Draft Review of San Francisco Policies Related to Synthetic Turf Field Drainage and Groundwater Quality Protection
September 19, 2019

DRAFT TECHNICAL MEMORANDUM

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Subject: Draft Review of San Francisco policies related to synthetic turf field drainage and groundwater quality protection

Table 1 lists eleven synthetic turf athletic fields installed in San Francisco since 2006, all but one of which belong to San Francisco Recreation and Parks Department (SFPRD). As shown in Figure 1, four are located within the Westside Groundwater Basin: South Sunset Playground, Beach Chalet Soccer Fields, Minnie Lovie Field, and University of San Francisco's (USF) Benedetti Field.

Background

A representative of USF called SFPUC WRD in November 2018 for guidance on how to conduct a test that potentially could allow USF to percolate storm drainage[1] from its synthetic turf field rather than direct it to the combined sewer system. Synthetic turf was installed with organic infill material at its Benedetti Field in 2016, located in the northeast corner of the Westside Groundwater Basin (Figure 1). SFPUC WRD and Wastewater Enterprise (WE) staff had informed USF in 2015 that water quality sampling would be required before field drainage could be allowed to percolate to groundwater. SFPUC and SFRPD had prepared draft synthetic turf drainage sampling plans in 2010 and 2011 and sampled storm drainage from two SFRPD synthetic turf fields during 2010-2012. As of November 2018, policies and guidelines for synthetic turf drainage remained draft, the collected field data were not fully analyzed, and there was a lack of consensus among SFPUC divisions and other City departments on this subject.

Objectives

To prepare a reply to USF and support the establishment of a consensus policy, this technical memorandum presents (a) a summary of past studies, discussions, and draft policies related to the use of synthetic turf in San Francisco; (b) an analysis of the field data collected in 2010-2012; and (c) an updated literature review. These are presented in Appendices A, B, and C, respectively, and summarized below. Comments on this document will be solicited from SFPUC water resources and wastewater staff, SFRPD, and San Francisco Department of Public Health

[1] As used here, storm drainage refers to the combination of rainfall runoff and infiltration (or leachate) captured by a synthetic turf field drainage collection system.

(SFDPH), with the goal of reaching a consensus policy. Given the approaching wet season, USF will be advised of the existing guidance for sampling drainage from its synthetic turf field.

Existing Guidance for Evaluating Synthetic Turf Drainage

Appendix A chronologically lists (Table A-1) and summarizes 24 documents and documented discussions from 2007 to 2018 related to stormwater drainage from synthetic turf Fields in San Francisco.

The most recent guidance for evaluating whether drainage from a synthetic turf athletic field may be allowed to percolate to groundwater is from the May 2011 *First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan* prepared by SFPUC and SFRPD. This plan and the 2010 draft plan it replaced guided SFPUC's collection of stormwater drainage from synthetic turf installed at SFRPD's South Sunset Playground and Garfield Square Park during 2010-2012.

The 2011 plan recognized the potential for greater degradation of synthetic turf materials after frequent field use during the dry summer, which could lead to higher contaminant loading during the first rain events of the season. For this reason, the plan called for collecting three samples, one hour apart, beginning as soon as possible after rainfall begins during the first substantial rain event (greater than 0.25 inches) of the season (i.e., seasonal "first flush"). The 2010 plan called for collecting one sample from a storm's "first flush" (i.e., as soon as possible after a storm begins) without targeting a particular time of the season. As recommended by the 2008 San Francisco Playfields Task Force, percolation to groundwater would not be allowed unless the sampled drainage meets drinking water standards.

South Sunset Playground and Garfield Square Park Sample Results

Appendix B provides a review of the 2010-2012 results from sampling synthetic turf drainage at South Sunset Playground and Garfield Square Park. A total of eight samples were collected on five different dates from each field under a wide range of conditions (mid-season and early season; wet and dry years; storm rainfall at the time of sample collection ranging from approximately 0.14 to 1.1 inches; samples collected from 3 to 31 hours after storm rainfall began; see Table B-1).

Samples collected from South Sunset Playground during two early-season rainfall events in 2011-2012 did not meet drinking water quality standards for dissolved iron and a semi-volatile organic compound (SVOC). These events occurred four or more years after the fields were installed. Excluding total metal concentrations,[2] all of the Garfield Square Park samples met drinking water standards.

Three South Sunset Playground samples collected from early-season events in 2011-2012 had concentrations of the SVOC bis-(2-ethylhexyl)-phthalate that equaled or exceeded the 4 µg/L drinking water maximum contaminant level (MCL) for this compound. Bis-(2-ethylhexyl)-

[2] The potential for metals to reach groundwater is indicated significantly more by dissolved metals than total metals.

phthalate is a plasticizer used to soften rubber that may have been released from the SBR turf infill (styrene butadiene rubber, or crumb rubber, from recycled tires and tire shreds) or other components of the drainage system. This SVOC was detected in four of the other eight samples collected in 2010-2011 at concentrations below the MCL. For the early-season event when three samples were collected one hour apart, concentrations of this SVOC ranged from below detection to 57 µg/L. Dissolved iron concentrations exceeded the secondary drinking water MCL in the second two of the three hourly samples (possibly derived from steel belts and beads included in the tire source material). These detections became the basis for not allowing the infiltration of synthetic turf drainage at South Sunset Playground or the Beach Chalet soccer fields where SBR infill also was used.

These results suggest the following:

- The potential for contaminant concentrations in synthetic turf drainage to exceed drinking water standards may be greatest within fairly narrow windows of time during early-season rainfall events.
- Because drinking water standards were exceeded in samples collected four or more years after the synthetic turf was installed, these fields may provide an ongoing contaminant source as a result of degradation of the turf materials.

Stormwater Management Perspective

At a March 2015 meeting, SFPUC water resources and wastewater staff and management and the San Francisco City Attorney discussed the potentially conflicting goals of stormwater management and groundwater quality protection in the Westside Basin (see item 20, Table A-1). Stormwater guidelines promote the use of green infrastructure and best management practices (BMPs) to infiltrate stormwater without testing for water quality. The City Attorney expressed that requiring synthetic turf drainage to meet drinking water standards before allowing it to percolate to groundwater was too stringent and set a poor precedent for implementing green infrastructure. Developers have pointed out inconsistencies between policies and believe that a requirement to meet drinking water standards is unreasonable. Other jurisdictions (e.g., Santa Clara Valley Water District) at that time generally lacked groundwater protection standards for synthetic turf fields.

The May 2016 San Francisco Stormwater Management Requirements and Design Guidelines (see item 22, Table A-1) cites groundwater recharge as one of the benefits of "treating stormwater as a resource rather than a waste product." Stormwater controls for large projects must be designed to infiltrate, evapotranspire, bioretain, and/or biotreat stormwater generated by the 90th percentile, 24-hour storm (approximately 0.75 inches of rain with a rainfall intensity of approximately 0.24 inches per hour). Pre-treatment may be needed to allow stormwater to recharge groundwater, including biological processes to "filter pollutants." "Full treatment" may be required where the infiltration rate exceeds 5 inches per hour. A 10-foot minimum vertical separation is required between the base of an infiltration BMP and the seasonal high groundwater level. The guidelines lack specificity on how to evaluate the potential for groundwater contamination. Nor is it clear how all types of dissolved contaminants can be sufficiently "filtered" by biological processes and a 10-foot vertical separation from groundwater. The guidelines make no specific reference to synthetic turf.

In a July 2018 discussion by email (see item 23, Table A-1), SFPUC water resources staff confirmed that the requirements for sampling synthetic turf apply even where alternative materials are used, whereas wastewater staff said this requirement may be worth revisiting. Wastewater staff said that they and SFRPD had determined that the maintenance and eventual replacement of synthetic turf (e.g., every 10 years) would not trigger the Stormwater Management Ordinance.

Other Reviewed Literature

Appendix C presents a chronological list of 23 references related to the environmental effects of synthetic turf and summarizes their findings relevant to potential groundwater impacts.

A 2009 study by the New York State Department of Environmental Conservation concluded that application of a dilution-attenuation factor could support the use of crumb rubber as a synthetic turf infill material without causing significant impacts to groundwater quality. As synthetic turf drainage moves through soil to the groundwater table, contaminant concentrations are attenuated by adsorption and degradation, and further reduced by dilution when mixed with groundwater. Similarly, a 2010 study by the Connecticut Department of Environmental Protection did not identify significant risks to groundwater from synthetic turf fields.

A 2010 Stanford study (Cheng and others, 2014) concluded that relatively effective natural attenuation of contaminants from synthetic turf can be expected in surface water and groundwater. A 2014 journal publication by the same authors stated that dilution by infiltrating rainwater and groundwater is expected to reduce the toxicity of synthetic turf drainage and lower the associated ecological risk. Concentrations of heavy metals and organic contaminants in field drainage were generally below regulatory limits.

A 2015 study of scrap-tire leachate offered no confirmation that synthetic turf fields are safe and warned that acidic rainwater or groundwater could increase the rate of leaching (Selbes and others, 2015).

A 2018 risk assessment concluded that a growing body of literature suggests that recycled rubber infill in synthetic turf poses negligible risks to human health (Peterson and others, 2018).

Conclusions

This review supports the following conclusions and recommendations:

- Maintain the requirement that synthetic turf drainage must be sampled before allowing it to percolate to groundwater, as prescribed in the 2011 *First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan*. However, based on the 2010-2012 sampling results for two SFRPD synthetic turf fields, it should be recognized that the required sampling may not coincide with potentially narrow windows of time when contaminant concentrations are greatest. Whether or not to require additional or ongoing sampling could be considered in future revisions to this policy.

- Consider evaluating the fate of contaminants if synthetic turf drainage is allowed to migrate to and reach groundwater. As stated in the 2008 New York study, application of a dilution-attenuation factor could support allowing synthetic turf drainage to contribute to groundwater recharge without causing significant impacts to groundwater quality because of the processes of adsorption, degradation, and dilution.
- Further discussions between SFPUC divisions and other City departments are needed to achieve consensus on these issues and resolve potential inconsistencies between stormwater management and groundwater protection policies.

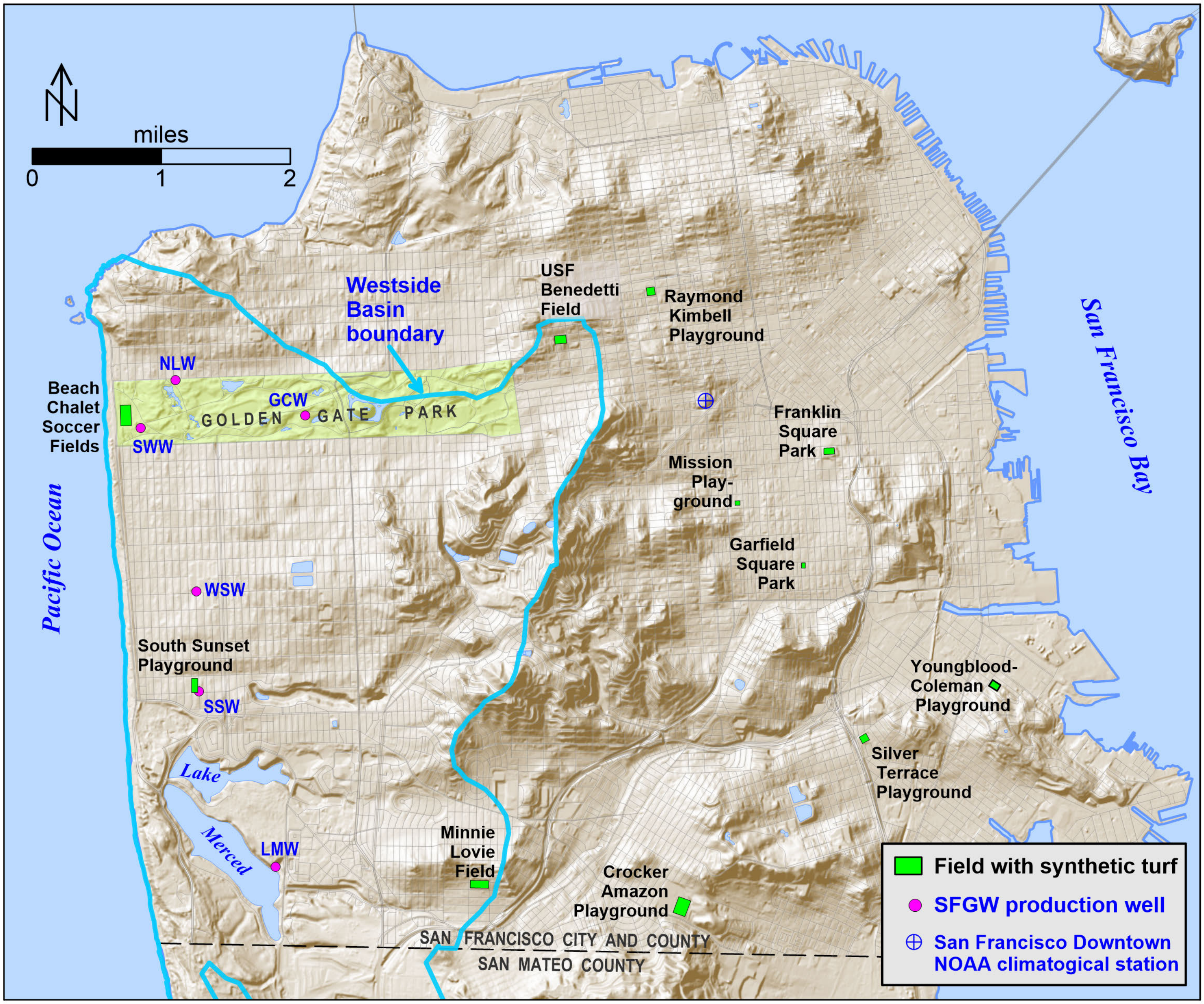
Attachments

Synthetic Turf Athletic Fields	Year Installed	West-side Basin	Approx-imate Acreage	Percent of Park Land
San Francisco Recreation & Parks Dept.				
1. Franklin Square Park	2003		1.9	0.05%
2. Silver Terrace Playground	2003		3.1	0.09%
3. Crocker Amazon Playground	2006-08		8.9	0.25%
4. Garfield Square Park*	2006-08		0.9	0.03%
5. South Sunset Playground*	2006-08	●	2.2	0.06%
6. Youngblood-Coleman Playground	2006-08		2.5	0.07%
7. Raymond Kimbell Playground	2010		3.0	0.09%
8. Mission Playground	2012		0.4	0.01%
9. Minnie Lovie Field	2014	●	5.3	0.15%
10. Beach Chalet Soccer Fields	2015	●	8.2	0.23%
All synthetic turf fields			36.4	1.0%
Natural turf athletic fields			177	5.1%
All other park land			3,303	94.4%
Total park land			3,500	100%
Other				
11. USF Benedetti Field	2016	●	2.1	

* Field runoff or leachate sampled February, March, and December 2010, February and October 2011, and January 2012.

Sources: SFRPD, 2008, 2009, https://sfrecpark.org/permits-and-reservations/athletic-fields/athletic-fields-directory/, and Google Earth.

Table 1
San Francisco Athletic Fields with Synthetic Turf



Synthetic Turf Athletic Fields (All RPD except #10)	Year Installed	Approx-imate Acreage
Beach Chalet Soccer Fields	2015	8.2
Crocker Amazon Playground	2006-08	8.9
Franklin Square Park	2003	1.9
Garfield Square Park*	2006-08	0.9
Minnie Lovie Field	2014	5.3
Mission Playground	2012	0.4
Raymond Kimbell Playground	2010	3.0
Silver Terrace Playground	2003	3.1
South Sunset Playground*	2006-08	2.2
USF Benedetti Field	2016	2.1
Youngblood-Coleman Playground	2006-08	2.5
Total		38.5

*Drainage sampled February, March, and December 2010, February and October 2011, and January 2012.

Figure 1
San Francisco Athletic Fields with Synthetic Turf

Appendix A: Summary of Previous Plans, Policies, Discussions, and Evaluations Regarding Synthetic Turf Fields in San Francisco

Table A-1 lists 24 documents and documented discussions chronologically from 2007 to 2018 regarding synthetic turf in San Francisco. The summaries of these materials that are provided below focus on aspects related to groundwater quality.

2007 Evaluation by for San Francisco Department of the Environment

In December 2007, the Washington Toxics Coalition provided an evaluation of synthetic turf prepared for the San Francisco Department of the Environment (SFE) (Table A-1, items 1 and 2). The objective of this evaluation was to inform decision making regarding the purchasing of synthetic turf given the potential leaching of toxic substances from turf components. The evaluation found that prior studies on this topic had been inconsistent and/or inconclusive regarding environmental issues associated with synthetic turf.

The evaluation noted that infill material derived from recycled rubber tires contains several components of potential water quality concern, including zinc, polycyclic aromatic hydrocarbons, nonylphenol, bromine, and lead. Zinc toxicity is relatively low for humans but more significant to aquatic life. The presence of bromine may indicate that a material contains brominated flame retardants, or polybrominated diphenyl ethers (PBDEs). The study noted that natural turf treated with fertilizers and pesticides also cannot be considered risk free.

The evaluation screened 25 different elements in representative samples of synthetic turf, backing, infill, and shock pads using an x-ray fluorescence analyzer. The highest measured bromine content of infill and shock pad samples was 0.4 percent. The highest lead content was about 0.2 percent in some backing and shock pad samples. Most of the infill and some of the turf samples contained significant amounts of zinc, generally ranging from 4 to 10 percent of the material tested.

The study recommended requesting manufactures disclose the full list of synthetic turf ingredients and staying abreast of developments regarding the need and potential to recycle synthetic turf materials at the end of their useful life.

2008 Synthetic Playfields Task Force

A Synthetic Playfields Task Force convened by SFPRD presented its findings and recommendations in an August 2008 report (Table A-1, item 3). The task force reviewed and evaluated available scientific research on potential environmental and human health risks associated with synthetic turf playfields, including potential groundwater contamination from synthetic turf drainage.

The task force's water quality study group reviewed 22 studies and papers regarding the occurrence, leaching, and fate of heavy metals (particularly lead and zinc) and other known carcinogens associated with synthetic turf. Its findings included instances of detected contaminants in synthetic turf drainage that impacted localized areas but declined in concentration over time. SFE commented that concentrations in synthetic turf drainage were not expected to approach levels of concern in "normal" synthetic turf installations above the water table.

The recommendations of the task force included the following:

- Screen proposed synthetic turf materials by requiring that manufacturers list all ingredients and provide material safety data sheets (MSDS); perform leachate tests on synthetic turf samples to determine if the leachate meets drinking water quality standards; evaluate alternative products; and confer with other users of synthetic turf.
- Conduct, or participate in, field tests to evaluate the water quality of synthetic turf drainage.
- Install synthetic turf fields above the water table and in areas that do not flood. Construct drainage systems that allow leachate to either infiltrate and percolate to groundwater or discharge to the combined stormwater and wastewater system. Consult with the San Francisco Public Utilities Commission (SFPUC) to weigh the relative benefits of water conservation, groundwater recharge, and water quality protection.
- Allow infiltration to groundwater if the synthetic turf drainage meets drinking water standards; otherwise, collect the turf drainage and discharge it to the sewer system (after detaining on site as necessary to manage system capacity).

2009 San Francisco Synthetic Turf Standards

SFRPD developed synthetic turf standards in 2009 for the composition, post-consumer recycled content, and recyclability of synthetic turf products used in San Francisco (Table A-1, item 4). The vendor must submit an analysis quantifying the content of their product. The maximum soluble concentrations allowed for chromium and lead are 0.05 and 0.0025 milligrams per liter (mg/L), respectively, whereas the maximum allowed concentration for soluble zinc is 250 mg/L in SBR (styrene butadiene rubber, or crumb rubber, from recycled tires and tire shreds) infill and 0.081 mg/L in non-SBR infill materials. Although the zinc standard for SBR infill is higher than the drinking water maximum contaminant level (MCL), the acidic solution used by the Waste Extraction Test is more aggressive at dissolving constituents from a material than water.

2010 Evaluation of Stormwater Management Alternatives for Beach Chalet Soccer Fields

A February 2010 evaluation of alternative stormwater management systems was conducted for the planned installation of synthetic turf at the Beach Chalet soccer fields in Golden Gate Park within the Westside Groundwater Basin (Fall Creek Engineering, 2010; Table A-1, item 5).

At this location the water table is approximately 10 feet below ground surface and soils have a relatively high permeability on the order of $1x10^{-3}$ centimeters per second. The expected drainage from these fields was assumed to contain fine sediment, possibly trace metals from the infill material, and bacteria.

The recommended alternative was to construct unlined bioretention swales to manage and treat field drainage. This was the only alternative with the ability to treat and infiltrate the design 0.75-inch rainfall event without needing a retention facility or direct connection to the combined sewer system. This ecological approach would rely on plants, soil, and soil microbes to capture, treat, filter, transpire, infiltrate, and remove pollutants from stormwater as a result of chemical, biological, and physical processes. Its simple design and operation was expected to achieve a high level of treatment, an overall reduction in stormwater volume, and the attenuation of peak flows. The size could be reduced if the fields remained unlined and some drainage was allowed to infiltrate directly below the fields.

2010 Draft Synthetic Turf Stormwater Quality Monitoring and Sampling Plan

SFPRD and SFPUC collaborated on a draft *Synthetic Turf Stormwater Quality Monitoring and Sampling Plan* to implement the recommendations of Synthetic Playfields Task Force and address public health and safety concerns that arose after SFPRD installed several synthetic turf playfields in San Francisco (Table A-1, item 6). A draft plan was released in February 2010. The objectives of the plan were to collect stormwater quality data, determine potential impacts to groundwater, and assist with the planning and design of San Francisco playfields.

The synthetic turf fields at South Sunset Playground and Garfield Square Park were selected for sampling during the first and one subsequent storm event of the 2009-2010 and 2010-2011 rainy seasons. The San Francisco Groundwater Supply Project (SFGW) South Sunset well was constructed in 2007 adjacent to South Sunset Playground. Grab samples were to be collected as early as possible after the beginning of each storm to characterize the water quality characteristics of the storm's "first flush." The samples would be analyzed for physical parameters (pH, temperature, specific conductance, turbidity, total dissolved solids, and suspended solids); metals (total and dissolved); and volatile and semi-volatile organic compounds (VOC; SVOC). The draft plan specified lab, detection, and method limits; the collection of duplicate samples and trip blanks; and laboratory quality control procedures.

2010 February, March, and December Sampling Events at South Sunset Playground and Garfield Square Park

As part of assisting SFPRD with the design of the stormwater drainage system for the Beach Chalet synthetic turf playfields, SFPUC staff conducted stormwater quality monitoring in February, March, and December 2010 to evaluate the presence of contaminants in drainage from two existing synthetic turf playfields, South Sunset Playground and Garfield Square Park (the former is within the Westside Groundwater Basin) (Table A-1 item 7). The sampling objectives and protocol were consistent with the 2010 Draft Synthetic Turf Stormwater Quality Monitoring and Sampling Plan. As summarized below, the initial results were discussed in a meeting between SFPUC and SFPRD in April 2010.

2010 Beach Chalet Field Renovation Project, Synthetic Turf Stormwater Discussion

SFPUC staff prepared a May 2010 memorandum summarizing SFPRD's Beach Chalet synthetic turf project and the initial results from sampling stormwater drainage at two existing synthetic turf playfields. Additionally, SFPUC responded to action items from an April 2010 meeting with SFPRD at which the monitoring results were discussed (Table A-1, item 8).

The proposed 8.2 acres of synthetic turf playfields are approximately 300 feet or more from the South Windmill production well (constructed in 2000, this well was originally used for Golden Gate Park irrigation but is now being converted to potable use as part of the SFGW project). The depth to groundwater was 15 feet in October 2009 and could rise to less than 10 feet during the rainy season.

SFPUC directed SFRPD to design and implement an appropriate Best Management Practice (BMP) consistent with San Francisco's Stormwater Design Guidelines if the project EIR determined that stormwater drainage from the playfields required collection and/or treatment before being allowed to infiltrate and percolate to groundwater. A stormwater BMP must be at least 150 feet from drinking water wells and comply with depth-to-groundwater limitations.

The February and March 2010 samples of synthetic turf drainage at two existing playfields were collected after more than 70 percent of average seasonal rainfall had occurred (see Table B-1), and thus were not representative of a seasonal first flush. No volatile or semi-volatile organic compounds were detected. Concentrations of total iron and manganese exceeded their respective California secondary MCLs in several of these samples, however concentrations of dissolved iron and manganese did not. The potential for metals to reach groundwater is indicated significantly more by dissolved metals than total metals. The sample results for pH, electrical conductivity, total dissolved solids, and dissolved zinc differed between the two fields, and total metal concentrations appear to have correlated positively with total suspended solids, suggesting that pretreatment to remove suspended solids may be needed. See Appendix B for a more detailed discussion of the sample results.

Coordination with the SFPUC Wastewater Enterprise would be needed to determine if pre-treatment is necessary. The EIR process should not be expected to provide technical standards protective of groundwater. If water quality concerns remained after completion of the sampling plan, SFPUC would ask for a drainage system design that either does not directly percolate to groundwater or discharges to the sewer system. To ensure the long-term protection of groundwater, SFPUC may recommend leachate tests of the proposed synthetic turf materials, a post-construction stormwater monitoring plan, and an operation and maintenance plan. SFPUC encouraged SFPRD to continue evaluating alternative infill materials.

2011 First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan

SFPRD and SFPUC completed a revised version of the synthetic turf sampling plan in May 2011, entitled *First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan* (Table A-1, item 9). This plan followed the 2009-10 and 2010-11 collection of mid-season samples of synthetic turf drainage from South Sunset Playground and Garfield Square Park. The plan recognized the potential for greater degradation of the synthetic turf materials after frequent use of the fields during the long, dry summer, which could lead to higher contaminant loading during the first rain events of the season. For this reason, the revised plan called for collecting seasonal first-flush samples at these same locations during the first substantial rain event (>0.25 inches) of the 2011-12 wet season.

The plan called for collecting three samples, one hour apart, as soon as possible after the beginning of a rain event. The plan's sampling and analysis procedures and methods were essentially the same as the 2010 draft plan. SFPUC was to interpret and report on the sample results in a brief memorandum.

2011-2012 Sampling Events at South Sunset Playground and Garfield Square Park

SFPUC staff collected additional stormwater quality samples of synthetic turf drainage at South Sunset Playground and Garfield Square Park in February and October 2011 and January 2012 (see Table B-1). The sampling objectives and protocol were consistent with the 2011 revised Synthetic Turf Stormwater Quality Monitoring and Sampling Plan. Cumulative seasonal rainfall when these samples were collected ranged from 2 to 68 percent of San Francisco's approximate 21 inches of average annual rainfall. As discussed in greater detail in Appendix B, two South Sunset Playground samples collected after completion of the draft EIR exceeded the MCL for the SVOC bis-(2-ethylhexyl)-phthalate (a plasticizer used to soften rubber). Concentrations of total iron and total manganese (possibly derived from steel belts and beads included in the tire source material) exceeded secondary MCLs in several of the South Sunset Playground samples, and dissolved iron exceeded the secondary MCL in two of these samples. The concentration of total iron exceeded the secondary MCL in one sample from Garfield Square Park. The potential for transport to groundwater is most indicated by dissolved rather than total metal concentrations. Per the 2011 Beach Chalet Athletic Fields EIR, a majority of the samples from both fields exceeded dissolved copper environmental screening levels for marine surface water and groundwater.[3]

2011 Beach Chalet Athletic Fields Renovation Draft Environmental Impact Report (EIR)

As described in the October 2011 EIR for the Beach Chalet playing fields (Table A-1, item 10), the proposed synthetic turf consists of four components: fiber, infill, backing, and underlayment. As designed, the fiber (synthetic grass) consists of polyethylene, the infill consists of approximately 70 percent SBR and 30 percent sand, the backing consists of permeable woven and un-woven polypropylene fabrics that provide strength and vertical drainage, and the underlayment consists of drainage tile or an aggregate rock base. The composition of SBR infill material can vary widely due to the variable composition of the tire source material. At the end

[3] Environmental screening levels established by the San Francisco Regional Water Quality Control Board. Per the EIR, exceedances do not necessarily indicate that adverse effects could occur given the conservative assumptions used in developing the screening levels. The 3.1 µg/L screening level for copper in groundwater assumes potential discharge to aquatic habitat. The California Regulatory Action Level for copper in drinking water is 1,300 µg/L.

of its anticipated 10 or more year lifespan, the turf would be returned to a turf manufacturer for reuse/recycling and replaced with new synthetic turf.

A literature review conducted for the EIR summarized the following prior studies in addition to some of the studies summarized above:

- A 2007 study by the California Integrated Waste Management Board concluded that leachate from tire shreds used in outdoor applications, such as playground surfaces, was unlikely to cause adverse effects, particularly where playfields are installed above the water table.
- A 2007 study conducted in France found that concentrations of metals and organic chemicals detected in synthetic turf leachate samples were generally lower than the applicable drinking water standards. The samples exhibited slight acute and chronic toxicity 15 days after installation, but none of the samples showed toxicity three months after installation.
- A 2009 report on studies conducted by New York State found that synthetic turf has the potential to leach zinc, aniline, phenol, and benzothiazole, although the laboratory procedures used were more aggressive than would occur due to rainfall. One sample of stormwater drainage from synthetic turf contained zinc, chromium, copper, lead, and nickel at concentrations below New York surface water standards. Semi-volatile organic compounds were not detected in groundwater samples collected down gradient of four synthetic turf installations.
- Connecticut State agencies conducted laboratory studies in 2010 that found a potential for synthetic turf to leach metals, especially copper and zinc. Stormwater samples collected from four fields contained benzothiazole (associated with dyes and rubber), barium, copper, iron, vanadium, and zinc. Concentrations of aluminum, barium, and zinc exceeded aquatic toxicity criteria in at least one sample. Zinc was identified as a potential risk to surface waters.

The EIR concluded that the project's potential to impact groundwater quality was less than significant given that the synthetic turf drainage would be collected by an underdrain and discharged to the combined sewer system until sampling by SFRPD indicated that the water quality was suitable for infiltration. SFPUC was expected to provide guidance on the required number of sampling events and the sampling parameters. The EIR recommended that future studies evaluate the concentration of metals in runoff from grass fields to help assess the contribution of metals due to synthetic turf.

As described above, the SVOC bis-(2-ethylhexyl)-phthalate was detected above its MCL in two samples of synthetic turf drainage at South Sunset Playground after completion of the draft EIR. As a result, the infiltration of synthetic turf drainage has not been allowed at either South Sunset Playground or the Beach Chalet athletic fields following construction.

2013 Draft Synthetic Turf Requirements for the Large Landscape Grant Program

The SFPUC Water Resources and Wastewater divisions prepared an internal memorandum in July 2013 discussing draft synthetic turf requirements for the Large Landscape Grant Program (LLGP) (Table A-1, item 11). The memorandum states that (a) synthetic turf provides substantial water savings by reducing the amount of potable water used for irrigation and (b) installations outside of the Westside Groundwater Basin would not be subject to additional requirements.

For projects within the Westside Basin, additional measures to protect groundwater quality would be required to apply for LLGP grant funding. Such requirements "may vary depending on the project size, location, and scope." The memorandum's recommended requirements remained uncertain and incomplete given that its bullet lists of requirements ended with several blank, queried lines (i.e., "• ??").

Generally, however, dual-liner systems are needed for synthetic turf installations in the Westside Basin to allow drainage to either percolate to groundwater or discharge to the combined sewer system. Percolation to groundwater would be allowed only if the water quality of collected drainage samples met drinking water standards. In cases where percolation is not allowed, synthetic turf drainage during peak rainfall events must be held in detention basins for at least 15 minutes prior to discharging to the combined sewer.

Prior to submitting an LLGP-grant application for synthetic turf, the memorandum states that LLGP applicants within the Westside Basin must provide SFPUC with the project location and size; a description of the proposed drainage system; the manufacturer and type of synthetic turf; and the type of infill (e.g., SBR, sand, cork) in order for SFPUC to make a preliminary determination regarding any additional requirements.

2013 Environmental Testing Protocols for Procuring Synthetic Turf Products

A consultant for SFPUC reviewed and proposed environmental testing protocols for procuring synthetic turf products in an August 2013 report (D. Teeter Consulting, 2013; Table A-1, item 12). As proposed, potential suppliers of synthetic turf products would need to submit samples for testing (a) to ensure compliance with Proposition 65 and (b) to ensure that they do not leach contaminants at concentrations that could adversely impact groundwater. The report proposed calculating target leachate concentrations by multiplying water quality screening levels or goals by a dilution attenuation factor of 20.

2013-2014 SFSU Recreation Wellness Center

As proposed, the SFSU Recreation Wellness Center (RWC) included a synthetic turf recreation field. At a December 2013 meeting on the proposed project, SFPUC water resources and wastewater staff described the guidelines for installing and monitoring synthetic turf fields to prevent groundwater contamination (Table A-1, items 13 and 14). The granulated rubber and the ethylene propylene diene monomer (EPDM) rubber mat can leach zinc, lead, and other pollutants. Rainfall and stormwater runoff penetrating through the synthetic turf must meet drinking water standards before being allowed to recharge the Westside Groundwater Basin aquifer. The typical approach is to construct the field with a liner, initially divert all the turf drainage to the combined sewer system and collect and test samples to determine if the drainage meets drinking water standards. If the drainage meets these standards, it may be allowed to infiltrate and percolate to groundwater; if it does not, the water must be directed to the sewer system. Some synthetic turf materials are less likely to leach heavy metals, such as those made of natural materials (e.g., coconut fiber, cork). However, none of the materials are known to be free of potential contaminants.

SFPUC Water Enterprise's guidelines for synthetic turf were summarized in a follow-up January 2014 email (Table A-1, item 15):

> Synthetic turf fields located within the boundary of the Westside Groundwater Basin in San Francisco should be designed and monitored to protect groundwater quality. Water, including rainfall and stormwater runoff, penetrating through the synthetic turf system must meet drinking water standards before being allowed to percolate downward to recharge the aquifer in the Westside Basin.

Notes from a subsequent meeting in January 2014 (Table A-1, items 16 and 17) provided the following list of synthetic turf materials with possibly lower leaching potential: virgin EPDM rubber; other virgin polymers; thermoplastics (TPE); polymer-coated quartz sand; ceramic-coated beads; and organic infill made from a blend of shredded coconut husk and cork. The long-term durability and performance of these materials is uncertain, however.

2014 SFPUC Position on Synthetic Turf

In March 2014 SFPUC provided the following response to a public inquiry about its position on synthetic turf (Table A-1, item 18): synthetic turf fields within the boundary of the Westside Groundwater Basin in San Francisco should be designed and monitored to protect groundwater quality. Water, including rainfall and stormwater runoff, that infiltrates the synthetic turf system must meet drinking water standards before being allowed to percolate and recharge the aquifer.

2015-2018 USF Benedetti Baseball Field

A USF representative conferred with SFPUC water resources and wastewater staff in February 2015 regarding the proposed design for reconstructing USF Benedetti Baseball Field with synthetic turf (Table A-1, item 19). As proposed, the design included a fully lined field with a drainage detention system that discharged to the combined sewer system. Instead of SBR, the design used an organic infill material with available information on its chemical composition. USF wished to allow the drainage to percolate to groundwater after conducting any required testing. SFPUC staff said they would review the sampling plan and analytical results for field drainage under as-built conditions in order to determine whether to allow infiltration, regardless of whether the infill material was organic or SBR.

After constructing the field with coconut husk and sand infill material in 2016, a USF representative contacted SFPUC in November 2018 to ask about required testing prior to allowing the synthetic turf drainage to infiltrate into dry wells constructed under the field (Table A-1, item 24). USF's approved Final Stormwater Control Plan stated that SFPUC would permit infiltration after post-construction monitoring demonstrated that the field drainage met drinking water standards. The USF representative asked: if those requirements were still applicable; whether the City had pre-approved any synthetic turf materials; what sampling procedures and frequency were needed; and whether full Title 22 analyses were needed.

2015 Synthetic Turf Policy Discussion Meeting Minutes

Staff and management for the SFPUC water resources and wastewater enterprises, along with the San Francisco City Attorney, met March 4, 2015 to discuss the potentially conflicting goals of stormwater management and groundwater quality protection in the Westside Basin (Table A-1, item 20). Stormwater design guidelines promote the use of green infrastructure and BMPs to infiltrate stormwater without testing for water quality. Whereas, draft policies to protect Westside Basin groundwater quality require synthetic turf drainage to meet drinking water standards before allowing it to percolate to groundwater, consistent with the 2008 Synthetic Playfields Task Force report.

The City Attorney expressed that requiring synthetic turf drainage to meet drinking water standards before allowing it to percolate to groundwater was too stringent and set a poor precedent for the implementation of green infrastructure. Also, developers have pointed out the conflicts between these policies and believe that requirements to meet drinking water standards are unreasonable. It was noted that other jurisdictions (e.g., Santa Clara Valley Water District) have widely varying standards regarding setbacks between stormwater infiltration infrastructure and drinking water wells, and generally lacked groundwater protection standards for synthetic turf fields.

2016 Public Works Code, Stormwater Management Requirements, Ordinance 64-16

San Francisco adopted its first *Stormwater Management Ordinance* in 2010, requiring the installation and maintenance of stormwater management controls for development and redevelopment projects meeting specific area and project type criteria (Table A-1, item 21). A revised Stormwater Management Ordinance was approved in April 2016. The revised ordinance specifies Stormwater Management Requirements intended to reduce the volume of stormwater entering the City's combined and separate sewer systems, and to protect and enhance the quality of receiving waters.

As stated in the ordinance, pollutants of concern that potentially occur in urban runoff include sediments, non-sediment solids, nutrients, pathogens, bacteria, oxygen-demanding substances, petroleum hydrocarbons, heavy metals, floatables, polycyclic aromatic hydrocarbons (PAHs), trash, pesticides, and herbicides. Potential sources of these pollutants include vehicle emissions, wastes from vehicle maintenance, pesticides, household hazardous wastes, pet wastes, and trash. Potential impacts from these pollutants include increased turbidity, nutrient enrichment, bacterial contamination, toxic compounds, temperature increases, and increased trash and debris.

The ordinance calls for Post-Construction Stormwater Controls designed to (a) reduce pollution in stormwater runoff and/or (b) reduce the rate or volume of runoff through infiltration, retention, non-potable reuse, detention, direct plant uptake, and filtration. These controls are intended to enhance the function and capacity of the City's separate and combined sewer systems by reducing stormwater runoff rates or volumes; controlling the discharge of contaminants from spills, dumping, or disposal into the City's sewer and drainage systems; and providing pretreatment. These controls must be safe and properly maintained.

Per the ordinance, "natural vegetated soil can both absorb rainwater and remove pollutants, providing a very effective purification process." The ordinance calls for Post-Construction Stormwater Controls using green infrastructure that mimics pre-development drainage patterns and hydrologic processes by increasing retention, detention, infiltration, and treatment of stormwater at its source.

2016 San Francisco Stormwater Management Requirements and Design Guidelines

The May 2016 *San Francisco Stormwater Management Requirements and Design Guidelines* were prepared by SFPUC and others to facilitate compliance with the 2016 revised Stormwater Management Ordinance (Table A-1, item 22). Increased groundwater recharge as a result of these requirements is cited as one of the benefits of "treating stormwater as a resource rather than a waste product." The following paragraphs are paraphrased from this document.

Green infrastructure is aimed at removing pollutants and treating the first flush, defined in this case as the runoff generated during the beginning of a rain event that mobilizes most of the pollutants and debris accumulated since the last rain.

Stormwater controls for large projects under SFPUC jurisdiction must be designed to infiltrate, evapotranspire, bioretain, and/or biotreat the stormwater volume generated by the 90th percentile, 24-hour storm (approximately 0.75 inches of rain with a rainfall intensity of approximately 0.24 inches per hour).

Because these systems facilitate infiltration, the potential for groundwater contamination must be carefully evaluated, especially if the receiving groundwater is used as a potable water supply. Stormwater treatment needed to allow groundwater recharge includes pre-treatment to remove solids and oils, and biological processes to "filter pollutants." Subsurface infiltration systems, infiltration trenches, and infiltration basins may effectively remove sediments, nutrients, organic matter, and trace metals. However, where the infiltration rate exceeds 5 inches per hour (e.g., in the case of coarse sands) the runoff must be "fully treated" prior to infiltration, or by installing an 18-inch ASTM C33 sand layer at the base of the infiltration BMP.

To protect groundwater quality, a 10-foot minimum vertical separation is required between the base of an infiltration BMP and the seasonal high groundwater level (a 4-foot separation may be allowed in some cases). Infiltration systems are unsuitable for sites that use or store chemicals or hazardous materials, unless those materials can be effectively prevented from entering the system.

Accidental spills or leaks that result in the unauthorized and unexpected discharge of waste materials into the stormwater conveyance system can pose a hazard to human health and the environment. Appropriate precautionary measures should be in place to prevent the accidental discharge of pollutants and to handle such events should they occur. This may include, but is not limited to, maintaining equipment and storage receptacles, training staff on the safe handling of waste materials, ensuring that potential pollutants are handled and stored in designated areas, and posting emergency contact information in the event of a spill.

The guidelines lack specificity on how to conduct an evaluation of potential groundwater contamination. Nor is it clear how dissolved contaminants of all types can be sufficiently “filtered” by biological processes and a 10-foot vertical separation from groundwater. The guidelines make no specific reference to synthetic turf.

2018 Discussion of Synthetic Turf Policies

SFPUC water resources and wastewater staff conducted a July 2018 discussion by email regarding policies for synthetic turf drainage (Table A-1, item 23). Wastewater staff acknowledged SFPUC’s requirement that drainage from large synthetic turf fields in the Westside Basin must be captured and tested before allowing infiltration. Water resources staff confirmed that these requirements apply even if alternative materials are used (e.g., organic, non-SBR infill materials). Wastewater staff commented this may be worth revisiting.

Wastewater staff clarified that (a) they do not regulate or comment on small artificial turf installations (e.g., at schools or playgrounds), (b) they do not allow synthetic turf as a component of stormwater BMPs, and (c) they have determined in coordination with SFPRD that the maintenance and eventual replacement of synthetic turf (e.g., every 10 years) does not trigger the Stormwater Management Ordinance.

Item	Year	Month	Document	Authors	Document Type / Recipient	Additional Recipients / Meeting Attendees
1.	2007	December	Synthetic Turf Versus Natural Turf for Playing Fields	Washington Toxics Coalition (P. Dickey)	White papers prepared for San Francisco Department of the Environment (SFE)	
2.	2007	December	Occurrence of Bromine, Lead, and Zinc in Synthetic Turf Components			
3.	2008	August	Synthetic Playfields Task Force Findings and Department Recommendations	SFRPD	Report (50 p. and attachments) prepared for SFRPD Commission	
4.	2009	July	San Francisco Synthetic Turf Standards	SFRPD		
5.	2010	February	Evaluation of Alternative Stormwater Management Systems, Beach Chalet, San Francisco	Fall Creek Engineering (P. Hasse)	Letter report (9 p.) and attachments prepared for Verde Design	
6.	2010	February	Draft Synthetic Turf Stormwater Quality Monitoring and Sampling Plan	SFRPD / SFPUC (B. Eagon)	Draft plan (3 p. and attachments)	
7.	2010-12	various	Results of Seven Synthetic Turf Infiltration Sampling Events at South Sunset Playground and Garfield Square Park	SFRPD and SFPUC	2 tables	
8.	2010	May	Beach Chalet Field Renovation Project Synthetic Turf Stormwater Discussion	SFPUC (B. Eagon, J. Gilman)	Comments on draft plan (3 p.)	
9.	2011	May	First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan	SFRPD & SFPUC (B. Eagon, S. Rhodes)	Monitoring and sampling plan (7 p.)	
10.	2011	October	Beach Chalet Athletic Fields Renovation Draft Environmental Impact Report	San Francisco Planning Department	Draft EIR	
11.	2013	July	Draft Synthetic Turf Requirements for the Large Landscape Grant Program	WRD, WW, WC (A. Dougherty, J. Gilman, K. Kortkamp)	Internal SFPUC memo to P. Kehoe, J. Ortiz, M. Jurosek (2 p.)	
12.	2013	August	Environmental Testing Protocols for the Procurement of Synthetic Turf Products	David Teeter Consulting, San Francisco	Letter report (69 p.) prepared for SFRPD	
13.	2013	December	SFSU Recreation Wellness Center Coordination with CCSF	SF State, URS (W. Bloom, A. Sansevero)	Agenda package (7 p.), meeting notes (2 p.), sign-in sheet	SFMTA (C. Rivasplata, J. Robbins), SFDPW (N. Elsner), SF Planning (A. Contreras, A. Smith), SFPUC (K. Eickman, J. Gilman; K. Kortkamp, F. Lau, B. Pearl), Sandis (M. Kuykendall), Nelson Nygaard (J. Alba, F. Napolitan), URS (A. Sansevero), SF State (W. Bloom)
14.	2014	January	SFPUC follow up to SFSU Recreation Wellness Center Project Meeting December 3, 2013	SF Bureau of Environmental Management (I. Torrey)	Letter to SFSU (W. Bloom) (2 p.)	
15.	2014	January	SFSU Recreation & Wellness - Follow Up Meeting on Synthetic Turf Field	SFPUC, SFSU (W. Bloom, J. Gilman)	Email string	URS (A. Sansevero), Sandis (M. Kuykendall, A. Fortun), wrns studio (E. Kim), SFPUC (P. Kehoe)
16.	2014	January	Design Options Related To Artificial Turf SF State Recreation Wellness Center Project SFPUC Meeting, January 8, 2014	URS (A. Sansevero)	Meeting agenda (2 p.)	
17.	2014	January	SFSU Recreation Wellness Center Sanitary Sewer Load Projections	SFPUC, SFSU (W. Bloom, J. Gilman, K. Kortkamp, K. Eickman)	Email string	URS (A. Sansevero), Sandis (A. Fortun, M. Kuykendall), SFDPW (C. Wong)
18.	2014	Feb-March	Does SFPUC have a position on artificial turf?	SFPUC (J. Ortiz, A. Frink), question from public (N. Buffum)	Email string	SFPUC (J. Gilman, A. Dougherty, P. Kehoe)
19.	2015	February	USF Benedetti Baseball Field	SFPUC (J. Gilman, K. Kortkamp), Hornberger+Worstell (J. Davis)	Email string	USF (M. London, E. Miles), ARUP (R. Roderick-Jones, J. Mong), Sports Plan Studio (J. Leider), HWI Architects (B. Miller), SFPUC (K. Kortkamp, P. Kehoe)
20.	2015	March	Artificial Turf Policy Discussion Meeting Minutes	SFPUC WWE & WE (Z. Krystal)	Meeting minutes (2 p.)	T. Moala, S. Richie, J. Roddy, L. Regler, J. Gilman, K. Kortkamp
21.	2016	April	Stormwater Management Ordinance	Deputy City Attorney (J. Roddy)	Public Works Code Ordinance 64-14	
22.	2016	May	SF Stormwater Management Requirements and Design Guidelines	SFPUC, Parsons, Port of SF, Louts Water, Water Resources Engineering	(132 p.)	S. Ramirez, P. Kehoe, S. Minick, S. Bloom
23.	2018	July	Discussion of Artificial turf policies	WW, WC, & WRD (K. Kortkamp, Ken, J. Scarpulla, J. Ortiz)	Email string	S. Ramirez, P. Kehoe, S. Minick, S. Bloom
24.	2018	November	USF Benedetti Baseball Field -- Groundwater Infiltration of Artificial Turf Runoff	Hanson Bridgett LLP (A. Bishop), SFPUC (N. Johnson)	Email string	

Table A-1
Timeline of Documents Related to Stormwater Drainage from Synthetic Turf Athletic Fields in San Francisco

Appendix B: Review of 2010-2012 Sampling of Synthetic Turf Drainage at South Sunset Playground and Garfield Square Park

Synthetic turf fields constructed with SBR (styrene butadiene rubber) infill were installed at South Sunset Playground (2.2 acres) and Garfield Square Park (0.9 acre) in San Francisco during 2006-2008 (Table 1). South Sunset Playground is within the Westside Groundwater Basin and Garfield Square Park is in the Mission District (see Figure 1 in main body of technical memorandum).

Following the recommendations of the August 2008 Synthetic Playfields Task Force[4] convened by the San Francisco Recreation and Parks Department (SFRPD), storm drainage from these two fields was sampled during seven 2010-2012 storm events to evaluate whether the drainage met drinking water standards and could be allowed to percolate to groundwater. These samples were collected 2 to 4 years after the two synthetic turf fields were installed.

The sampling protocol for the first five storm events followed the February 2010 draft Synthetic Turf Stormwater Quality Monitoring and Sampling Plan[3], which called for collecting grab samples as early as possible after the beginning of each storm in order to characterize the water quality of the storm's "first flush."

The final two storm events followed the May 2011 First Flush Synthetic Turf Stormwater Quality Monitoring and Sampling Plan[3], which recognized the potential for greater contaminant loading during the first rain event of the season. The 2011 plan called for collecting seasonal first-flush samples at these same two fields during the first substantial rain events (greater than 0.25 inches) of the 2011-12 wet season. The plan specified collecting three samples, one hour apart, as soon as possible after the beginning of a rain event.

Sampled Storm Events

Staff from the Water Resources Division (WRD) of the San Francisco Public Utilities Commission (SFPUC) collected drainage samples from South Sunset Playground and Garfield Square Park during seven 2010-2012 storm events, as summarized in the following table:

	Field Drainage Sample Dates						
Storm event:	1	2	3	4	5	6	7
Synthetic Turf Athletic Field	Feb 22-23, 2010	Mar 2, 2010	Dec 8, 2010	Dec 21-22. 2010	Feb 16-17, 2011	Oct 4-5, 2011	Jan 19-20, 2012
South Sunset Playground	●	●	●		●	●	●
Garfield Square Park	●	●		●	●	●	●

A total of eight samples were collected on five different dates from each field. Single samples were collected during the first six events and three samples were collected one hour apart at each

[4] Summarized in Appendix A.

field during the final sampling event in January 2012 (Table B-1). Because this field work was conducted by a single team, samples were collected from the two synthetic turf fields at different times and after different amounts of storm rainfall for events when both fields were sampled.

Table B-1 provides the following information for each sampled storm event:

- The time of day the sample was collected (not available for the February 2010 and October 2011 events).
- Seasonal rainfall through the day prior to sample collection, expressed as a percent of average water-year rainfall (i.e., October-September).
- Storm rainfall (inches) up to the time of sample collection.
- A summary of water quality constituents detected at concentrations approaching or exceeding applicable standards.

The daily and hourly rainfall data used in this analysis are from the NOAA San Francisco Downtown station located in the Lower Haight near the corner of Hermann and Buchanan streets, about three-quarters of a mile east of the Westside Basin boundary (Figure 1). This station is approximately 4.5 miles from the South Sunset Playground and 1.6 miles from Garfield Square Park. Although rainfall data may be available for stations nearer to these fields, the NOAA Downtown San Francisco station was selected for its accessibility, reliability, hourly data, and nearly complete record. Table B-2 provides the 1921-2019 monthly rainfall record for the Downtown San Francisco station. Average water-year rainfall for the entire record is approximately 21 inches.[5]

Samples were collected under a wide range of conditions. Based on the NOAA Downtown San Francisco gauge:

- Total rainfall was approximately 112, 125, and 67 percent of average during the 2009-10, 2010-11, and 2011-12 water years, respectively (Figure B-1).
- Storm-event rainfall at the time the samples were collected ranged from 0.14 to 1.07 inches (Table B-1). At least two samples from South Sunset Playground were collected after less than 0.25 inches of storm rainfall.
- Sample times ranged from 3 to 31 hours after the beginning of each storm event.
- The February and March 2010 and February 2011 sampling events were conducted after 68 to 78 percent of average water-year rainfall had occurred (Table B-1, Figure B-1). These events were not representative of a seasonal first flush.
- Samples collected during two storms in December 2010 followed days of equal or greater rainfall and after 26 to 44 percent of average water-year rainfall had occurred.

[5] This record appears to combine the historical records of other nearby stations, including the NOAA Mission Dolores station.

- Samples were collected in October 2011 and January 2012 after only 2 and 17 percent of average annual rainfall, respectively (Table B-1). Although collected months apart during the same wet season, both samples may be considered representative of a seasonal first flush given generally low-rainfall conditions during the 2011-12 water year.

Figures B-2 and B-3 provide plots of hourly and cumulative storm rainfall in relation to the time each sample was collected at South Sunset Playground and Garfield Square Park, respectively.

Sample Results

Tables B-3 and B-4 provide the analytical results for water quality samples collected from synthetic turf drainage at South Sunset Playground and Garfield Square Park, respectively. Both total and dissolved metal concentrations were analyzed. Potential transport to groundwater is indicated by dissolved concentrations more so than total concentrations.

At South Sunset Playground (Table B-3):

- Concentrations of total iron ranged from 110 to 3,624 µg/L. Elevated iron (and manganese) may be derived from steel belts and beads included in the tire source material for the SBR infill
- Concentrations of dissolved iron ranged from less than 7 to 849 µg/L, exceeding the secondary maximum contaminant level (MCL) of 300 µg/L in two samples collected during the last monitored event.
- Concentrations of total manganese ranged from 19 to 144 µg/L, whereas concentrations of dissolved manganese ranged from less than 1 to 26 µg/L, below the secondary MCL of 50 µg/L.
- The semi-volatile organic compound (SVOC) bis-(2-ethylhexyl)-phthalate was detected in six samples and exceeded the MCL (4 µg/L) in samples collected during the last two storm events, ranging up to 57 µg/L. Bis-(2-ethylhexyl)-phthalate is a plasticizer used to soften rubber that may have been released from the SBR infill.
- Concentrations of dissolved copper exceeded marine surface water and groundwater environmental screening levels in samples from four of the events.[6]

At Garfield Square Park (Table B-4):

- Concentrations of total iron ranged from 14 to 1,742 µg/L, exceeding the secondary MCL in one sample. None of the dissolved iron concentrations exceeded the MCL.

[6] Environmental screening levels established by the San Francisco Regional Water Quality Control Board. Exceedances do not necessarily indicate that adverse effects could occur given the conservative assumptions used in developing the screening levels (San Francisco Planning Department, 2011). The 3.1 µg/L screening level for copper in groundwater assumes potential discharge to aquatic habitat. The California Regulatory Action Level for copper in drinking water is 1,300 µg/L.

- Concentrations of dissolved copper exceeded marine and groundwater environmental screening levels in samples from six of the events, exceeding screening levels by four to seven times in samples from the early-season storms (events 6 and 7).

Interpretation

Table B-5 provides a summary of water quality constituents detected at elevated concentrations in samples of synthetic turf drainage at South Sunset Playground and Garfield Square Park.

For iron and manganese samples collected from both fields, total versus dissolved concentrations were fairly uncorrelated or possibly inversely correlated. The highest concentrations of total iron and manganese tended to occur in samples collected during mid-season storms (events 1 through 5), whereas the highest dissolved concentrations of iron and manganese occurred during early-season storms (i.e., seasonal first flush; events 6 and 7).

At the South Sunset Playground, the SVOC bis-(2-ethylhexyl)-phthalate was detected in six of the eight samples, and equaled or exceeded the MCL of 4 µg/L in three samples. The highest concentrations (7 to 14 times the MCL) occurred in field drainage from the early-season storms (events 6 and 7).

The sample results for the early-season storms (events 6 and 7) appear to demonstrate that concentrations of dissolved metals (at both fields) and bis-(2-ethylhexyl)-phthalate (at South Sunset Playground) peak during the seasonal first flush. These events occurred four or more years after the fields were installed, suggesting that (a) the fields provide a continual source of these constituents or (b) the source is generated over time through degradation of the turf materials.

During the seventh storm event, concentrations of bis-(2-ethylhexyl)-phthalate in the drainage from South Sunset Playground declined from 57 µg/L to 4 µg/L to below detection in three samples collected one hour apart about 30 hours after the storm began. This observation, combined with detections of approximately 1 µg/L or less during the first four sampled events, suggest that elevated concentrations of bis-(2-ethylhexyl)-phthalate in the drainage from this field occur within a narrow window of time under particular storm conditions. Nevertheless, these detections became the basis for not allowing the infiltration of synthetic turf drainage at South Sunset Playground or the Beach Chalet soccer fields where SBR infill also was used.

Storm Event	South Sunset Playground: Sample Date & Time		% Avg. Water-Year Rainfall thru Prior Day*	Storm Duration Up to Time of Sample (hrs)	Storm Rainfall Up to Time of Sample (inches)	Detec-tions	Garfield Square Park: Sample Date & Time		% Avg. Water-Year Rainfall thru Prior Day*	Storm Duration Up to Time of Sample (hrs)	Storm Rainfall Up to Time of Sample (inches)	Detec-tions
1	2/23-24/2010	*NR*	71%	-	-	a,c,f	2/23-24/2010	*NR*	75%	-	-	f
2	3/2/10	6:30	78%	3	0.18	a,c,d	3/2/10	8:20	78%	4	0.32	a,f
3	12/8/10	10:05	26%	4	0.14	a,d,f	-	-	-	-	-	-
4	-	-	-	-	-	-	12/22/10	8:15	44%	12	0.58	f
5	2/17/11	11:05	68%	15	0.73	a,c,d	2/17/11	11:40	68%	16	1.03	f
6	10/5/11	*NR*	2%	-	-	e,f	10/5/11	*NR*	2%	-	-	f
7	1/20/12	18:45	17%	29	0.85	a,e,f	1/20/12	6:35	17%	17	0.32	f
		19:45		30	0.94	a,b,d,f		7:30		18	0.34	f
		20:45		31	1.07	a,b,f		8:40		19	0.38	f

NR Not recorded, unable to estimate event rainfall prior to sample.

* Water year (Oct-Sep) average approximately 21 inches.

Samples collected and analyzed by SFPUC.

Rainfall data for San Francisco Downtown, NOAA Station USW00023272.

Detections summarized from Tables B-3 and B-4:

[a] Total iron above secondary MCL.
[b] Dissolved iron above secondary MCL.
[c] Total manganese above secondary MCL.
[d] Bis-(2-ethylhexyl)-phthalate below MCL.
[e] Bis-(2-ethylhexyl)-phthalate above MCL.
[f] Dissolved copper above environmental screening levels for marine surface water and groundwater.

Table B-1
Rainfall Associated with Synthetic Turf Drainage Sampling Events at South Sunset Playground and Garfield Square Park, 2010-2012

NOAA Station **San Francisco Downtown, California**

USW00023272 https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00023272/detail

Lat	Long	Elev.
37.77	-122.4	45.7

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY	% of All-Yr Avg		No. Yrs
1921	-	-	-	6.30	1.38	2.28	0.54	0.52	0.00	0.00	0.00	0.35	-	-		
1922	0.52	1.43	6.39	2.41	5.15	3.41	0.47	0.55	0.26	0.00	0.00	0.00	20.59	96%		
1923	2.95	3.77	7.77	2.84	0.77	0.03	3.92	0.06	0.06	0.00	0.01	0.44	22.62	106%		
1924	0.50	0.49	1.91	2.75	3.30	1.96	0.30	0.00	0.00	0.00	0.01	0.00	11.22	53%		
1925	2.98	1.50	7.37	1.62	7.90	2.63	2.73	4.02	0.05	0.06	0.00	0.45	31.31	147%		
1926	0.31	2.32	1.01	5.48	5.40	0.25	5.26	0.15	0.00	0.00	0.04	0.00	20.22	95%		
1927	1.90	7.21	1.04	3.77	6.85	2.19	1.95	0.10	0.38	0.00	0.00	0.00	25.39	119%		
1928	1.93	3.18	3.94	1.43	1.97	4.65	1.31	0.26	0.00	0.00	0.00	0.03	18.70	88%	88%	13
1929	0.13	3.35	4.89	1.32	2.14	1.56	1.01	0.01	0.86	0.00	0.00	0.00	15.27	71%		
1930	0.01	0.00	3.09	4.99	2.94	3.53	1.56	0.16	0.00	0.00	0.00	0.10	16.38	77%		
1931	0.89	1.56	0.98	5.47	1.10	1.68	0.31	1.10	0.32	0.00	0.00	0.00	13.41	63%		
1932	0.68	2.93	9.24	3.23	3.00	0.86	0.47	0.65	0.03	0.16	0.00	0.00	21.25	99%		
1933	0.01	1.00	2.75	5.68	1.13	2.93	0.06	1.36	0.01	0.00	0.00	0.14	15.07	71%		
1934	1.49	0.00	4.19	1.03	4.68	0.07	0.51	0.12	0.68	0.01	0.00	0.13	12.91	60%		
1935	0.88	3.76	4.06	6.23	2.38	2.31	3.45	0.01	0.00	0.00	0.25	0.08	23.41	110%		
1936	1.44	1.24	3.25	5.77	10.06	1.01	1.09	0.49	0.28	0.03	0.02	0.00	24.68	116%		
1937	0.69	0.01	2.94	5.26	4.88	7.05	2.14	0.06	0.60	0.00	0.00	0.00	23.63	111%		
1938	0.90	2.46	3.73	2.65	8.49	5.73	1.52	0.00	0.00	0.01	0.00	0.15	25.64	120%		
1939	1.33	0.88	1.48	3.07	1.94	2.62	0.42	0.63	0.00	0.00	0.00	1.06	13.43	63%		
1940	0.17	0.20	0.94	10.03	7.81	5.32	0.94	0.63	0.01	0.00	0.00	0.59	26.64	125%	110%	12
1941	1.05	2.22	6.25	8.24	6.71	4.75	4.05	1.18	0.01	0.01	0.03	0.00	34.50	161%		
1942	0.93	1.99	7.29	4.76	4.27	2.62	3.79	1.11	0.00	0.01	0.00	0.18	26.95	126%		
1943	0.95	4.46	2.87	6.15	1.95	3.18	1.88	0.13	0.13	0.00	0.00	0.02	21.72	102%		
1944	0.74	0.80	2.69	4.31	5.34	0.83	2.07	0.94	0.12	0.01	0.02	0.00	17.87	84%		
1945	1.70	6.24	3.97	1.33	3.43	4.15	0.32	0.64	0.01	0.00	0.00	0.04	21.83	102%		
1946	1.95	3.24	9.84	1.76	2.03	2.34	0.05	0.37	0.02	0.06	0.00	0.06	21.72	102%		
1947	0.15	2.73	2.77	1.35	2.65	3.64	0.17	0.67	0.64	0.00	0.00	0.00	14.77	69%		
1948	2.09	1.39	1.84	1.00	2.32	3.08	3.04	0.54	0.01	0.02	0.02	0.09	15.44	72%	76%	4
1949	0.20	1.18	4.76	2.20	3.04	5.85	0.00	0.93	0.00	0.06	0.04	0.00	18.26	85%		
1950	0.08	1.18	2.77	7.40	2.33	1.65	0.87	0.37	0.03	0.00	0.00	0.00	16.68	78%		
1951	2.72	4.96	6.01	4.41	3.00	1.32	0.89	0.65	0.04	0.01	0.43	0.08	24.52	115%		
1952	0.81	3.33	7.92	10.69	2.62	4.90	1.08	0.30	0.39	0.00	0.01	0.00	32.05	150%	121%	3
1953	0.07	2.42	9.06	3.26	0.04	1.83	3.42	0.38	0.61	0.00	0.07	0.00	21.16	99%		
1954	0.34	1.88	0.82	3.11	2.42	4.56	0.82	0.11	0.14	0.03	0.20	0.00	14.43	68%		
1955	0.24	2.55	5.67	4.05	1.18	0.29	1.49	0.04	0.00	0.02	0.00	0.02	15.55	73%		
1956	0.03	2.38	11.47	8.72	2.03	0.12	1.68	0.68	0.02	0.00	0.01	0.33	27.47	129%	102%	5
1957	1.14	0.04	0.37	2.84	3.58	2.39	1.09	3.19	0.06	0.01	0.00	1.46	16.17	76%		
1958	3.46	1.13	3.60	4.38	7.78	8.22	5.47	0.88	0.09	0.05	0.00	0.04	35.10	164%		
1959	0.12	0.09	1.48	3.96	4.04	0.30	0.36	0.02	0.00	0.00	0.02	2.06	12.45	58%		
1960	0.00	0.00	1.71	4.04	3.57	2.06	1.16	0.85	0.00	0.00	0.00	0.00	13.39	63%		
1961	0.48	3.35	2.31	2.79	0.96	2.27	0.79	0.88	0.04	0.00	0.02	0.22	14.11	66%		
1962	0.09	4.44	2.13	1.08	6.58	2.76	0.36	0.00	0.00	0.00	0.07	0.22	17.73	83%		
1963	5.51	0.60	2.81	3.35	1.92	3.87	3.35	0.45	0.00	0.00	0.00	0.06	21.92	103%		
1964	1.39	3.52	0.87	3.37	0.19	2.12	0.01	0.22	0.57	0.00	0.01	0.00	12.27	57%		
1965	1.90	3.99	5.35	3.97	0.94	2.92	3.21	0.00	0.00	0.02	0.49	0.00	22.79	107%		
1966	0.01	4.79	3.51	3.27	2.72	0.80	0.36	0.19	0.17	0.06	0.10	0.10	16.08	75%	84%	14
1967	0.01	4.80	3.87	9.49	0.22	4.35	4.90	0.09	1.42	0.00	0.00	0.04	29.19	137%		
1968	0.53	1.10	2.12	4.54	2.28	3.15	0.48	0.22	0.00	0.00	0.03	0.06	14.51	68%		
1969	0.62	2.67	3.91	7.74	7.26	1.01	1.74	0.00	0.05	0.00	0.00	0.01	25.01	117%		
1970	2.61	0.45	6.15	7.81	1.56	1.55	0.06	0.03	0.57	0.00	0.00	0.00	20.79	97%		
1971	0.84	6.44	5.39	2.04	0.26	2.91	0.72	0.19	0.00	0.01	0.01	0.22	19.03	89%		
1972	0.11	1.92	3.93	1.32	2.13	0.23	1.07	0.00	0.11	0.01	0.04	0.54	11.41	53%		

Table B-2
Monthly Rainfall, Downtown San Francisco NOAA Station, 1921-2019

NOAA Station	**San Francisco Downtown, California**													Lat	Long	Elev.
USW00023272	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00023272/detail													37.77	-122.4	45.7
Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY	% of All-Yr Avg		No. Yrs
1973	5.41	6.40	3.53	9.38	6.32	2.63	0.02	0.08	0.00	0.00	0.00	0.33	34.10	160%		
1974	1.81	8.64	4.21	3.66	1.54	5.47	2.20	0.00	0.10	0.73	0.00	0.00	28.36	133%	125%	3
1975	0.91	0.40	1.83	2.85	4.30	5.97	1.30	0.01	0.03	0.21	0.02	0.00	17.83	83%		
1976	1.94	0.28	0.58	0.33	1.96	1.04	0.75	0.01	0.02	0.00	0.80	0.45	8.16	38%	44%	2
1977	0.43	1.18	2.53	1.85	0.93	2.31	0.05	0.55	0.00	0.00	0.00	0.96	10.79	50%		
1978	0.16	2.22	3.33	6.94	4.14	5.90	4.21	0.00	0.00	0.00	0.00	0.19	27.09	127%		
1979	0.00	1.67	0.16	7.45	5.07	1.95	0.85	0.12	0.00	0.07	0.00	0.02	17.36	81%	97%	4
1980	1.94	3.69	4.12	4.63	6.44	1.73	1.29	0.27	0.02	0.05	0.00	0.00	24.18	113%		
1981	0.06	0.29	2.09	4.97	2.09	4.73	0.19	0.16	0.00	0.00	0.00	0.03	14.61	68%		
1982	2.00	5.30	5.11	9.78	3.78	7.73	3.03	0.00	0.06	0.00	0.00	0.72	37.51	176%		
1983	2.79	5.62	2.22	5.77	8.06	9.04	3.48	0.47	0.00	0.01	0.06	0.68	38.20	179%		
1984	0.26	8.20	7.72	0.50	2.34	1.32	0.92	0.16	0.30	0.00	0.24	0.10	22.06	103%	138%	5
1985	2.94	7.45	2.10	0.59	1.98	3.94	0.27	0.09	0.31	0.00	0.00	0.38	20.05	94%		
1986	0.80	4.83	2.47	4.77	8.29	6.25	0.76	0.13	0.00	0.03	0.01	1.32	29.66	139%		
1987	0.11	0.20	1.64	4.26	3.77	2.31	0.14	0.06	0.01	0.00	0.00	0.00	12.50	59%		
1988	1.07	3.09	5.09	4.93	0.40	0.07	1.73	0.66	0.70	0.00	0.00	0.00	17.74	83%		
1989	0.64	3.70	4.23	1.26	1.49	5.28	0.70	0.06	0.07	0.00	0.05	0.98	18.46	86%		
1990	1.18	1.33	0.00	4.02	2.45	1.34	0.58	2.38	0.01	0.00	0.04	0.12	13.45	63%	80%	8
1991	0.20	0.52	1.94	0.60	3.29	5.89	1.07	0.36	0.05	0.00	0.42	0.00	14.34	67%		
1992	2.35	0.50	2.32	2.09	6.34	4.41	0.38	0.00	0.39	0.00	0.02	0.00	18.80	88%		
1993	1.16	0.40	6.03	9.82	4.48	2.90	0.71	0.87	0.27	0.00	0.00	0.00	26.64	125%		
1994	0.33	2.16	2.25	2.77	4.87	0.35	1.12	1.31	0.06	0.00	0.00	0.22	15.44	72%		
1995	0.33	10.49	2.69	8.97	0.24	7.88	1.61	0.97	0.62	0.00	0.00	0.00	33.80	158%		
1996	0.06	0.08	8.13	6.71	5.28	1.28	1.56	1.79	0.00	0.00	0.00	0.04	24.93	117%		
1997	1.05	4.72	7.61	7.59	0.32	0.58	0.29	0.16	0.30	0.00	0.73	0.04	23.39	109%		
1998	1.00	6.97	2.77	12.08	14.89	2.54	2.13	3.92	0.15	0.01	0.01	0.09	46.56	218%		
1999	0.91	4.02	1.42	4.41	7.35	2.34	2.62	0.23	0.12	0.00	0.10	0.59	24.11	113%		
2000	0.65	2.32	0.62	6.41	8.96	2.04	1.66	1.40	0.16	0.02	0.02	0.21	24.47	115%		
2001	2.38	0.85	0.90	3.76	7.73	1.58	1.89	0.00	0.15	0.01	0.05	0.18	19.48	91%	130%	12
2002	0.51	5.18	10.75	2.13	2.59	2.27	0.52	0.84	0.03	0.00	0.03	0.01	24.86	116%		
2003	0.01	2.00	12.03	1.75	1.80	1.71	3.60	0.93	0.00	0.00	0.06	0.00	23.89	112%		
2004	0.04	2.22	7.69	3.40	5.67	1.16	0.12	0.12	0.00	0.00	0.05	0.04	20.51	96%		
2005	2.62	2.07	7.98	4.82	5.19	4.67	2.19	1.32	0.94	0.02	0.01	0.00	31.83	149%		
2006	0.51	2.21	11.19	3.52	2.81	8.74	5.02	0.41	0.00	0.00	0.00	0.00	34.41	161%		
2007	0.63	3.05	5.31	0.72	4.79	0.52	1.44	0.43	0.00	0.02	0.00	0.09	17.00	80%		
2008	2.01	0.96	3.16	8.86	1.87	0.33	0.14	0.03	0.00	0.00	0.01	0.00	17.37	81%	82%	3
2009	0.35	2.31	2.82	0.90	7.92	2.76	0.24	0.80	0.00	0.00	0.00	0.28	18.38	86%		
2010	3.11	0.45	2.77	6.66	3.42	2.79	3.59	0.95	0.07	0.00	0.01	0.02	23.84	112%	124%	2
2011	1.81	3.10	6.71	1.55	4.94	7.02	0.56	1.13	2.02	0.08	0.03	0.00	28.95	135%		
2012	1.38	1.74	0.14	2.68	1.09	5.71	1.43	0.02	0.14	0.01	0.01	0.00	14.35	67%		
2013	1.47	4.50	7.11	0.49	0.85	0.97	1.01	0.04	0.15	0.00	0.04	0.39	17.02	80%	69%	5
2014	0.00	1.26	0.39	0.06	5.82	2.95	1.59	0.03	0.01	0.08	0.01	0.55	12.75	60%		
2015	0.46	2.29	11.70	0.00	1.47	0.12	1.30	0.09	0.12	0.09	0.02	0.09	17.75	83%		
2016	0.00	1.43	5.18	6.94	0.98	6.83	1.46	0.15	0.00	0.02	0.02	0.00	23.01	108%		
2017	2.43	2.21	4.39	9.42	7.60	3.93	2.25	0.00	0.10	0.00	0.01	0.10	32.44	152%	113%	5
2018	0.31	2.83	0.15	5.21	0.21	4.54	3.91	0.04	0.01	0.00	0.00	0.00	17.21	81%		
2019	0.21	3.56	2.18	5.13	7.94	4.31	0.43	1.94	0.00	0.00	0.00		*25.70*	*120%*		
N	98	98	98	99	99	99	99	99	99	99	99	98	98	98	16	
Averages																
All years	1.07	2.66	4.06	4.32	3.74	3.03	1.51	0.53	0.16	0.02	0.05	0.19	21.37	100%	99%	6
1989-2018	1.00	2.60	4.68	4.32	4.22	3.18	1.56	0.69	0.20	0.01	0.06	0.13	22.65	106%	104%	5
1981-2010	1.07	3.12	4.44	4.63	4.48	3.29	1.46	0.70	0.16	0.00	0.06	0.20	23.61	110%	111%	6
All yrs min	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	8.16	38%	44%	2
All yrs max	5.51	10.49	12.03	12.08	14.89	9.04	5.47	4.02	2.02	0.73	0.80	2.06	46.56	218%	138%	14

Table B-2

Monthly Rainfall, Downtown San Francisco NOAA Station, 1921-2019

	water year:	2009-10		2010-11		2011- 12				
	sample date:	2/23/10	3/2/10	12/8/10	2/17/11	10/5/2011 [a]	1/20/12 [b]			
	sample time:	*NR*	6:30	10:05	11:05	*NR*	18:45	19:45	20:45	MCL[c]
Analyte	Units									
pH		6.3[d]	6.6	6.8	8.1	7.4	7.0	6.9	6.8	
Temperature	°F	52[d]	56	54	62	62	53	53	53	
Specific Conductance	µmhos/cm	237[d]	224	197	113	160	209	238	244	900[e]
Total Dissolved Solids	mg/L	102	62	54	74	96	80	164	132	500[e]
Turbidity	NTU	49[(4)]	117	28.9	65.2	11	-	-	-	
Total Suspended Solids	mg/L	25	45	20	23	11	<7	7.0	16.5	
Antimony	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	<2.4	<0.5	<0.5	<0.5	6
dissolved [h]	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	<2.4	<0.5	<0.5	<0.5	
Arsenic	µg/L	< 2	< 2	< 2	< 2	<2	<2	<2	<2	10
dissolved	µg/L	< 2	< 2	< 2	< 2	3.7 J	<2	<2	<2	
Barium	µg/L	70.0	108	76.5	59.2	16.0	26.1	38.9	43.5	1000
dissolved	µg/L	50.1	61.1	61.0	32.8	8.2	24.4	34.7	39.5	
Beryllium	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	<0.24	<0.5	<0.5	<0.5	4
dissolved	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	<0.24	<0.5	<0.5	<0.5	
Cadmium	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	<1	<0.25	<0.25	<0.25	5
dissolved	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	<1	<0.25	<0.25	<0.25	
Chromium	µg/L	5.13	12.25	4.11	6.66	<1.5	1.67	4.26	4.83	50
dissolved	µg/L	1.54	0.84	0.90	0.79	<1.5	1.35	3.34	3.55	
Cobalt	µg/L	1.10	2.64	0.87	1.34	<0.53	0.43	1.01	1.16	-
dissolved	µg/L	0.16	0.08	0.19	0.13	<0.53	0.30	0.67	0.75	
Copper	µg/L	4.39	8.99	4.86	4.69	5.80	4.74	5.78	5.87	1000[d]
dissolved	µg/L	**4.32**	2.40	**3.52**	1.40	**4.2 J**	**4.37**	**5.49**	**5.52**	3.1[f]
Iron	µg/L	**1,387**	**3,624**	**1,426**	**2,440**	**110**	**382**	**1,159**	**1,240**	300[e]
dissolved	µg/L	15.1	5.50	7.56	10.8	<7.2	262	**826**	**849**	
Lead	µg/L	0.64	1.59	0.61	0.91	<1.4	0.51	0.82	0.81	15
dissolved	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	<1.4	<0.5	<0.5	<0.5	
Manganese	µg/L	**51.2**	**144**	41.9	**66.2**	**19.0**	18.6	37.7	39.7	50[e]
dissolved	µg/L	2.36	0.37	0.67	0.43	1.8 J	12.7	26.0	25.8	
Mercury	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	<0.036	<0.2	<0.2	<0.2	2
dissolved	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	<0.036	<0.2	<0.2	<0.2	
Molybdenum	µg/L	0.46	0.34	0.31	0.23	<0.67	<0.35	0.66	0.63	-
dissolved	µg/L	0.57	0.42	0.36	0.34	3.9 J	<0.35	0.62	0.65	
Nickel	µg/L	7.57	18.54	5.59	10.3	<0.83	2.15	5.21	6.05	100
dissolved	µg/L	< 1	< 1	< 1	< 1	<0.83	1.72	3.78	4.09	
Selenium	µg/L	< 2	< 2	< 2	< 2	<3.2	<2	<2	<2	50
dissolved	µg/L	< 2	< 2	< 2	< 2	4.5 J	<2	<2	<2	
Silver	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	<0.62	<0.25	<0.25	<0.25	100[e]
dissolved	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	<0.62	<0.25	<0.25	<0.25	
Thallium	µg/L	< 1	< 1	< 1	< 1	<2.4	<1	<1	<1	2
dissolved	µg/L	< 1	< 1	< 1	< 1	<2.4	<1	<1	<1	
Vanadium	µg/L	3.70	8.83	3.29	4.23	6.40	5.52	4.49	4.38	50[g]
dissolved	µg/L	1.33	1.31	1.30	0.86	5.10	5.34	3.67	3.48	
Zinc	µg/L	31.4	32.3	21.3	27.1	180	124	86.2	74.2	5000[e]
dissolved	µg/L	6.40	3.72	7.37	6.13	97	81.2	65.6	54.8	
VOCs	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	
Semi VOCs: Bis-(2-ethylhexyl)-phthalate	µg/L	<0.3	0.41 J	1.05	0.76 J	**29**	**57.3**	**3.97**	<0.77	**4**

Exceeds environmental screening level.
Exceeds primary MCL.
Exceeds secondary MCL.

MCL Maximum Contaminant Level
ND Not detected
NR Not recorded
J Qualified result

[a]Not in LIMS
[b]"First flush" event.
[c]California MCL.
[d]Used field duplicate value.
[e]Secondary MCL.
[f]Marine and groundwater screening levels.
[g]California Dept. Public Health notification level.
[h]All "disolved" samples were field filtered.
Samples collected and analyzed by SFPUC.

Table B-3

Results of Synthetic Turf Runoff or Leachate Sampling, South Sunset Playground, 2010-2012

	water year:	2009-10		2010-11		2011-12				
	sample date:	2/24/10	3/2/10	12/22/10	2/17/11	10/5/2011[a]	1/20/12[b]			
	sample time:	NR	8:20	8:15	11:40	NR	6:35	7:30	8:40	MCL[c]
Analyte	Units									
pH		7.2	7.1	7.78	7.5	7.5	7.0	7.0	7.2	
Temperature	°F	56	58	54	60	62	54	52	52	
Specific Conductance	µmhos/cm	382	390	304	228	330	648	374	373	900[d]
Total Dissolved Solids	mg/L	212	152	136	126	250	468	282	294	500[d]
Turbidity	NTU	1	43	2	13.8	13	-	-	-	
Total Suspended Solids	mg/L	< 7	28.5	7.0	7.0	< 5	< 7	< 7	< 7	
Antimony	µg/L	0.67	0.70	0.59	0.54	< 2.4	0.52	0.67	0.70	6
dissolved[g]	µg/L	0.61	0.62	0.57	< 0.5	< 2.4	0.55	0.71	0.69	
Arsenic	µg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	10
dissolved	µg/L	< 2	< 2	< 2	< 2	< 2.4	< 2	< 2	< 2	
Barium	µg/L	56.7	138	59.2	56.1	120	196	65.5	80.7	1000
dissolved	µg/L	54.6	68.8	55.8	39.8	94.0	183	67.2	71.7	
Beryllium	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.24	< 0.5	< 0.5	< 0.5	4
dissolved	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.24	< 0.5	< 0.5	< 0.5	
Cadmium	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	< 1.0	< 0.25	< 0.25	< 0.25	5
dissolved	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	< 1.0	< 0.25	< 0.25	< 0.25	
Chromium	µg/L	< 0.5	1.81	< 0.5	< 0.5	< 1.5	0.76	< 0.5	0.75	50
dissolved	µg/L	< 0.5	0.54	< 0.5	< 0.5	1.5 J	0.75	< 0.5	0.59	
Cobalt	µg/L	0.22	1.72	0.20	0.57	< 0.53	0.31	0.55	0.84	-
dissolved	µg/L	0.22	0.18	0.16	0.19	1.1 J	0.31	0.55	0.58	
Copper	µg/L	5.48	8.91	5.70	5.75	26.0	12.0	14.4	15.8	1000[d]
dissolved	µg/L	**5.90**	**4.67**	**5.49**	**4.82**	**23.0**	**11.7**	**14.4**	**15.7**	3.1[e]
Iron	µg/L	14.4	**1,742**	15.0	188	160	47.8	47.2	255	300[d]
dissolved	µg/L	< 2.5	< 2.5	2.98	5.99	< 7.2	26.9	36.9	39.3	
Lead	µg/L	< 0.5	1.69	< 0.5	< 0.5	< 1.4	< 0.5	< 0.5	< 0.5	15
dissolved	µg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 1.4	< 0.5	< 0.5	< 0.5	
Manganese	µg/L	0.87	35.0	0.68	5.00	7.00	3.08	1.81	6.97	50[d]
dissolved	µg/L	1.87	0.53	0.30	1.50	2.6 J	1.88	1.73	3.87	
Mercury	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	0.38	< 0.2	< 0.2	< 0.2	2
dissolved	µg/L	< 0.2	< 0.2	< 0.2	< 0.2	0.28	< 0.2	< 0.2	< 0.2	
Molybdenum	µg/L	8.69	8.26	9.35	7.32	13.0	6.13	10.7	10.6	-
dissolved	µg/L	8.44	7.37	9.51	7.83	11.0	6.17	10.6	10.0	
Nickel	µg/L	3.80	7.34	4.01	3.58	8.00	6.00	4.95	7.09	100
dissolved	µg/L	3.64	3.89	3.78	2.53	6.20	5.79	4.97	6.05	
Selenium	µg/L	< 2	< 2	< 2	< 2	< 3.2	< 2	< 2	< 2	50
dissolved	µg/L	< 2	< 2	< 2	< 2	8.7 J	< 2	< 2	< 2	
Silver	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	< 6.2	< 0.25	< 0.25	< 0.25	100[d]
dissolved	µg/L	< 0.25	< 0.25	< 0.25	< 0.25	< 6.2	< 0.25	< 0.25	< 0.25	
Thallium	µg/L	< 1	< 1	< 1	< 1	< 3.0	< 1	< 1	< 1	2
dissolved	µg/L	< 1	< 1	< 1	< 1	< 3.0	< 1	< 1	< 1	
Vanadium	µg/L	1.60	6.52	1.62	2.07	5.70	4.68	1.53	2.45	50[f]
dissolved	µg/L	1.49	2.14	1.34	1.39	3.8 J	4.47	1.54	1.89	
Zinc	µg/L	58.5	137	51.6	41.0	82.0	140	46.6	104	5000[d]
dissolved	µg/L	42.2	72.8	60.3	29.5	63.0	127.3	52.1	87.9	
VOCs	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	
Semi VOCs	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	

Exceeds environmental screening level.

Exceeds secondary MCL.

MCL Maximum Contaminant Level

ND Not detected

NR Not recorded

J Qualified result

[a]Not in LIMS

[b]"First flush" event.

[c]California MCL.

[d]Secondary MCL.

[e]Marine and groundwater screening levels.

[f]California Dept. Public Health notification level.

[g]All "disolved" samples were field filtered.

Samples collected and analyzed by SFPUC.

Table B-4

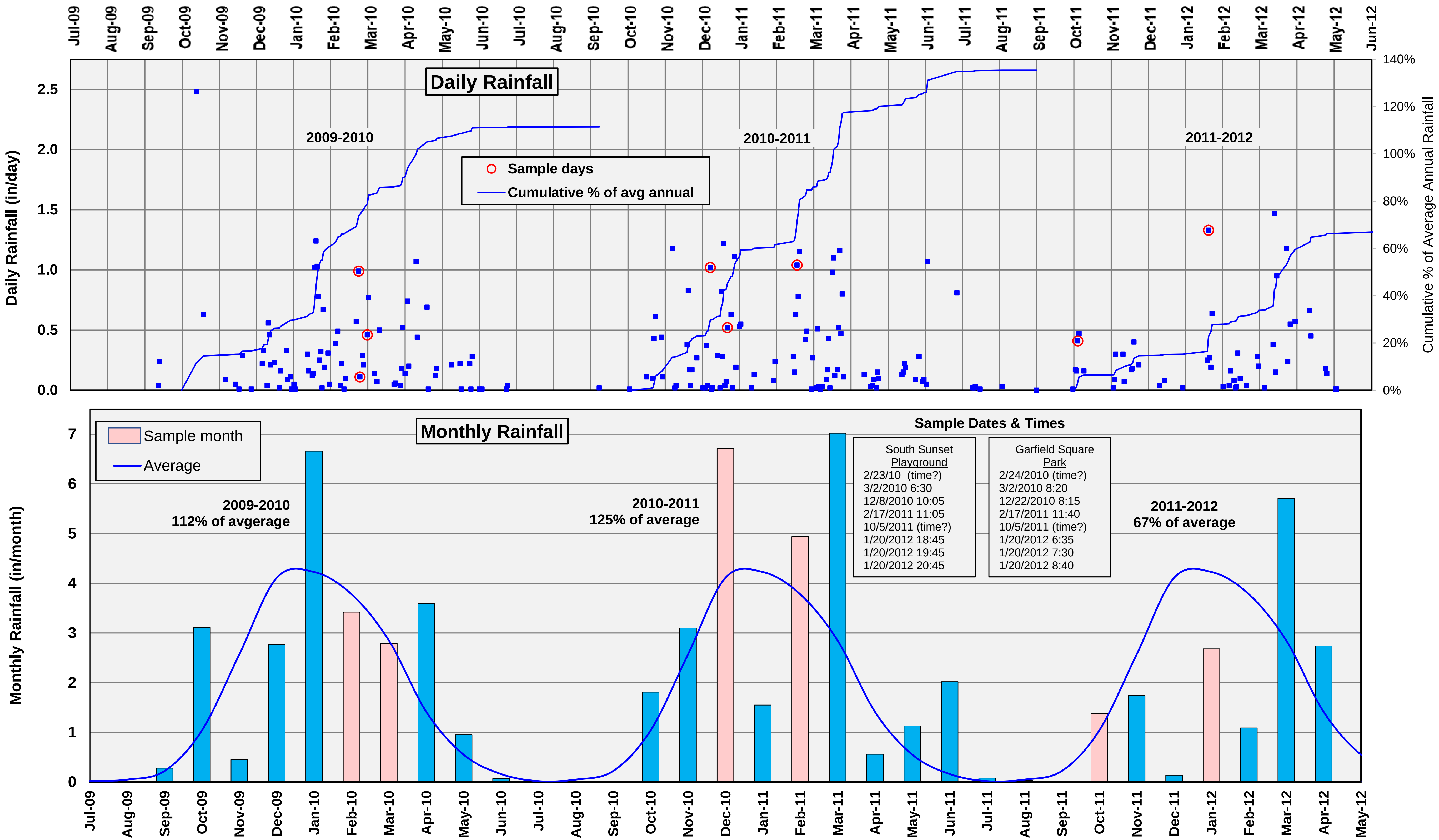
Results of Synthetic Turf Runoff or Leachate Sampling, Garfield Square Park, 2010-2012

Storm Event	Sample Date & Time		% Avg. Water-Year Rainfall thru Prior Day[a,b]	Approx. Storm Duration Up to Time of Sample (hrs)	Approx. Storm Rainfall Up to Time of Sample (inches)[b]	Specific Conductance	Total Iron	Dissolved Iron	Total Manganese	Dissolved Manganese	Bis-(2-ethylhexyl)-phthalate	Dissolved Copper
						(µg/L)						
	Applicable Standards:					*900* [c]	*300* [c]		*50* [c]		*4* [d]	*3.1* [e]
South Sunset Playground												
1	2/23-24/10	NR	71%	-	-	237	1,387	15.1	51	2.4	<0.3	**4.3**
2	3/2/10	6:30	78%	3	0.18	224	3,624	5.5	144	0.4	0.4	2.4
3	12/8/10	10:05	26%	4	0.14	197	1,426	7.6	42	0.7	1.1	**3.5**
5	2/17/11	11:05	68%	15	0.73	113	2,440	10.8	66	0.4	0.8	1.4
6	10/5/11	NR	2%	-	-	160	110	<7.2	19	1.8	**29**	**4.2**
7	1/20/12	18:45	17%	29	0.85	209	382	262	19	13	**57**	**4.4**
		19:45		30	0.94	238	1,159	**826**	38	26	4.0	**5.5**
		20:45		31	1.07	244	1,240	**849**	40	26	<0.77	**5.5**
Garfield Square Park												
1	2/23-24/10	NR	75%	-	-	382	14	< 2.5	0.9	1.9	ND	**5.9**
2	3/2/10	8:20	78%	4	0.32	390	1,742	< 2.5	35	0.5	ND	**4.7**
4	12/22/10	8:15	44%	12	0.58	304	15	3.0	0.7	0.3	ND	**5.5**
5	2/17/11	11:40	68%	16	1.03	228	188	6.0	5.0	1.5	ND	**4.8**
6	10/5/11	NR	2%	-	-	330	160	< 7.2	7.0	2.6	ND	**23**
7	1/20/12	6:35	17%	17	0.32	648	48	27	3.1	1.9	ND	**12**
		7:30		18	0.34	374	47	37	1.8	1.7	ND	**14**
		8:40		19	0.38	373	255	39	7.0	3.9	ND	**16**

[a] Water year (Oct-Sep) average approximately 21 inches.
[b] Rainfall data for San Francisco Downtown, NOAA Station USW00023272.
[c] Secondary MCL; typically applied to dissolved concentrations.
[d] Primary MCL.
[e] Marine surface water and groundwater environmental screening level.

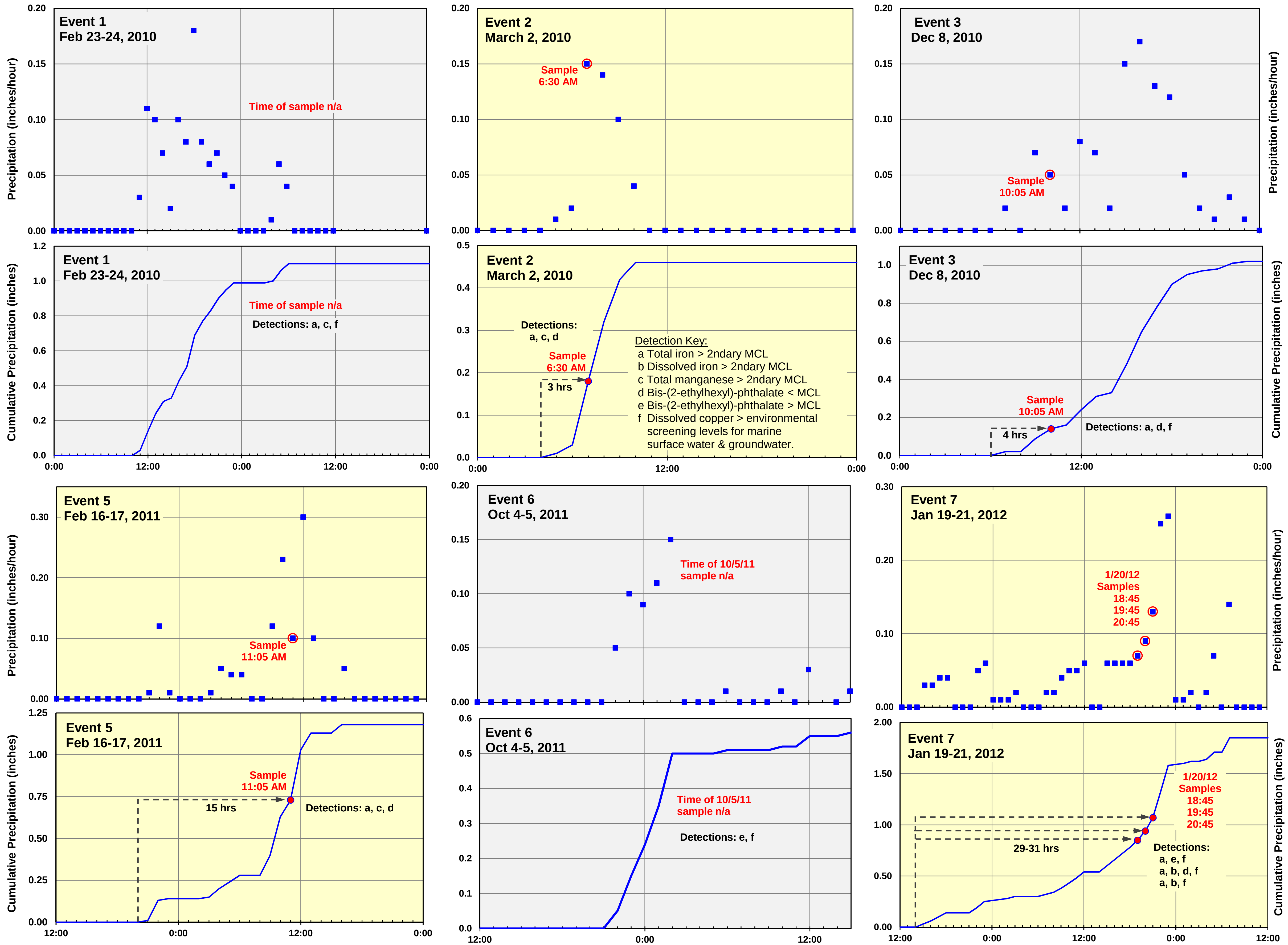
NR not recorded
ND not detected
MCL maximum contaminant level
bold exceeds standard

Table B-5
Summary of Water Quality Constituents with Elevated Concentrations Detected in Synthetic Turf Drainage at South Sunset Playground and Garfield Square Park



Rainfall data for San Francisco Downtown, NOAA Station USW00023272.
Both fields installed 2006-08

Figure B-1
Monthly and Daily Rainfall Relative to Synthetic Turf Drainage Sample Dates, 2010-2012

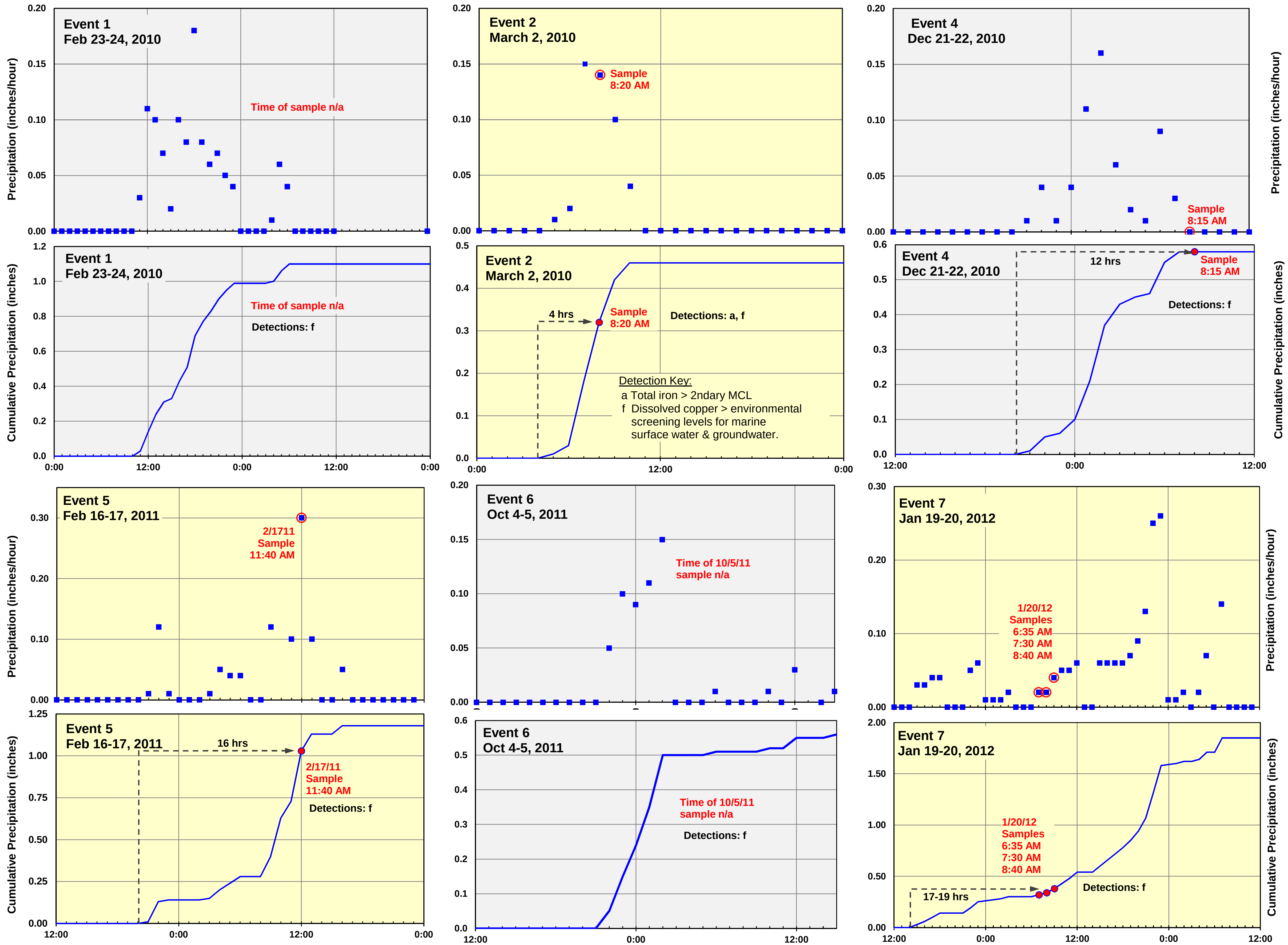


)23272.

n/a not available

Figure B-2

Hourly Rainfall During Storms When Synthetic Turf Drainage Sampled at South Sunset Playground



Rainfall data for San Francisco Downtown, NOAA Station USW00023272.
Note differences in scale of axes.
n/a not available

Figure B-3
Hourly Rainfall During Storms When Synthetic Turf Drainage Sampled at Garfield Square Park

Appendix C: Review of Other Literature Related to Synthetic Turf

This appendix provides the results of a search for literature pertaining to potential water quality impacts from synthetic turf. Twenty-three documents are listed chronologically and aspects relevant to groundwater are quoted or summarized. Many of the studies pertain to surface water and other above-ground exposures. Citations lacking a summary or quoted text indicate that little or no information relevant to groundwater impacts was found.

2006, *An Assessment of Environmental Toxicity and Potential Contamination from Artificial Turf using Shredded or Crumb Rubber*, Ardea Consulting, report by J.P. Sullivan prepared for Turfgrass Producers International, 43 p., March.

"The actual amount of contamination leaching from artificial turf used on playgrounds or athletic fields needs further research to determine the potential harm to human health or the environment… Tire chips should be used below the groundwater table only where higher levels of iron and manganese can be tolerated… In almost all studies, the iron level exceeded the Recommended Allowable Level… Iron is not an ingredient in rubber compounds. Its presence in some of the groundwater tests indicates that the steel belts and beads were not completely extracted during the tire recycling operation. Consideration should be given to establishing a maximum allowable steel content for recycled tire rubber… Because metals can be leached at low pH and organic compounds can be leached at high pH, unbound shredded tires should be used in environments where the soil and groundwater are at a fairly neutral pH."

2008, *A Review of Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill*, TRC, report prepared for New York City Department of Health and Mental Hygiene, 200 p., May.

2008, *The Effects of Crumb Rubber on Water Quality*, The Coastal Marine Resource Center, white paper by C. Graham for CMRC.org, NY, 9 p., September.

2008, *Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields*, Milone & MacBroom, compendium of three white papers: (1) Thermal Effects Associated with Crumb Rubber In-filled Synthetic Turf Athletic Fields; (2) Evaluation of Benzothiazole, 4-(tert-octyl) Phenol and Volatile Nitrosamines in Air at Synthetic Turf Athletic Fields; (3) Evaluation of Stormwater Drainage from Synthetic Turf Athletic Fields, 46 p., December.

2009, *An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb-Rubber Infilled Synthetic Turf Fields*, New York State Department of Environmental Conservation and Health, report by L. Lima and R. Walker, 140 p., May.
http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

"The objectives of the groundwater survey were to collect samples from downgradient wells at existing synthetic turf fields and to measure the concentrations of SVOCs that may leach from the crumb rubber. The concentrations of these compounds were compared to the NYS Groundwater Quality Standards (NYSDEC 1998b). To obtain samples in a timely manner, the survey focused on areas where sandy soil is predominant. In 2008, four turf fields were selected ranging from less than 1 to 7 years old… Two to three downgradient wells were installed at each field and samples were collected at various depths… The thirty-two groundwater samples at these sites have a depth to the groundwater table ranging from 8.3 ft to 70 ft… Based on test results of 32 groundwater samples**,** no organics or zinc were detected at the turf fields… Application of the dilution-attenuation factor (DAF) to the leachate results in this study demonstrates that crumb rubber can be used as an infill without significant impact on groundwater quality."

"Highly varied concentrations of chemicals and metals were found in samples from within each artificial turf field tested… Results indicated that significant concentrations of zinc, aniline, phenol and benzo-thiazole (BZT) were leaching from the [crumb rubber].

"Groundwater test results at the two artificial turf fields targeted for this survey identified no chemicals or metals in groundwater. However, the groundwater was collected from deep wells and researchers noted that they would perform additional testing at more shallow depths in the future to better characterize the potential risk… The study cautioned that sufficient distance and soil barriers must be placed between the contaminating synthetic turf fields and groundwater in order to protect public health.

"As leachate moves through soil to the groundwater table, contaminant concentrations are attenuated by adsorption and degradation, and further reduced by dilution when contaminants are mixed with groundwater. An analysis of attenuation and dilution mechanisms and the associated reduction factors indicates that crumb rubber may be used as an infill without significant impact on ground- water quality, assuming the limitations of mechanisms, such as separation distance to groundwater table, are addressed."

2010, *Field, Pilot, and Laboratory Studies for the Assessment of Water Quality Impacts of Artificial Turf*, Cheng, H., and Reinhard, M., Dept. Civil and Environmental Engineering, Stanford University, report prepared for Santa Clara Valley Water District, 100 p., June.

"An exploratory study commissioned by Santa Clara Valley Water District (SCVWD) found heavy metals (barium, chromium, copper, and particularly, zinc) and organic compounds (benzoic acid and phenol) leaching from two artificial turfs (from two different manufacturers) using the Toxicity Characteristic Leaching Procedure (TCLP). Benzoic acid and phenol are deemed of lesser concern because they can be photochemically or biologically degraded. Thus, in surface and groundwater, relatively effective natural attenuation of these contaminants can be expected. Results of the TCLP study are difficult to extrapolate to environmental conditions because conditions were far more aggressive than those encountered in the environment."

2010, *Artificial Turf Study, Leachate and Stormwater Characteristics*, Connecticut Department of Environmental Protection (DEP), 24 p., July.

"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."

2011, *Effectiveness of Field Turf Artificial Turf for Management of Stormwater*, AKRF, Inc and D. S. Thaler and Associates, report prepared for Field Turf, 22 p., June.

"A study of four artificial turf fields in Connecticut (Connecticut Department of Environmental Protection, 2010) found that zinc leaching from artificial turf fields was a potential risk to surface waters, but in evaluating the potential risks of stormwater runoff the study goes on to state that, '*Since the mean concentration of zinc in the stormwater samples is below 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.'* A recent Montgomery County, Maryland report (Montgomery County Staff Work Group, 2011) reported that samples obtained from an on-going San Francisco Public Utilities synthetic turf monitoring study showed total zinc levels above the Maryland Toxic Substances Criteria for Ambient Surface Waters (120 µg/l) standard but showed dissolved zinc levels below the acute toxicity level."

2011, *Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five Fields in Connecticut*, Ginsberg, G., Toal, B., Simcox, N., Bracker, A., Golembiewski, B., and Kurland, T., Hedman, C., Journal Toxicol Environ Health, v. 74, n. 17, pp. 1150-74.

"The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials."

2011, *Nature Grass vs Synthetic Turf Report*, Department of Local Government, Sport and Cultural Industries, Chapter 7, Broader Environmental Considerations, Government of Western Australia.

2014, *Bio-Accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers*, Pavilonis, B.T., Weisel, C.P., Buckley, B., and Lioy, P.J., Risk Analysis, v. 34, n. 1, pp. 44-55, January.

2014, *Environmental and Health Impacts of Artificial Turf: A Review*, Cheng, H., Hu, Y., and Reinhard, M., Environmental Science and Technology, v. 48, n. 4, pp. 2114-2132, January.

"A number of field studies have been conducted to investigate the impact of tire shreds and chips used in civil engineering applications on the quality of surface water and groundwater through sampling of existing sites and field trials with follow-up monitoring of up to 2 years. In general, Fe, Mn, Zn, and Al appeared to be the major contaminants of concern even though their concentrations did not exceed the respective maximum contaminant levels (MCLs) for drinking water in most cases, while the organic contaminants (e.g., amines, aniline, quinoline, amides, and

benzothiazole) occurred only at trace levels. These results suggest that scrap tire materials may affect surface water and/or groundwater and warrant further field study with controls.

"Even though leachate from tire chips and tire rubber crumb can be toxic to some aquatic life, dilution (i.e., by infiltrating rainwater and groundwater) in natural systems is expected to reduce its toxicity and lower the associated ecological risk.

"A limited number of studies have shown that the concentrations of volatile and semi-volatile organic compounds in the air above artificial turf fields were typically not higher than the local background, while the concentrations of heavy metals and organic contaminants in the field drainages were generally below the respective regulatory limits."

2014, *Artificial Turf*, Santa Clara Valley Water District, fact sheet, publication 503, March, 1 p.

2015, *Science May Get Sidelined in Artificial Turf Debate*, Mole, B., Science News, https://www.sciencenews.org/blog/growth-curve/science-may-get-sidelined-artificial-turf-debate, 3 p., April.

2015, *Consideration of Artificial Turf Pilot Study: Follow-up to Questions Raised at June 23, 2015 Board Meeting*, East Bay Municipal Utilities District, presentation to Board of Directors, 10 p., July.

2015, *Leaching of Dissolved Organic Carbon, Dissolved Nitrogen, and Inorganic Constituents from Scrap Tires*, Selbes, M., Yilmaz, O., Khan, A.A., and Karanfil, T., Chemosphere, v. 139, November, http://www.sciencedirect.com/science/article/pii/S004565351500082X.

"This study offers no confirmation that synthetic turf fields are safe… The results of testing suggest that exposure to acidic rainwater or groundwater may increase the rates at which dissolved organic carbon and some inorganic compounds leach from crumb rubber infill. The study also found rapid initial leaching rates for compounds they measured… While these rates may drop to a constant level over time, this observation raises a health concern about an increased risk of exposures, especially to children, from new fields and playgrounds containing recycled rubber infill and mulch, as well as from fields and playgrounds that are routinely refilled to replenish the surface cushion because of infill and mulch migrating due to use and weather. Finally, the identification of lead in all samples observed in this study is of great concern."

2016, *Understanding Rainfall and Drainage in Synthetic Turf Systems*, Brock International, presentation to ASBA, 31 p., January.

2016, *Ordinance Amending Section 17.612.010 of the Sacramento City Code Relating to Landscape Requirements and the Use of Artificial Turf City of Sacramento*, Community Development Department, City Council Report, 14 p., December.

2017, *Synthetic Turf Industry's Claims Versus the Science: A Careful Analysis of Studies that Industry Uses to Justify Safety Claims*, Environment & Human Health, Inc., report, 112 p.

2018, *Comprehensive Multipathway Risk Assessment of Chemicals Associated with Recycled ("Crumb") Rubber in Synthetic Turf Fields*, Peterson, M.K., Lemay, J.C., Shubin, P., and Prueitt, R.L., Environmental Research, v. 160, pp. 256-268.

"…results add to the growing body of literature that suggests recycled rubber infill in synthetic turf poses negligible risks to human health."

2019, *Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan*, USEPA/ORD and Centers for Disease Control and Prevention Agency for Toxic Substances and Disease Registry and, Final Report Part 1–Tire Crumb Rubber Characterization Appendices, Volume 2, 456 p., July.

2019, *Synthetic Turf News*, California Office of Environmental Health Hazard Assessment (OEHHA), https://oehha.ca.gov/risk-assessment/synthetic-turf-studies.

2019, *Synthetic Turf Health and Environmental Impacts*, Center for Sports Surface Research, Penn State College of Agricultural Sciences, bibliography, https://plantscience.psu.edu/research/centers/ssrc/research/synthetic-turf-health.

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