75%. In cases where background signal was observed in reagent and/or method blanks, the reporting limit was raised to account for this. The reporting limit chosen for each analyte also represents the lowest calibration standard that resulted in acceptable back calculated recovery (within +/- 25% of theoretical value). Appendix I provides the WOHL analytical laboratory reports.

Tables 17-22 in Appendix I provide the results of the targeted rubber-related SVOCs.

Table 17. Targeted Rubber-Related SVOC concentrations in ng/m^3 at Field A.
(on turf concentations higher than two times background are in bold)

SVOCs	**P1**	**P2**	**6" on field NAP**	**3' on field NAP**	**6" on field AFAP**	**3' on field AFAP**	**6" back ground**	**3' back ground**
Benzothiazole	<81	**130**	**160**	**240**	**230**	<81	<84	<82
2-mercapto benzothiazole	<81	<81	<83	<84	<82	<81	<84	<82
4-tert-octyl	<40	<40	<41	<42	22	<41	<42	26
BHA	<40	<40	<41	<42	<41	<41	<42	<41
BHT	<81	<81	<83	<84	86	<81	150	<82

Abbreviations: NAP=near active play;AFAP=away from active play

Table 18. Targeted Rubber-Related SVOC concentrations in ng/m^3 at Field B.
(on turf concentations higher than two times background are in bold)

SVOCs	**P1**	**P2**	**6" on field NAP**	**3' on field NAP**	**6" on field AFAP**	**3' on field AFAP**	**6" back ground**	**3' back ground**
Benzothiazole	<80	<83	**210**	**210**	**180**	<85	<85	<84
2-mercapto benzothiazole	<80	<83	<80	<85	<85	<85	<85	<84
4-tert-octyl	<40	<41	<40	<43	<42	<42	<43	<42
BHA	<40	<41	<40	<43	<42	<42	<43	<42
BHT	<80	<83	<80	<85	<85	<85	<85	<84

Abbreviations: NAP=near active play;AFAP=away from active play

Table 19. Targeted Rubber-Related SVOC concentrations in ng/m^3 at Field C.
(on turf concentations higher than two times background are in bold)

SVOCs	**P1**	**P2**	**6" on field NAP**	**3' on field NAP**	**6" on field AFAP**	**3' on field AFAP**	**6" back ground**	**3' back ground**
Benzothiazole	<82	<81	**220**	<74	**220**	<82	<81	<80
2-mercapto benzothiazole	<82	<81	<73	<74	<82	<82	<81	<80
4-tert-octyl	<41	<41	<36	<37	<41	<41	<40	<40
BHA	<41	<41	<36	<37	<41	<41	<40	<40
BHT	<82	<81	<73	<74	<82	<82	<81	<80

Abbreviations: NAP=near active play;AFAP=away from active play

Table 20. Targeted Rubber-Related SVOC concentrations in ng/m^3 at Field D.
(on turf concentations higher than two times background are in bold)

SVOCs	P1	P2	6" on field NAP	3' on field NAP	6" on field AFAP	3' on field AFAP	6" back ground	3' back ground
Benzothiazole	**240**	<82	610	**210**	1200	**280**	700	<77
2-mercapto benzothiazole	<81	<82	<78	<80	<82	<84	<79	<77
4-tert-octyl	<40	<41	<39	<40	<41	<42	<40	<38
BHA	<40	<41	<39	<40	<41	<42	<40	<38
BHT	<81	97	**160**	**130**	<82	<84	<79	<77

Abbreviations: NAP=near active play;AFAP=away from active play

Table 21. Targeted Rubber-Related SVOC concentrations in ng/m^3 at Field K.
(on turf concentations higher than two times background are in bold)

SVOCs	P1	P2	6" on field NAP	3' on field NAP	6" on field AFAP	3' on field AFAP	6" back ground	3' back ground
Benzothiazole	**11000**	**13000**	**14000**	**12000**	**11000**	**12000**	<82	<82
2-mercapto benzothiazole	<82	<86	<81	<83	<82	<82	<82	<82
4-tert-octyl	<41	<43	<41	<42	<41	<41	<41	<41
BHA	<41	<43	<41	<42	<41	<41	<41	<41
BHT	**1300**	**1800**	**2100**	**3900**	**2100**	**1900**	88	<82

Abbreviations: NAP=near active play;AFAP=away from active play

Table 22. SVOC concentrations in ng/m^3 at Field L.

SVOCs	3' on grass
Benzothiazole	<83
2-mercapto benzothiazole	<83
4-tert-octyl	<42
BHA	<42
BHT	280

3.4.3 Nitrosamines

Air Sampling: Personal and air samples for Nitrosamine were collected using sampling pumps fit with Thermosorb/N™ tubes. The pumps were pre and post calibrated at approximately 2 liters per minute. The samples were collected for two hours.

At fields A-D and K, the personal samples were collected by placing the pumps at waist-height on two study team members involved in active play. Two area samples were collected on the fields away from active (AFAP) at 6 inches and 3 feet above the ground, and two area samples were collected at the upwind background location at 6 inches and 3 feet above the ground. At Field L, one area sample was collected at 3 feet. At Field D during the six hour sampling event, two on field area samples (6 inches and 3 feet) were collected. A field blank was collected at each field. A total of 40 samples were collected including 7 field blanks. Upon arrival to WOHL, one field sample had a cracked inlet

Analysis: All samples were analyzed by WOHL using NIOSH 2522 for the following nitrosamines: N-nitrosodimethylamine (NDMA), N-nitrosomorpholine (NMOR), N-nitrosopyrrolidine (NPYR), N-nitrosodiethylamine (NDEA), N-nitrosopiperdine (NPIP), N-nitrosodipropylamine (NDPA), and N-nitrosodibutylamine (NDBA). Nitrosamines were not found in the field blanks.

Results: Table 23 provides the results of the nitrosamine sampling. Concentrations are reported in $\mu g/m^3$. All concentrations were below the reporting limits. Appendix J provides the WOHL analytical laboratory reports for nitrosamine sampling.

Table 23. Nitrosamine concentrations in μg/m³ at each field (A-D, K-L)

Field	Location	Nitrosamine μg/m³
A	6" on field AFAP	<0.41
A	3' on field AFAP	<0.32
A	6" background	<0.42
A	3' background	<0.41
A	Personal	<0.42
A	Personal	<0.41
B	6" on field AFAP	<0.34
B	3' on field AFAP	<0.41
B	6" background	<0.35
B	3' background	<0.43
B	Personal	<0.39
B	Personal	<0.41
C	6" on field AFAP	<0.41
C	3' on field AFAP	<0.34
C	6" background	<0.39
C	3' background	<0.32
C	Personal	<0.38
C	Personal	<0.38
D	6" on field AFAP	<0.42
D	3' on field AFAP	<0.42
D	6" background	<0.38
D	3' background	<0.35
D	Personal	<0.39
D	Personal	<0.40
D-6hr	6" on field AFAP	<0.14
D-6hr	3' on field AFAP	<0.14
K	6" on field AFAP	<0.40
K	3' on field AFAP	<0.39
K	6" background	<0.31
K	3' background	<0.34
K	Personal	<0.39
K	Personal	<0.41
L	3'	<0.25[a]

Abbreviations: AFAP=away from active play.
[a] The sampler had a cracked inlet upon arrival to WOHL.

3.4.3 Air Particulate Matter (PM_{10})

Air Sampling: Area Air samples for particulate matter (PM_{10}) were collected using the Harvard Impactor (MS&T Area Sampler, Air Diagnostics and Engineering, Harrison, ME, USA). Samples were collected onto 37 mm Teflon filters (2.0 um) at a flow rate of 20 Liters/minute (Pump Model SP-280, Air Diagnostics and Engineering Inc., Harrison, ME;S/N 30637 and 30565). Two samples were collected at 3 feet above the ground per field: on turf near the middle of the field and upwind off-turf (background). Field blanks were collected and analyzed at every sampled field. Extension cords were connected to electrical outlets in external buildings to provide power to the sampling pumps. The airflow rate was measured with a rotameter (AALBORG, Orangeburg, NY, S/N 227-202-4) before and after sampling with a representative sample medium according to HSPH Type Impactor SOP Protocol (6-26-00-Air Diagnostics and Engineering, Harrison, ME, USA). Flow rates after sampling were within $\pm$ 5% of the initial flow rate at each sampling field.

Twelve field samples and six field blanks were collected (two field samples and one blank per field). Filters were shipped to the WOHL laboratory on the same day as sampling on ice and frozen upon receipt until weight analysis.

Analysis: Samples were weighed according to CFR Title 40 Part 50 (Appendix L) before and after sampling to determine PM_{10} concentration. Tare (before sampling) and post sampling weights were measured three times on a Mettler Toledo Model MX5 Balance (weighs to 0.001mg). These measurements were averaged, and the difference between the average tare and post sampling concentrations were used to calculate PM_{10} concentration as micrograms per cubic meter of air (µg/m^3). Final PM_{10} concentrations for field samples were corrected by field blanks (samples at fields C and K were corrected).

Results: Table 24 provides the PM_{10} concentrations for all fields. PM_{10} concentrations were greater in background locations than on the turf at all fields with the exception of Field B. However, the concentration on turf at Field B, 5.89 µg/m^3, was within the range of background concentrations (4.96-17.79 µg/m^3). The protocol for sampling at Field A was not followed properly and, therefore, data is not available.

Table 24. Concentrations of Airborne Particulate Matter (PM_{10}) at 3 feet above the surface at fields (A-D, K-L).

Field ID	Location Type	Pm_{10}Concentration (ug/m^3)	
		On Turf	**Background**
A	Outdoor	--- [a]	--- [a]
B	Outdoor	5.89	<0.38
C	Outdoor	16.54[b]	17.79[b]
D	Outdoor	4.52	4.96
L	Outdoor (non-turf site)	NA[c]	8.81 8.61
K	Indoor	7.22	9.04

[a] --- Sampling protocol was not followed during sampling.
[b]Pesticide application occurred adjacent to field during sampling day (~10 minutes)
[c]NA is non applicable because sampling occurred in an suburban grass field (non-turf).

Air Particulate Matter (PM_{10}) Characterization

Following gravimetric analysis, samples were stored at room temperature until particulate characterization analyses. Six samples were selected for Microscopic Particle Identification and characterization by Polarized Light Microscopy (WP001.20 Analysis), Scanning Electron Microscopy, and Energy Dispersive X-Ray (EDXA) analyses. These samples were collected from Fields B, D, K (on turf) and L (suburban grass). Appendix K provides the WOHL analytical laboratory reports for PM_{10}. Other samples were not analyzed as planned because rubber fragments were not easily detected and identification of particles were inconclusive.

4.0 Summary Findings

This report identifies and measures chemicals across several synthetic crumb rubber turf fields and background locations. The measurements collected from background locations are necessary to better understand the data because many of these chemicals are present in ambient air as a result of air pollution.

The following algorithm was used to identify a possible turf-related VOC, targeted SVOC or nitrosamine: Chemicals found in: A) either 6" or 3' samples; or B) in both personal and either 6" or 3' samples, greater than two times the background concentration measured near the field, were considered to have originated from the turf. The attribution of a chemical to the turf was considered stronger if the chemical was also found in at least one field's crumb rubber head space.

For PAHs and general SVOC's the following algorithm was used to identify a possible turf related chemical: Chemicals found in turf air samples but: A) not in background air samples or B) at twice the field's background concentration, were considered to have originated from the turf. Attribution of a chemical to an origin in the turf was considered stronger if this finding held on at least two fields.

4.1 Crumb Rubber Infill Bulk VOCs

The most commonly found VOCs (range of concentrations in parts per billion-ppbV) detected in crumb rubber infill include: acetonitrile (60-300ppbV), methylene chloride (dichloromethane) (20-430ppbV), methyl alcohol (33-270ppbV), and methyl isobutyl ketone (21-150ppbV). Bulk crumb rubber from the newer fields (A, B and D) contained more than ten VOCs. Crumb rubber from other fields contained less than 5 VOCs.

Bulk crumb rubber can act as a sink for organic compounds in the environment. Some VOCs, such as methylene chloride, methyl alcohol and acetone, were also found in a laboratory blank where the crumb rubber field samples were processed for the head space analysis. Presence of a VOC in the head space of the bulk crumb rubber infill as well as in air samples at two times greater than background levels is considered more suggestive that crumb rubber infill is the source of the VOC.

4.2 Air VOCs-Possibly Turf-Related

Of the 60 VOCs tested, 4 VOCs appear to be associated with turf. The concentration of methyl isobutyl ketone (35.98 $\mu g/m^3$) was the highest VOC detected in area samples collected on the turf (Field K). Acetone was the second highest VOC found in area samples on the turf, and it was also found in the air of the background location at lower concentration. Inter-player variability of total VOC air concentrations was notable on fields B (28.99 vs. 240.51 $\mu g/m^3$) and K (292.47 vs. 424.27 $\mu g/m^3$). The highest air concentrations on the turf for most VOCs were found at Field K.

Table 25 summarizes one possible algorithm for determining which VOCs may be related to crumb rubber emissions. Chemicals meeting these criteria are bolded, and most frequently found in Field K, the indoor facility, and not in the outdoor fields. Chemicals found in personal samples (at two times greater concentrations than background) but not in 6" or 3' or any bulk crumb rubber head space sample are unlikely to be turf related.

The belts and aprons that held the personal samplers in place during simulated soccer play emit a number of chemicals. Trace levels of acrolein were detected seven months later in mesh belt and cloth apron. Other sources of VOCs, such as sweat or the players' use of personal care products (e.g. sunscreen, deodorant, etc,) may be contributing to the VOC levels found in the personal results; however, it is difficult to determine this. In the future, personal samples should also be collected on grass (non-turf) field in order to better interpret the data.

Table 25. VOC exposure assessment- screening algorithm for chemicals' relationship to crumb rubber emissions.

Screen for each field	Chemical	Field
Either 6" or 3' two times > background for this field Chemical in this field's crumb rubber head space	**Toluene**	**D**
Either 6" or 3' two times > background for this field Chemical not in field's crumb rubber head space but in at least one other field's crumb rubber head space	**Acetone**[c]	**C**
	Ethyl Benzene	**K**
	Methyl Isobutyl Ketone	**K**
	Toluene	**K**
Either 6" or 3' two times > background for this field Chemical is not in any field's crumb rubber head space	Carbon Disulfide	K
	Cyclohexane	B, K
	M/P-Xylene	K
	O-Xylene	K
Personal two times > background for this field Chemical is two times background in 6" or 3' sample Chemical is in this field's crumb rubber head space	**Toluene**	**D**
Personal two times > background for this field Chemical is two times background in 6" or 3' sample Chemical not in field's crumb rubber head space but in at least one other field's crumb rubber head space	**Acetone**[c]	**C**
	Ethyl Benzene	**K**
	Methyl Isobutyl Ketone	**K**
	Toluene	**K**
Personal two times > background for this field Chemical is two times background in 6" or 3' sample Chemical is not in any field's crumb rubber head space	Carbon Disulfide	K
	Cyclohexane	B, K
	M/P-Xylene	K
	O-Xylene	K
Personal two times > background for this field Chemical is not two times > background in 6" or 3' sample Chemical is in this field's crumb rubber head space	Acetone[c]	A, B
	Hexane	B, C
	Methylene Chloride	B
	Methyl Isobutyl Ketone	B, D
	Toluene	A, B
	(Acetonitrile)^	B
	(Isopropyl Alcohol)^	A, B
Personal two times > background for this field Chemical is not two times > background in 6" or 3' sample Chemical not in field's crumb rubber head space but in at least one other field's crumb rubber head space	Acetone[c]	D
	Benzene[c]	B
	Ethyl Benzene	B
	Hexane	A
	Toluene	B, C
	(Acetonitrile)^	K
	(Isopropyl Alcohol)^	C, D, K
Personal two times > background for this field Chemical not two times > background in 6" or 3' sample Chemical is not in any field's crumb rubber head space	Acrolein	A, B, K
	Bromodichloromethane	K
	Bromoform	A, K
	Carbon Disulfide	B
	Ethyl Acetate	A, B, C, D, K
	Heptane	B, C, D
	M/P-Xylene	B
	O-Xylene	B
	Propene	B, C, D, K
	Styrene	B, K
	Tetrachloroethylene	B, K
	Tetrahydrofuran	B, K
	Trichloroethylene	B, K
	Vinyl Acetate	K
	1,2-Dichloropropane	B
	1-Ethyl-4-Methyl Benzene	B, K
	1,2,4-Trimethyl Benzene	B, K
	1,3,5-Trimethyl Benzene	B, K

^ tentative identification with NIST Library

[c]Compound was detected in the background sample of the laboratory used to analyze the bulk crumb rubber head space.

Air VOCs-Background

Twenty VOCs of 60 were found in upwind background locations (Table 26). Five of these VOCs (chloromethane, dichlorodifluormethane, halocarbon 11, hexane and methyl ethyl ketone) were found in the upwind background locations at all five fields. Air concentrations of acetone, carbon tetrachloride and toluene were found at four background sites, whereas benzene and methylene chloride were detected at three sites.

Table 26. VOC Concentrations in upwind background locations at all fields.

VOCs	Fields	Range of VOC Concentrations µg/m^3	(parts per billion ppbV)
1,1,-2-Trichlorotrifluoroethane	K	1.53	(0.20)
1,1,2-Trichloroethane	K	0.76	(0.14)
1,2-Dichloropropane	K	0.69	(0.15)
1,2-Dichloroethane	K	0.68	(0.17)
1,1,2,2-Tetrachloroethane	A	1.02	0.15)
Acetone	A, B, D, L	7.11-12.33	(3.0-5.2)
Benzene	A, D, L	0.41-0.64	(0.13-0.20)
Carbon Tetrachloride	A, B, K, L	0.75-1.30	(0.14-0.21)
Chloroform	K	0.68	(0.14)
Chloromethane	A, B, D, K, L	1.06-1.33	(0.52-0.65)
Dichlorodifluoromethane	A, B, D, K, L	2.23-2.47	(0.45-0.5)
Ethyl Acetate	A	0.61	(0.17)
Halocarbon 11	A, B, D, K, L	0.53-1.96	(0.13-0.35)
Heptane	K	0.53	(0.13)
Hexane	A, B, D, K, L	0.88-9.40	(0.25-2.6)
Methyl Ethyl Ketone	A, B, D, K, L	1.06-1.74	(0.36-0.62)
Methylene Chloride	A, K, L	0.48-1.83	(0.14-0.32)
Propene	L	0.48	(0.28)
Toluene	A, B, K, L	0.75-0.1.09	(0.2-0.29)
Vinyl Acetate	A	1.02	(0.29)

4.3 Air PAHs and SVOCs-Possibly Turf Related

The EPA Method TO-13A was followed to collect and analyze ten air samples for 115 SVOCs. Table 27 provides the range of concentrations of PAHs across all the fields on outdoor turf, indoor turf and upwind background locations.

Table 28 summarizes one possible algorithm for determining which miscellaneous SVOCs may be related to crumb rubber emissions. The criteria used to determine if a chemical is potentially turf-related includes: Chemicals found in turf air samples but : A) not in background air samples or B) at twice the field's background concentration, were considered to have originated from the turf. Attribution of a chemical to an origin in the turf was considered stronger if this finding held on at least two fields.

At Field K, several compounds were ten fold higher on turf than background including five PAHS (1-methylnaphthalene, 2-methylnaphthalene, fluorene, naphthalene, and pyrene) and 7 general SVOCs (dotriacontane, heptacosane, hexacosane, octanoic acid, pentacosane, tetracosane, and tetradecane).

Table 27. Range Concentrations of PAHs in ng/m^3 On Outdoor Turf and Upwind Background Locations.

PAH	Outdoor On Turf Range ng/m^3 (n=5*)	Indoor On Turf Concentration ng/m^3 (n=1)	Background Range ng/m^3 (n=4)
1-Methylnaphthalene	3.72-9.31	ND	4.08.6.91
2,6 Dimethylnaphthalene	ND-7.65	28.70	ND-10.37
2-Methylnaphthalene	1.88-4.24	63.38	ND-3.31
Acenaphthene	2.14-3.45	17.37	ND-0.3.99
Acenaphthylene	ND-6.59	6.78	ND-0.77
Anthracene	ND-ND	ND	ND-0.02
Benz(a)anthracene	ND-ND	ND	ND-0.03
Benzo(a)pyrene	ND-0.19	ND	ND-0.05
Benzo(b)fluoranthene	ND-0.21	ND	ND-0.07
Benzo(e)pyrene	ND-0.26	ND	ND-0.06
Benzo(GHI)fluoranthene	ND-0.08	ND	ND-ND
Benzo(GHI)perylene	ND-0.14	ND	ND-0.06
Benzo(k)fluoranthene	ND-0.08	ND	ND-0.04
Chrysene	ND-0.34	ND	ND-0.04
Fluoranthene	1.68-6.76	5.55	0.58-3.96
Fluorene	2.21-4.09	53.70	2.43-3.59
Indeno(1,2,3-cd)pyrene	ND-0.05	8.90	ND-0.05
Naphthalene	5.99-14.57	113.00	4.50-16.94
Phenanthrene	5.07-14.34	32.26	6.11-13.05
Pyrene	0.97-6.92	11.84	0.37-3.16

ND=nondetectable; see appendix for reporting limits.
*Four fields were sampled, and one field (D) was sampled twice.

Table 28. SVOC exposure assessment- screening algorithm for chemicals' relationship to crumb rubber emissions.

Screen for each field	Chemical	Field
PAHs detected on the turf field and not detected in background, and found on at least 2 fields	**Acenaphthylene**	D and K
PAHs detected on the turf field at more than two times the concentration of background levels, and found on at least 2 fields	**1-Methylnaphthalene** **2- Methylnaphthalene** **Fluoranthene** **Phenanthrene** **Pyrene**	D and K D and K D and K D and K D and K
Miscellaneous SVOCs detected on the turf field at more than two times the concentration of background levels, and found on at least 2 fields	**Eicosane** **Eicosanic acid** **Heneicosane** **Hexadecanoic acid** **Octadecanoic acid** **Phytane** **Tetradecanoic acid** **Tetratriacontane** **Tricosane**	D and K D and K D and K D and K A and D D and K D and K A and K D and K

4.4 Targeted SVOCs-Possibly Turf-Related

Of the five targeted SVOCs in air, Benzothiazole and BHT were the only chemicals detected above background (Table 29). Concentrations of benzothiazole were higher on the turf at six inches away from active play than in background locations at all fields. Most concentrations of benzothiazole and BHT were an order of magnitude lower among the outdoor turf fields than the indoor field, ranging from <80-1200 ng/m^3 and <80-130 ng/m^3, respectively. Indoor concentrations of benzothiazole and BHT on the turf range from 11000-14,000 and 1240-3900 ng/m^3, respectively. The indoor field contained the highest concentration of benzothiazole in the crumb rubber. 4-tert-(octyl)-phenol was detected in the crumb rubber head space in all fields (A-K), however, it was only found in two air samples (on turf level was less than background). BHT was detected in air at 3 feet at the grass background Site L (280 ng/m^3).

Table 29. Field locations where air concentrations are greater than relative background concentration for each field.

	Personal	6” NAP	3’NAP	6” AFAP	3’ AFAP
Benzothiazole	A*, D#, K	A, B, K	B, D, K	A, B, C, D, K	D, K
2-mercaptobenzothiazole	none	none	none	none	none
4-tert-octyl	none	none	none	none	none
BHA	none	none	none	none	none
BHT	D*, K	K	D, K	K	K

Abbreviations: NAP=near active play;AFAP=away from active play

* one of two personal samples exceeded background

one of two personal samples exceeded 6” background but not 3’ background

Table 30 summarizes one possible algorithm for determining which targeted SVOC may be related to crumb rubber emissions. Chemicals found in: A) either 6” or 3’ samples; or B) in both personal and either 6” or 3’ samples, greater than the background concentration measured near the field, were considered to have originated from the turf. The attribution of a chemical to the turf was considered stronger if the chemical was also found in at least one field’s crumb rubber head space. Chemicals meeting these criteria are bolded. Benzothiazole and BHT met this criteria.

Table 30. Targeted SVOCs exposure assessment- screening algorithm for chemicals’ relationship related to crumb rubber emissions.

Screen for each field	Chemical	Field
Either 6” or 3’ two times > background for this field Chemical in this field’s crumb rubber head space	**Benzothiazole** **BHT**	A, B, C, D, K K
Either 6” or 3’ two times > background for this field Chemical not in field’s crumb rubber head space but in at least another field’s crumb rubber head space	**BHT**	D
Personal two times > 3’ background for this field Chemical is in 6” or 3’ sample two times background Chemical is in this field’s crumb rubber head space	**Benzothiazole** **BHT**	A, D, K K
Personal two times > 3’ background for this field Chemical is in 6” or 3’ sample two times background Chemical not in field’s crumb rubber head space but in at least another field’s crumb rubber head space	**BHT**	D

Nitrosamine

All samples were below the reporting limit including the crumb rubber infill.

Particulate Matter (PM_{10})

PM_{10} concentrations measured on the turf are typical levels found in background locations. Rubber fragments were not easily detected and analyses of particles were inconclusive.

Lead

All of the composite samples of artificial turf fibers and crumb rubber were below the level EPA considers as presenting a “soil-lead hazard” in play areas (400ppm). This definition, however, applies to residential buildings and to soil rather than other surfaces.

5.0 Limitations

The primary objective of this project was to characterize human exposure via inhalation to a targeted group of chemicals that are associated with crumb rubber synthetic turf. Other routes of exposures, such as ingestion and contact, were not within the scope of this study. Some chemicals of potential concern, such as natural rubber latex, were not included as part of the targeted chemicals in our study but should be included in future studies. There are several limitations to this project. This project has a potential for selection bias because participation was voluntary and self-selected. The sample size was small (4 outdoor fields and 1 indoor field), however, goals of the project were met in recruiting outdoor turf fields, an indoor facility and a suburban grass field.

During the summer of 2009, temperature conditions for the sampling events were on average lower than normal. The 30-year monthly average maximum temperature for the month of July is 84.9 °F, and during July 2009, the average was 79.9 °F. Most notably, wind conditions were low, and little cloud overcast occurred on most sampling days.

Personal sampling occurred at waist height, and not in the normal breathing zone of the study team players. The placement of 1.4 L SUMMAs and personal sampling pumps at this height is not a conventional industrial hygiene personal sampling method. This method was chosen to better represent a child's height. Some VOCs (e.g. acrolein) were found in personal samples and not on the turf or in the background areas. Players wore the SUMMAs close to their bodies, and they were up against the sampling belts and plastic ties that players wore to hold all the sampling equipment. The belts were purchased new, and may have had some coatings on them. SUMMAs are a very sensitive air sampling method, and may have collected VOCs associated with personal care products and sampling belts worn by the team players. Players were asked not to wear products to limit any contamination. Because of the intense heat and sun exposure, some players wore sun protection and all players sweated. WOHL conducted a follow-up experiment to determine if the new belts and plastic ties were capable of releasing compounds. WOHL detected trace levels of several compounds in the 7 month old belt, apron and tie. Any future personal sampling must address these kinds of issues, and "control" team members playing on the grass (non turf setting) should be included in the sampling strategy. There are many factors to consider for "control" team members, including the type of player clothing, personal product use, personal characteristics (sweat and exhaled breath), laundering practices, and behavior.

Field coordination for this project was challenging at times. For example, it is unfortunate that background samples were not collected at two fields with the PS-1 Samplers as a result of media breakage issues during transportation. In addition, one of the fields (C) was contaminated by a pesticide application which may explain the larger number of VOCs found in comparison to the other outdoor fields. The indoor field had multiple uncharacterized potential point sources.

Sampling for two hours was a limitation. Although the 6-hour sampling at Field D allowed for greater sensitivity, similar patterns were observed with both strategies. Benzothiazole is not a targeted SVOC for the TO-13A Method, and more validation studies are needed to better understand how to collect air samples with the PS-1 Samplers and analyze them for benzothiazole. NIOSH Method 2550 (modified) was adequate to capture concentrations of benzothiazole at the three levels, and other targeted SVOCs.

The lab was not able to identify rubber particles on the Teflon filters from several fields, and therefore, SEM analysis was not completed for all field samples. U.S. EPA's study used polycarbonate filters with the same air sampling method and reported similar difficulties. More research is needed to better characterize particulate matter containing crumb-rubber.

The airborne concentrations of VOCs, Targeted SVOCs (e.g. benzothiazole) and SVOCs were highest in the indoor field. These data were collected from only one indoor facility. The crumb rubber of the indoor facility was manufactured by the same company as Field B, and installed one year earlier. The air in the indoor field was not influenced by outdoor factors that may degrade and off gas chemicals, such as sunlight, high temperatures, rain, and other weather conditions. Furthermore, potential point sources were identified in the facility, (electric carts, portable chargers, and maintenance supplies), and the indoor facility did not have its exhaust system operating on the day samples were collected. The use of the exhaust system in this facility varies according to need. More research is needed to better understand chemical exposures in indoor facilities.

6.0 Connecticut Academy of Science and Engineering Review (CASE): CASE performed a peer review of this final report in June 2010. The scope of the technical review for this report included an examination of the appropriateness of the methods used to sample targeted compounds and the laboratory analytical methods. Based on CASE comments, this report was revised to: 1) clarify laboratory quality control and assurance laboratory procedures for VOCs by WSLH and WOHL, 2) strengthen the criteria of the algorithm used to identify a turf-related compound to take into account variability among concentrations (e.g. turf-related compound was reported as twice a field's background concentration), 3) move tables presenting concentrations of miscellaneous SVOCs commonly found in the environment to appendices and 4) include a description of the similarities and source locations of the bulk crumb rubber samples collected from UCHC and CAES. CASE also highlighted that the SVOC air contaminants found above the field are consistent between fields, and are also consistent with air contaminants reported in other similar studies. Issues raised by the CASE review are addressed below and incorporated into the report.

Design of Experiment: Analysis of crumb rubber for latex antigen was beyond the scope of the current investigation. This should be included in future studies.

Explain why PM10 was measured and not PM2.5: During our planning for this study, several states and US EPA were finishing reports related to synthetic turf. We discussed their findings, and used data that best represents inhalation exposure while playing on a turf field. In US EPA's scoping study, two kinds of PM10 integrated air samples were collected (one for particle mass and metals analysis and another for scanning electron microscopy analysis). NYCity did not reveal meaningful differences in concentrations between the results for the samples collected upwind and those on the field. In addition, they did not find rubber dust in the respirable range. Because of these findings, we decided to use the PM10 range.

Concern with VOC Results: Precautions used by the laboratories to prevent VOC contamination were added in the UCHC final report as recommended by CASE. The OEM UCHC sub-contracted laboratory analyses to three AIHA accredited laboratories: Wisconsin Occupational Health Laboratory (WOHL), the Wisconsin State Laboratory of Hygiene (WSLH) and the ESIS Environmental Health Laboratory (EHL) in Cromwell, Connecticut. WOHL is a full service industrial hygiene chemistry laboratory that is part of the Wisconsin State Laboratory of Hygiene (WSLH) at the University of Wisconsin-Madison. WSLH analyzed air samples for VOCs, SVOCs and PM_{10}. WOHL analyzed bulk crumb rubber head space for VOCs and targeted SVOCs (e.g. benzothiazole), and air samples for nitrosamines and targeted SVOCs. Additional bulk samples were analyzed for lead by the ESIS Environmental Health Laboratory (EHL).
The following precautions were taken for the personal and area VOC analysis by WSLH: WSLH followed the quality control and assurance protocols defined in the EPA TO-15 Method. Each analytical run included one method blank per batch of samples. If an analyte in the method blank was greater than its limit of detection (LOD), the result for that analyte was flagged to indicate blank contamination. As indicated in the report, one set up samples contained acetone in the blank sample (1.5 ppb), and concentrations were corrected. Duplicate analysis was performed on one sample per analytical batch. Duplicate analyses were always within 25% for each compound. Daily quality control checks were performed using a second source standard. Analytes in the quality control/QC check standard were always within 30% of the corresponding calibration standards.

The following precautions were taken for the bulk crumb rubber VOC analysis by WOHL and added to the final report: 1) bulk crumb rubber samples were stored in teflon lined screw capped jars and were opened only when removing sample for analysis;2) the 340mL LVSH were baked at 70^{o}C overnight; and 3) one of the LVSH units was analyzed empty with each analytical run as a method blank, and any VOCs detected above reporting limit noted in the analytical report. In addition, a laboratory background VOC air sample was collected in the storage cooler of the bulk crumb rubber samples. As indicated in the report, six VOCs were found and reported in this sample. These six VOCs were flagged as a footnote in tables presenting results.

Criteria used to determine concentrations greater than background: CASE recommended that qualifiers be included for the VOC and SVOC data for concentrations greater than background. UCHC agrees with CASE and modified the report. The criteria for identifying a possibly turf-related chemical of concern was changed: all concentrations greater than two times background were indicated in tables and bolded.

Semivolatile Organic Compound (SVOC) Results: CASE recommended leaving out the miscellaneous SVOCs since it appears that few, if any, of these pertain to crumb rubber or artificial turf. UCHC agrees with CASE, and moved the data into an appendix.

Off-Gas Findings: DPH risk assessment discusses the consistency of the SVOC concentrations across fields. The UCHC final report provides the data for the risk assessment.

Reference Lead Levels: CASE identified other reference levels for lead (e.g. Consumer Product Safety Commission standard for children's products). UCHC is referencing the EPA lead in soil standard (400ug/g) in the final report because it is the most comparable standard for athletic playing fields.

Analytical Results- CAES versus WOHL: CASE recommended including more information to describe the similarities and differences between CAES and WOHL samples. In the final report, UCHC included a description of the similarities and source locations of the bulk crumb rubber samples collected from UCHC and CAES. CAES collected and analyzed samples of crumb rubber material supplied by several manufacturers [5]. Their crumb rubber samples included material from only two of UCHC outdoor fields (A and D). These two crumb rubber fields were manufactured by two different companies. The results are difficult to compare between the two laboratories (WOHL and CAES) because they used different analytical methods.

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7.0 Appendices (available upon request)

Appendix A Sampling Map

Appendix B Meteorological Report

Appendix C Crumb Rubber Head Space VOC WOHL Reports

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FINAL REPORT

Artificial Turf Study

Leachate and Stormwater Characteristics

Connecticut Department of Environmental Protection
July 2010

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APPENDICES

1. PROJECT OVERVIEW

In December 2008, four Connecticut State agencies, the University of Connecticut Health Center, The Connecticut Agricultural Experiment Station, the Connecticut Department of Environmental Protection and the Connecticut Department of Public Health, agreed to jointly develop and implement a study to evaluate the health and environmental impacts associated with artificial turf fields. The overall objectives of the study were to:

1. Identify comprehensively substances, including organic compounds and elements, which derive from the crumb rubber infill used on synthetic turf fields, as well as currently available alternative infill products, through off-gassing and leaching pathways;
2. Establish the level of chemical variability for infill at individual synthetic turf fields and between different synthetic fields in Connecticut;
3. Measure levels of off-gassed compounds and airborne particulate matter in the normal breathing zone of children during a "simulated worse-case scenario" at athletic field(s) in Connecticut (inhalation risk);
4. Measure levels of leached compounds in storm water runoff collected in actual field conditions (environmental risk); and
5. Utilize collected data to make environmental and public health risk assessments regarding outdoor artificial turf fields.

The Department of Environmental Protection ("DEP") was specifically tasked with: (1) collecting stormwater runoff samples from the four artificial turf fields selected for the study; (2) analyzing the stormwater samples for levels of compounds leached from the artificial turf materials; (3) scientifically evaluating the laboratory analysis results; and (4) developing an environmental risk assessment for the artificial turf fields.

This report is not intended to be a comprehensive investigation of the environmental risks associated with artificial turf fields, but a basic assessment of water quality data collected from a limited number of fields during a three-month period. It should be understood, that the ultimate conclusions in the report are based on eight stormwater sampling events, essentially a "snapshot", of an ongoing chemical and physical process.

2. SITE SELECTION

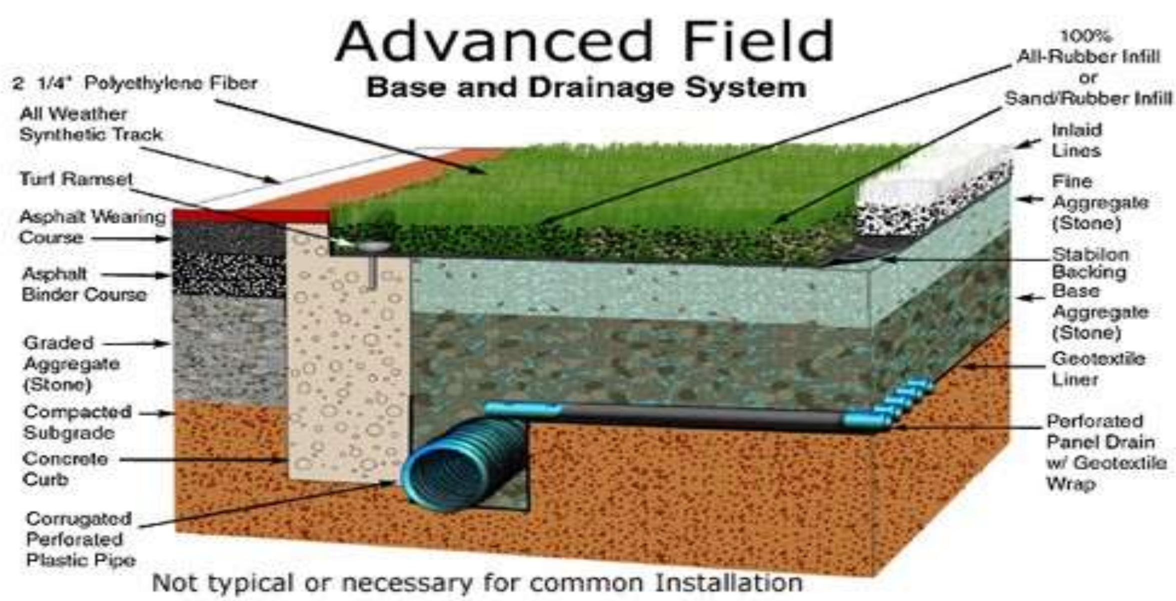
The four artificial turf fields selected for DEP's stormwater sampling plan were the same fields sampled in the summer of 2009 by the University of Connecticut Health Center for airborne contaminants. Specific field selection criteria included: crumb rubber infill, owner permission, installation date, different manufacturers and site location. The owners of the selected four fields provided engineered drainage plans to DEP. DEP staff reviewed the drainage plans and established sampling points that <u>only</u> collected stormwater draining from the artificial turf field.

3. ARTIFICIAL TURF FIELD SYSTEMS

The artificial turf fields selected were installed by different engineering, synthetic turf and construction companies, but are similar in general design. The fields are composed of a top layer of polyethylene or polypropylene grass fibers, with a crumb rubber (sometimes intermixed with sand) infill layer, and underlain by crushed stone/gravel with a piped drainage system (see Figures 1 and 2 below).

Figure 1.

Figure 2. (source: www.suncountrysystems.com/.../syntheticgrass.jpg)



The critical field component for this study is the infill layer, which includes crumb rubber materials produced from recycled tires. The infill layer can be composed of entirely styrene-butadiene rubber (SBR) granules, produced by ambient and/or cryogenic grinding process, or intermixed with quartz crystals (sand). The assumption for this study, and the sampling plan, is that precipitation lands on the surface of the artificial turf field, flows downward through the infill and rock/gravel layers, collects in the subsurface drain pipes and then ultimately discharges from the field. The artificial turf drainage pipes often discharge to existing subsurface drainage systems at catch basin and/or manhole connections. The subsurface drainage pipes utilized under the fields can be solid or perforated.

4. SAMPLING PROTOCOLS

DEP staff reviewed EPA protocols and previous artificial turf leaching studies and established the following stormwater sampling plan:

1. Sampling Plan
    a. One sampling station was established at each of the four artificial turf fields;
    b. The sampling stations were located at a point where runoff was only from the artificial turf field;
    c. The size of the drainage area (in square feet) to each sampling station was calculated;
    d. Grab samples were collected and delivered to the laboratory by qualified individuals during the fall of 2009; and
    e. Samples were analyzed by an EPA certified laboratory.

2. Storm Event Criteria
    a. Samples were collected from discharges resulting from a storm event that was greater than 0.1 inch in magnitude and that occurred approximately 72 hours after any previous storm event of 0.1 inch or greater;
    b. Grab samples were collected during the first 30 minutes of a storm event discharge, or as close thereto as possible, and were completed as soon as possible;
    c. The following information was collected for the storm events monitored:
        i. The date, temperature, time of the start of the discharge, time of sampling, and magnitude (in inches) of the storm event sampled; and
        ii. The duration between the storm event sampled and the end of the previous measurable (greater than 0.1 inch rainfall) storm event.

3. Sampling Procedures
    a. Grab sample collection, chain of custody and laboratory delivery were performed in accordance with the EPA NPDES Stormwater Sampling Guidance Document (EPA 833-B-92-001, 7/92); http://www.epa.gov/npdes/pubs/owm0093.pdf
    b. Laboratory analysis of grab samples included the following:
        i. Acute Toxicity 48 hour LC50 *Daphnia pulex* & 48 hour and 96 hour LC50 *Pimephales promelas* (EPA 821-R-02-012).
        ii. EPA Method 130.1, Hardness, Total (mg/L as $CaCO_3$)
        iii. EPA Method 150.2, pH
        iv. EPA Method 200.7, (Antimony, Arsenic, Barium, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Thallium, Vanadium and Zinc)
        v. EPA Method 624, Volatile Organic Compounds
        vi. EPA Method 625, Semivolatile Organic Compounds (TIC's for Benzothiazole, Butylated hydroxyanisole (BHA), n-hexadecane and 4-(t-octyl) phenol.

5. FIELD SAMPLING METHODS

In September of 2009, the stormwater sampling plan was implemented at the four artificial turf fields: Field A, Field B and Field D all constructed in 2007; and Field C constructed in 2005. Stormwater samples were successfully collected from Fields A, C and D. Field B was visited during five precipitation events and no discharge from the established sampling station was observed. A total of eight stormwater samples were collected from Fields A, C and D between 9/11/09 and 12/3/09. Based on DEP staff observations, Fields B and C did not appear to regularly discharge runoff during or after precipitation events, while Fields A and D discharged during and after every precipitation event monitored. For the one sample collected from Field C, DEP staff was fortunate to experience an extremely hard (downpour) rain event that exceeded the infiltration rate of the perforated underdrain system. DEP staff reviewed the engineered drainage plans and determined that Fields B and C utilized perforated drainage pipes causing the stormwater to normally infiltrate into the soil beneath the fields. Fields A and D utilized solid drainage pipes, which discharge the stormwater to local drainage systems at the sites, similar to an impervious surface.

For each precipitation event, stormwater collected at the fields was sampled for total metals, hardness, pH, volatile organic compounds, semi-volatile organic compounds (including rubber Tentatively Identified Compounds found by The Connecticut Agricultural Experiment Station in a 2007 study), pesticides/ polychlorinated biphenyls (PCBs) and acute aquatic toxicity (48 hours for *Daphnia pulex* (Dp)and 96 hours for *Pimephales promelas*(Pp)). Stormwater samples were analyzed at the Connecticut Department of Public Health Laboratory, Environmental Chemistry Division, Inorganic Chemistry Section, 10 Clinton Street Hartford, CT 06106 for pH, Hardness and Total Metals; at Phoenix Environmental Laboratories, Inc. 587 East Middle Turnpike, Manchester, CT 06040 for volatile organic compounds, semi-volatile organic compounds, pesticides, PCBs; and at GZA GeoEnvironmental, Inc., 120 Mountain Avenue, Bloomfield, CT 06002 for acute toxicity. A summary of the tests performed on the samples collected are shown in Table A below.

Table A

Location	Date	pH	Hardness	Metals	Volatiles	Semivolatiles	Pesticides and PCBS	Aquatic Toxicity LC50		
								Dp 48 hrs	Pp 48 hrs	Pp 96 hrs
Field C	9/11/09			√	√	√	√	√		
Field A	9/27/09	√	√	√	√	√	√	√		√
Field A	10/7/09	√	√	√	√	√	√	√		√
Field A	10/18/09	√	√	√	√	√	√	√	√	
Field D	10/18/09	√	√	√	√	√	√	√	√	
Field D	10/28/09	√	√	√	√	√	√	√		√
Field D	11/20/09	√	√	√	√	√		√		√
Field D	12/3/09	√	√	√	√	√	√	√		√

6. DEP STORMWATER SAMPLING RESULTS

a) Method 624/Method 625 and Tentatively Identified Compounds(TICs):

No standard volatile or semi-volatile organic compounds were detected in any sample using the EPA 624 and 625 analytical methods. All samples were analyzed for non-standard semi-volatile organic compounds, including the following rubber compounds benzothiazole, butylated hydroxyanisole (BHA), n-hexadecane and 4-(t-octyl) phenol. The semi-volatile analysis detected the analytical peaks of twenty-two compounds, of which nine were tentatively identified (see Table B below). The concentrations of these compounds ranged from 1 ug/l to 150 ug/l. The grey columns in Table B correspond to the three stormwater samples determined to be acutely toxic. Table C details the aquatic toxicity information found for the other tentatively identified compounds listed in Table B.

b) Pesticides and PCBs (Method 608)

Pesticides

Pesticides were detected in the samples of stormwater collected on September 11, 2009 from Field C and on October 28, 2009 from Field D. DEET and heptachlor were detected at estimated concentrations of 6.9 ug/l and 0.18 ug/l, respectively. It is assumed that these substances were not derived from the artificial turf, but were a result of pesticide applications at the site.

PCBs

No PCBs were detected during the stormwater sampling events.

c) pH, Hardness and Metals:

The results from the pH, hardness and metals analysis conducted on the stormwater runoff from the fields are presented in the table below.

pH

The pH of the stormwater samples ranged from 6.6 to 8.0. The pH of stormwater in Connecticut is generally considered to be between 5.6 and 6.0. Based on this fact, the pH of the stormwater samples are more alkaline than expected. It is possible that the crushed stone used as a sub-base in the fields affected the pH of the stormwater as it drained through the field.

The pH alone does not exhibit toxic effects unless it falls below 5 or is higher than 10. However, metals are often more soluble and toxic at lower pH's. The observed neutral pH in the stormwater may have reduced the concentrations and toxicity of the metals leaching from the fields.

TABLE B

Location:			Field C	Field A	Field A	Field A	Field D	Field D	Field D	Field D
Sample #			**A**	**B**	**C**	**E**	**D**	**F**	**G**	**H**
Sample date			9/11/2009	9/27/2009	10/7/2009	10/18/2009	10/18/2009	10/28/2009	11/20/2009	12/3/2009
Parameter:	**Tentatively identified Compounds**	**CAS#**								
Heptachlor							<0.10	0.18	NT	<0.05
Retention Times (min)										
3.55			6.2							
5.04					150					
6.12			4.3							
6.63										9.5
6.81					4.1					
6.83	2- propyl-methyl pentanoic acid	22632-59-3			14	6.6				
6.85	Benzothiazole	95-16-9		1	4.9					
6.88					6.1					
7.07									5.1	
7.08	methyl 2alpha -D-xylofuranoside	32469-86-6				5.8				
7.10	2 ethyltetra hydro thiopene	1551-32-2				28				
7.13	4-methyl4-Heptanol	598-01-6				7.4				
7.15	2- butyl tetrathydrothiopene	1613-49-6				12				
7.77										10
7.96								6.6		
8.13					7.4					
8.23									7	
9.48	Benzamide, N-N- diethyl-3-methyl	134-62-3	6.9							
9.56	2(3H)- Benzo thiazolone	934-34-9			5.7					
10.28						4.1				
12.60	2-2-7 trimethyl-3-Octyne	55402-13-6					4.5			
16.88			8.4							

TABLE C

Location: Sample # Sample date			Max Concentration	Location	Acute Water Quality Criteria	Chronic Water Quality Criteria	Comments
Parameter:	**Tenatively identifeid Compounds**	**CAS#**					
Heptachlor			0.18	D	0.26	.0038	CT WQS 2002
Retention Times (min)							
3.55			6.2	A			
5.04			150	A			
6.12			4.3				
6.63			9.5	D			
6.81			4.1	A			
6.83	2- propyl-methyl pentanoic acid	22632-59-3	14	A	2812.5	312.5	Toxicity info on pentanoic acid tier 2
6.85	Benzothiazole	95-16-9	4.9	A			One data point tier 2
6.88			6.1	A			
7.07			5.1	D			
7.08	methyl 2alpha -D-xylofuranoside	32469-86-6	5.8	A			No data
7.10	2 ethyltetra hydro thiopene	1551-32-2	28	A			No data
7.13	4-methyl4-Heptanol	598-01-6	7.4	A			No data on Heptanol either
7.15	2- butyl tetrathydrothiopene	1613-49-6	12	A			No data
7.77			10	D			
7.96			6.6	D			
8.13			7.4	A			
8.23			7	D			
9.48	Benzamide, N-N- diethyl-3-methyl	134-62-3	6.9	C	89.3	9.9	DEET tier 2
9.56	2(3H)- Benzo thiazolone	934-34-9	5.7	A	47.3	8.1	Different CAS # 149304 tier 2
10.28			4.1	A			
12.60	2-2-7 trimethyl-3-Octyne	55402-13-6	4.5	D			No data
16.88			8.4				

Hardness

The hardness of the stormwater samples ranged from 8 to 59 mg/L. Hardness in the range of 0 to 60 mg/L is generally termed “soft”. Hardness can also influence the toxicity of metals; the greater the hardness, the less toxic the metals. It is not expected that the observed hardness had much effect on metal concentrations in the stormwater.

Metals

The metal parameters which had results reported above the detection limit are listed in Table C below. Silver, molybdenum, thallium and beryllium were analyzed but were below the detection limit for every sample. In Table C, the values bolded and underlined exceed Connecticut’s acute aquatic life criteria. Metal concentrations in excess of the acute aquatic life criteria for more than one hour could cause mortality to the more sensitive organisms in the receiving surface waters. The values bolded meet or exceed Connecticut’s chronic aquatic life criteria. Average metal concentrations which exceed the chronic life criteria for more than 4 continuous days are expected to impact the ability of organisms to survive, reproduce or grow. EPA recommends that neither of these criteria be exceeded more than once in three years (EPA TSD EPA/505/2-90-001). The samples highlighted in grey also exhibited acute toxicity. Since stormwater is an intermittent discharge, the acute criteria for aquatic toxicity are more applicable. A review of the data indicates that only zinc consistently violates the acute criteria.

TABLE D

Location	Sample #	Sample date	pH	Hardness	Conductivity	Cu ug/l	Zn ug/l	Ba ug/l	Fe ug/l	Al ug/l	V ug/l
Field C 2005	**A**	9/11/09	6.6	NA	18	4	**150**	4	320	**210**	40
Field A 2007	**B**	9/27/09	6.6	8	20	1.5	**130**	1.5	20	25	1.5
Field A 2007	**C**	10/7/09	7.5	29	65	1.5	10	6	50	**160**	5
Field A 2007	**E**	10/18/09	7.5	39	86	1.5	20	7	20	60	1.5
Field D 2007	**D**	10/18/09	7.6	53	130	5	**260**	**220**	170	**120**	6
Field D 2007	**F**	10/28/09	7.9	59	157	4	50	8	80	80	8
Field D 2007	**G**	11/20/09	8	56	153	4	30	7	160	**110**	9
Field D 2007	**H**	12/3/09	8	58	147	4	20	5	170	**100**	8
		acute standard	**<5.0 >10**			**14.3**	**65**	**2000**		**780**	**150**
		chronic standard	**<5.0 >10**			**4.8**	**65**	**220**	**1000**	**87**	**44**

d) Aquatic Toxicity

The toxicity tests conducted on the stormwater measured both an LC50 value (the concentration of stormwater that is lethal to 50% of the test organisms) and an NOAEL (No Observable Acute Effect Level, the concentration of stormwater where no acute toxicity is observed). Toxicity tests conducted on the samples of stormwater collected indicate that 3 out of 8 sampling events were acutely toxic. Acute toxicity is observed when there is less than 90% survival of the test organisms in the undiluted effluent. The frequency of occurrence for acute toxicity was at least one sample per field. Where both *Pimephales promelas*(Pp) and *Daphnia pulex*(Dp) toxicity tests were conducted, the fathead minnow (*Pimephales promelas*) seemed to be slightly more sensitive to the contaminants in the stormwater discharge. Due to laboratory issues, the test duration for the fish, *Pimephales promelas*, for the October 18, 2009 Field A and Field D samples was limited to only 48 hours. If the test duration was extended to 96 hours, both samples could have had an LC50 value less than the 100% reported. The results for the aquatic toxicity testing conducted are shown in Table E below.

TABLE E

Location:	Sample #	Sample date	Dp % Surv 100%	Dp LC50	Dp NOAEL	Pp % Surv in 100%	Pp LC50	Pp NOAEL
Field C 2005	*A*	9/11/2009	65.0	>100	12.5	NT	NT	NT
Field A 2007	*B*	9/27/2009	70.0	>100	50	45	93.89	50
Field A 2007	*C*	10/7/2009	100.0	>100	100	100	>100	100
Field A 2007	*E*	10/18/2009	100.0	>100	100	96	>100	100
Field D 2007	*D*	10/18/2009	70.0	>100	6.25	50	100	25
Field D 2007	*F*	10/28/2009	100.0	>100	100	95	>100	100
Field D 2007	*G*	11/20/2009	100.0	>100	100	100.0	>100	100
Field D 2007	*H*	12/3/2009	100.0	>100	100	95	>100	100

acutely toxic

7. CAES LABORATORY HEADSPACE AND LEACHING RESULTS

The CAES performed both headspace (off-gassing) and SPLP (Standard Precipitation Leaching Procedure) evaluations on seventeen samples of crumb rubber materials used as infill for artificial turf fields. These studies indicated the primary contaminants likely to be found in the stormwater coming from these sites. Organic compounds were identified by head space analysis, with results shown in Table F below. The other organic compounds detected from the crumb rubber infill, but not quantified in the analysis, included hexadecane, fluoranthene, phenanthrene and pyrene.

TABLE F. (Table 2. From CAES 2009) Concentration (ng /ml) of Volatile Compounds in Headspace Over Crumb Rubber Samples Analyzed at CAES (average of two analyses per sample)

DEP Sample ID	1-methyl naphthalene	2-methyl naphthalene	4-(t-octyl)-phenol	benzothiazole	butylated hydroxytoluene	naphthalene	butylated hydroxyanisole
A1001	0.13	0.19	0.28	3.98	n.d.	0.42	0.50
A1002	0.11	0.15	0.31	5.59	n.d.	0.31	0.61
A1003	0.03	0.07	0.19	8.67	n.d.	0.10	0.68
A1004	0.04	0.07	0.31	6.52	0.15	0.16	0.69
A1005	0.08	0.09	0.23	2.35	0.09	0.23	0.46
A1006	0.08	0.14	0.31	4.89	0.12	0.23	0.75
A1007	0.13	0.20	0.52	3.50	n.d.	0.23	0.69
A1008	0.06	0.10	0.18	1.93	n.d.	0.22	0.43
A1009	0.03	0.06	0.13	2.89	0.13	0.08	0.50
A1010	0.07	0.11	0.22	4.91	0.13	0.20	0.64
A1011	0.04	0.06	0.30	3.94	0.16	0.11	0.62
A1012	0.08	0.14	0.46	2.70	0.13	0.28	0.64
A1013	0.09	0.12	0.45	4.45	n.d.	0.30	0.65
A1014	0.10	0.15	0.49	4.25	n.d.	0.31	0.65
B1002	n.d.	n.d.	0.43	1.21	0.67	0.09	0.36
B1009	n.d.	n.d.	0.07	1.29	0.48	0.06	0.35
B1010	n.d.	n.d.	0.06	1.03	0.40	0.05	0.34

CAES also performed simulated weathering experiments on the crumb rubber samples to determine trends in organic compound emissions over time. The weathering test results show that, except for 4-(t-octyl)-phenol, all other detected volatile compounds significantly decreased in concentration after only 20 days of outdoor exposure. By the end of the eight week study, benzothiazole, butylated hydroxanisole and 4-(t-octyl)-phenol were detected at the highest concentrations. The results are shown in Table G. below.

TABLE G: (Table 9 from CAES, 2009) Concentrations (ng /ml) of Volatile Compounds in Headspace Over Crumb Rubber Samples Aged at CAES (average of two analyses per sample)

Sample ID (week)	benzothiazole	1-methyl naththalene	2-methyl naphthalene	naphthalene	4-(t-octyl)-phenol	butylated hydroxyanisole
T0	3.75	0.12	0.24	0.40	0.35	0.77
T1	1.95	0.05	0.09	0.12	0.28	0.45
T2	0.97	0.04	0.06	0.06	0.31	0.40
T3	1.56	0.04	0.07	0.08	0.31	0.44
T4	1.77	0.04	0.08	0.08	0.30	0.43
T5	1.59	0.05	0.07	0.10	0.30	0.48
T6	1.20	0.04	0.06	0.05	0.25	0.36
T7	0.99	0.04	0.06	0.04	0.24	0.33
T8	1.17	0.05	0.05	0.06	0.23	0.41

CAES also performed an SPLP test on the same seventeen samples of the crumb rubber infill material. The resulting leachate was then analyzed for metals and organic compounds. Based on communications with CAES, the leachate contained the same organic compounds that were identified in the head space analyses, however, only benzothiazole concentrations were estimated for the test. A summary of compounds detected and their concentrations are listed in Table H below. Based on these results, the predominant contaminant leaching from artificial turf fields is zinc, followed by barium, manganese and lead. It should be noted some metals associated with tires and rubber products were not analyzed in this experiment, such as iron and vanadium.

In Table H, the values which exceed Connecticut's acute aquatic life criteria are highlighted in yellow. The summary shows that zinc is present in the leachate at concentrations about 500 times greater than the toxicity criteria. The leachate study indicates that there is a high potential for the artificial turf to leach acutely toxic levels of metals especially copper and zinc. Certain samples of crumb rubber also leached acutely toxic levels of cadmium, barium, manganese and lead.

TABLE H

	Benzothiazole	Cr	Mn	Ni	Cu	Zn	As	Cd	Ba	Pb
ug/l										
average	0.153	6.24	263.16	19.88	22.31	34170.5	3.35	1.60	313.88	11.57
80th	0.209	11.28	348.45	27.48	20.41	50269.8	1.50	0.50	463.62	7.77
Max	0.268	31.47	1443.19	57.15	143.32	71535.5	27.94	17.01	502.91	69.90
Acute	21333.000	323	616	260.5	14.3	65	340	2.02	2000	30
Chronic	3200.000	42		28.9	4.8	65	150	1.35	220	1.2

8. DISCUSSION

a) Potential Contaminants

The analyses performed on the stormwater samples were focused on compounds previously documented to leach from crumb rubber material derived from recycled tires, primarily volatile organic compounds, semi-volatile organic compounds and metals. The stormwater samples were also assessed for whole effluent toxicity. Other potential parameters of concern in the stormwater were identified from the results of the CAES off-gassing and leaching laboratory studies performed on the crumb rubber material.

b) Organic compounds

The stormwater generated at the artificial turf sites did not include many readily identifiable, volatile or semi-volatile organic compounds, as evidenced by no detections using EPA Methods 625 and 624. Additional semi-volatile compound investigations were performed on the stormwater samples, resulting in nine tentatively identified compounds and thirteen unidentified chromatograph peaks. Benzothiazole, which CAES also detected in their leaching analysis, was identified in the September 27 and October 7, 2009 samples from Field A at concentrations of 1 and 4.9 ug/l, respectively. Of the compounds that were tentatively identified such as benzothiazole, pentanoic acid, and thiopenes, none of these compounds are considered particularly toxic to aquatic organisms at the estimated concentrations.

Although it is not possible to determine the potential impact of the unidentified semi-volatile compounds, it is important to note, that the six highest concentrations of the unidentified semi-volatile compounds detected (150 ug/l, 28 ug/l, 14 ug/l, 12 ug/l, 10 ug/l and 9.5 ug/l) did not correspond to the three acutely toxic samples of stormwater determined in the study.

The results from the CAES laboratory headspace, leaching and simulated weathering tests suggest that benzothiazole, 4-(t-octyl)-phenol, 1-methyl naphthalene, 2-methyl naphthalene, naphthalene, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are the likely semi-volatile compounds to be found in the stormwater discharge from artificial turf fields. The test results also suggest that Benzothiazole, 4-(t-octyl)-phenol and butylated hydroxytoluene (BHT) would be the most persistent SVOCs in the crumb rubber as the artificial turf fields aged.

Comparing the VOCs and SVOCs results to EPA's Maximum Contaminant Levels for drinking water (MCLs) and DEP's Remediation Standards Regulations, Section 22a-133k-1 through 22a-133k-3of the Regulations of Connecticut State Agencies (June 1996), no exceedences of groundwater standards have been identified.

Based on our results, no VOCs or SVOCs have been identified as risks to surface and groundwater resources.

c) Metals

The laboratory leaching analyses performed by CAES as part of the State of Connecticut Artificial Turf Study detected the following metals: arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn). Zinc was present in concentrations orders of magnitude greater than the other metals. CAES's leaching analyses indicated that both copper (Cu) and zinc (Zn) concentrations exceeded acute aquatic toxicity criteria for 80% of the tests, with limited (<20%) exceedences of acute criteria for cadmium (Cd), manganese (Mn) and lead (Pb).

The stormwater analysis results show that the artificial turf fields in our study leached significantly less contaminants, specifically zinc and copper, than predicted by the CAES leaching test results. The lower metal concentrations observed in the stormwater could be a result of alkaline pHs, the weathering (2-4 years since installation) of the crumb rubber infill, or the conservative approach inherent in the SPLP methodology.

The stormwater analysis results showed that zinc was the only metal to exceed the acute aquatic toxicity criteria (65 ug/l), with one exceedence at each of the three study fields. The overall mean concentration of zinc in the stormwater samples analyzed was 84 ug/l, with a maximum of 260 ug/l and a minimum of 10 ug/l. The stormwater analysis results showed that aluminum, barium, copper and zinc all exceeded chronic aquatic toxicity criteria at least once during the sampling. Since chronic toxicity criteria apply to four days of continuous discharge, these exceedences are not of significant concern for these intermittent discharges.

No metal concentrations exceeded EPA's and DEP's drinking water standards. However, the concentration of zinc in three stormwater samples did exceed the surface water protection criteria of 123 ug/l established in the Appendix D to Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies Surface-water Protection Criteria for Substances in Ground Water (June 1996). Since the mean concentration of zinc in the stormwater samples (84 ug/l) is below the surface water protection criteria, the discharge from the artificial turf fields to groundwater is intermittent, and zinc is immobilized in soils by adsorption, absorption and precipitation, the potential for impacts to surface waters being recharged by this groundwater is minimal.

Based on our results, zinc has been identified as a potential risk to surface waters. No other metals have been identified as a risk to groundwater or surface waters.

9. ENVIRONMENTAL RISK ASSESSMENT

a) Potential Risk to Surface Waters

The only potential risk to surface waters identified in the stormwater collected from the artificial turf fields is zinc, since it was the only chemical parameter that was detected above the acute aquatic life criteria of 65 ug/l. Acute toxicity is assumed to occur when the zinc concentration in-stream exceeds 65ug/l for one hour in any three year period. In three of the eight stormwater samples analyzed, zinc concentrations were detected at 130, 150 and 260 ug/l, well above the acute aquatic life criteria. It is important to note, that the three stormwater samples with acutely toxic levels of zinc were also determined to exhibit aquatic toxicity (<90% survivorship) for both species *Pimephales promelas* and *Daphnia pulex* in the whole effluent toxicity testing.

Other than the acute aquatic toxicity criteria, there are no specific zinc standards or permit limits that are applicable to artificial turf fields. For industrial sites that discharge to surface waters, DEP has set a stormwater general permit guideline (Section 5 (c) (1) (F) (i) of the General Permit) for total zinc of 200 ug/l. This industrial stormwater total zinc guideline assumes a default 5:1 dilution factor for the receiving surface water at the 7Q10 flow. The 7Q10 is the lowest flow expected to occur for seven continuous days at a frequency of every 10 years. The 7Q10 flow is the critical low flow used when evaluating toxicity and toxic impacts (CT WQS 2002). Based on the results of our study, the stormwater discharges from artificial turf fields would not be expected to regularly exceed this zinc limit.

However, the estimated 7Q10 flows for the receiving watercourse from Fields A, C and D did not meet the 5:1 dilution factor for stormwater discharges from artificial turf football fields (57,600 square feet), assuming a one inch rain storm over one hour with direct discharge to the watercourse over an hour. It is important to note, that this a conservative approach, which assumes the watercourse receives no other stormwater runoff from its representative watershed. For the three receiving streams in the study, the highest dilution factor at the DEP estimated 7Q10 flow was equivalent to a 0.14:1 ratio. Given this dilution ratio of the receiving streams in the study, there is a potential for acute toxicity due to zinc loading.

Since zinc concentrations in stormwater from artificial turf fields may pose a risk to surface waters, especially to smaller watercourses, it is important to note that these fields are not the only sources of stormwater runoff in any given watershed. During the sampling at Fields A, C and D, DEP staff observed stormwater runoff, generated by acres of parking lots, roadways and buildings, entering the same drainage systems that collected runoff from the artificial turf fields. Based on these observations, it appears that stormwater runoff from the artificial turf fields is combined with the runoff from the adjacent impervious surfaces prior to ultimate discharge at the site.

This is an interesting phenomenon, since the levels of zinc in urban runoff are comparable to the concentrations detected in the discharge from artificial turf fields. It has been well established that urban runoff contains many contaminants such as nutrients, suspended solids, hydrocarbons and heavy metals, including zinc. The average concentration of zinc in urban stormwater runoff has been estimated at 129 ug/l in recent studies (Smullen 1998). EPA's Nationwide Urban Runoff Program (NURP) has collected runoff data and determined that for urban sites the median concentrations of total zinc ranged from 179 -226 ug/l. The National Stormwater Quality Database (NSQD, version 1.1), dated February 16, 2004, compiled zinc concentration data in runoff from various land uses across the United States, which is shown in Table L below.

TABLE I

Land Uses	**Zinc Total (ug/l) Median**
Overall (All Uses)	117
Residential	73
Mixed Residential	99.5
Commercial	150
Mixed Commercial	135
Industrial	210
Mixed Industrial	160
Institutional	305
Freeways	200
Mixed Freeways	90
Open Space	40
Mixed Open Space	88
CT Artificial Turf Stormwater	**84 (mean)**

Since zinc concentrations in the runoff from artificial turf fields are consistent with those associated with urban runoff, it would be a logical step to apply the same best management practices (BMPs) to mitigate the toxicity effects to surface waters. The 2005 Stormwater Management Manual for Western Washington specifically recommends the following BMPs to remove dissolved zinc (and other metals) from stormwater runoff: stormwater treatment wetlands, wet ponds, infiltration structures, compost filters, sand filters and biofiltration structures. The 2004 Connecticut Stormwater Quality Manual suggest the same measures since these treatment practices incorporate biological removal mechanisms that are more effective in removing pollutants than systems that strictly rely on gravity or physical separation of particles in the stormwater. The 2004 Connecticut Stormwater Quality Manual further recommends a treatment train approach, which provides a series of BMPs each designed to provide targeted pollution control benefits.

The University of New Hampshire Stormwater Center has field tested many of these stormwater BMPs that demonstrate significant removal of dissolved zinc. For example, the Retention Pond, Subsurface Gravel Wetland and Bioretention System (Bio II) stormwater treatment measures, over a two year period, removed between 90% and 100% of the soluble zinc, based on a median annual influent Event Mean Concentrations (EMC) of 60ug/l (see Appendix B for fact sheets). The three highest zinc concentrations detected in the stormwater from artificial turf fields in our study were 130, 150 and 260 ug/l, respectively. Assuming 80% removal of zinc from the stormwater prior to discharge to surface waters, all three of the highest zinc concentrations would meet the acute aquatic toxicity criteria (26, 30 and 52 ug/l, respectively). To mitigate the risk to aquatic life and surface waters, the DEP strongly recommends that the aforementioned stormwater best management practices be incorporated into the design of the drainage system for artificial turf fields.

10. ENVIRONMENTAL RISK ASSESSMENT IN RECENT STUDIES

Several other studies were conducted to determine the risk to surface waters and groundwater from the stormwater discharges from artificial turf fields**.** Since artificial turf fields can either discharge to groundwater or surface water, the ecological risks must be evaluated for both potential pathways. This was confirmed by Nillson et al (2008), that drainage from artificial turf fields can enter the environment by either seeping through the underlying soil and potentially contaminate the groundwater, or alternatively, by stormwater runoff entering the adjacent watercourses.

a) Overall Surface Water Contamination Risk

1) Organic Compounds

The studies conducted by Plesser (2004) indicated that concentrations of the common polycyclic aromatic hydrocarbons (PAHs) anthracene, fluoranthene and pyrene, as well as nonylphenols, would exceed the limits for freshwater specified in the Canadian Environmental Quality Guidelines. Torsten (2005) from the Norwegian Institute for Water Research (2005) also predicted that concentrations of alkyl phenols and octylphenol in particular would exceed the limits for environmental effects in the scenario which was allowed a 10:1dilution of run-off. Torsten (2005) further determined that the leaching of chemicals from the materials in the artificial turf system would decrease slowly, so that environmental effects could occur over many years. However, Torsten (2005) anticipated only localized impacts due to the relatively small concentration of the leaching pollutants. The SVOCs analysis of the stormwater in our study, utilizing EPA Method 625, and a specific search for 4-(t-octyl)-phenol, detected no anthracene, flouranthene, pyrene or standard phenol compounds.

Kolitzus (2006) detected no appreciable PAHs concentrations in the runoff analyzed from artificial surface systems. The PAHs that were found above detection limit were ubiquitous substances in the environment. The PAH concentrations in the unbound supporting layer were determined to be in the range of analytic determination limit (0.02 μg/l). The sum of all 16 PAHs was 0.1 to 0.3 μg/l. Similarly, in a recent New York study (Lim et al 2009), no standard organics were detected utilizing EPA Method 624 and 625 in the stormwater sample collected. The

SVOC analysis of the stormwater in our study, utilizing EPA Method 625, detected no standard PAHs.

In surface systems with EPDM and recycled rubber infill, Kolitzus (2006) found several aromatic amino complexes and benzothiazole detected in the range of 10 – 300 µg/l. These concentrations were similar to the results of simulated normal tire wear tests. Lim et al (2009) reported a semi-volatile rubber compound, benzothiazole, at 1,000 ug/l as a Tentatively Identified Compound (TIC) in one stormwater sample. The SVOC analysis of the stormwater in our study, utilizing EPA Method 625, detected no standard aromatic amines, but further TIC analysis did detect identified and unidentified organic compounds. Benzothiazole was detected in two stormwater samples at estimated concentrations of 1.0 and 4.9 ug/l, respectively, which is significantly lower than concentrations found by Lim et al (2009). The Connecticut acute and chronic toxicity benchmark for benzothiazole are 21,333 ug/l and 3,200 ug/l, respectively, based on available toxicity information. The estimated concentrations of benzothiazole are insignificant compared to both the acute and chronic toxicity criteria. Also, a number of unidentified organic compounds were detected during the SVOC TIC analysis at concentrations ranging from 1 ug/l to 150 ug/l, with a median concentration of 6.6 ug/l. The 10/7/09 Field C stormwater sample, which the maximum unidentified compound concentration of 150 ug/l was detected in, was not found to be acutely toxic.

The results from our study appear to be consistent with the results from Kolitzus (2006) and Lim et al (2009), including the detection of benzothiazole in the stormwater samples. Overall, our study did not identify any organic compounds at sufficient concentrations to be considered a potential contamination risk to surface waters.

2) Metals

Based on our analysis of the stormwater collected from the artificial turf fields, zinc is the only metal detected in concentrations which could pose a risk to surface water resources. This finding is consistent with many recent studies which analyzed leachate and stormwater from crumb rubber infill, which indicate that zinc is the primary contaminant of concern coming from artificial turf sites. In sites with limited dilution both the Norwegian Pollution Control Authority (2005) and Verschoor (2007) conclude that the concentration of zinc in the leachate would exceed applicable water quality standards. The Norwegian Pollution Control Authority classifies artificial turf runoff as Environmental Quality Class V (very strongly polluted water) due to the high concentration of zinc in the leachate. The risk assessment conducted by Norwegian Institute for Water Research (2005) shows that the concentration of zinc poses a significant local risk of environmental effects in surface water which receives run-off from artificial turf fields.

Verschoor (2007) also conducted a risk assessment concluding that the estimated concentrations of zinc in the drainage water from artificial football fields to be between 1100-1600 ug/L. This concentration exceeded the Dutch legal criterion for surface water Maximum Permissible Chronic Concentration (MPC) of 40 ug/l by a factor of 27-40. Verschoor explained that drainage water concentrations would be diluted in the receiving surface waters, but indicated that zinc in “small ditches” could exceed MPA (Maximum Permissible Acute). Verschoor espoused a general discharge impact rule that only 10% of the permissible concentration of a contaminant (=

4 ug/l) may be consumed by a particular source. This would imply that the concentration of zinc in smaller receiving water would exceed the water quality criteria by a factor of 45-80. Verschoor identified zinc as a potential eco-toxicological risk to surface water, but did indicate that if the crumb rubber were to be replaced by infill materials with a lower zinc emission, the pollutant concentrations in runoff and adjacent surface water should drop quickly.

Lim et al (2009) conducted a mathematical assessment of the risks to aquatic life from crumb rubber leachate based on the SPLP test results for zinc, aniline and phenol. Based on these concentrations, NYSDEC's Division of Fish, Wildlife and Marine Resources concluded that there may be a potential aquatic life impact due to zinc being release from crumb rubber solely derived from truck tires. However, New York State also concluded that an impact is unlikely if the crumb rubber material is from mixed tires and concentrations of zinc from a column test were used rather than the SPLP. It should be noted, that for the column test to better simulate field conditions, the material in the column must reflect local soil conditions and pH.

Several recent studies analyzed stormwater samples collected from artificial turf fields for metals. Lim et al (2009) and Kolitzus (2006) detected concentrations of zinc at 59.5 ug/l and 20 ug/l, respectively. Milone and MacBroome (2008), conducted field studies and detected zinc in the stormwater from four of the six sampling dates , with a maximum concentration of 31 ug/l which is below acute aquatic toxicity criteria of 65 ug/l.

The zinc concentrations in our stormwater samples were significantly higher than those of Lim, Kolitzus and Milone and MacBroom, with three of the eight the samples tested exceeding acute surface water quality criteria. If not mitigated with appropriate stormwater treatment measures, the zinc concentrations found in our study could contribute to the environmental risk of aquatic organisms in surface waters.

3) Aquatic Toxicity

Wik (2006) studied the toxicity of various tire brands and determined that different formulas for rubber contributed to varying degrees of toxicity in the leachates to *Daphnia magna*. By conducting a toxicity identification evaluation on various tire leachates (EPA 600/6-91/003), Wik determined that although zinc was prevalent, the semi-volatile non polar organics also heavily influenced the toxicity of the resulting leachate. Passing the simulated tire leachates through carbon filters was the only manipulation that consistently reduced toxicity. Compared to the results from Milone and MacBroom (2008), this study reported significantly higher levels of both aquatic toxicity and zinc. This study found that three of the eight stormwater samples tested were acutely toxic to both the invertebrate (*Daphnia pulex*) and the fathead minnow (*Pimephales promelas*). These acutely toxic samples directly coincided with the exceedences of the acute aquatic life criteria for zinc. Consequently, zinc seems to be the primary pollutant of concern. This study indicates that there is risk associated with whole effluent toxicity and zinc.

b) Overall Groundwater Contamination Risk

Stormwater from the fields can impact groundwater directly by percolating through the artificial turf via an "open" underground drainage system (perforated pipes, coarse bedding materials, stone trenches). The stormwater discharges to the underlying soil layers, and ultimately, enters the ground water. Based on the nature of the underlying soil and the depth to groundwater, the field stormwater is likely to physically and chemically interact with a mineral soil layer (vadose zone) prior to encountering groundwater. This stormwater/soil interaction would be affected by pH, volume of stormwater and soil characteristics, such as moisture, chemistry, mineralogy, soil texture, hydraulic conductivity and drainage class. These interactions would likely influence the concentrations of contaminants found in the groundwater.

There are two primary concerns with the contamination of groundwater in the environment - the threat to drinking water and the threat to surface water resources via groundwater recharge. Several other studies were conducted on the crumb rubber fill from 2004 to 2009; (Plesser(2004), Nillson et al (2008), the Norwegian Institute for Water Research (2005) , Verschoor, A.J., RIVM Report 601774011/2007(2007) Study, (Milone & MacBroom Study 2007),NYSDEC May 2009 an Kolitzus, Hans J. (2006). These studies compared the relative concentration of contaminants found in laboratory leachates and/or artificial turf generated stormwater with various drinking water and aquatic life criteria.

1) Organic Compounds

It should be noted that substances, to a varying degree, will be absorbed by the sand/clay layers which the drainage water passes. Although Nillson et al (2008) found that concentrations of nonylphenols in the contact water from leaching tests were in the order of 20-800 times above the threshold values for drinking water, it was uncertain as to whether this concentration would be significant in the actual groundwater. The EPA aquatic life acute criteria for nonylphenol for freshwater and saltwater resources are 28 ug/l and 7.0 ug/l, respectively. It is important to note that nonyphenol has been associated with the disruption of fish endocrine systems at concentrations below EPA's criteria. No data was available for phthalates and nonylphenols under such realistic conditions from lysimeter data. Nillson determined that the assessment of the impact on water systems also requires more realistic lysimeter tests or measurements on drainage water from artificial turf fields over time.

Plesser (2004) compared leachate results with Canadian Environmental Quality Guidelines for ground water. Groundwater guidelines are developed for both protection of drinking water and protection of surface water via groundwater recharge. Plesser identified anthracene, fluoranthene, pyrene and nonylphenols as compounds in the leachate that could exceed the more protective criteria for groundwater. Plesser also concluded that analyzing possible paths and changes in leaching properties over time is necessary to determine the degree to which the concentrations of these compounds are actually harmful to people and the environment.

Lim et al (2009) conducted a leachate (SPLP) test on rubber crumble material, and analyzed for zinc, phenol and aniline. The results from recent leaching studies indicated a potential for release of aniline, benzothiazole, phenol, and zinc to the groundwater. However, concentrations of the organic contaminants analyzed were below levels that would impose a risk to drinking water. Lim also collected 32 groundwater samples from wells installed downgradient of four artificial turf fields and analyzed them for SVOCs, including aniline and benzothiazole, using SW-846 Method 8270C. The wells were installed in sandy textured soils with depth to the groundwater ranging from 8.3 to 70 feet. All test results were below the limit of detection for all groundwater samples analyzed. Based on test results of 32 samples, no organics were detected in the groundwater at the turf fields.

Our results are consistent with the leachate and groundwater sampling results in Lim et al (2009). The concentrations of organic compounds in our study did not exceed groundwater protection criteria.

2) Metals

In general, metals are immobilized in soils by adsorption, absorption and precipitation. All of these, mechanisms impede movement of the metals to ground water. Metal-soil interaction is such that when metals are introduced at the soil surface, downward transportation does not occur to any great extent unless the metal retention capacity of the soil is overloaded, or metal interaction with the associated waste matrix enhances mobility.

Zinc is the most prevalent contaminant in the leachate and stormwater studies. In several of these studies, zinc concentrations measured in leachate exceeded drinking water standards. Most of the zinc in soil is absorbed to the soil as zinc hydroxide or oxide and does not dissolve in water. Zinc does show moderate mobility under relatively acid soil conditions (pH 5–7) because of increased solubility and formation of soluble complexes with organic lignands (Elliott et al. 1986; Stevenson and Fitch, 1986; Klamberg et al. 1989). Zinc is retained in an exchangeable form at low pH in iron and manganese oxide dominated soils but becomes non-exchangeable as the pH was increased above 5.5 (Stahl and James, 1991). Therefore, depending on the acidity of the soil and water, some zinc may reach groundwater.

Nillson et al (2008) determined that although leachate concentrations of zinc were in excess of the drinking water quality standards, similar concentrations were not observed in (field) lysimeter tests. Nillson concluded that the concentration of zinc in the lysimeter tests were a more accurate reflection of zinc in the groundwater and, therefore, zinc concentrations would not exceed drinking water standards.

Lim et al (2009) was the only study that did not report concentrations of zinc in the SPLP leachate that exceeded drinking water standards.

Verschoor (2007) concluded that, for the majority of situations, the risks of zinc to public health are minimal since it is not very toxic to humans and the World Health Organization (WHO) drinking water criteria was not exceeded in tests. However, Verschoor (2007) did note that in sandy areas discharges to groundwater may exceed Dutch Intervention Values by a factor of 1.5 to 2.2. In sandy soils, infiltration of water with dissolved zinc will result in weak binding of zinc to the soil matrix and could cause protection criteria to be exceeded by a factor of 12. Verschoor concluded that zinc was a potential eco-toxicological risk to groundwater and soil.

Plesser (2004) and CAES (2009) indicated that zinc was the most likely contaminant to exceed drinking water standards in the leachate. All studies indicate that, although compounds were present in the leachate or stormwater, it was uncertain as to what affect the underlying soils and groundwater would have on the actual concentration of contaminants in the groundwater. Actual groundwater testing may be necessary to determine the impact.

The leachate results reported by CAES showed zinc concentrations up to ten times the drinking water standards and up to 500 times the surface water protection criteria. Our study detected concentrations of zinc in the stormwater significantly lower than CAES results, with no exceedences of drinking water standards and no significant concerns for groundwater quality. It is important to note that no groundwater samples were collected for our study.

11. CONCLUSIONS

The DEP concludes that there is a potential risk to surface waters and aquatic organisms associated with whole effluent and zinc toxicity of stormwater runoff from artificial turf fields. Zinc concentrations in the stormwater may cause exceedences of the acute aquatic toxicity criteria for receiving surface waters, especially smaller watercourses. The DEP suggests that use of stormwater treatment measures, such as stormwater treatment wetlands, wet ponds, infiltration structures, compost filters, sand filters and biofiltration structures, may reduce the concentrations of zinc in the stormwater runoff from artificial turf fields to levels below the acute aquatic toxicity criteria. Individual artificial turf field owners may want to evaluate the stormwater drainage systems at the fields and the hydrologic and water quality characteristics of any receiving waters to determine the appropriateness of a stormwater treatment measure.

This study did not identify any significant risks to groundwater protection criteria in the stormwater runoff from artificial turf fields. It is important to note, that the DEP study did not directly collect and analyze groundwater at these artificial turf fields. Consequently, this conclusion regarding consistency with groundwater protection criteria is an extrapolation of the stormwater results collected and the evaluation of data presented in recent studies, such as Nillson et al (2008) and Lim et al (2009). To make a final conclusion regarding the overall risk from exposure to groundwater affected by stormwater runoff from artificial turf fields, further sampling and analysis of groundwater at the artificial turf fields would be required.

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Attachment F
Natural and Artificial

Facilities Management Sustainability: BuildingGreen [Contact BuildingGreen]

BuildingGreen

Natural Landscaping and Artificial Turf: Achieving Water Use and Pesticide Reduction

By Alex Wilson and Jessica Boehland

What's Wrong with the Conventional Lawn?

Throughout North America today, the dominant landscaping aesthetic is a broad, open lawn punctuated by trees and shrubs. While this landscaping system has been engrained into us through our culture and media, it creates an ecologically depleted landscape that requires significant amounts of resources and chemicals to maintain, especially in dry climates.

Conventional lawns require inputs of water and energy while causing air, water, and noise pollution. Annually in the U.S. we spend tens of billions of dollars caring for them. In some areas we use over half of our municipal freshwater to irrigate lawns, and we fortify them with millions of tons of fertilizer and thousands of tons of pesticides. What's wrong with this picture?

From an environmental, health, and even economic standpoint, a lot is wrong with conventional turf. Maintenance of turf necessitates regular mowing during the growing season, which is responsible for approximately 5% of the nation's air pollution, according to the U.S. Environmental Protection Agency (EPA)—and a good deal more in many metropolitan areas. A typical 3.5 horsepower gas mower emits about the same quantity of volatile organic compounds (VOCs) in one hour as a late-model car driven 340 miles (550 km), according to the California Air Resources Board. On top of that, EPA estimates that users of such equipment spill 17 million gallons of fuel each year—which is more than the Exxon Valdez oil spill!

Watering lawns consumes 30% of municipal freshwater in the eastern U.S. and 60% in the West. A *U.S. News & World Report* article reported that a 1,000 square-foot (93 m2) lawn requires, on average, 10,000 gallons (37,850 liters) per summer. With droughts continuing in the West and expected to increase in severity as a result of global climate change, this is a growing concern.

To maintain lush lawns, we use a lot of fertilizer—some 70 million tons (64 million tonnes) per year in the U.S. We use more fertilizer on our lawns in the U.S. than India uses on its food crops. Nitrogen fertilizers are produced by converting molecular nitrogen (N2) in the air into ammonia through the Haber-Bosch process, which is extremely energy-intensive, requiring approximately 18,000 Btus per pound (41 GJ/tonne) of primary energy input, which comes primarily from natural gas. Worldwide, ammonia production accounts for approximately 1% of global primary energy use.

Insecticides, herbicides, fungicides, and other pesticides are a growing concern with lawns. U.S. homeowners use 67 million pounds (30 million kg) of pesticides on lawns each year, according to EPA. Our suburban lawns and gardens receive heavier pesticide applications than our agricultural land: between 3.2 and 9.8 pounds per acre (3.6—11 kg/ha) vs. an average of 2.7 pounds per acre (3.0 kg/ha) for agricultural lands.

Along with the resource and environmental burdens of producing fertilizers and pesticides, a significant portion of these chemicals applied to lawns ends up in stormwater runoff and in groundwater. According to EPA, 40—60% of the nitrogen applied to lawns ends up in surface water or groundwater. Stormwater runoff from turf is one of North America's biggest sources of water pollution.

Noise pollution is another concern. Lawnmowers, weed whackers, hedge trimmers, and leaf blowers cause significant noise pollution, a very real but often overlooked health hazard.

Due to the need for all this maintenance, lawns are a huge expense. Homeowners spend roughly $27 billion per year on lawn care, according to the National Wildlife Federation (NWF)—ten times more than we spend on school textbooks. At the business level, the lawn care industry did approximately $61 billion in business in 1997 and has been experiencing roughly 20% annual growth in recent years. On a per-acre basis, maintenance costs for mowing, irrigation, and application of fertilizer and pesticides average $1,120 per year, according to the organization Wild Ones Natural Landscapers.

Benefits of Natural Landscaping

Natural prairie landscaping is projected to save the Metropolitan Water Reclamation District of Chicago thousands of dollars per year compared with the turf that is being replaced.

Just as there are significant environmental burdens and costs associated with conventional turf landscaping, there are benefits associated with natural landscaping. The primary benefits are described below.

Reduced air pollution. Native landscaping generally does not require regular mowing, which eliminates or greatly reduces the air pollution resulting from turf landscapes. There can be pollution emissions from natural landscaping, however—see discussion below on pollution from fire management.

Reduced nutrient runoff. Native landscaping does not require fertilizer, so the runoff and infiltration of nutrients is eliminated. Buffers of natural landscaping can be used to capture runoff from hard surfaces or less permeable turf to keep the pollutants in that stormwater from entering surface waters. Keeping nutrients out of the groundwater also protects surface waters, because groundwater surfaces in springs and flows into streams and rivers.

Reduced pesticide use. Because natural landscaping involves the establishment of balanced ecosystems, the use of herbicides, insecticides, and other pesticides is generally not required (though herbicides are often used to remove invasive plants during the establishment of natural landscapes). Reduced operation of lawnmowers and other lawn-care-related power equipment reduces air pollution both locally and regionally, thus improving health. And keeping pollutants out of water supplies also protects our health.

Increased biodiversity. Natural landscapes inherently support greater biodiversity than conventional turf landscapes. Native plants provide diverse food and habitat for birds, small mammals, insects, reptiles, and amphibians. In heavily developed urban areas, even small patches of natural landscape can be critical in maintaining populations of native fauna and flora.

Cost avoidance. Significant savings in landscape management costs can be realized by converting lawns to natural landscapes. While the initial costs of creating natural landscapes can be relatively high, annual operating costs of established natural landscapes are generally far lower than annual operating costs of lawn area. Operating cost savings were a primary motivation for the Metropolitan Water Reclamation District of Chicago to convert turf area to tall-grass prairie—to date, approximately 20 acres (8 ha) of turf has been restored to natural landscape, with guidance from Conservation Design Forum of Elmhurst, Illinois.

Downsides of Natural Landscaping

While the arguments for natural landscaping are compelling, there are some challenges:

- The aesthetic palette is more limited. Strict adherence to an all-native landscaping program restricts plant choices, which many property owners (as well as landscape architects and landscapers) object to.
- Establishing and maintaining natural landscapes requires new knowledge and skills. There are both direct and indirect costs associated with building these skills, and there is often inherent resistance to change in any profession.
- Fire management, a key component of many—if not most—natural landscapes, poses obvious risk and liability. These risks gained national attention when, on May 4, 2000, a prescribed burn at Bandelier National Monument in Los Alamos, New Mexico, got out of hand and burned nearly 48,000 acres (19,400 ha), destroying 400 homes and causing more than a billion dollars in damage.
- Fire management also generates air pollution. Depending on the type of landscape and the weather conditions during a prescribed burn, however, these emissions are usually fairly low.

Establishing Natural Landscapes

The key to establishing natural landscapes is careful planning to ensure that adequate management and stewardship is carried out until the landscape is established, at which point maintenance requirements become fairly minimal. Natural habitat landscaping is not about individual plant species but about ecosystems. With natural landscaping, the goal is to create balanced, self-sustaining ecosystems, not just assemblages of individual native plants. Because almost any ecosystem existing today has been degraded to some extent, creating a healthy, largely self-sustaining landscape often requires significant restoration work.

Dealing with invasive plants

Invasive exotic plants are the bane of natural landscaping. Hundreds of plant species are wreaking havoc in ecosystems throughout North America. Each region of the country has particular invasive plant species that are problematic: from kudzu in the Southeast to honeysuckle and Japanese knotweed in the Northeast to cheatgrass and garlic mustard in the Midwest and West.

Strategies for removal of invasive plants all have advantages and disadvantages: hand-pulling is labor-intensive but safe for the environment; herbicides (such as Roundup©) are fast and easy but may have unintended consequences for other organisms in the ecosystem; turning over the soil (to kill turf grass, for example) avoids chemicals but may damage the soil structure and soil microorganisms; prescribed burns are often the best method to control invasives and allow the ecosystem to return to a pre-European settlement balance, but they cause safety concerns and air pollution.

The success of invasive plants is often related to changes in overall habitat conditions. When conditions that favor native species are restored through such restoration management tools as selective clearing to provide appropriate light levels and annual burn management, the invasive species are often gradually eliminated.

Converting turf to natural landscapes

A number of approaches can be taken to convert turf or other invasive vegetation to natural (restored) ecosystems. Short-lived herbicides are effective, and have the advantage of keeping root systems in place to help prevent erosion while new species are being established. Mechanical strategies, including repeated discing and harrowing, are also effective, and do not present any toxicity concerns Sometimes simply easing off on mowing allows native species to gradually return—if native species are growing nearby—but this approach yields less certain results than complete replacement of the existing vegetation, and often nearby intact habitats do not exist.

In designing landscapes that will be managed with controlled burns, firebreaks often make sense. Roads can serve as firebreaks. Bands of turf grass along road corridors and around building can make sense to keep fire under control.

Increasing people's comfort with natural ecosystems

Given the American infatuation with lawns, social and psychological factors often emerge as barriers to natural landscape designs. Joan Nassauer, Ph.D., FASLA, of the University of Michigan, has researched human responses to various landscape designs.

Her research suggests that most Americans (indeed, people in most Western cultures) are uncomfortable with landscapes that they perceive to be wild or unmaintained, but are attracted to natural plantings within an obviously managed context. Signs of human care and attention to a space, whether it is a recently mown lawn or a freshly painted picket fence, represent what Nassauer calls "cues to care." Thus, boundaries of well-maintained turf around naturally landscaped areas not only provide firebreaks but also increase most people's comfort level with the native plantings.

Which Grass is Greener? Comparing Natural and Artificial Turf

Another alternative to the resource-intensive conventional lawn is artificial turf. Early adopters of plastic grass were professional sports teams, who had the cash to spend on the newest technologies. Artificial turf continues to replace natural playing fields not just for the pros but for college-level athletes and Little Leaguers alike.

And it doesn't stop there. Artificial turf is replacing grass in a variety of applications, ranging from community parks to parking-lot medians, and even outside American homes. Plastic grass sidesteps many of natural turf's downsides, but could it possibly be greener than grass itself?

Early Artificial Turf

The first artificial turf, which would become known as AstroTurf, was made by the Chemstrand Company, a subsidiary of the Monsanto Company, and installed in 1964 at the Moses Brown School in Providence, Rhode Island. In 1965, Monsanto's artificial turf was laid in Houston's AstroDome, the largest indoor sports facility in the world at the time.

Popular for its convenience, early artificial turf was largely loathed by the athletic community. First-generation artificial turf was typically stiff, low-pile polypropylene or nylon fiber adhered to a concrete or asphalt base. The fibers caused "turf burn," the hard base was less forgiving than soil, and athletes are united in their claims that first-generation turf caused more injuries than grass. Although this primitive turf is still available, it has been largely superseded by softer, safer, more naturalistic surfaces.

In the early 1990s, artificial turf began expanding from playing fields to other uses. Increasing incidences of drought, concern over the dangers posed by pesticides, and the grasslike look and feel of modern artificial turf have led to increasingly use of plastic grass in parks, day care centers, dog runs, and the yards of homes and businesses.

Second-Generation Artificial Turf

FieldTurf ushered in the second generation of artificial turf. Unlike the original AstroTurf, this "infilled" turf includes a layer of sand and rubber pellets to surround polyethylene fibers. Infilled products are safer than earlier systems and feel remarkably similar to real turf grass.

Second-generation artificial turf is significantly evolved from earlier products. The part of artificial turf that is the equivalent of the blades of natural grass is generally made of a green-colored, UV-stabilized polyethylene or polypropylene fiber in piles of two inches or higher. These blades are tufted into a porous backing, generally made of polyethylene, polypropylene, or polyurethane. Surrounding the blades of grass is a crumb layer of silica sand and/or rubber bits ranging in diameter from 0.5 to 1.5 millimeters. After the crumb layer is added, the blades typically stand about 3/ 4" tall (19 mm), though different heights can be specified for different applications. Many products include a shock pad. Finally, most manufacturers incorporate a drainage layer of crushed stone below the backing layer, and a few incorporate perforated-pipe drainage systems. Artificial turf systems are generally warranted for about eight years, but the actual life expectancy is unknown.

Benefits of Artificial Turf

Recycled Content and Reusability.
The rubber bits in the crumb layer of artificial turf are often made from recycled tires. Memorial Stadium field at the University of Nebraska—Lincoln used 14,000 recycled Nebraska tires. Some artificial turf also incorporates recycled tennis shoes. If it is replaced before it is worn out, artificial turf can be reused. When Aloha Stadium, in Honolulu, Hawaii, upgraded its fields in 1999, and again in 2003, state officials donated the used AstroTurf to local high schools. RS Global, Inc., based in Carrollton, Texas, has removed artificial turf from more than one hundred used fields over the past three years. RS Global breaks the turf into pieces for use in smaller applications, such as batting cages.

Reduced water use.
From an environmental perspective, the potential for water savings is probably the most significant benefit of artificial turf. Plastic grass, of course, needs no irrigation to stay green. The only water used on artificial turf is to cool it down in extremely hot conditions or clean it, if necessary. The City of San Marcos, Texas awarded Southwest Texas State University with a Water Efficiency Achievement Award in 2003 for converting the natural field at Bobcat Stadium to SRI's AstroPlay ©, a move which the school estimates is saving more than 2 million gallons (7.5 million liters) of water each year.

Reduced pesticide and fertilizer use.
Since artificial turf needs no regular chemical treatment, it eliminates a major source of non-point-source groundwater pollution and human exposure to chemicals. For residential applications, artificial turf also offers the benefit of reducing the amount of chemicals (and dirt) tracked into homes. Artificial turf's chemical-free care may make it especially appropriate for daycare centers and dog yards, because children and pets spend more time than adults in close contact with grass, and they are affected more severely by contact with pesticides.

Reduced maintenance.
Artificial turf needs no mowing, watering, fertilizing, aerating, or reseeding, and it will not outgrow its painted field lines; synthetic grass, though, demands its own maintenance regimen. Caring for residential artificial turf generally involves just the occasional use of a leaf blower or a carpet rake. When necessary, artificial turf can be washed with a garden hose. Biological material, including leaves and feces, will not decompose as quickly on plastic as on natural grass, so when such materials find their way onto artificial turf, more maintenance is required to keep it tidy. Depending on its use, residential turf can often go six weeks or longer without any maintenance.

Turf, Air Quality, and the Atmosphere

Through the process of photosynthesis, grass converts carbon dioxide to oxygen and other gases. Turfgrass Producers International (TPI) claims that a 2,500 ft Â² (230 m Â²) lawn releases "enough oxygen for a family of four to breathe." Simultaneously, the absorption of carbon dioxide mitigates to some extent the process of global climate change. Another argument for natural grass is its ability to cool the surrounding area through evapotranspiration. According to TPI, lawns are 14Â°F (8Â°C) cooler than bare soil on hot days, or 30Â° (17Â°C) cooler than asphalt. Natural grass also helps to clean the air: grass areas trap 12 million tons (10.8 million tonnes) of dust and dirt from the air each year, TPI reports, and some studies have shown that grass absorbs carbon monoxide.

Artificial turf, in contrast, frequently offgasses volatile organic compounds (VOCs). This could be a concern for children, who are often more sensitive to emissions, and especially for the rapidly growing number of Americans with asthma. Artificial turf also contributes to the urban heat-island effect. Although they look green from an angle, artificial fields are often closer to black when viewed from above, owing to the rubber layer surrounding the blades. Darren Gill, marketing manager for artificial turf company FieldTurf, says that in direct sun, artificial turf averages between 6 and 10Â°F (3—6Â°C) warmer than grass, though he's seen differences as high as 15Â°F (8Â°C). He also mentioned that in especially warm climates, maintenance staff sometimes spray sports fields with water once or twice a day to keep them cool. This tendency to heat up in hot weather makes artificial fields less appropriate in southern climates. Gill stresses that artificial turf cools quickly when it's not in direct sun.

Ecology

Of the 50 species cultivated for use as turf, only a handful dominate the market. In colder climates, four or five species are typically mixed for each application, according to Joyce, while in warmer climates turf is generally close to a true monoculture. The species of grass we commonly use on our lawns did not evolve here and are not adapted to America's climates and ecologies. Left to their own devices, most of these grasses would happily go dormant and turn brown during dry spells. Even where these species are native, they do not naturally grow in a monoculture, bereft of other plant species, as we expect them to do on our lawns and golf courses. Intruding plants and animals are called weeds and pests, and we obliterate them with chemicals. DDT, once a popular turf grass pesticide, was actually marketed as "the atomic bomb of the insect world."

A new movement in turf management shows some promise of improvement for biodiversity. In order to avoid the need for pesticides, fertilizers, and irrigation, some homeowners are planting grass species that are drought-tolerant or native to their climates. Buffalo grass, for example, native to America's central and southern Great Plains, is gaining popularity in hot climates. The Prairie Nursery Corporation, based in Wisconsin, has been marketing a mix of native fescue grasses for lawns since 1993. Their No Mow mix, including cool-season fescue grasses native to Oregon and Canada, was designed for the colder, less sunny climate of the northern U.S.

Kim Sorvig, research associate professor at the University of New Mexico, and co-author of *Sustainable Landscape Construction: A Guide to Green Building Outdoors*, is concerned about the soil conditions under artificial turf. "It blocks both water and sunlight either completely or in very large degree," he said, "and without that, you can't have a living system in the soil." Sorvig thinks it is ironic that artificial turf is heralded as a solution to water shortages, since it diminishes the health of the underlying soil, thereby decreasing its ability to hold water. "When you remove the vegetation from an area so completely," he said, "you're actually, in the long term, contributing to drought."

The only application for which Sorvig believes artificial turf is appropriate is indoor stadiums, since they are "already separated from the soil system." Ecology may be one area where neither artificial nor conventionally maintained natural turf can claim victory.

Biophilia

The biggest strength of artificial turf is also its biggest weakness. Artificial turf remains a "monofilament ribbon file product"; by definition, it can never be alive. So why bother to make it look or feel like the real thing? Nostalgia begins to explain our intangible trouble with artificial turf—gone are the stubborn grass stains and the smell of freshly mown grass. The best explanation, though, is that we feel an innate connection to good-old-fashioned grass.

Harvard biologist Edward O. Wilson sought to explain this phenomenon in his 1984 book *Biophilia: The Human Bond with Other Species.* Human beings, he argued, subconsciously seek a connection with other species and with life. Plastic grass will always feel foreign to us because it is not living and robs us of our cues to natural processes. It refuses to die—or even fade—as the seasons change.

So-called natural turf, it has been argued, is itself far from natural. Most turf grass yards and fields would be biological impossibilities without significant inputs of water, chemicals, and energy. Yet, grassy lawns feel natural. Perhaps our biophilic impulse is fooled by this seemingly natural landscape. Or perhaps it doesn't care—a living landscape is a living landscape, no matter how it came to be.

Final Thoughts

Conventionally managed natural turf carries a plethora of environmental burdens, but it does support soil organisms to some degree. The grass and these organisms play a crucial ecological role by purifying water as it leaches into the earth. It is questionable, though, whether this function is positive enough to offset the repercussions of watering, pest treatments, fertilization, and mowing.

Playing fields subject to heavy use, especially where pristine appearance is a priority, may represent a setting in which artificial turf can be justified. But the fact that it doesn't support soil organisms, and therefore is a biologically dead zone, suggests that its use should be limited.

In many situations, the optimal choice, at least from an environmental perspective, is a natural landscape of native or adapted plants. Approaching the condition of a natural ecosystem, such a landscape minimizes maintenance while offering biological diversity.

In places where a uniform, cropped surface is needed, natural turf managed in an ecologically sound manner is a good choice. Natural lawns and fields can be maintained responsibly by beginning with native and adapted species that require little or no water, allowing them to go dormant (and turn brown) at times, and feeding them appropriate, organic fertilizers. Even mowing, when necessary, can be done using low-emitting and quiet machinery. The result may not live up to the standards of the Garden Club of America, but other species will approve.

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Although the term Xeriscape* is relatively new in Kansas, the concept is not. It simply imitates nature's design: putting hardy, adapted plant materials in the places where they grow best. Once established, this kind of landscape requires little maintenance because it is designed to work in harmony with nature, not against it.

Estimates indicate that nearly 50 percent of water the average household uses is for outside landscape and turfgrass areas. You can reduce your water use by imitating nature with a low-maintenance landscape design. It is applicable to both homes and businesses, on new building sites or previously landscaped sites. To be successful, it requires careful consideration and planning.

Ultimately, you will realize a savings not only in water but also in time, labor, equipment, and materials such as fertilizers and herbicides, and that's dollars in your pocket. Furthermore, because of increasing demands on a limited water supply, a landscape with a record of low water bills may boost the resale value of your home.

A water-conserving landscape design involves using hardy, adapted plant materials which are suited to your particular location in Kansas, its soil and its climate. More specifically, it requires selecting plants according to soil type, slope and available rainfall. It means arranging these plant materials in such a way that they actually can contribute further to water conservation by reducing the evaporative effects of wind and sun in your yard or business site.

Typically the design would include native plant species, those that grow naturally in Kansas, but certainly is not restricted to them and is not boring. In fact, choosing this type of design can result in a greater diversity of plant materials from one yard to the next.

The seven Xeriscape principles are Planning and Design, Limited Turf Areas, Efficient Irrigation, Soil Improvement, Mulching, Lower Water-Demand Plants, and Appropriate Maintenance.

*Xeriscape is a trademark term of the National Xeriscape Council.

Designs can be simple or elaborate, but every plan should take into consideration factors that affect water use. Steep slopes or grades encourage water runoff and soil erosion. Drought-tolerant groundcovers, shrubs and trees can be used to slow down and absorb water, and to reduce evaporation by shading the soil. Terracing with plants is another possibility.

South- or west-facing exposures get maximum sunlight and can benefit from use of mulches or drought-tolerant plants. Wind increases the amount of plant moisture lost through evapotranspiration. Fences and screens can greatly reduce the amount of supplemental water needed by slowing or blocking the wind. Using trees and shrubs as windbreaks can be effective, if the species don't require watering.

As trees provide shade which reduces the soil temperature and lowers water lost through evaporation, they also reduce air temperatures, which reduces water loss. Trees such as maples should be avoided in the low water use landscape. Their invasive surface-feeding roots compete with nearby plants for water and nutrients.

Plant trees and shrubs in attractive compositions and arrange plant materials along water-need zones to prevent overwatering some plants while underwatering others.

Turfgrass areas usually require the most water and maintenance in a landscape. Limit irrigated turfgrass areas to places with high use. Use low-maintenance and native grasses for other areas. The lawn must fit the landscape, but avoid making it long and narrow, which is more difficult to irrigate effectively. Select hardy, adapted lawn grasses suited to the site. Manage your lawn for stress, deep watering when needed.

Warm-season grasses—bermudagrass, zoysiagrass and buffalograss—are drought resistant. Cool-season grasses—bluegrass, fescue and ryegrass—require watering for maintenance (See table). Keep in mind that warm-season grasses do not grow well in shade. When nature is left to take its course, warm-season grasses will dominate sunny areas and cool-season grasses will dominate shady

Turfgrass	Drought Resistence
Burmudagrass	excellent
Buffalograss	excellent
Zoysiagrass	excellent
Tall fescue	good
Bluegrass	fair
Ryegrass	poor

areas. You may see this as a patchwork look because the two types of grasses are different in texture and color. But the total water required will be reduced, and both types of grasses will grow best in the areas suited to them.

Cool-season grasses green up earlier in the spring and stay green later in the fall, which means a longer growing season. They also require more water than warm-season grasses during hot weather—most of the summer in Kansas.

An increased interest in using native grasses for lawns has developed in recent years due to their low water and maintenance requirements and naturalistic appearance. Most native grasses are warm-season grasses and must be planted in areas that receive full sunlight. Buffalograss is the most common native grass used in lawns. It grows best in areas with less than 25 inches of annual rainfall.

Native grasses should be watered and fertilized sparingly or not at all. Watering and fertilizing these grasses causes them to become weedy and you lose the low maintenance aspect of a native grass lawn. Under suitable conditions, native grasses can save water and maintenance, but the cost of seed is high and some watering to get them established is recommended. Weeds are the major problem in establishing a native grass lawn.

Lawn watering and maintenance reduction must be accompanied by a reduction in the amount of fertilizer applied and adjustment of other cultural practices. Taller mowing helps control weeds and reduces watering and mowing frequency. The amount of fertilizer you put on a lawn determines your maintenance program.

The amount of mowing, watering, problems and pests is largely related to the amount and timing of fertilizer

Total Nitrogen per Year

Cool-season grasses	lbs.	Warm-season grasses	lbs.
		(low to high range)	
High maintenance	4*	Bermudagrass	2-4*
Good maintenance	3	Buffalograss	0-2
Low maintenance	2	Zoysia	1-3
Minimal maintenance	1		

*lbs. AN/1000 sq. ft. (AN = actual nitrogen)

applications. The table above provides guidelines for the total seasonal nitrogen. Phosphorus and potassium should be applied as indicated by a soil test.

Efficient watering is part of the low-maintenance design. Your landscape design should incorporate zones for water need areas—high, medium, low or none at all.

Prevent runoff; harvest water! Collect or redirect water from the downspouts to areas of the landscape that need it. Select and combine different irrigation systems—drip, trickle, sprinkler. Water slowly, deeply and infrequently.

Each type of plant has a maximum depth to which its roots will grow. Roots will penetrate only to that depth where water, air and nutrients are present. Deep watering encourages deep rooting, increasing the reservoir of water so plants can go longer between watering. Deeply placed water is also less subject to loss by evaporation from the soil surface.

The roots of most small trees and shrubs may reach up to 6 feet deep, while smaller shrubs or flowers may root 2–4 feet deep. Consider grouping plants together that may be shallow rooted and require more frequent watering such as flower beds or a mixed border of small shrubs.

It is important to water only long enough to wet the soil to the depth of the root system and not beyond because this is a waste of water. A soil probe or thin rod pressed into the soil will go in easily until it reaches the dry zone.

The most critical factor in determining water use is weather—temperature, humidity, wind, sunlight, and precipitation. There is a constant flow of water through plants, bringing nutrients to the upper plant parts. This transpiration flow of water increases as conditions cause greater movement of water through a plant.

Most of the absorption of water and nutrients occurs in the upper half of the root system, thus water should be applied directly to the soil surface or the root zone. Water applied to plant leaves and tops is wasted, especially in hot weather, because much of it will evaporate before it reaches the ground.

Most small trees and shrubs should be watered to wet the soil to a depth of 4 feet once a month or every 6 weeks. Plants with shallow roots require more frequent soaking, perhaps to a depth of 2–3 feet every 2–4 weeks. Remember, the water requirements for a mature landscape allow flexibility in this watering pattern; those of a newly planted landscape do not.

Know your soils. Improving the soil helps conserve water. Adding organic matter is by far the most important soil improvement affecting water use. A soil test, which is available through your county Extension office, will determine the organic matter level of your soil.

In sandy soils, organic matter slows down the rapid movement of water through the soil, making it more available to plant roots. In heavy clay soils, the addition of organic matter increases infiltration of moisture, which prevents runoff and wasted water.

Adding organic material is easiest and most effective before planting. Incorporate at least 2–3 inches of organic matter into the top 8 inches of the planting area unless your soil test indicates otherwise. Because organic matter continually decomposes, it needs to be replenished on a yearly basis. Applying an organic-type mulch is the most effective way to do this in an established landscape.

Types of Organic Matter

- Straw
- Well rotted manure
- Leaf mulch
- Peat moss
- Lawn clippings
- Compost
- Well rotted sawdust
- Wood chips
- Shredded bark
- Green manures

In areas with hardpan—an underlying layer of clay—subsoiling is recommended before planting. Plants growing on top of unbroken hardpan are more vulnerable to water fluctuations because of the shallow growing area. Planting a deep-rooted legume can be effective in breaking up hardpan, although it may take some time to accomplish.

Mulches can do much more than cut down on water use. They also can improve soil texture, suppress weeds, lower soil temperature, and add ornamental value to the landscape. How well a mulch conserves moisture is determined by its composition and how deeply it is applied.

Common mulches range from wood chips, stone and gravel to landscape fabric, plastic and polyethylene film. Deciding which mulch to use will depend on its cost, availability, ease of use, durability and appearance in your particular landscape. Each mulch has advantages and disadvantages.

Plastic or polyethylene film prevents moisture evaporation effectively; is thin, lightweight, and inexpensive. Perforated plastic is more expensive. Some disadvantages are you must punch holes to let in water and air; it is unsightly; must be covered with another material; doesn't improve soil; and can cause roots to concentrate at the soil surface, increasing drought susceptibility.

Landscape fabric—Geotextiles, Weed Barrier, Weed X, Weed Block—are water and air permeable; suppress most water-competing weeds; and are durable. They are, however, expensive; allow some weeds to grow; and must be covered by a top mulch layer.

Wood chips, tree trimmings, and shredded or chunk bark are relatively inexpensive; let in water and retain it in soil; break down to improve soil texture; and suppress weeds if the smaller size is used. The most effective depth for these mulches is 3–4 inches. These materials do break down in l–3 years, depending on particle size and type of tree used. Smaller sized particles may require addition of nitrogen for plants.

Stone and gravel allow moisture in and retain it in the soil; are long lasting; come in a variety of sizes; suppress weeds; and can have an ornamental appearance. Prices vary with size and type. They do not improve soil; are unattractive if used in a large area; increase soil temperature and glare; and tend to get scattered by lawn mowers and small children.

Selecting lower water use plant materials is essential. A partial list of plants appears at the end of this publication. Check with a nursery for your particular site needs.

Once the planning and planting are complete, maintenance becomes the key to a successful low water use landscape. Mowing, pruning, weeding, mulching and fertilizing will maintain your landscape in a healthy, productive and beautiful condition for years to come.

Selecting Plant Materials

Consider the importance of turfgrass qualities such as drought, cold, heat and shade tolerances, wearability, and fertilizer requirements in your landscape plan; then choose the species that meet your needs. (The following turfgrass information adapted from "Conserving Water in the Landscape," Nebguide published by Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska—Lincoln.)

- Drought tolerance of popular turfgrasses, ranging from most to least tolerant: buffalograss, bermudagrass, zoysiagrass, tall fescue, Kentucky bluegrass, perennial ryegrass.
- Cold tolerance of popular turfgrasses, ranging from most to least tolerant: Kentucky bluegrass, buffalograss, tall fescue, perennial ryegrass, zoysiagrass, bermudagrass.
- Heat tolerance of popular turfgrasses, ranging from most to least tolerant: buffalograss, bermudagrass, zoysiagrass, tall fescue, Kentucky bluegrass, perennial ryegrass.
- Shade tolerance of popular turfgrasses ranging from most to least tolerant: tall fescue, perennial ryegrass, Kentucky bluegrass, zoysiagrass, bermudagrass, buffalograss.

The shade tolerance of a grass depends on many conditions. Check with your county Extension agent for more information on suitability of turfgrass species for your specific site.

■ Wearability of popular turfgrasses, ranging from those that can withstand most wear to least wear: bermudagrass, zoysiagrass, tall fescue, perennial ryegrass, Kentucky bluegrass, buffalograss.

■ Fertilizer requirements for popular turfgrasses, ranging from most to least: Kentucky bluegrass, perennial ryegrass, tall fescue, bermudagrass, zoysiagrass, buffalograss.

While a lawn may exist on low amounts of fertilizer, a high-quality lawn will require moderate amounts. The cultivar, soil type and climate greatly influence fertilizer needs.

The following plants are adapted to all parts of Kansas though some may need protection in certain areas of the state. All require regular watering until well-rooted and established. This may take 1–2 years or more, depending on the type and size of plants. Only after the plants are established can water be reduced or, in some cases, eliminated. Remember, check with your nursery for your particular site needs!

■ **Tall Deciduous Trees (over 45')—** Black Walnut, Chinkapin Oak, Common Hackberry ('Prairie Pride' and other cultivars), Green Ash, Honeylocust ('Skyline' and other cultivars), Kentucky Coffeetree, Sawtooth Oak, Bur Oak.

■ **Medium Deciduous Trees (30–45')—** Aristocrat Pear, Goldenrain Tree, Lacebark Elm (True Chinese Elm), Osage Orange (thornless and fruitless), White Mulberry (fruitless).

■ **Small Deciduous Trees (under 30')—** Amur Maackia, Amur Maple, Flowering Crabapple, Green Hawthorn 'Winter King', Redbud, Russian Hawthorn, Russian Olive, Sandhill Plum, Thornless Cockspur Hawthorn, Washington Hawthorn, Western Soapberry, Wild Plum.

■ **Large Deciduous Shrubs (over 8')—** Autumn Olive, Beauty Bush, Border Privet, Chokecherry, Common Buckthorn, Elderberry, Lilac, Mountain Ninebark, Ninebark, Peking Cotoneaster, Rose of Sharon, Rough-leafed Dogwood, Siberian Pea Shrub, Silver Buffaloberry, Staghorn Sumac, Wahoo, Western Sandcherry, Winter Honeysuckle.

■ **Medium Deciduous Shrubs (4–6')—** Butterfly Bush, Cherry Prinsepia, Dwarf Ninebark, Flowering Quince, Forsythia, Fragrant Sumac, Japanese Barberry, Korean Lilac, Mentor Barberry, Mockorange, Serviceberry, Shining Sumac, Spirea (Vanhoutte), Spreading Cotoneaster, Tartarian Honeysuckle, Three Leaf Sumac.

■ **Small Deciduous Shrubs (under 4')—** Alpine Currant, Bluemist Spirea, Common Bladder Senna, Coralberry (Buckbrush), False Indigo, Golden Currant, Golden St. Johnswort, Gooseberry, Hardy Potentilla, Leadplant, New Jersey Tea, Prairie Rose, Pygmy Pea Shrub, Russian Sage.

■ **Evergreen Trees—** Austrian Pine, Red Cedar, Limber Pine, Pinyon Pine, Ponderosa Pine.

■ **Large Evergreen Shrubs—** Junipers, Mugho Pine.

■ **Medium Evergreen Shrub—** Junipers, Mahonia, Manhattan Euonymus.

■ **Small Evergreen Shrubs—** Compact Mahonia, Compact Mugho Pine, Juniper, Soapweed, Yucca.

■ **Groundcovers for shade (beneath trees, shrubs, or along north walls)—** Bergenia, Bishop's Weed, Hall's Honeysuckle, Mahonia, Creeping Grape Holly, Periwinkle, Potentilla (Cinquefoil), Sweet Woodruff.

■ **Groundcovers for full sun—** Baby's Breath (Creeping), Bachelor Buttons, Bird's Foot Trefoil, Crownvetch, Border Jewel (Himalayan), Buttercup (Creeping), Catmint, Creeping Junipers, Daylily (most species), Evergreen Candytuft, Gro-Low Fragrant Sumac, Hall's Honeysuckle, Hen and Chicks, Lilyturf, Mock Strawberry, Phlox (Creeping), Pussytoes, Ribbon Grass, Rock Soapwort, Sedum (Stonecrop), Silvermound, Snow in Summer, Spurge (Cushion), Spurge (Donkey-tail), Thyme (Creeping), Veronica (Rock Speedwell), Wintercreeper, Woolly Yarrow.

■ **Ornamental Grasses—** Big Bluestem, Blue Fescue, Blue Oat Grass, Feather Reed Grass, Fountaingrass (annual), Fountaingrass (perennial), Indiangrass, Little Bluestem, Oat Grass, Quaking Grass (annual), Ravenna Grass, Ribbon Grass, Sideoats Grama, Weeping Lovegrass.

■ **Perennials** (all grow in full sun; * indicates plant tolerates part shade)— Artemesia (Sagebrush), *Balloon Flower, Basket of Gold, Blanket Flower, Blue Star (Amsonia), Brown-eyed Susan (Rudbeckia), Butterfly Weed, Candy Tuft (Perennial), Coreopsis, Creeping Phlox, *Daylily, Euphorbia, Evening Primrose, *False Indigo, Gaura, *Globe Thistle, *Goldenrod, *Hibiscus (hardy), *Iris, *Kansas Gayfeather, Lambs' Ears, Lavender, *Mullein, Oriental Poppy, Pitcher's Salvia, Poppy Mallow, Prickly Pear Cactus, Purple Coneflower, Red Hot Poker (Torch Lily), Rock Rose, Sea Holly, Sea Lavender, Sea Thrift, *Sedum and 'Autumn Joy', Yarrow.

■ **Annuals** (all grow in full sun; * indicates plant tolerates part shade)—Baby's Breath (annual), Bachelor Buttons, *California Poppy, Celosia, *Cleome, Coreopsis (annual), Cosmos, Dusty Miller, *Four O'clock, Gomphrena, Kochia, Marigold, Morning Glory, *Nicotiana, Portulaca, Sanvitalia, Sunflower, Vervain, *Vinca, Zinnia.

For assistance with identifying low-maintenance, drought-tolerant plants for your home or business landscape design, contact your county Extension office.

Brand names appearing in this publication are used for product identification. No endorsement is intended, nor is criticism of similar products not mentioned.

low maintenance landscaping

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-1046 July 1992

City of Punta Gorda
Urban Design

City Hall Annex
326 West Marion Avenue
Punta Gorda, Florida 33950
(941) 575-3372

REQUEST FOR SPECIAL EXCEPTION FOR ARTIFICIAL TURF CHECK LIST

- ☐ Signed & Notarized Special Exception Application
- ☐ Signed Authorization for Agent Affidavit (if applicable)
- ☐ $750.00 Application Fee
- ☐ A copy of the deed or other evidence of ownership.
- ☐ Date applicant met with the representatives of Urban Design staff prior to the submission of a Special Exception Application ____________________
- ☐ Two copies (2) of a detailed signed and sealed site survey of the property that is less than one year old that indicates the location of existing trees and shrubs and all other improvements on the property.
- ☐ Two copies (2) of the landscape plot plan indicating the proposed location of the artificial turf and other landscape materials. Setbacks to the seawall will be required to be shown for any trees, large shrubs, curbing, areas of rock beds or boulder type landscape material that is planned. All landscape plans must meet minimum standards as denoted in this Article.
- ☐ If the property is zoned commercial or multi-family, a copy of an approved Southwest Florida Water Management District Permit shall be included in the permit application.
- ☐ Evidence that the artificial turf proposed will have a minimum tufted weight of 56 ounces per square foot, be a natural green in color, and have a minimum 8 year warranty. A sample of the turf proposed that meets these standards shall be submitted with the Special Exception application including a copy of the manufacturers specifications and warranty information.
- ☐ Evidence that all artificial turf installations will have a minimum permeability of 30 inches per hour per square yard and provide anchoring information as to the size and location of anchors to ensure the turf will withstand the effects of wind.
- ☐ Consideration of the percentage of living plant materials versus percentage of artificial turf proposed for any property shall be part of the review process. Evidence that living plant material will be drought tolerant and consist of 50 percent Florida native species including shrubs, vines, trees, and ground covers.
- ☐ **Certificate of Appropriateness application and application fee if** property is located within the *National Register Historic Overlay District*, listed on the National Register, or property listed on the Florida Master Site File by the State of Florida Department of State, Bureau of Historic Preservation of the Division of Historical Resources.

  Florida Master Site File No. ____________________ Contributing Structure ☐ Yes ☐ No

City of Punta Gorda
Urban Design

City Hall Annex
326 West Marion Avenue
Punta Gorda, Florida 33950
(941) 575-3372

REQUEST FOR SPECIAL EXCEPTION FOR ARTIFICIAL TURF

Date Received ________________________ File Number SE-________________________

Application Fee: $750.00
Continuance: $500.00

This application, with all required supplemental data and information, must be completed in accordance with the specific instructions in the application, and returned to the Urban Design before same will be advertised for a hearing.

IMPORTANT: The applicant or his representative **MUST** be present at the hearing. There will be a fee of $500.00 for a Voluntary Continuance (a request by the applicant to continue a petition before the appropriate board or council, or by the failure of the applicant to attend or be represented at the appropriate meeting).

1. Name of Applicant(s): ____
   Address: ________________________________ Phone: ______________

2. Owner(s) of Record: ____
   Address: ________________________________ Phone: ______________

4. Attorney or Agent: ____
   Address: ________________________________ Phone: ______________

5. Property Address or Street Name: ________________________________

6. Property Legal Description:

Parcel ID / Account #	Lot #	Block #	Section	Total Sq Feet/ Acres	Existing Zoning

7. Artificial Turf Use Location:

8. Written statement describing the proposed use:

9. What is the minimum tufted weigh per square foot______________________________

10. What is the permeability per hour per square yard:______________________________

11. What is the anchor size and location:____

12. How long is the manufactures warranty:____

13. Approval Criteria. The Planning Commission and City Council shall use the following criteria, in addition to other reasonable considerations, in making their decision please explain your position on the following:

    (1) The proposed use will not adversely affect the use of neighboring properties.

    (2) The use shall comply with applicable district regulations and applicable provisions of the adopted Comprehensive Plan and downtown plans.

    (3) The location, size and height of buildings structures, walls and fences, and the nature and extent of screening, buffering and landscaping shall be such that the use will not hinder or discourage the appropriate development and use of adjacent or nearby land and/or buildings.

    (4) The proposed use will be such that pedestrian and vehicular traffic generated will not be hazardous or conflict with the existing and anticipated traffic in the neighborhood and on the streets serving the site.

Any Special Exception granted to allow artificial turf shall include the following conditions:

1. Precautions for installation around existing trees shall be monitored and may be restricted to ensure tree roots are not damaged with the installation of the base material.
2. Rubber, sand and any other weighting or infill material is prohibited.
3. If artificial turf is planned to be installed next to the seawall, the artificial turf shall be pinned or staked behind the seawall. Nothing shall be attached directly to or placed on the seawall or seawall cap.
4. A copy of the Special Exception and conditions thereof shall be recorded in the Public Records of Charlotte County so that any subsequent purchaser will be on notice regarding the special rules relating to the artificial turf.
5. A landscape inspection shall be conducted after the installation of the artificial turf to ensure all living plant materials conform to the provided landscape plot plan and meet the drought tolerant and native species requirements.
6. If artificial turf is to be installed in the City right-of-way, a separate right-of-way permit must be obtained prior to commencing work.
7. Artificial turf shall be maintained in a green fadeless condition and shall be maintained free of dirt, mud, stains, weeds, debris, tears, holes, and impressions, as determined by Code Compliance. All edges of the artificial turf shall not be loose, and must be maintained with appropriate edging or stakes.
8. Artificial turf must be replaced if it falls into disrepair with fading or holes or loose areas, as determined by Code Compliance. Replacement shall be completed within 60 days of notification by Code Compliance.
9. If maintenance is required on the City right-of-way, or utility easement, it shall be the responsibility of the property owner to remove, replace and repair, at the owner's expense, any artificial turf that has been placed in the right-of-way or utility easement within 60 days.
10. If maintenance is required on the seawall and/or seawall cap, it shall be the responsibility of the property owner to remove, replace and repair, at the owner's expense, any artificial turf that has been placed in the rear yard of the property abutting the seawall within 60 days.
11. The City of Punta Gorda shall not be held liable for any damage to any artificial turf or other items placed within the right-of-way, within six feet of the seawall, or within any area covering any city utilities.

Special Exception
Affidavit

I, the undersigned, being first duly sworn, testify and say that I am the owner, attorney, attorney-in-fact, agent, lessee or representative of the owner(s) of all of the property described and which is the subject matter of the proposed hearing; that all answers to the questions in this application, and all sketches, data and other supplementary material attached to and made a part of the application are honest and true to the best of my knowledge and belief. I understand this application must be complete and accurate before the hearing can be advertised, and that I am authorized to sign the application by the owner or owners.

By submitting this application the owner(s) of the subject property does hereby grant his/her consent to the Zoning Official and his/her designee, to enter upon the subject property for the purposes of making any examinations, surveys, measurements, and inspections deemed necessary to evaluate the subject property relative to this application.

Sworn and subscribed before me this ___________ day of ________________, 20_____.

____   ____

Signature of Applicant or Authorized Agent   Type of Print Name and Title

Address: ________________________________   Phone: ____________________________

____

STATE OF ______________)

)

COUNTY OF ____________)

The foregoing instrument was acknowledged before me this ________ day of _____

__________________, 20___, by____, who is

personally known to me or who has produced _______________________________________ as identification and who did not take an oath.

____

Notary Public, State of Florida   **(Seal)**

My commission Expires: __________________

AFFIDAVIT

AUTHORIZATION FOR AGENT

I/We____, property owner(s), hereby authorize __________________________________to act as Agent on our behalf regarding a ______________________ application on the property described as: (legal description) ____, a/k/a ____ in Punta Gorda, Florida.

_________________________________   ______________________

Owner   Date

STATE OF _____________)
)
COUNTY OF ___________)

The foregoing instrument was acknowledged before me this ________ day of _____ _________________, 20___, by____, who is personally known to me or who has produced _____________________________________ as identification and who did not take an oath.

____
Notary Public, State of Florida   **(Seal)**

My commission Expires: __________________