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M E M O R A N D U M

TO:	Wayland Conservation Commission
FROM:	Weston & Sampson Design Team
DATE:	September 13, 2018
SUBJECT:	264 Old Connecticut Path (Wayland High School), DEP File No. 322-928 | 412 Commonwealth Road (Loker Conservation and Recreation Area), DEP File No. 322-XXX

The following information is submitted on behalf of Ben Keefe and other project proponents in response to numerous documents that have been submitted to the Wayland Conservation Commission as part of the Notice of Intent process for the two subject projects.

- Document #1 - "Wetland Pollution from Crumb Rubber Athletic Fields" PowerPoint presentation prepared by John Sax
- Document #2 – "Statement Re a Replacement High School Turf Field", submitted by Tom Sciacca, dated 10/23/18
- Document #3 – "Submission to the Conservation Commission", by Willow Brook Condominium Association, dated 10/23/18

Document #1 "Wetland Pollution from Crumb Rubber Athletic Fields" PowerPoint presentation prepared by John Sax

Response prepared by:
Weston & Sampson
Marie Rudiman
Toxicologist/Senior Risk Assessor

Weston & Sampson has reviewed the presentation and we provide the following responses related to:

1) the scientific data available regarding the potential health hazards of crumb rubber and the potential leaching of zinc into groundwater and surrounding surface water
2) the applicable MassDEP and EPA standards for protection of human and ecological health and how they apply to exposure to zinc concentrations that may leach from the artificial turf field and crumb rubber
3) innovations in crumb rubber that have greatly reduced the potential for leaching from crumb rubber
4) how rain water drains through the artificial turf.

Potential Health Hazards of Crumb Rubber

Mr. Sax asserts on slide 3, “Pending EPA study results, the jury is still out on the hazards of chemicals leached from Crumb Rubber in athletic fields. Some experts believe leached chemical interactions could enhance toxic effects.”

This is the statement on EPA’s website: “Concerns have been raised by the public about the safety of recycled tire crumb used in playing fields in the United States. Limited studies have not shown an elevated health risk from playing on fields with tire crumb, but the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb. Because of the need for additional information, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Consumer Product Safety Commission (CPSC) are launching a multi-agency Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds to study key environmental human health questions.”

https://www.epa.gov/chemical-research/federal-research-action-plan-recycled-tire-crumb-used-playing-fields

Based on their review of existing information, EPA initially came out with statement that there was not an elevated health risk from playing on fields with tire crumb and that artificial turf fields with crumb rubber in fill were safe for use. However, researchers and members of the public pointed out numerous data gaps that existed in the research. Due to the concerns about the lack of sufficient data, EPA pulled back that initial conclusion to complete more comprehensive studies on artificial turf fields and crumb rubber. While it is true that EPA has not completed the additional studies and more comprehensive review of the data on crumb rubber and the use of artificial turf fields, there is a growing body of scientific data indicating that they are safe for use and do not cause an adverse health risk in humans.

In addition to our independent evaluation of artificial turf at the Fenn School in Concord, MA that has previously been presented to the Town of Wayland, there are numerous studies that have concluded artificial fields are safe for use. Below is a partial list of the scientific literature that have found that artificial turf fields do not cause an adverse health risk in humans and are safe for use:

- “…it appears that the health risks for players who use artificial turf are not significant and that it is completely safe to engage in sports activities on this type of outdoor field.” Beausoleil, et al (2009).

- Researchers “designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment.” Birkholz, et al (2003).

- "PM2.5 and associated elements (including lead and other heavy metals) were either below the level of detection or at similar concentrations above artificial turf athletic fields and upwind of the fields." "The large majority of air samples collected from above artificial turf had VOC concentrations that were below the limit of detection. "Fewer bacteria were detected on artificial turf compared to natural turf." California Office of Environmental Health Hazard Assessment, (2010).

- “Health risk assessment studies suggested that users of artificial turf fields, even professional athletes, were not exposed to elevated risks. Preliminary life cycle assessment suggested that the environmental impacts of artificial turf fields were lower than equivalent grass fields.” Cheng, et al. (2014).

- "In spite of the conservative nature of the assessment, cancer risks were only slightly above de minimis levels for all scenarios evaluated including children playing at the indoor facility, the scenario with the highest exposure. The calculated risks are well within typical risk levels in the community from ambient pollution sources and are below target risks associated with many air toxics regulatory programs. Chronic non-cancer risks were not elevated above a Hazard Index of 1." "Cancer risks are slightly above de minimis in all scenarios." Connecticut Department of Public Health (CDPH), (2010).

- "Based on the information reviewed none of the risk assessments showed concentrations of contaminants that would be at a level of concern, even under conservative assumptions and thus it does not appear that the ingestion of tire crumb would pose a significant health risk for children or adults." Denly, et al. (2008).

- "Cancer and noncancer risk levels were at or below de minimis levels of concern. The scenario with the highest exposure was children playing on the indoor field. Based upon these findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks." Ginsberg, et al. (2011).

- "Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contact we conclude, that there is not a significant health risk due to the presence of rubber infill for football players an artificial turf pitch with rubber infill from used car tyres." Hofstra, U. (2007a).

- "On the basis of estimated exposure values and the doses/concentrations which can cause harmful effects in humans or in animal experiments, it is concluded that the use of artificial turf halls does not cause any elevated health risk. This applies to children, older children, juniors and adults. The estimated Margins of Safety (MOS) also give no cause for concern." Norwegian Institute of Public Health and the Radium Hospital. (2006).

- "...crumb rubber may be used as an infill without significant impact on groundwater quality...Analysis of crumb rubber samples digested in acid revealed that the lead concentration in the crumb rubber samples were well below the federal hazard standard for lead in soil...A risk assessment for aquatic life protection...found that for the three types of crumb rubber, aquatic toxicity was found to be unlikely...A public health evaluation was conducted on the results from the ambient air sampling and concluded that the measured levels of chemicals in air at the Thomas Jefferson and John Mullaly Fields do not raise a concern for non-cancer or cancer health effects for people who use or visit the fields...the findings do not indicate that these fields are a significant source of exposure to respirable particulate matter" New York Department of Environmental Conservation (NYDEC). (2009).

Potential Leaching of Zinc from Crumb Rubber that may Affect Aquatic Receptors

Mr. Sax asserts on slide 3, “Zinc leached from crumb rubber is toxic to wetlands aquatic life.” He goes on in slide 5 to present literature data that shows zinc leaches from crumb rubber at concentrations up to 488 ug/L (which was rounded up to 500 ug/l in a review article). He then compares that data to the EPA Ambient Water Quality Criteria (AWQC) of 120 ug/L and concludes on slide 7 that, “Zinc levels will exceed EPA standards for aquatic life.” Note that the EPA AWQC is a surface water standard.

The data that Mr. Sax references was all cited in a comprehensive review of leaching data from crumb rubber fields by Cheng, H., et al., 2014. Two other studies cited in the same review article but not presented in Mr. Sax’s presentation, Bristol and McDermott (2008), and Hofstra (2008), observed lower concentrations of zinc in leachate, <2 to 36 ug/L and a mean of 16 ug/L, respectively. The concentrations of zinc in those studies were well below the AWQC of 120 ug/L. The data that was cited by Mr. Sax was, in both cases, runoff water collected directly from the artificial field and not surface water. In the proposed artificial turf systems, rain water will percolate through the field, migrate into groundwater and eventually migrate into surface water rather than running off the field directly into surface water. A more appropriate standard to compare the field run off to would be the MassDEP Method 3 GW-3 standard for zinc in groundwater of 900 ug/L that is protective of potential affects to aquatic receptors. This standard is based upon the EPA AWQC but takes into account the potential for attenuation and dilution that may occur as surface runoff migrates into groundwater and then groundwater migrates into surface water. To the lay-person, this may seem like splitting hairs, however, it should be noted that aquatic receptors are not living in runoff water from an artificial field but rather the surface water that may be in nearby lakes, streams and/or wetlands.

This information aside, Weston & Sampson understands that the potential for zinc to migrate into nearby surface water and affect aquatic receptors is a serious concern to the public. The manufacturers of the crumb rubber inlay were also concerned about zinc in leachate from crumb rubber because zinc is a component of recycled tires used to make crumb rubber. Several studies were completed to determine the characteristics of crumb rubber that may contribute to zinc leaching into runoff. Studies indicate that pH, crumb rubber size, and leaching time (time that water is exposed to crumb rubber) all play important roles in zinc leaching from tire crumb rubber (Rhodes, 2012). Zinc leaching increases with decreasing pH. With regard to crumb rubber size, researchers found increased leaching from smaller crumb rubber because small-sized crumb rubber has more total surface area. Researchers also found that the amount of zinc that leaches into water from crumb rubber initially is higher when the crumb rubber is newly installed, but the concentrations quickly decrease with time. Based on this research, the manufacturing of crumb rubber has changed and the new product that is available has the following changes:

- The metal components of recycled tires are now removed prior to processing the recycled tires into crumb rubber
- New crumb rubber is sieved to remove smaller particles of crumb rubber that meets recent industry standards on particle size (small particles are removed)
- New crumb rubber goes through a triple washing process so that there is less of an initial elevated concentration that has been observed in studies of crumb rubber leachate.
- The rubber used is strictly screened and must meet all new ASTM standards.

These changes have greatly reduced the leaching potential of zinc into nearby water systems.

Weston & Sampson has partnered with another environmental firm that has completed a 5-year study of leaching potential of a crumb rubber field at the Fenn School in Concord, Massachusetts. This study has gone through peer review and is scheduled to be published later in 2018. The Fenn School field uses a crumb rubber inlay similar to what is proposed for the Wayland artificial fields. A graph displaying five years of groundwater data collected from monitoring wells proximate to and down gradient of the Fenn School field that was analyzed for zinc as shown in Figure 1. Groundwater was collected on a quarterly basis, (i.e., 4 times per year) to account for changes in the water table that might occur seasonally. As can be seen in Figure 1, the concentrations of zinc over 5 years has never been greater than 80 ug/L in groundwater; well below both the EPA AWQC and the MassDEP Method 1 GW-3 standard.

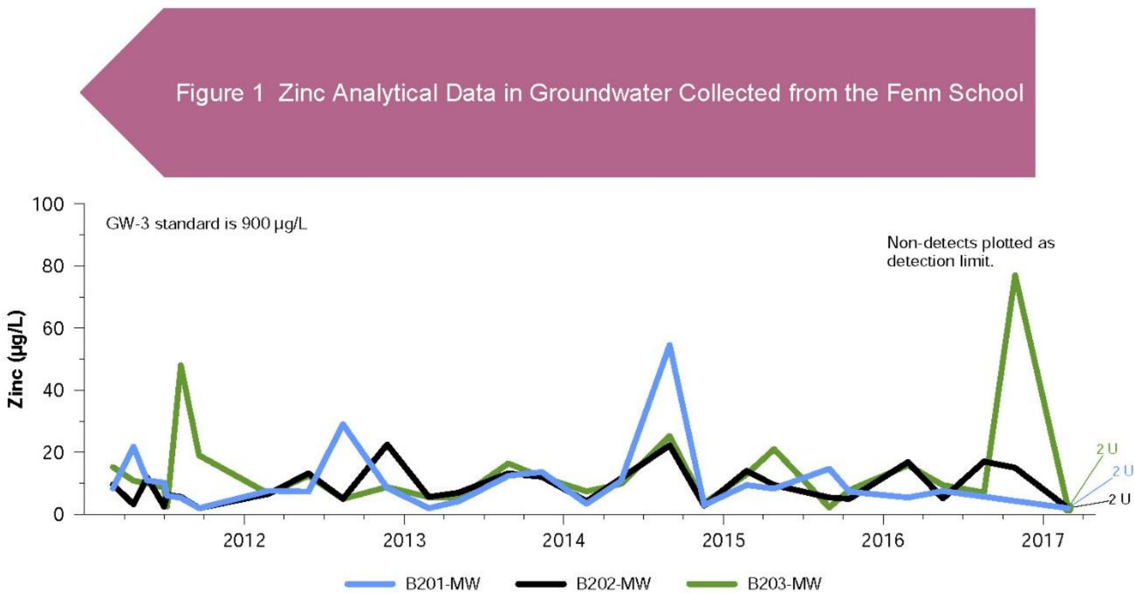

Figure 1: Zinc analytical data in groundwater collected from the Fenn School

Weston & Sampson also proposes to install monitoring wells in the areas surrounding the Wayland fields and to perform similar monitoring, as approved by the town, to ensure that any concentrations that may be observed in leachate from the artificial fields are at an acceptable concentration and do not affect any nearby aquatic receptors nor the drinking water wells in the town.

Artificial Turf Drainage Characteristics

The objective of artificial turf construction is to pass water through to recharge the aquifer and therefore not create surface water from precipitation. A failsafe or relief valve built into the system for large precipitation events is the drainage pipe that is constructed at the bottom of the 15-inch thick drainage stone. If the precipitation event is sufficiently intense as to overload the native material below the field, the drainage pipe would be accessed by rising groundwater to relieve the overflow. These drainage pipes are flat perforated pipe that collect the rising groundwater and direct it (now as surface water) into the wetlands to the north of the field. This was the design for the previous field and is the proposed design for the proposed field.

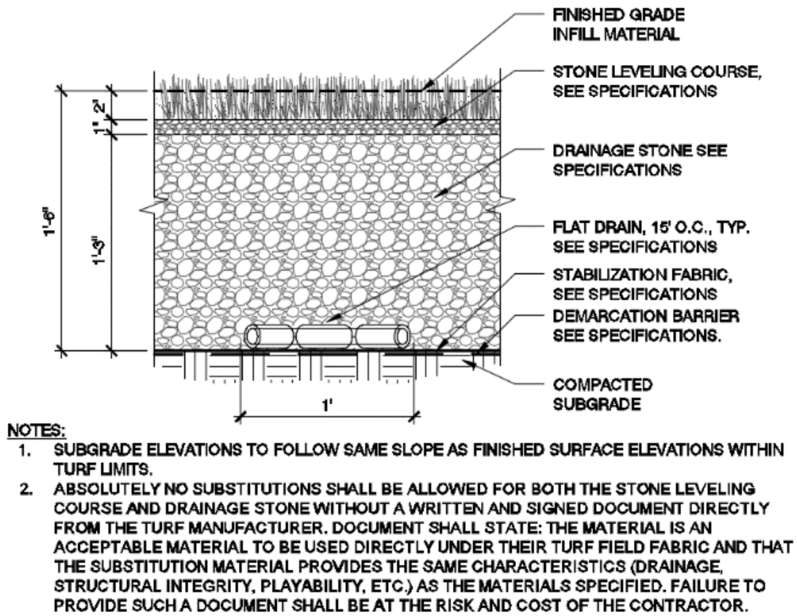

Figure 2: Artificial Turf Specification Details

Response to Comments on Water Flow and Field Design Exacerbating Zinc Leaching

Mr. Sax presents some information on water flow at the Loker Conservation and Recreation Area field site on slide 2 and claims that the field design exacerbates zinc leaching on slide 6. Mr. Sax's claims that: 1) "Crumb rubber will marinate in rainwater for extended periods;" 2) "On warm sunny days crumb rubber will reach 140F to 160F like putting water crumb rubber mixture in a crock pot set on medium;" 3) "Zinc concentration will increase as water evaporates on hot days…like maple syrup;" 4) "Zinc concentration increases with each rainfall and evaporation cycle;" and 5) Major rainstorm will flush Zinc laden water into Loker and Willow Brook wetlands.

The crumb rubber does not "marinate in water" nor is there an area within the system that collects water with the crumb rubber. Crumb rubber remains in-laid in the carpet of the artificial turf. Rain water is stored in the stone drainage layer below the field that does not contain crumb rubber and should percolate under the field into groundwater. If there is any water remaining in the crumb rubber on the field, it will evaporate in the sun.

Conclusions

In summary, our recommendation of crumb rubber as an in-fill is based on performance and lack of data indicating that crumb rubber and artificial turf are unsafe. There is a large body of scientific data indicating that artificial turf fields and crumb rubber in-lay do not cause an adverse health risk in humans and are safe for use. Our independent research at the Fenn School in Concord, Massachusetts also confirms these findings. The latest technology in manufacturing crumb rubber has greatly reduced the potential for zinc to leach from crumb rubber into surrounding groundwater or surface water. Crumb rubber is strictly screened and must meet all new ASTM standards. Therefore, it is our professional opinion that crumb rubber may be used as an infill without significant impact on groundwater quality and will not significantly affect aquatic receptors that may live in surrounding surface water bodies. Furthermore, Weston & Sampson proposes to install monitoring wells proximate and/or down gradient of the Wayland artificial fields to monitor for potential leaching of zinc and other constituents to ensure that concentrations remain below acceptable standards.

Document #2 "Statement Re a Replacement High School Turf Field", submitted by Tom Sciacca, dated 10/23/18

Response prepared by:
Weston & Sampson
Kevin MacKinnon, PG, CG, PH-GW
Senior Technical Leader | Water Resources

Weston & Sampson has reviewed Mr. Sciacca's letter and we provide the following responses related to:

1) how drainage in the turf field is designed to function
2) the groundwater flow regime within the Zone II wellhead protection area of the Happy Hollow Wellfield
3) the results of water quality testing at the Wayland High School site for the ten years it has been in place
4) a discussion of additional water quality concerns raised in the letter.

Happy Hollow Wellfield Flow Regime

To reply directly to the concerns raised in the letter, a brief narrative is provided below to describe the relationship between the public drinking water supply wells, the area in which the wellfield is capturing groundwater, and the location of the existing and proposed artificial turf field. This narrative is supported with a map (Figure 1) to document the work of others to delineate the Zone II of the Happy Hollow Wellfield. As stated in 310 CMR 22.02, a Zone II is:

> *That area of an aquifer which contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated (180 days of pumping at safe yield, with no recharge from precipitation). It is bounded by the groundwater divides which result from pumping the well and by the contact of the aquifer with less permeable materials such as till or bedrock. In some cases, streams or lakes may act as recharge boundaries. In all cases, Zone IIs shall extend up gradient to its point of intersection with prevailing hydrogeologic boundaries (a groundwater flow divide, a contact with till or bedrock, or a recharge boundary).*

In the case of the Happy Hollow Wellfield, groundwater under non-pumping conditions, flows regionally towards the Sudbury River located to the north of the wellfield. Locally, in the area of the turf field and wellfield, the groundwater flow direction is to the west towards the bordering vegetated wetlands that abut the Sudbury River. Under pumping conditions, groundwater head contours are altered as the withdrawal creates a cone of depression around the wellfield, establishing a groundwater gradient towards the well. Using the head contours developed from observing the groundwater elevation in a monitoring network surrounding the wellfield during a long-term pumping test, a Zone II is delineated and shown on Figure 1 below.

The Zone II in Figure 3 is overlain on a surficial geologic map. This map was constructed to assist the reader in understanding that the Happy Hollow Wellfield area is largely underlain by coarse stratified drift deposits of high permeability (defined in orange on the map). Additionally, the Zone II is specifically bounded by 1) the Sudbury River to the north as a downgradient stagnation point, 2) till (low permeability) deposit boundaries to the north and east, 3) and a sub-basin divide to the south and west. Using the Zone II and the groundwater contours (under pumping conditions) as a guide, one can define the percentage of flow from each area of the aquifer. Using this methodology, it is estimated that the area defined by the existing (and proposed) turf field contributes approximately 0.6% of the flow to the Happy Hollow Wellfield. Considering that the wellfield holds a permit from the DEP to withdraw up to 1.411 Million Gallons per Day (980 gallons per minute), this represents just under a 6 gpm contribution to the pumping rate of the Wellfield. If we consider the fact that a significant portion of the field is underlain by glaciolacustrine clay deposits (defined in blue in Figure 3) of low permeability, this value is most likely lower. This evaluation is supported by the 2010 Study funded by the Wayland Wellhead Protection Committee that Mr. Sciacca references. The study concludes that, *"Under pumping conditions, most of the groundwater that reaches the wells originates from the east and probably south of the Happy Hollow wells. The groundwater contribution from the area of the High School tennis courts and football field is expected to be minor, transmitted only through a thin upper layer of sand that overlies thick clay deposits."*

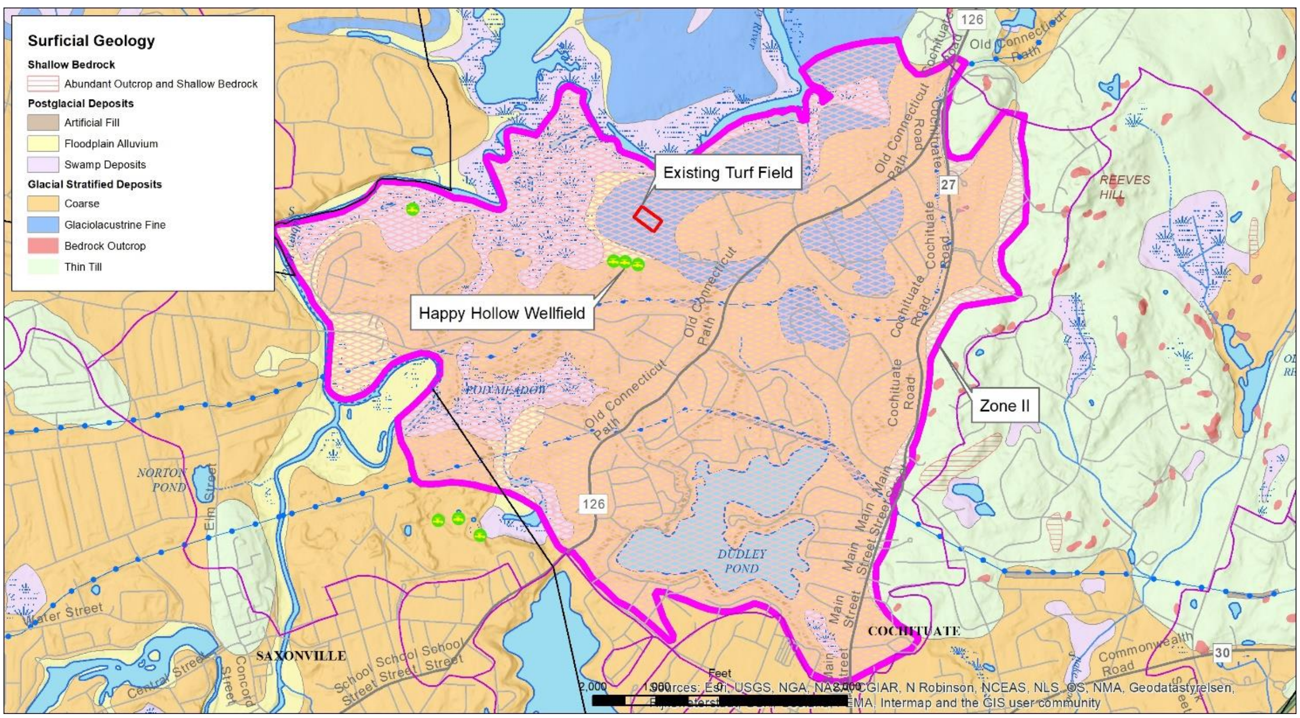

Figure 3: Happy Hollow Wellfield Zone II & Surficial Geology

Artificial Turf Drainage Characteristics

The objective of artificial turf construction is to pass water through to recharge the aquifer and therefore not create surface water from precipitation. A failsafe or relief valve built into the system for large precipitation events is the drainage pipe that is constructed at the bottom of the 15-inch thick drainage stone. If the precipitation event is sufficiently intense as to overload the native material below the field, the drainage pipe would be accessed by rising groundwater to relieve the overflow. These drainage pipes are flat perforated pipe that collect the rising groundwater and direct it (now as surface water) into the wetlands to the north of the field. This was the design for the previous field and is the proposed design for the proposed field.

Response to Comments

Mr. Sciacca contends that the 2007 Settlement Agreement provided in the Superseding Order of Conditions issued by the Massachusetts Department of Environmental Protection on May 17, 2007 had two major elements, including:

- A redesign of the drainage from the field so that water leaching through the carpet and infill would be captured and drain away from the wells to the north into a drainage swale, and then be conducted to the river.

- A program of sampling an analysis of the leachate from the drainage outfall to determine if any toxins were in fact coming from the field.

Mr. Sciacca's language reproduced herein seems to suggest that the project was to be redesigned to capture all the water percolating through the field. To be clear, the 'redesign' did indeed modify the design to direct <u>surface water</u> to the north into the wetlands, however no discussion of changing the design to capture all the water leaching through the field was in the Settlement Agreement. Furthermore, Mr. Sciacca implies that the field was not functioning as intended when he writes, "*However, after the field was built in September of that year, the drainage pipe and swale remained perfectly dry after precipitation events. They remained so until January, when groundwater in the area rose so as to fill the swale and submerge the pipe.".* This observation by Mr. Sciacca provides evidence that the field was draining as intended and capturing and discharging the overflow of groundwater into the stormwater drainage swale.

A Data Interpretation Report (attached) produced in October 2008 is the result of the 'program of sampling an analysis of leachate from the drainage outfall …'. This report provides results of leachate samples collected in January, March, July, and September of 2008 after large precipitation events and in some cases large precipitation events coupled with significant snow melt events. All detected contaminant concentrations were found to be below both the EPA Chronic Criterion Concentration for surface waters and the Method 1 Concentrations for GW-1 and GW-3 category groundwaters. Additionally, a relatively rigorous water quality sampling program was been initiated by the Wayland Department of Public Works Water Division on the Happy Hollow Wellfield. No concerns have been raised in the decade the existing field has been in place.

To address Mr. Sciacca's assertion that the synthetic turf field and/or crumb rubber, "*are a major source of endocrine disrupting chemicals (EDCs), which mimic hormones."* The letter goes on to indicate that, *"A specific issue found in the Sudbury River in recent years is the occurrence of intersex fish, presumably as a result of river contamination by EDCs. So directing drainage from a major source of plastic pollution to the river is not acceptable."*

While it is true that EDCs mimic hormones and have been found to potentially disrupt the reproductive system, particularly in male organisms, it is misleading to indicate that synthetic turf fields are a "major source" of EDCs or plastic pollution. EDCs include a chemical class of compounds called phthalates that are plasticizers found in many plastics. Phthalates are part of a class of compounds called semi-volatile organic compounds (SVOCs). Polycyclic aromatic hydrocarbons (PAHs) are also SVOCs found in the matrix of crumb rubber that are not considered to be EDCs but are linked to other health effects. Phthalates and PAH analysis are frequently performed at the same time and therefore, much of the data that was reviewed discusses phthalates and PAHs together as SVOCs.

Additionally, we offer the following from a literature review: A review of literature pertaining to leaching data of crumb rubber, which included data collected from laboratory leaching studies as well as field collected data, indicates that phthalates and PAHs were rarely detected in leachate (Cheng, et al., 2014). Field collected data would be more relevant because leachate would include any potential compounds that may leach from both the carpet base and crumb rubber in fill. Phthalates and PAHs analyzed in leachate were mostly at non-detectable levels in the literature. The relatively small number of detected concentrations of phthalates and PAHs were below MassDEP standards for protection of human health (Method 1 GW-1 standards) as well as for protection of aquatic/ecological health (Method 1 GW-3 standards).

From our independent analysis of data from the Fenn School in Concord, MA: Groundwater was collected from monitoring wells installed proximate and down gradient from a synthetic turf field installed at the Fenn School in Concord, Massachusetts. Since this is field data, groundwater collected from the Fenn School represents what may leach from both the carpet base and crumb rubber in fill. Analysis for SVOCs was completed on a quarterly basis between June 2011 and December 2012. SVOC analysis was suspended after approximately 2 years because SVOCs were detected infrequently and at trace levels. It was noted by the researcher that the phthalates (2 compounds) and PAH (1 compound) detected were in "trace" amounts and could well be laboratory contaminants since it is common to see them in lab reports. Bis (2-ethylhexyl) phthalate was detected in 3 of 33 groundwater samples at concentrations ranging from 1.53 to 2.35 ug/L. Di-n-octyl phthalate was detected in 2 of 33 groundwater samples at concentrations ranging from 1.52 to 1.8 ug/L. Naphthalene was detected in a single sample out of 33 samples at a concentration of 1.52 ug/L. All these detection concentrations were well below the MassDEP Method 1 GW-1 standards that are protective of use of the groundwater as drinking water and Method 1 GW-3 standards that are protective of aquatic receptors that may live in surrounding surface water.

While it is true that 3 male largemouth bass (LMB) collected from the Sudbury River were found to have intersex characteristics, it is misleading to try to relate potential leachate from the existing or future synthetic turf fields to intersex LMB. Intersex LMB were found not only in the Sudbury River but also in the Assabet and Concord Rivers. The locations that intersex LMB were collected are not directly downgradient of synthetic turf fields but the location in the Sudbury River where intersex LMB were collected was near a Waste Water Treatment Plant (WWTP). The literature reviewed on this topic indicates that researchers believe that the intersex LMB are related to endocrine disruptors, including estrogens excreted by women that use birth control, that are within effluent from WWTP along the rivers (Beede, 2014; Beede and Field-Juma, 2014). The amount of "endocrine disruptors" that discharge from a WWTP would dwarf any load of plasticizers coming from the field(s).

In summary, from both the literature and our independent investigation, the concentrations of plasticizers that might be released from the fields is infinitesimally small, especially when compared to other possible sources of EDCs to the Sudbury River.

Document #3 Submission to the Conservation Commission, by Willow Brook Condominium Association, dated 10/23/18

Response prepared by:
Weston & Sampson
James Pearson, PE
Project Manager | Stormwater Management

A revised stormwater report with a revision date of September 10, 2018 has been submitted to the commission in response to comments provided by its peer review engineer. We believe that the revised report, along with the supplemental information provided below, fully address the concerns of the Meadow Brook Condominium Association. Specifically, please note of the following:

1) We acknowledge that the Cornell Study rainfall data generally provides for higher rainfall values for each storm event in comparison with the TP-40 rainfall data, though the latter data set is considered acceptable under the Wetland Protection Act. That being said, we have not used TP-40 or Cornell data for our analysis. We have used NOAA Atlas 14 rainfall data, which is an even newer data set than the Cornell data and yields even higher and more conservative rainfall values than either TP-40 or the Cornell data for this specific site. A printout of both the Cornell rainfall values and the NOAA Atlas 14 rainfall values are included with this memo for reference (Exhibit C). By using this rainfall data, the condominium association and the conservation commission can be assured that our analysis more than meets the requirements of both the local bylaws and the Wetlands Protection act. This approach is also consistent with the Commission's rules which indicate "Rainfall data must consider the Cornell Study, TR-40, and <u>other sources</u> [emphasis added] of rainfall to justify the amount used for each storm event."

2) The revised report includes an analysis for the 0.5" and 1" 24-hour storm events. While a table has been included in that report comparing pre-development and post-development runoff rates, the report does not provide a table comparing pre-development and post-development runoff stormwater volumes that are generated by the site. A summary table is provided as an attachment to this memo (Exhibit A). This summary table is consistent with the information provided in the September 10, 2018 Stormwater Report. It should be noted that in all cases, post-development peak discharges for the 0.5-inch storm through the 100- year storm do not exceed pre-development peak discharges. This is also the case for post vs. pre-development volumes for all storm events with the exception of the 100-year storm. For the 100-year storm, there is a slight increase in the surface water volume discharged from the site of approximately 206 cubic feet. Under the Commission's rules, the Commission "requires no increase in volume for the 10-year, 25-year storm events, and generally no increase for the 100-year storm events." In practice, the phrase "generally no increase" means that there are cases where an increase can be determined to not be detrimental. In the case of an increase, the regulations ask for information as to "where, if an increase is proposed, that increase will occur." That increase will occur for stormwater discharging to the ponds at the frontage of the site along Commonwealth Road (Exhibit B). The combined area of these ponds is approximately 20,450 square feet. The additional volume of 206 cubic feet of water in the 100-year storm spread over the combined area of these ponds would constitute an increase of only 0.01 feet (approximately 1/8-inch) in water surface elevation. This does not rise to the level of concern from a flood protection standpoint and is therefore easily approvable by the Commission.

3) Attachment E in the stormwater report provides a "TSS Removal Calculation Worksheet." This is a standard worksheet that DEP has provided for use in calculating the effectiveness of BMPs to meet the regulatory Total Suspended Solids (TSS) removal requirements of the Wetland Protection Act. As indicated by the spreadsheet, the BMPs that are being used onsite consist of the Deep Sump and Hooded Catch Basin as well as a Subsurface Infiltration Structure. The former provides 25% TSS removal and the latter provides 80% TSS removal for a composite removal efficiency of 85%, which exceeds the 80% TSS removal requirements of both the local and state regulations.

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Separate Attachments for MacKinnon Responses

Data Interpretation Report, Leachate Sampling for Synthetic Turf Field (October 24, 2008)

Separate Attachments for Pearson Responses

Exhibit A: Pre-development and post-development peak discharges and volumes from the site
Exhibit B: Existing pond areas southern side of Loker Conservation and Recreation Area
Exhibit C1: Cornell Rainfall Data
Exhibit C2: NOAA Atlas 14 Rainfall Data

October 24, 2008

Mr. Frederic E. Turkington
Town Administrator
Town of Wayland
41 Cochituate Road
Wayland, MA 01778

Re: Data Interpretation Report
Leachate Sampling for Synthetic Turf Field
Wayland High School
246 Old Connecticut Path, Wayland, MA
Norfolk Project Number 1213.1.1

Dear Mr. Turkington:

In accordance with our proposal dated September 27, 2007 (Proposal M0907162) as follows is a summary of the results of the leachate sampling and analysis for the synthetic turf field located at Wayland High School.

Background

Based on information provided by the Town of Wayland, the Wayland turf field is composed of recycled rubber tire crumbs. A leachate collection sub-drain, consisting of two 10-inch perforated HDPE pipes at the west and east sides of the turf field, discharge, via a 15-inch HDPE pipe (Outfall 1), to an above-grade drainage ditch located at the northeast side of the turf field. A drainage plan which depicts the basic drainage design is attached to this report as Figure 3.

The purpose of the leachate sampling program was to evaluate potential adverse impacts on drinking water and wetlands resources in proximity to the site. According to the drainage plan (Figure 3), the north ½ of the drainage swale is situated within the 100-foot buffer of a wetland which borders the north side of the site. According to the Mass DEP Priority Resource Map (Figure 2), the swale is located within a designated Zone II of a public water supply well and is also proximate to a medium-yield potentially productive aquifer.

Sampling Methods

Leachate samples were collected from the discharge outfall on January 10, 2008 following a heavy rain and significant snow melt. Samples were additionally collected on March 10, 2008, July 24, 2008, and September 29, 2008 following approximately 3 inches of rainfall over the preceding two-day or three-day periods. Prior to sampling. flow from the outfall was checked using a plastic float. During all sampling events, the outfall appeared to be partially submerged by water which was backed up in the drainage swale. Flow from the outfall was observed to be present but was weak. Photographs of the swale and outfall are attached in Appendix B.

Table 1:
Analytical Summary for Detected Parameters: Outfall 1
Samples Collected January 10, 2008 through September 29, 2008
Wayland Turf Field, Wayland, MA

Detected Parameter	Date / Concentration (ug/L)				EPA Freshwater CCC* (ug/L)	MADEP Method 1 GW-1 / GW-3** (ug/L)
	January 10, 2008	March 10, 2008	July 24, 2008	September 29, 2008		
Chromium	<5	2	<5	<5	570	100 / 600
Copper	<10	5	<5	3.2	13	NE
Zinc	21	31	<47.5	35.8	120	5,000 / 900
Bis(2-ethylhexl) phthalate	<5	<5	<6.25	3.18	NE	6 / 50,000
Di-n-octyl phthalate	<5	<5	<6.25	1.13	NE	(10,000)[1]
Total Suspended Solids (TSS)	8,700	<2,000	<5,000	<5,000	NE	NE
Biochemical Oxygen Demand (BOD)	3,700	<2,000	<3,000	<3,000	NE	NE
pH (in standard units)	7.1	7.0	8.24	7.16	6.5 to 9.0	NE

* = Chronic Criterion Concentration for fresh surface water per U.S. EPA National Recommended Water Quality Criteria, 2006, Office of Science and Technology Document 4404T
** = Method 1 Concentrations for GW-1 and GW-3 Category Groundwaters per 310 CMR 40.0974(2) as amended February 2008
NE = Not Established for this analyte
( )[1] = Although there are no established Method 1 risk-based concentrations, the MADEP has established a Reportable Concentration of 10,000 ug/L for this analyte in GW-1 Category Groundwater areas.

Leachate samples were collected at the mouth of the outfall using a Teflon™ sampling ladle which was cleaned with distilled water prior to use. Samples were transported under chain-of-custody protocol to a Massachusetts-certified laboratory for analysis. Analytical parameters included semi-volatile organic compounds by EPA method 8270C, selected soluble metals (cadmium, chromium, copper, lead, selenium and zinc) using EPA 6000/7000 series methods, biochemical oxygen demand (BOD) by Standard Method SM521B, total suspended solids (TSS) by Standard Method SM2540D, and, pH by ASTM method 1293-99B.

Laboratory Results

Laboratory results compared to EPA National Recommended Water Quality Criteria and MassDEP Method 1 Groundwater Standards are summarized on Table 1. Laboratory reports are included in Appendix C. Laboratory results indicate detectable concentrations of chromium, copper, and zinc, with zinc being the most elevated and the most prevalent. Bis (2-ethylhexl) phthalate and di-n-octyl phthalate were detected in the latest sample collected on September 29, 2008. All detected contaminant concentrations are below the EPA Chronic Criterion Concentrations and applicable MassDEP Method 1 concentrations, where established. The pH is within the acceptable range and the BOD and TSS values are lower than is typical for most storm water runoff.

Contaminant Sources

A likely source for the metals detected in the leachate samples are rubber vulcanization accelerators and rubber polymerization peptizers used in the manufacture of tires (MacCaskie, 2003 and 2006). The leaching of naturally occurring metals from soils and fill materials is another potential source of these metals. Bis (2-ethylhexl) phthalate and di-n-octyl phthalate are common plasticizers that are used in the manufacture of rubber and various plastics (EPA, 2005, p 37). Laboratory contamination is also a possible, though unlikely, source of the pthalates.

Conclusions and Recommendations

Based on the above observations and findings, it appears that potentially significant adverse impacts to surface water via direct leachate discharge and to groundwater by leachate infiltration appear to be unlikely. Additional testing or drainage design modifications are not recommended at this time based on available data.

Should it be determined that additional sampling is to be performed, Norfolk recommends that *hardness* be included as an additional analytical parameter. The EPA Chronic Criterion Concentrations for copper and zinc are hardness dependent and may require numerical adjustment (EPA, 2006, p. 23).

Should you have any questions regarding these findings and recommendations, please contact the undersigned at (508) 478-1276.

Sincerely,
NORFOLK RAM GROUP, LLC

Stephen R. Lemoine
Project Manager

Brian V. Moran, P.E., L.S.P.
Principal

Attachments:

Appendix A: Figures
Appendix B: Photographs
Appendix C: Laboratory Reports
Appendix D: References

			Peak Flow (cfs)		Volume (cf)	
Point of Interest	Storm Frequency	Storm Depth (in)	Pre-Development	Post-Development	Pre-Development	Post-Development
P1	0.5-inch	0.50	0.04	0.02	115	57
	1.0-inch	1.00	0.09	0.04	286	142
	2 Year	3.31	0.32	0.16	1113	555
	10 Year	5.19	0.51	0.25	2034	1211
	25 Year	6.36	0.65	0.35	2973	1841
	100 Year	8.17	1.03	0.75	5008	3072
P2	0.5-inch	0.50	0.40	0.24	1091	656
	1.0-inch	1.00	0.96	0.58	2714	1633
	2 Year	3.31	3.48	2.09	10570	6376
	10 Year	5.19	5.50	3.30	18193	14173
	25 Year	6.36	6.84	4.37	24311	21746
	100 Year	8.17	10.02	9.89	35812	36018

EXHIBIT A:
PRE-DEVELOPMENT AND POST-DEVELOPMENT PEAK DISCHARGES AND VOLUMES FROM THE SITE

EXHIBIT B:
EXISTING POND AREAS SOUTHERN SIDE OF LOKER CONSERVATION AND RECREATION AREA

Exhibit C1:
Cornell Rainfall Data

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	71.343 degrees West
Latitude	42.326 degrees North
Elevation	0 feet
Date/Time	Thu, 13 Sep 2018 10:52:01 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.28	0.43	0.54	0.71	0.88	1.11	**1yr**	0.76	1.05	1.29	1.63	2.07	2.64	2.84	**1yr**	2.33	2.74	3.23	3.88	4.55	**1yr**
2yr	0.35	0.54	0.67	0.88	1.11	1.40	**2yr**	0.96	1.28	1.61	2.02	2.53	3.16	3.48	**2yr**	2.80	3.35	3.85	4.59	5.21	**2yr**
5yr	0.42	0.65	0.81	1.09	1.39	1.77	**5yr**	1.20	1.61	2.05	2.56	3.19	3.97	4.43	**5yr**	3.52	4.26	4.89	5.81	6.50	**5yr**
10yr	0.47	0.74	0.93	1.27	1.65	2.11	**10yr**	1.43	1.90	2.46	3.08	3.82	4.73	5.33	**10yr**	4.18	5.12	5.87	6.96	7.69	**10yr**
25yr	0.56	0.89	1.14	1.56	2.07	2.67	**25yr**	1.79	2.38	3.12	3.90	4.84	5.95	6.79	**25yr**	5.27	6.53	7.47	8.83	9.60	**25yr**
50yr	0.63	1.02	1.31	1.83	2.47	3.21	**50yr**	2.13	2.82	3.76	4.70	5.80	7.09	8.17	**50yr**	6.28	7.86	8.97	10.57	11.37	**50yr**
100yr	0.73	1.18	1.52	2.15	2.94	3.85	**100yr**	2.54	3.34	4.51	5.64	6.95	8.45	9.83	**100yr**	7.48	9.45	10.78	12.66	13.46	**100yr**
200yr	0.84	1.37	1.78	2.54	3.51	4.61	**200yr**	3.03	3.97	5.40	6.76	8.31	10.08	11.84	**200yr**	8.92	11.38	12.95	15.17	15.93	**200yr**
500yr	1.02	1.68	2.19	3.17	4.43	5.85	**500yr**	3.82	4.98	6.87	8.60	10.54	12.73	15.13	**500yr**	11.27	14.55	16.53	19.28	19.94	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.23	0.35	0.42	0.57	0.70	0.84	**1yr**	0.61	0.82	1.02	1.44	1.78	2.27	2.45	**1yr**	2.01	2.35	2.91	3.45	3.93	**1yr**
2yr	0.33	0.51	0.63	0.86	1.06	1.26	**2yr**	0.91	1.23	1.44	1.89	2.43	3.06	3.37	**2yr**	2.71	3.24	3.68	4.47	5.09	**2yr**
5yr	0.38	0.59	0.73	1.00	1.27	1.49	**5yr**	1.09	1.46	1.72	2.24	2.87	3.63	4.02	**5yr**	3.21	3.87	4.44	5.43	6.08	**5yr**
10yr	0.42	0.65	0.80	1.12	1.45	1.69	**10yr**	1.25	1.65	1.88	2.53	3.23	4.12	4.59	**10yr**	3.64	4.42	5.02	6.27	6.94	**10yr**
25yr	0.48	0.73	0.91	1.30	1.71	1.98	**25yr**	1.47	1.93	2.19	2.97	3.79	4.86	5.46	**25yr**	4.30	5.25	5.89	7.61	8.26	**25yr**
50yr	0.52	0.79	0.99	1.42	1.91	2.23	**50yr**	1.65	2.18	2.46	3.36	4.28	5.50	6.21	**50yr**	4.87	5.98	6.60	8.82	9.45	**50yr**
100yr	0.57	0.86	1.07	1.55	2.13	2.52	**100yr**	1.83	2.47	2.75	3.42	4.83	6.24	7.05	**100yr**	5.53	6.78	7.38	10.24	10.81	**100yr**
200yr	0.61	0.93	1.17	1.70	2.37	2.85	**200yr**	2.04	2.79	3.09	3.79	5.47	7.07	8.00	**200yr**	6.26	7.69	8.22	11.90	12.35	**200yr**
500yr	0.69	1.02	1.31	1.91	2.71	3.35	**500yr**	2.34	3.27	3.59	4.33	6.47	8.33	9.44	**500yr**	7.37	9.08	9.36	14.53	14.76	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.32	0.49	0.60	0.81	0.99	1.19	**1yr**	0.86	1.17	1.36	1.81	2.28	2.89	3.21	**1yr**	2.56	3.08	3.49	4.18	4.99	**1yr**
2yr	0.37	0.57	0.70	0.95	1.18	1.37	**2yr**	1.02	1.34	1.58	2.08	2.66	3.29	3.64	**2yr**	2.91	3.50	4.04	4.73	5.38	**2yr**
5yr	0.46	0.71	0.88	1.20	1.53	1.81	**5yr**	1.32	1.77	2.04	2.63	3.34	4.36	4.87	**5yr**	3.86	4.68	5.35	6.24	6.97	**5yr**
10yr	0.55	0.84	1.05	1.46	1.89	2.25	**10yr**	1.63	2.20	2.59	3.19	4.01	5.41	6.11	**10yr**	4.79	5.87	6.67	7.76	8.50	**10yr**
25yr	0.71	1.08	1.34	1.92	2.52	2.99	**25yr**	2.18	2.92	3.45	4.11	5.11	7.21	8.26	**25yr**	6.38	7.95	8.99	10.29	11.07	**25yr**
50yr	0.86	1.31	1.63	2.34	3.15	3.71	**50yr**	2.72	3.63	4.29	4.98	6.13	8.98	10.39	**50yr**	7.94	10.00	11.28	12.74	13.53	**50yr**
100yr	1.05	1.58	1.98	2.86	3.93	4.62	**100yr**	3.39	4.51	5.34	6.68	7.37	11.19	13.08	**100yr**	9.90	12.58	14.20	15.78	16.54	**100yr**
200yr	1.27	1.92	2.43	3.51	4.90	5.73	**200yr**	4.23	5.61	6.65	8.23	8.85	13.95	16.48	**200yr**	12.35	15.85	17.91	19.54	20.19	**200yr**
500yr	1.67	2.48	3.19	4.64	6.60	7.60	**500yr**	5.70	7.43	8.89	10.88	11.27	18.70	22.39	**500yr**	16.55	21.53	24.41	25.93	26.32	**500yr**

Powered by ACIS
Northeast Regional Climate Center

Exhibit C2: NOAA Atlas 14 Rainfall Data

NOAA Atlas 14, Volume 10, Version 2
Location name: Wayland, Massachusetts, USA*
Latitude: 42.3259°, Longitude: -71.3415°
Elevation: 187.41 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.322 (0.251-0.407)	0.391 (0.304-0.495)	0.504 (0.390-0.640)	0.598 (0.460-0.764)	0.727 (0.543-0.977)	0.827 (0.605-1.14)	0.926 (0.660-1.33)	1.06 (0.711-1.56)	1.23 (0.797-1.88)	1.36 (0.862-2.13)
10-min	0.457 (0.355-0.576)	0.555 (0.431-0.701)	0.715 (0.553-0.907)	0.847 (0.652-1.08)	1.03 (0.769-1.38)	1.17 (0.857-1.61)	1.31 (0.935-1.89)	1.50 (1.01-2.20)	1.74 (1.13-2.67)	1.93 (1.22-3.02)
15-min	0.537 (0.418-0.678)	0.652 (0.507-0.824)	0.841 (0.651-1.07)	0.997 (0.767-1.27)	1.21 (0.905-1.63)	1.38 (1.01-1.90)	1.54 (1.10-2.22)	1.76 (1.19-2.59)	2.05 (1.33-3.14)	2.27 (1.44-3.55)
30-min	0.735 (0.571-0.927)	0.891 (0.692-1.13)	1.15 (0.887-1.46)	1.36 (1.05-1.74)	1.65 (1.23-2.22)	1.88 (1.37-2.58)	2.10 (1.50-3.02)	2.40 (1.61-3.53)	2.79 (1.81-4.26)	3.09 (1.95-4.82)
60-min	0.932 (0.724-1.18)	1.13 (0.877-1.43)	1.45 (1.12-1.84)	1.72 (1.32-2.20)	2.09 (1.56-2.81)	2.38 (1.74-3.27)	2.66 (1.89-3.82)	3.03 (2.04-4.46)	3.53 (2.28-5.39)	3.90 (2.47-6.09)
2-hr	1.20 (0.937-1.50)	1.46 (1.14-1.83)	1.89 (1.47-2.38)	2.24 (1.74-2.84)	2.73 (2.06-3.66)	3.11 (2.30-4.27)	3.49 (2.52-5.02)	4.04 (2.73-5.90)	4.77 (3.10-7.24)	5.32 (3.38-8.25)
3-hr	1.39 (1.09-1.73)	1.69 (1.33-2.11)	2.19 (1.72-2.75)	2.61 (2.03-3.29)	3.18 (2.41-4.25)	3.63 (2.69-4.97)	4.07 (2.95-5.85)	4.74 (3.21-6.89)	5.63 (3.66-8.50)	6.30 (4.01-9.72)
6-hr	1.78 (1.41-2.21)	2.18 (1.72-2.70)	2.82 (2.23-3.52)	3.36 (2.64-4.21)	4.10 (3.12-5.43)	4.67 (3.49-6.36)	5.24 (3.83-7.49)	6.12 (4.16-8.84)	7.29 (4.76-10.9)	8.17 (5.21-12.5)
12-hr	2.26 (1.80-2.78)	2.76 (2.20-3.40)	3.58 (2.85-4.42)	4.26 (3.37-5.30)	5.20 (3.98-6.83)	5.92 (4.45-7.99)	6.64 (4.87-9.40)	7.73 (5.28-11.1)	9.18 (6.02-13.7)	10.3 (6.58-15.6)
24-hr	2.69 (2.16-3.28)	3.31 (2.66-4.05)	4.34 (3.48-5.32)	5.19 (4.13-6.40)	6.36 (4.91-8.31)	7.27 (5.50-9.74)	8.17 (6.03-11.5)	9.56 (6.55-13.6)	11.4 (7.50-16.8)	12.8 (8.22-19.3)
2-day	3.01 (2.44-3.64)	3.77 (3.05-4.56)	5.01 (4.04-6.10)	6.04 (4.85-7.40)	7.47 (5.81-9.70)	8.56 (6.54-11.4)	9.66 (7.20-13.6)	11.4 (7.87-16.1)	13.8 (9.10-20.2)	15.6 (10.0-23.3)
3-day	3.26 (2.66-3.93)	4.08 (3.32-4.92)	5.41 (4.39-6.55)	6.52 (5.25-7.94)	8.04 (6.28-10.4)	9.21 (7.06-12.3)	10.4 (7.77-14.5)	12.3 (8.49-17.3)	14.9 (9.83-21.7)	16.8 (10.8-25.0)
4-day	3.51 (2.87-4.22)	4.35 (3.55-5.24)	5.73 (4.66-6.92)	6.87 (5.55-8.35)	8.44 (6.62-10.9)	9.65 (7.42-12.8)	10.9 (8.15-15.1)	12.9 (8.88-18.0)	15.5 (10.3-22.5)	17.5 (11.3-25.9)
7-day	4.22 (3.48-5.04)	5.10 (4.19-6.10)	6.54 (5.35-7.85)	7.73 (6.29-9.34)	9.38 (7.38-12.0)	10.6 (8.21-14.0)	11.9 (8.94-16.4)	13.9 (9.66-19.4)	16.6 (11.0-24.0)	18.6 (12.1-27.4)
10-day	4.90 (4.05-5.83)	5.81 (4.79-6.91)	7.29 (5.99-8.71)	8.51 (6.95-10.2)	10.2 (8.05-12.9)	11.5 (8.88-15.0)	12.8 (9.60-17.5)	14.8 (10.3-20.4)	17.4 (11.6-25.0)	19.4 (12.6-28.4)
20-day	6.91 (5.75-8.15)	7.89 (6.56-9.32)	9.48 (7.85-11.2)	10.8 (8.89-12.9)	12.6 (10.00-15.8)	14.0 (10.8-17.9)	15.4 (11.5-20.5)	17.2 (12.1-23.5)	19.5 (13.1-27.8)	21.3 (13.9-31.0)
30-day	8.58 (7.17-10.1)	9.61 (8.02-11.3)	11.3 (9.39-13.3)	12.7 (10.5-15.1)	14.6 (11.6-18.1)	16.1 (12.4-20.4)	17.6 (13.0-23.0)	19.2 (13.5-26.0)	21.3 (14.3-30.0)	22.9 (14.9-33.0)
45-day	10.7 (8.96-12.5)	11.8 (9.86-13.8)	13.5 (11.3-15.9)	15.0 (12.5-17.7)	17.0 (13.6-20.9)	18.6 (14.4-23.3)	20.2 (14.9-26.1)	21.6 (15.2-29.1)	23.4 (15.8-32.9)	24.9 (16.2-35.8)
60-day	12.4 (10.5-14.5)	13.5 (11.4-15.8)	15.4 (12.9-18.0)	16.9 (14.1-19.9)	19.0 (15.2-23.2)	20.7 (16.0-25.7)	22.3 (16.5-28.6)	23.6 (16.7-31.7)	25.3 (17.1-35.4)	26.6 (17.4-38.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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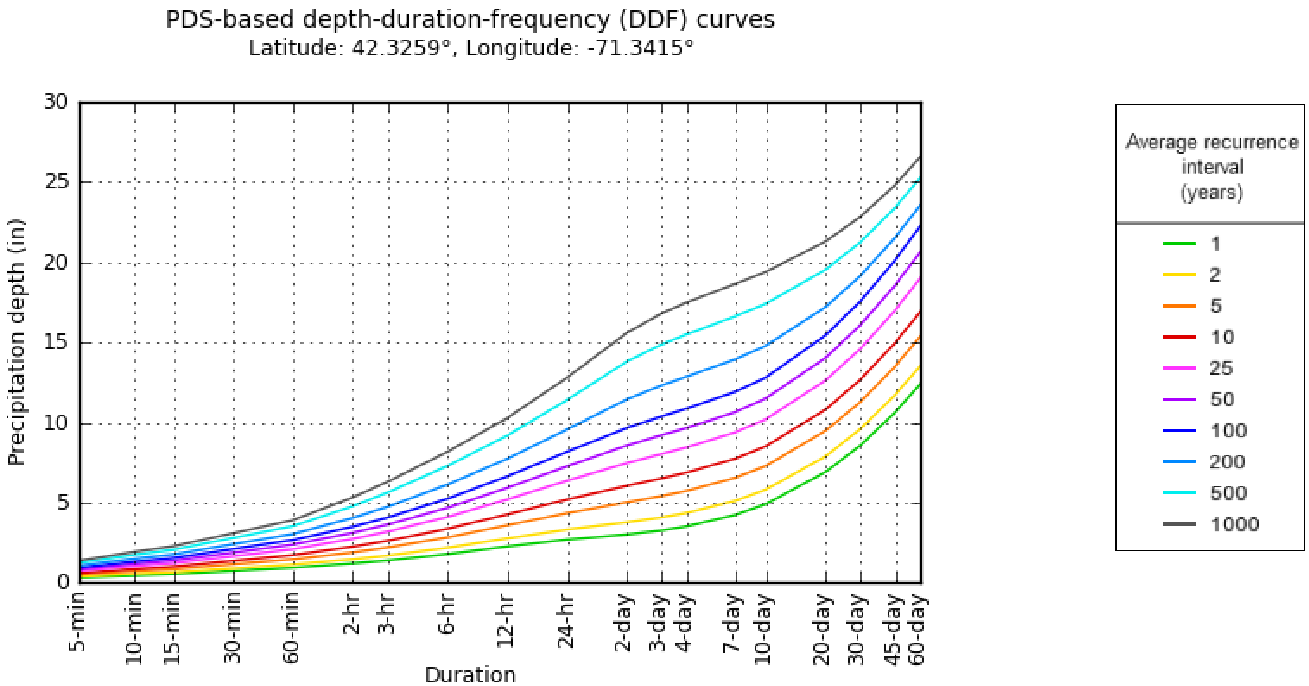
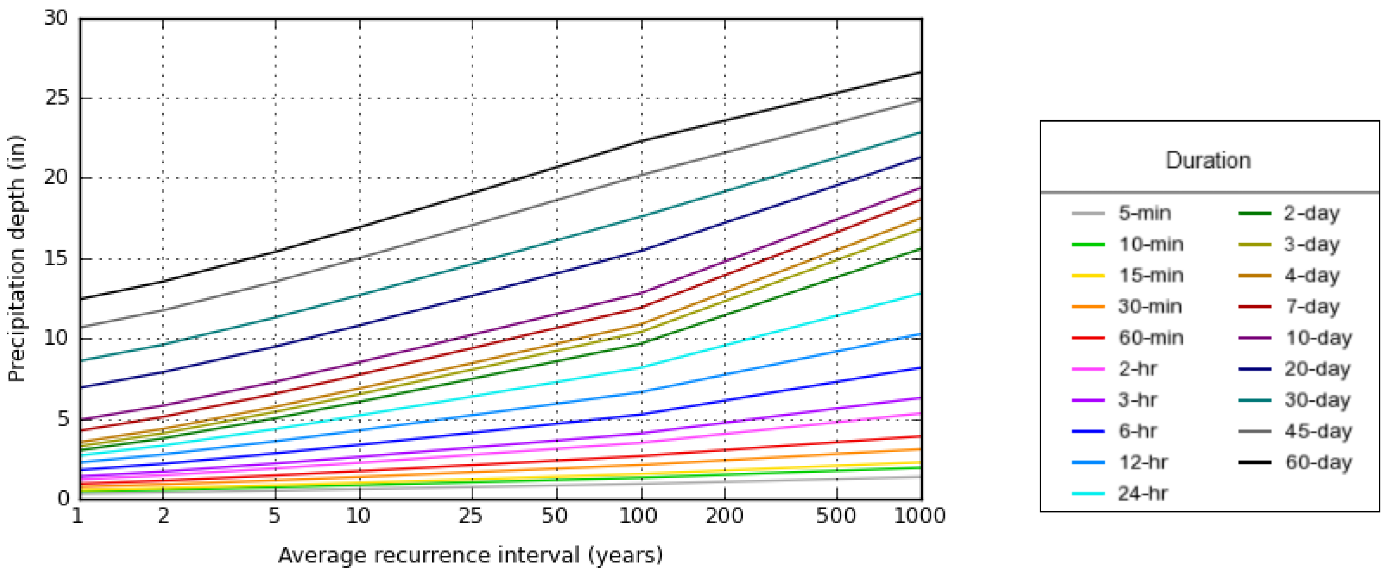
PF graphical





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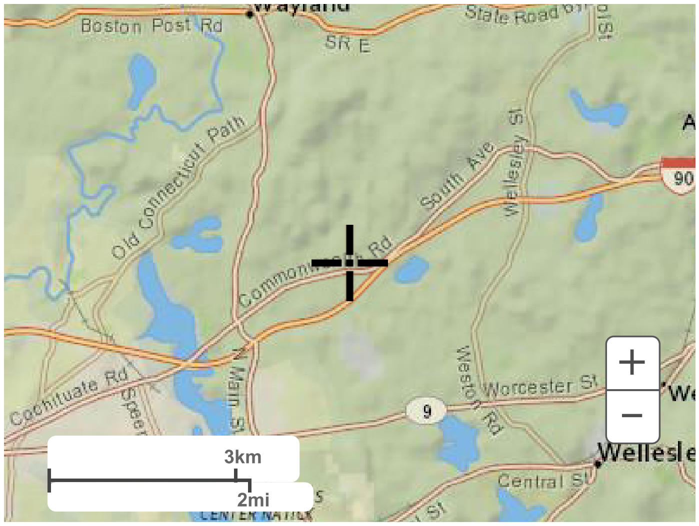
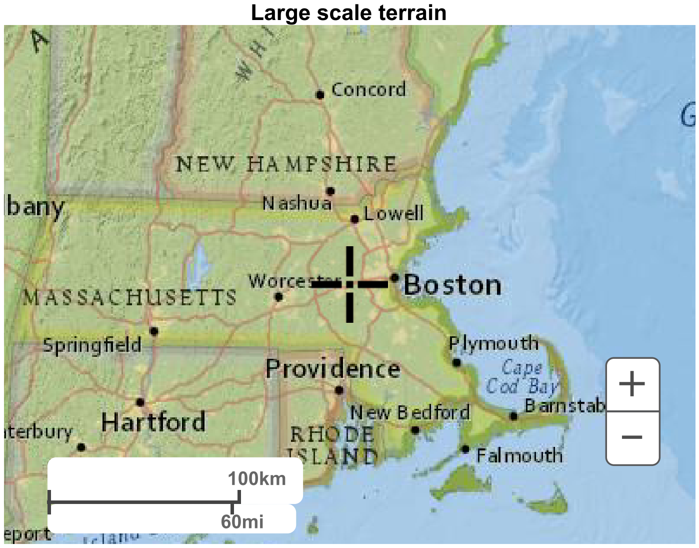
Maps & aerials

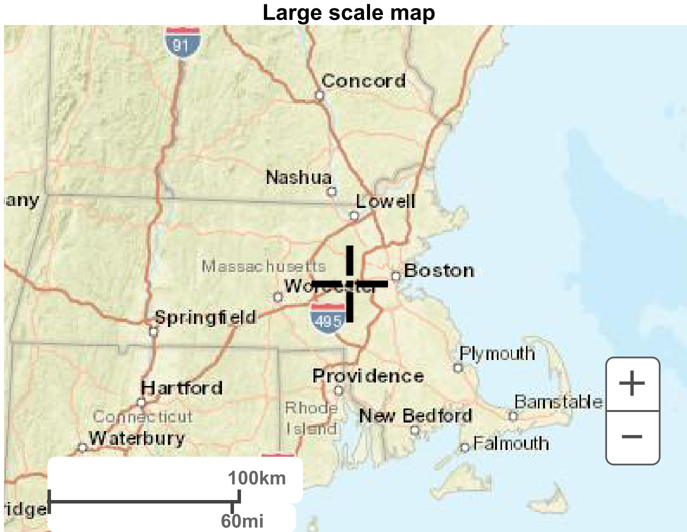
Small scale terrain



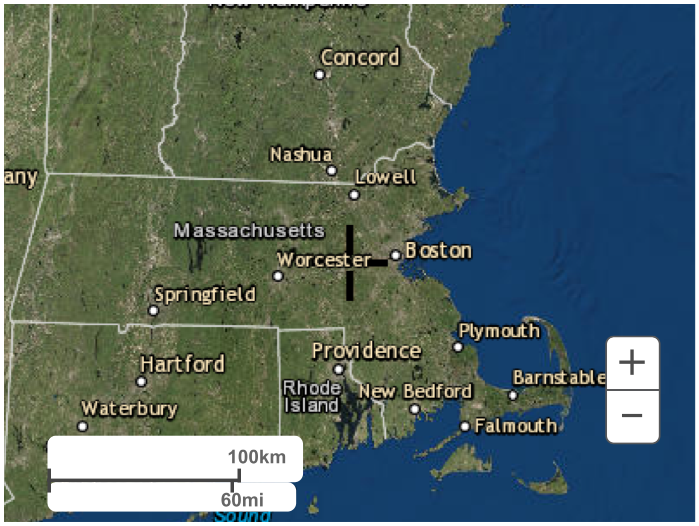
Large scale terrain



Large scale map



Large scale aerial



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