Greenscapes to Brownscapes

A Study on Impacts to Landscapes Adjacent to Highways

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Executive Summary

In the wake of postwar highway expansion in the United States, many communities were marginalized and isolated by roadway construction. The health and social consequences of disinvestment in landscapes and neighborhoods adjacent to highways is an emerging area of focus by scientists and designers alike. Exposure to Traffic Related Air Pollutants (TRAP) can lead to negative health outcomes. The Health Effects Institute considers exposure within 300-500 meters of a road to be a health concern. Over 45 million people in the US live, work or attend school within 300 feet of a major road, airport or railroad. There is evidence linking TRAP to a suite of outcomes including stroke, COPD, cancer, birth defects, low birth weight, delayed childhood cognitive development, autism, Parkinson's disease, and Alzheimer's disease. Nearly 4.2 million deaths worldwide are related to exposure to outdoor air pollution. In the United States, 84% of counties exhibit a racial disparity, where Black and Hispanics are over-represented in living within 500 meters of highways.

This pilot study examined the deposition and accumulation of traffic-related air pollutants in landscapes along the I-95 corridor with the goal of finding novel ways to ameliorate their impacts. The research, completed in March 2022, included field measurement data from two sites along the eastern section of I-95 within the limits of the City of Philadelphia. Field testing consisted of bi-monthly soil and vegetation sampling of heavy metals and PAH's that are considered harmful to human health. Air monitoring continuously logged PM2.5 and utilized Purple Air and Airnote monitors which were mounted adjacent to plots.

Initial hypothesis of quick accumulation of heavy metals or PAHs in soil was not seen through the period of field study. However, an increase in accumulation of pollutants was found on the vegetation. Trends were seen in the air quality samples, including a spike in PM2.5 concentration when the predominant wind or wind gust was in the direction of the highway.

The pilot study included multi-disciplinary engagement sessions with the advisors. A survey questionnaire was prepared to facilitate a conversation around industry perspectives; gaps and growing fields of interest that would impact landscapes adjacent to highways; and sub-themes such as design, human health, equity, policy, and research. Engagement sessions included the following: presentations with discussion regarding the current state of highway-adjacent landscapes, methodologies for effective outreach to stakeholders, engagement with communities affected by poor roadside air quality, understanding the risks for different users and mitigation opportunities for the development of roadside landscapes.

The lessons learned from the pilot study generally fell into three categories: variable control, effective engagement, and logistics. Variable control issues included the complexity of the urban environment, potential of seeping of materials, and security. Logistical challenges were experienced in project siting, including: permission from land owners, sourcing reliable electricity for air quality monitors, and refining a project goal to address numerous urban variables. Lastly, developing relationships within the advisory group served well for open and productive conversation. The review of pre-surveys were valuable in facilitating conversation. The results of this pilot study are intended to inform how the process as well as design of landscapes adjacent to highways can be improved.

This work has been presented at conferences including Landscape Architecture Foundation, American Institute of Architects, GreenBuild, Transportation Research Board, and Council of Educators in Landscape Architecture. The group has presented on early knowledge gathering, methodology, and findings from the engagement process to educate the broader community including transportation consultants about Traffic Related Air Pollutants (TRAP) and its effect on the adjacent landscapes and communities with the intent to deploy the learnings for the future development of these strained landscapes.

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Profeta, Tim. "Air Pollution Now Top Environmental Health Risk." National Geographic

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→ Image: View of I-95 at Penn's Landing
Philadelphia, PA | Philadelphia's Delaware waterfront is cut... | Flickr. (n.d.). Retrieved February 16, 2023, from https://www.flickr.com/photos/jasonparis/3623994505/

Introduction + Background

With major growth and projected population increases of US Cities, the urban fabric will compress against, cover, and mine under the major transportation threads that cut through our cities. Landscapes adjacent to these routes are a trending last frontier for development and green place-making. The Environmental Protection Agency presently advises to not dwell within 1,500 feet of a major roadway; but how does this apply to outdoor play, gardening, and exercising?

Air pollution is considered to be the leading cause of death worldwide. The World Health Organization estimates that outdoor air pollution, in particular, kills over 4.2 million people annually. [1] The juxtaposition of green social spaces and increased pollution, machine-waste environments is therefore a critical problem for the designers of these spaces to consider in their work.

The risks associated with breathing bad air are not spread evenly across geography or populations. While over 50 million Americans live within 100 meters of major transportation corridors, minority families are overrepresented in these increased pollution zones in 84% of counties. [2] About 1 in 3 counties do not have even a single EPA air monitor. [3] In urban areas, these trends can be attributed in large part to the racist land development and redlining practices that built highways through historic Black and Brown neighborhoods. [4] Within communities, children, pregnant persons, and the elderly are particularly at risk for air pollution related disease outcomes. [5]

Ecological communities also face critical risks from outdoor air pollution in the U.S. and abroad. In fact, a recent study suggested that ozone pollution in 33 of the most-visited U.S. national parks was on par with the largest urban areas in the country. [6] Air pollution can negatively impact the development of plant and animal communities in a variety of ways, including stunted growth, acid rain, and contaminated runoff. [7] [8]

It is apparent that near-road air pollution presents a complex and multi-faceted conundrum. To make inroads in this area requires an interdisciplinary understanding of the issues and environmentally sensitive design solutions for development in roadside zones.

In 2019, the project team undertook an extensive literature review and multidisciplinary interview process to understand the state of best practices for reducing human exposure to air pollution in near-road landscapes. The exercise yielded conflicting and sometimes counter-intuitive findings, including cases where widely-used design interventions can enhance negative human exposure to pollution, rather than reduce it.

Building tunnels and walls around roadways, for example, was shown to strongly improve air quality immediately adjacent to the road, but created patches of highly pollution laden air within the roadways, at the tops of walls, and near tunnel exits (see diagram 4). [9] Furthermore, urban street canyons created by tall buildings tended to keep air pollution from dissipating, and street trees in these canyons were shown to sometimes trap that pollution beneath their canopies in the human inhalation zone (see diagram 2). [10] The research around vegetation barriers was overall far more complex than anticipated, showing that depending on the size, density, and species of plants selected, the impact of such barriers could range from beneficial to neutral to harmful (see diagram 1 and 3). [11]

Similar contradictions appeared in the literature related to exercise in areas with elevated air pollution including roadside landscapes. Depending on the rate of respiration (i.e. exercise intensity), an individual will eventually hit a duration of exercise after which the health benefits associated with physical activity were outweighed by the health risks of inhaling toxic air (see diagram 5). [12]

In addition to worsened air quality, sites near sources of traffic pollution are also prone to settlement of airborne pollutants onto ground surfaces, furthering inhalation exposure when particles are resuspended into the air. Accumulation of toxic particulates can occur in absorptive materials, such as soils in community gardens, and on interactive surfaces, such as play equipment. New landscapes constructed in these zones - often deemed “clean” to citizens - will continually be exposed to settlement of traffic pollution, including heavy metals. The study interrogated the time period it would take for a “clean” site to become compromised or contaminated.

The team studied the impacts of airborne pollutants on landscapes within 500-feet of Interstate 95 in downtown Philadelphia. The study was conducted over thirteen months using air, surface, and soil monitoring.

The I-95 corridor was selected for its array of elevational, barrier, and adjacent landscape typologies over a relatively short distance, and the team’s existing relationships with adjacent landowners.

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6. Daley, Jason. “Signficant Air Pollution Plagues Almost All U.S. National Parks.” Smithsonian Magazine, May 9, 2019.

7. S.L. Honour et al. “Responses of Herbaceous Plants to Urban Air Pollution: Effects on Growth, Phenology and Leaf Surface Characteristics.” Environmental Pollution 157, no. 4 (2009): 1279-286.

8. Silva, Shamali De, Andrew S. Ball, Trang Huynh, and Suzie M. Reichman. “Metal Accumulation in Roadside Soil in Melbourne, Australia: Effect Of road Age, Traffic Density and Vehicular Speed.” Environmental Pollution 208 (2016): 102-09

9. Baldauf, Richard. “Summary of EPA Research on Near-Road Air Quality: Impacts of Solid Noise Barriers and Roadside Vegetation.” CARB/EPA Conference Call - Presentation. PDF. EPA, July 11, 2016.

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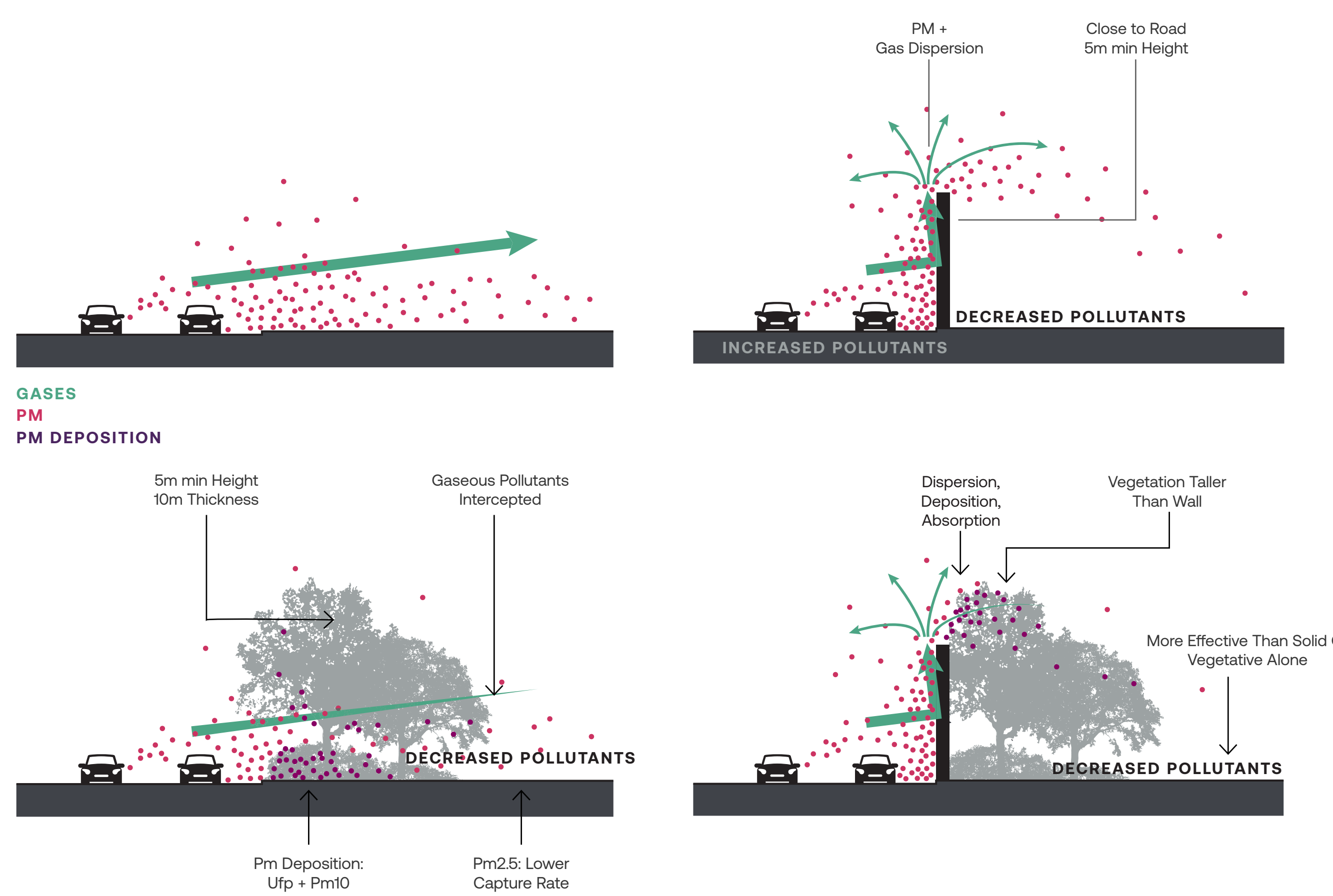
The first phase of the study established an "environmental health baseline", monitoring air, sampling soils, and swabbing interactive surfaces at selected sites located in established public landscapes. These data points were paired with publicly available air quality data.

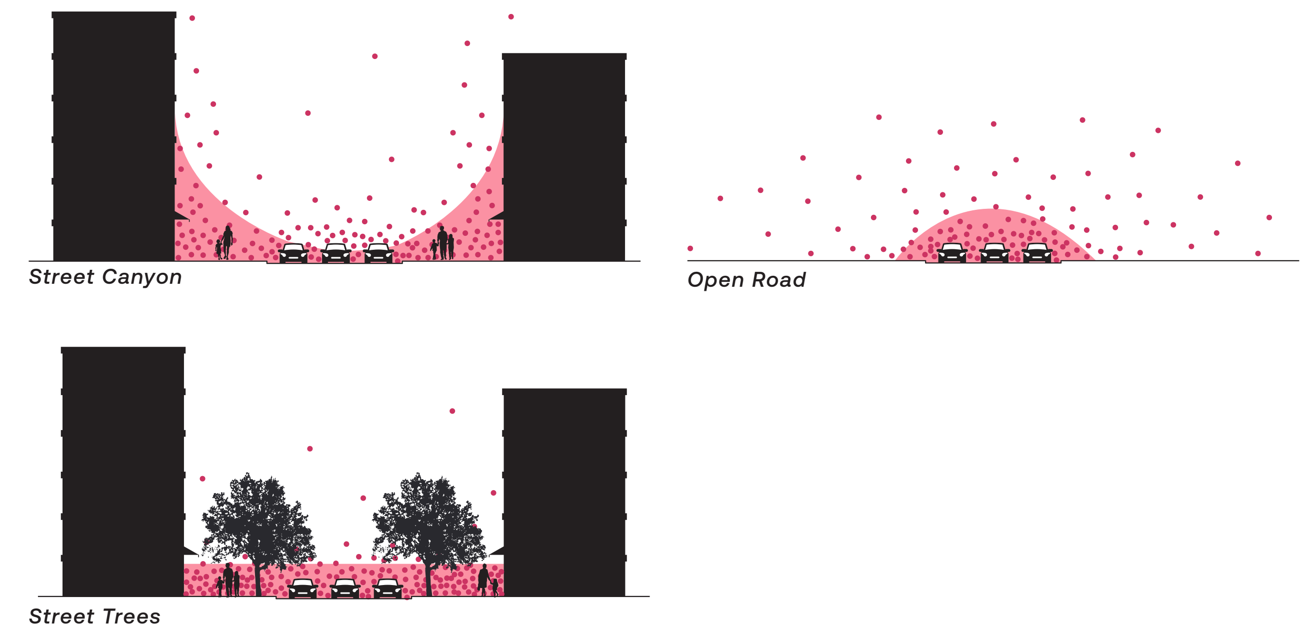
The second phase of the study was focused on controlled soil plot and surface studies. Over a 12-month period, data points were collected through soil sampling, surface swabbing, and air monitoring to understand rates of accumulation of pollutants deposited through exposure to airborne traffic pollution and precipitation events.

As this topic spans the boundaries of human health, ecosystem health, equity, environmental sciences, design, and policy, the approach included a close collaboration with a multidisciplinary advisory board. This included conducting engagement sessions with industry experts, academics, community advocates, landowner/managers, and city agencies. These members were integral to crafting a detailed approach, advising during the pilot study, participating in engagement sessions, and interpreting sampling results to encompass multiple vantage points and expand the use of the study.



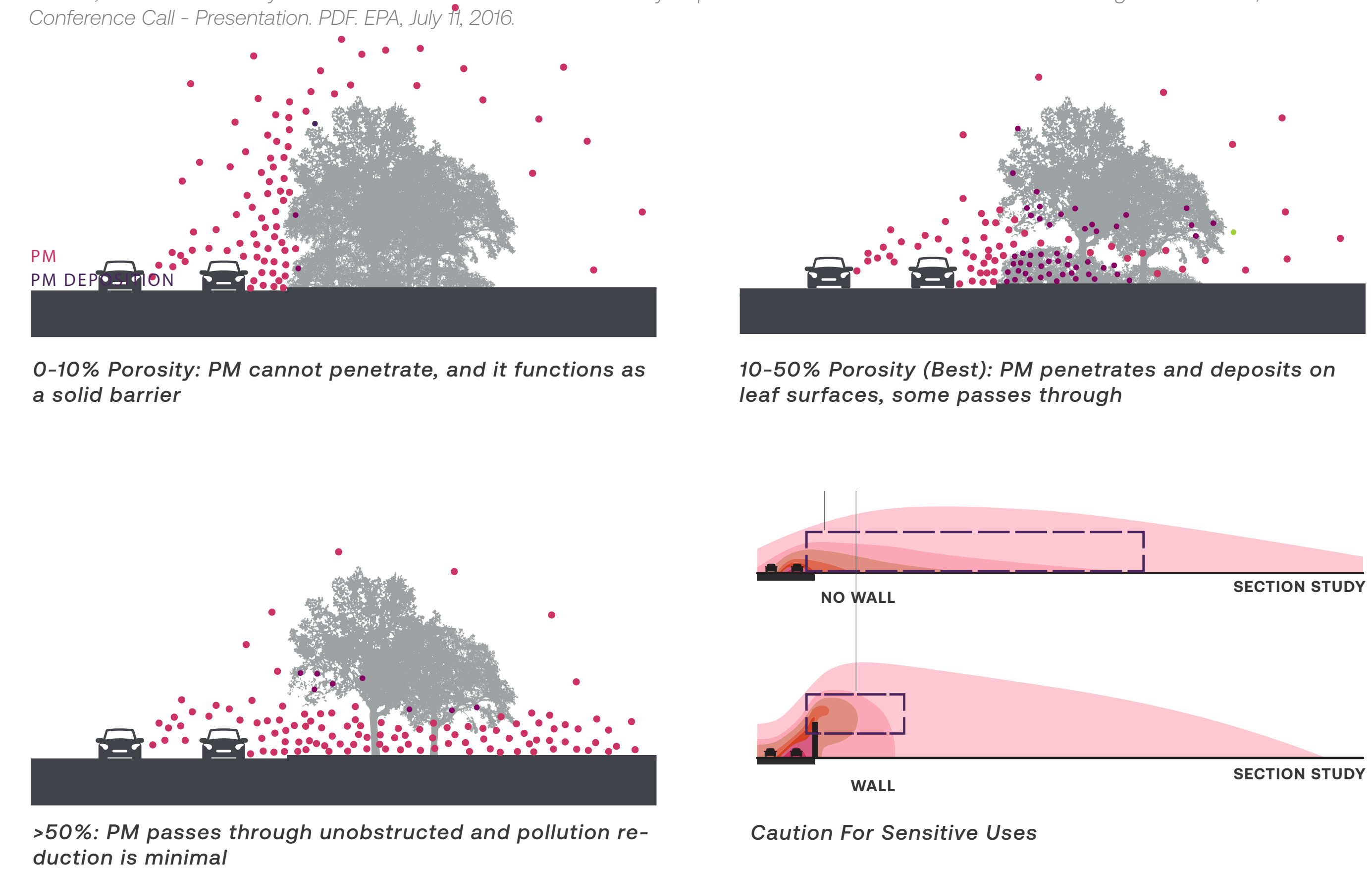
↑ Diagram 1: Role of hard and soft barriers for air quality.

Baldauf, Richard. "Summary of EPA Research on Near-Road Air Quality: Impacts of Solid Noise Barriers and Roadside Vegetation."



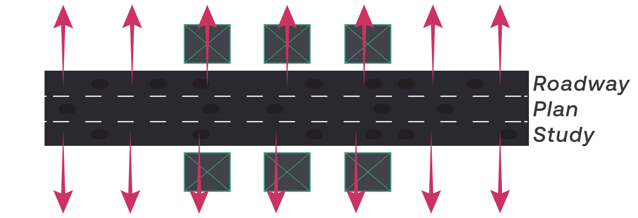
↑ Diagram 2: Green Washing can trap air pollutants.

Baldauf, Richard. "Summary of EPA Research on Near-Road Air Quality: Impacts of Solid Noise Barriers and Roadside Vegetation." CARB/EPA Conference Call - Presentation. PDF. EPA, July 11, 2016.



↑ Diagram 3: Role of Different Barrier in tackling air quality

Baldauf, Richard. "Summary of EPA Research on Near-Road Air Quality: Impacts of Solid Noise Barriers and Roadside Vegetation."



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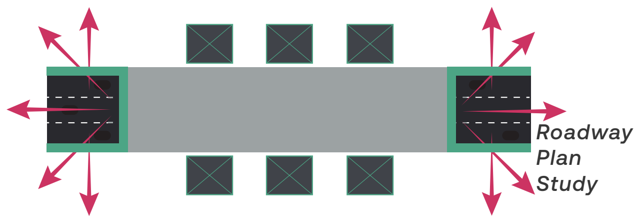
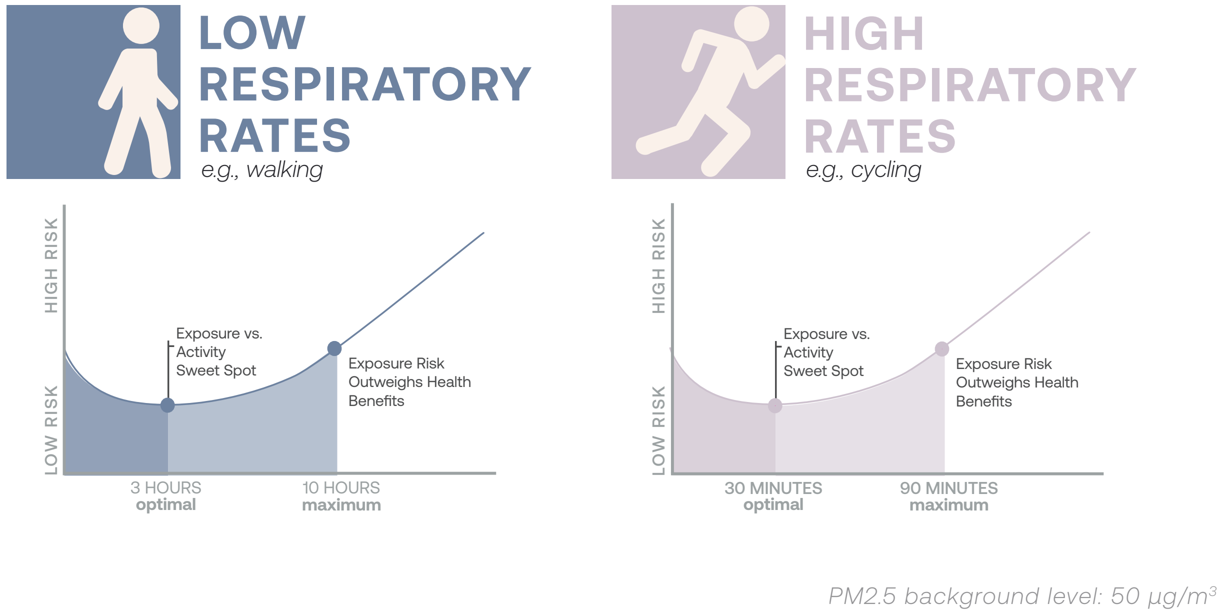


Elevated At Exits, Lowered Roadside

↑ Diagram 4: Fluid Dynamics of the air causing zones of concentration, depositions, and relief.



↑ Diagram 5: Exposure to PM 2.5 vs Respiratory Rates

Morici G, Cibella F, Cogo A, Palange P and Bonsignore MR (2020) Respiratory Effects of Exposure to Traffic-Related Air Pollutants During Exercise. Front. Public Health 8:575137. doi: 10.3389/fpubh.2020.575137 https://www.frontiersin.org/articles/10.3389/fpubh.2020.575137/full

The Field Study

INTRODUCTION

The goal of the pilot field study was to develop and test a repeatable methodology that could be used to assess the accumulation of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in public landscapes. Common landscape materials, including soil and plants, were targeted as mediums to capture airborne particulate matter over time, potentially creating long-term or legacy accumulation of materials that would be harmful to human health. These were also selected for being materials that humans commonly interact with. Low-cost air monitors were positioned adjacent or near to the pilot plot areas to assess general air quality conditions and temporal modulations of the specific site. Air quality data was also assessed for viability in correlation to plant swabs and soils data. The methodology in the pilot study established a foundational baseline for future partnered-studies and opportunity to identity future improvements.

The following section outlines the process of site selection, determination of particulates to monitor and sampling methodologies which monitors soil accumulation, dust accumulation on plants, and air monitoring. The pilot field study also included an assessment of adjacent sites to understand surrounding conditions that may be relevant to the pilot plots.

SELECTION OF CHEMICALS OF CONCERN

Early engagement of the advisory group included collaborative discussions to determine particulate matter, specifically heavy metals and polycyclic aromatic hydrocarbons (PAHs), which should be measured and monitored as a key part of the field study. This multi-industry group provided a diverse perspective to what heavy metals and PAHs (henceforth referred to as sample materials) were of (1) most concern to their specialty areas; (2) have documented effect on health by short-term/ chronic exposure; (3) pose concern in emerging research; and/ or (4) which sample materials can be linked back to a roadway origin through either a vehicular combustion process or vehicular mechanical wear. Consultation with the advisory board yielded a list of nine heavy metals and nineteen PAHs that would be monitored over the course of a 12-month sampling period.

The sample materials include:

Metals:

Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu):
Lead (Pb)
Manganese (Mn)
Nickel (Ni)
Zinc (Zn)

PAHs:

Anthracene
Acenaphthene
Acenaphthylene
Benzo(a)anthrancene
Benzo(a)pyrene
Benson(b)fluoranthene
Benzo (g,h,i)perylene
Benzo(k)fluoranthene
Chrysene
Dibenz(a,h,)anthracene
Dibenzofuran
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Pyrene
1-Methylnaphthalene
2-Methylnaphthalene
2-Chloronapthalene

CHEMICAL OF CONCERN CONSIDERATIONS

Each chemical of concern was considered for its relevance to human and environmental wellness as well as correlation to vehicular use. Metals such as Copper, Chromium, Nickel, Zinc and Lead are found in urban and motorway dusts. In oarticular, Copper and Chromium are well-recognized tracers of non-exhaust break wear emissions that contribute to road dust contamination (13). The PAHs are typically generated as a by-product of incomplete combustion as well as release of petroleum products. (14)The following summarizes key considerations that led to the selection of each sample material:

Heavy Metals:

Arsenic (As): Arsenic is carcinogenic and when exposed to humans can lead to chronic arsenic poisoning, which includes skin lesions and cancer of the skin, liver, bladder, and lungs.

Barium (Ba): Barium is known to increase blood pressure.

Cadmium (Cd): Acute inhalation exposure (high levels over a short period of time) to cadmium can result in flu-like symptoms (chills, fever, and muscle pain) and can damage the lungs. Chronic exposure (low level over an extended period of time) can result in kidney, bone and lung disease.

Chromium (Cr): Adverse health effects associated with Cr(VI) exposure include occupational asthma, eye irritation and damage, perforated eardrums, respiratory irritation, kidney damage, liver damage, pulmonary congestion and edema, upper abdominal pain, nose irritation and damage, respiratory cancer, skin irritation, and erosion and discoloration of the teeth. Some may also develop an allergic skin reaction.

Copper (Cu): High levels of copper can be harmful. Breathing high levels of copper can cause irritation of nose and throat. Ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very-high doses of copper can cause damage to the liver and kidneys, and can even cause death.

Lead (Pb): Exposure to high levels of lead may cause anemia, weakness, and kidney and brain damage. Very high lead exposure can cause death. Lead can cross the placental barrier, which means pregnant women who are exposed to lead also expose their unborn child. Lead can damage a developing baby's nervous system. Generally, lead affects children more than it does adults. Children tend to show signs of severe lead toxicity at lower levels than adults. People with prolonged exposure to lead may also be at risk for high blood pressure, heart disease, kidney disease, and reduced fertility.

Manganese (Mn): Manganese is contained in water, air, and soils. Manganese can release to the air through automobile exhaust. Continued exposure can damage the lungs, liver, and kidneys. Exposure to manganese dust or fumes can also lead to a neurological condition called manganism.

Nickel (Ni): Nickel is found in ambient air at very low levels as a result of releases from oil and coal combustion, nickel metal refining, sewage sludge incineration, manufacturing facilities, and other sources. Dermatitis is the most common effect in humans from chronic dermal exposure to nickel. Cases of nickel dermatitis have been reported following occupational and non-occupational exposure, with symptoms of eczema (rash, itching) of the fingers, hands, wrists, and forearms. Chronic inhalation exposure to nickel in humans also results in respiratory effects, including a type of asthma specific to nickel, decreased lung function, and bronchitis.

Zinc (Zn): Zinc Oxide affects when breathed in. Exposure to Zinc Oxide causes metal fume fever.

PAHs:

Anthracene: Once inside the body, anthracene appears to target the skin, blood, stomach and intestines and the lymph system. Exposure to high doses of anthracene for a short time can cause damage to the skin. It can cause burning, itching and edema, a build up of fluid in tissues. Humans exposed to anthracene experienced headaches, nausea, loss of appetite, inflammation or swelling of the stomach and intestines. In addition, their reaction time slowed and they felt weak.

Acenaphthene: This PAH can effect the skin if breathed in and by passing through the skin. It can cause skin and eyes irritation. Inhaling Acenaphthene can also cause nose, throat, and lung irritation. It may affect the liver and the kidneys.

Acenaphthylene: Acenaphthylene can irritate the skin, eyes, and lungs. It may also affect liver and kidneys. It is a cancer and reproductive hazard.

Benzo(a)anthrancene: This is a probable carcinogen.

Benzo(a)pyrene: Benzo(a)pyrene is a probable carcinogen. It can cause dermatitis and bronchitis. It targets respiratory system, skin, bladder, and kidneys.

Benson(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k) fluoranthene: These are probable carcinogens.

Chrysene: Chrysene may induce immunosuppression similar to certain other PAHs and is a probable human carcinogen.

Dibenz(a,h,)anthracene: This is a probable carcinogen. Contact with this PAH can irritate the skin and eyes. Prolonged or repeated contact can cause a skin rash, dryness and redness. Exposure to sunlight can greatly aggravate these effects. Inhaling Dibenz(a,h)anthracene can irritate the nose and throat causing coughing and wheezing. Exposure to Dibenz(a,h)anthracene can cause headache, dizziness, nausea and vomiting.

Fluoranthene: Effects from exposure to Fluoranthene may include contact burns to the skin and eyes, nausea, tachycardia, cardiac arrhythmias, liver injury, pulmonary edema, and respiratory arrest. This is an occupational carcinogen.

Fluorene: Exposure to Fluorene can cause skin irration and eye burn.

Indeno (1,2,3-cd)pyrene, Pyrene: These are probable carcinogens.

Phenanthrene: Exposure to Phenanthrene may cause skin allergy and irritate the nose and throat.

Nepthalene: Acute exposure of humans to naphthalene by inhalation, ingestion, and dermal contact is associated with hemolytic anemia, damage to the liver, and neurological damage. Possibly causes cataract and is a probable human carcinogen.

1-Methylnaphthalene, 2-Methylnaphthalene: There is not much evidence around human health effects of these.

[13] Adamiec, E., Jarosz-Krzemińska, E., & Wieszała, R. (2016). Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. Environmental Monitoring and Assessment, 188, 369. https://doi.org/10.1007/s10661-016-5377-1

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→ Image: View of I-95 at Penn's Landing
Philadelphia, PA | Philadelphia's Delaware waterfront is cut… | Flickr. (n.d.). Retrieved February 16, 2023, from https://www.flickr.com/photos/jasonparis/3623994505/

SITE SELECTION

Site selection for the field study considered several aspects, including accessibility, relationship to the roadway, access to power, and adjacent variables that are a part of the urban environment.

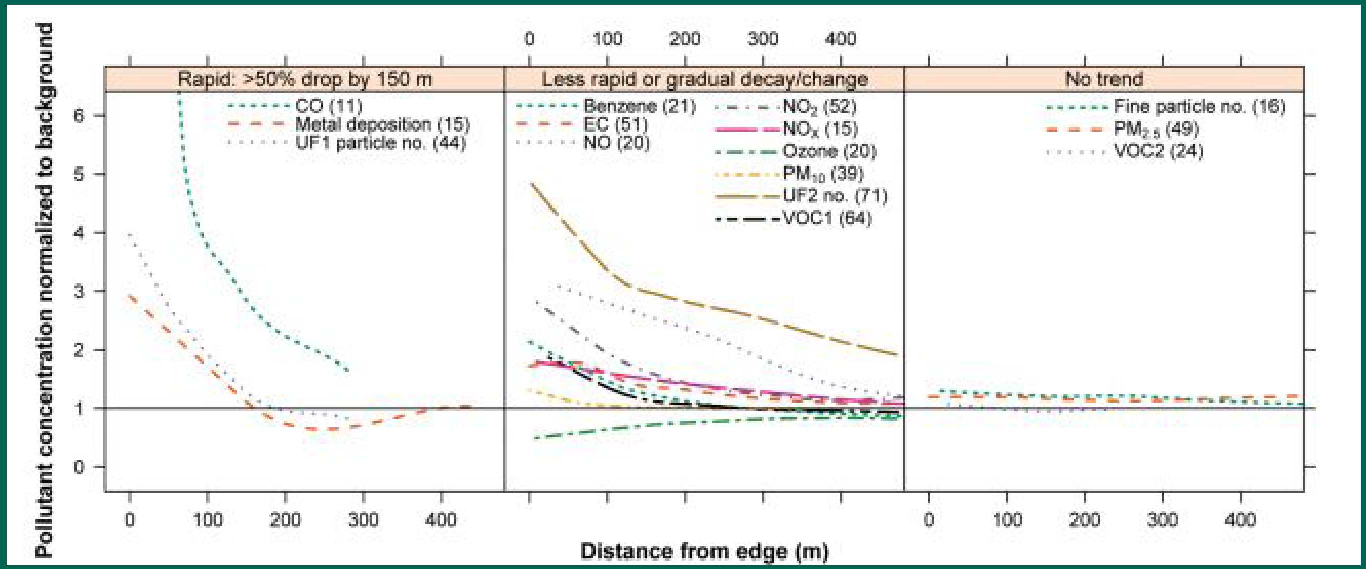
Accessibility needs most importantly focused on what land the research team could secure permission to set up on for over a 12-month period. Ultimately the Team collaborated with the City of Philadelphia and Delftware River Waterfront Corporation - both members of the Advisory Board - to assess viability of plots on property owned and/or managed by these entities. Additionally it was required that the selected site be accessible to the Research Team on a weekly basis. Close proximity to public transportation proved to be highly valuable to closely monitor vandalism and natural impacts to the study plot.

The study sought to ensure that plots were within 100 meters of the roadway. This parameter considered findings (shown below) published in "Near-roadway air quality: synthesizing the findings from real-world data." authored by Karner, Alex A., D. Eisinger and D. Niemeier and published in Environmental Science & Technology 44 14 (2010): 5334-44. This relevant research illustrates a decay curve of the of metal deposition, benzene, and other materials.

A total of twenty-three potential sites were considered for the study and offered a range of relationships to Interstate 95 (I-95). Within the city limits of Philadelphia, the roadway of I-95 is sunken, elevated, and set at the existing grade. In the majority of locations, roadway access to open lands is protected by permeable fencing, impermeable acoustic barriers, and/or vegetation. It was the aim of this study to select a site that would be the most likely to provide measurable readings of the material samples. The sites that were at grade and had permeable security fencing were preferred. For the same reasons, the selection of a site downwind, on the eastern side of the interstate, was most desirable.

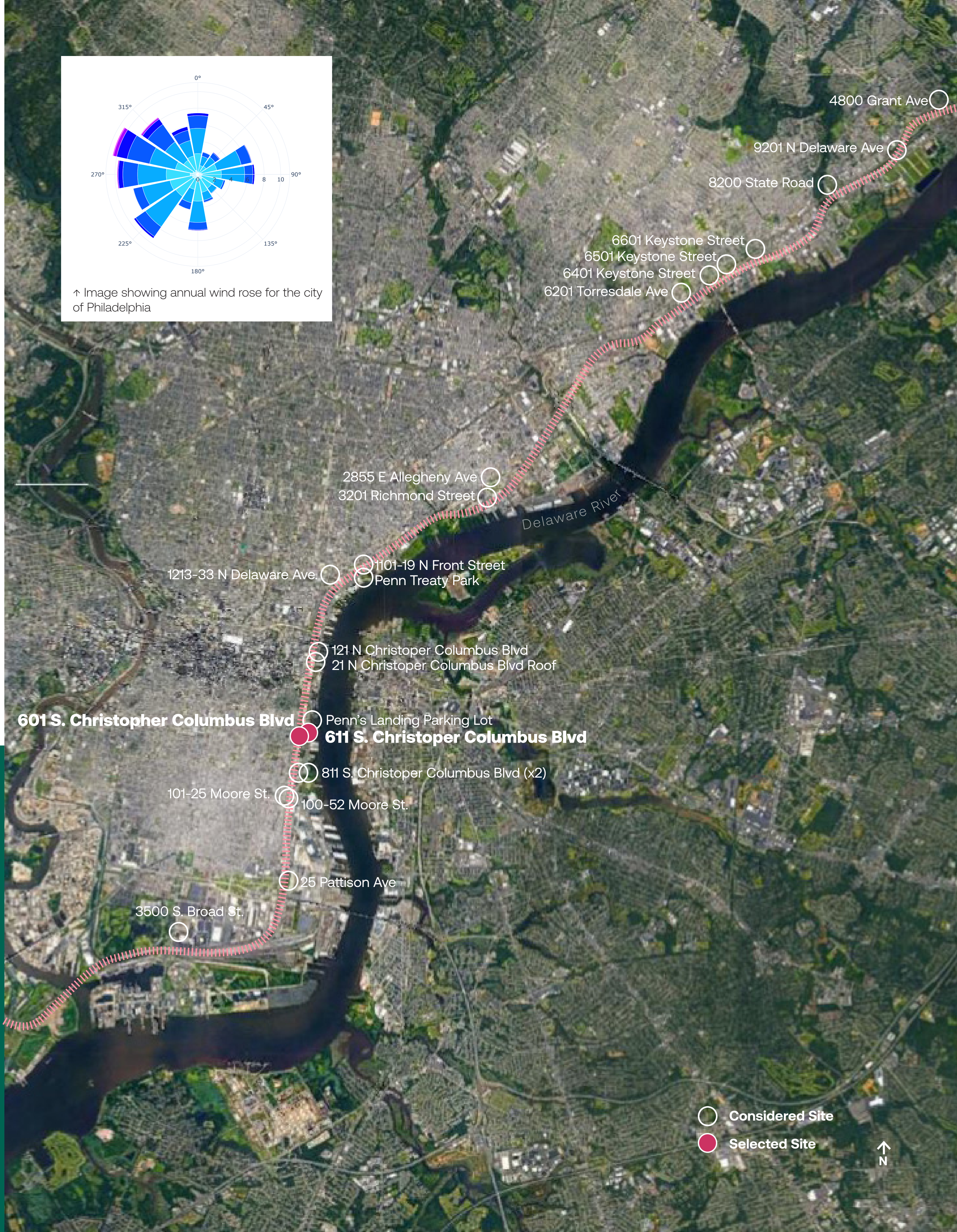
The nature of urban environments brings numerous additional variables to any site. Such variables include on/off ramps, adjacent roads with signals, adjacent railways, and different surrounding land uses. With this consideration, the pilot study selected two sites that were in close proximity so that urban variables were generally shared and impacted each site. The potential overall impact of these variables to individual sites still vary.

Lastly, access to power was an important consideration of the selected site. All potential sites did not have access to Wi-Fi and relied on existing buildings or site furnishings for power. The study utilized a hard-wired card-recording Purple Air Monitor that were ultimately connected to power sources at a maintenance building and light pole. In the last quarter of the study, an AirNote cellular monitor was tested. AirNote and Purple Air monitors utilize the same PM detector and provided comparable results.



↑ Diagram showing decay curve of pollutant accumulation with distance.
Source: Karner, Alex A., D. Eisinger and D. Niemeier "Near-roadway air quality: synthesizing the findings from real-world data." Environmental science & technology 44 14 (2010): 5334-44

↑ Image showing annual wind rose for the city of Philadelphia



SELECTED TEST SITE: INTERSTATE 95 (I-95)

The I-95 site at South Street bridge was selected due to its boundary conditions such as proximity to the highway, no blank walls, limited barriers. The testing plot was set at 15 ft. from the highway while the air monitor was sited about 150 ft from the highway as it needed access to the power. The plots were installed on grade with a porous fence between the roadway and the testing area.

↑ Image: Pre-installation. Plot site, looking south

↑ Image: Installed plot site, looking north

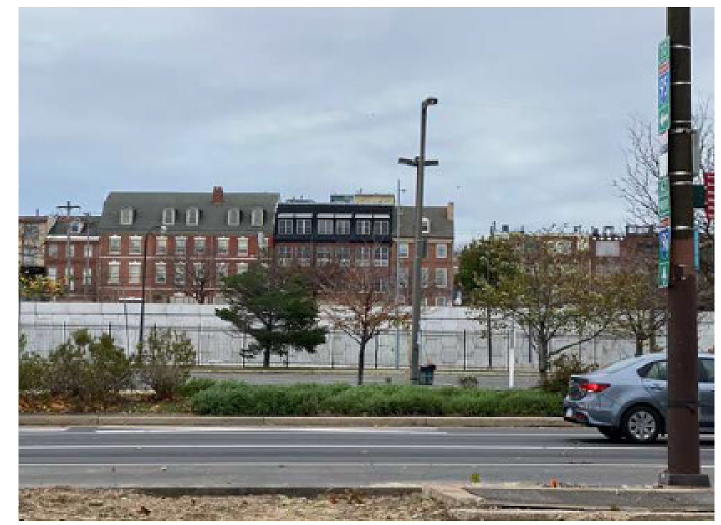
↑ Image: Pre-installation. Plot site, looking northwest

↑ Image: Aerial Image with sited plot

↑ Image: Pre-installation. Plot site, looking southwest

SELECTED TEST SITE: CHRISTOPHER COLUMBUS BOULEVARD

The site was at a distance of 270 ft from the highway with no fence conditions, and had provision for a power outlet with no limited barrier conditions to adjacent roadway. This site was above grade compared to the highway which had a fence along it.



↑ Image: Pre-installation. View from plot site, looking west

↑ Image: Pre-installation. view from the intersection.

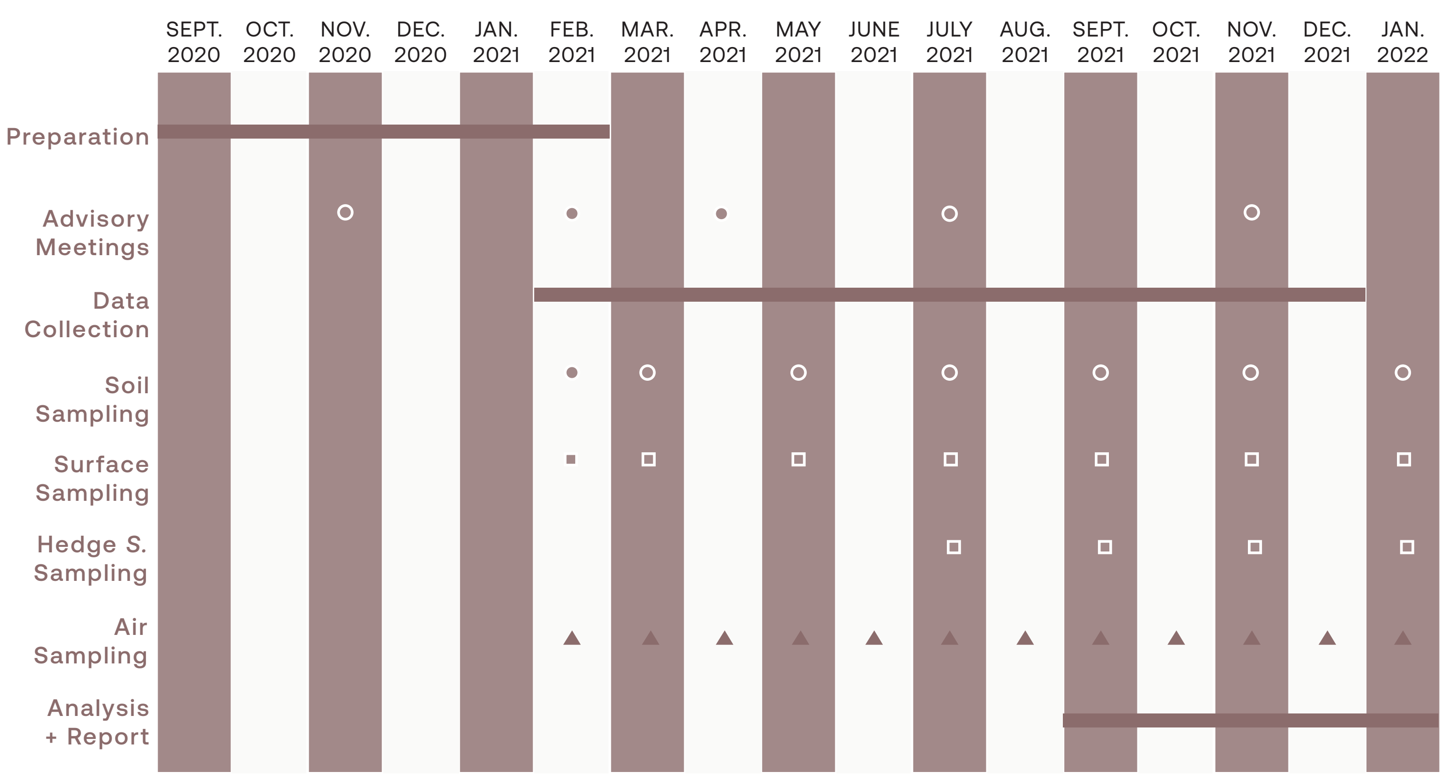
↑ Image: Aerial Image with sited plot

↑ Image: Site-visit to identify locations for air monitors

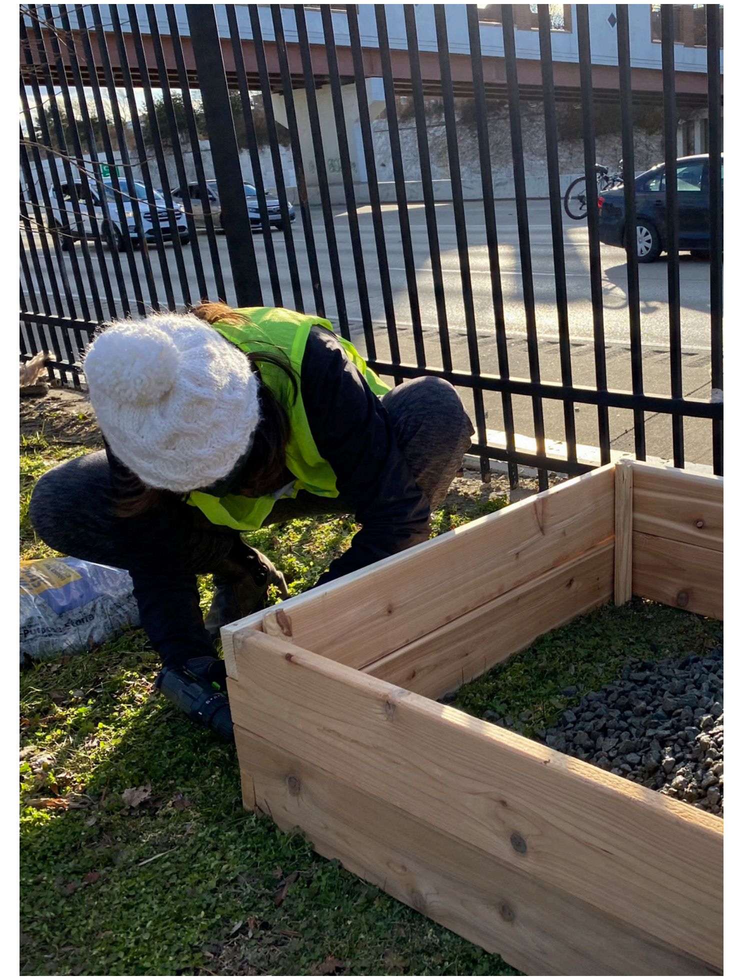
FIELD SAMPLING

The field study commenced with a virtual training conducted by Braun Intertec staff for the OJB research team members. Training included proper techniques for soil sampling, plant wipe sampling, and air monitoring. Prior to sampling, OJB research team members constructed two test plots. Each test plot contained one soil box, two potted yucca plants, and one air monitor. These materials comprised the testing site for a 12-month period.

The field testing piloted an affordable methodology to study particulate matter settlement on/in the soils and plants. Air sampling was performed to monitor background trends and levels of air pollution at the plot locations. With the soil and surface sampling, the research team recorded the flux of pollutant accumulation over time. Testing was conducted at two sites, one adjacent to the highway and the other within 150m from the highway. The two sites were tested independently of each other. Additionally, some nearby existing landscaped sites was to be sampled for context mapping.

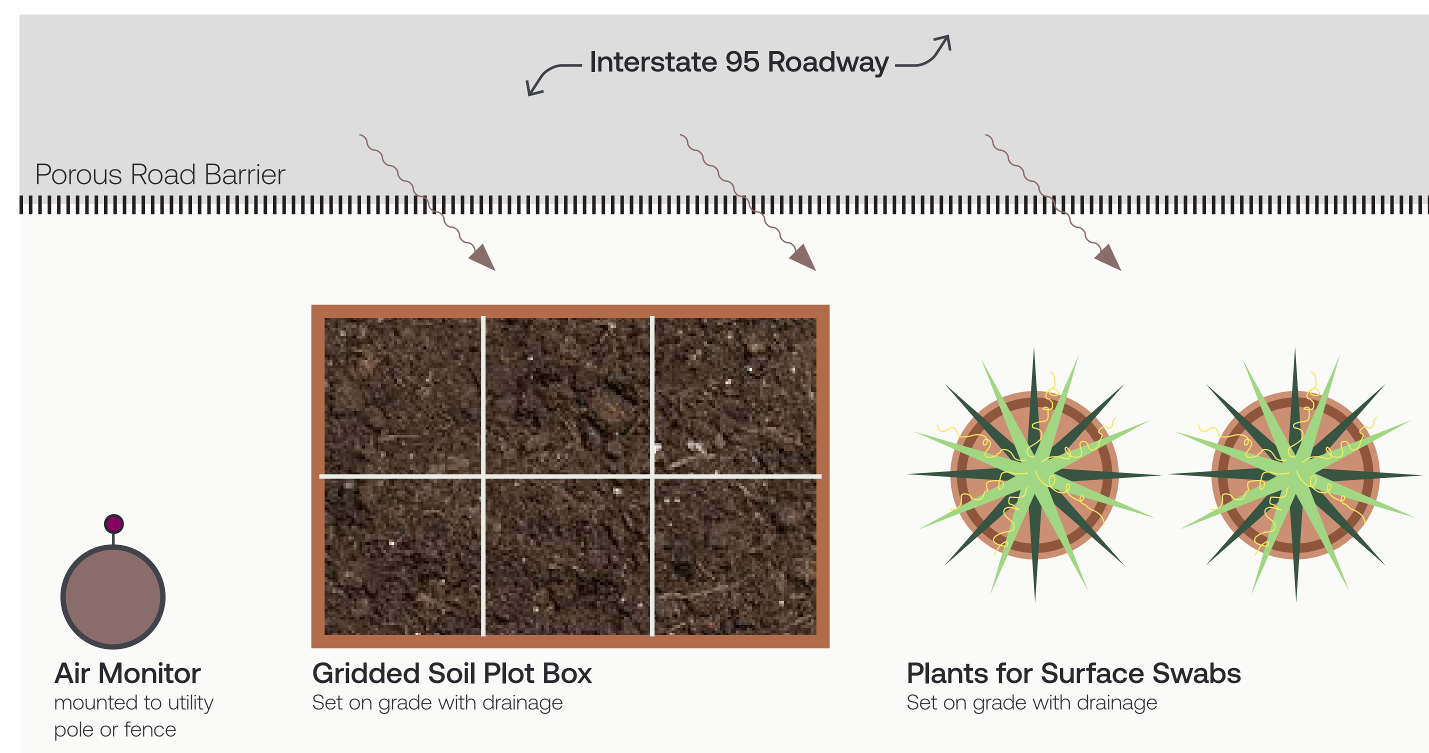


↑Diagram: Project Timeline



↑ Image: Installation of soil plots

As mentioned in the field testing methodology, the planter boxes, plants and air monitors were assembled and installed on the site. The site for installation was selected based on consultation with the advisory group and land owners/managers. The air monitoring unit at the edge of I-95 had to be relocated to the next nearest power source, which was not immediately adjacent to the soil test plot. The air monitor was placed on a shed about 150 ft from the edge of I-95 in the same parking lot which was easily accessible as well as had a constant power supply outlet



↑ Image: Diagram showing layout of test plot

Testing Plot Installation

The soil plots were constructed of pre-fabricated cedar planting boxes, set over a layer of gravel and filter fabric. The test plots were 3ft x 3ft x 1 ft and filled with a total of 6" gravel, a layer of filter fabric, and 6" of clean topsoil. This plot was further sub-divided into plots of 1'x1.5' each in plan for individual soil test sites. Adjacent vegetation was tagged at preferred sampling locations with arborist tags. The site was close to an outdoor power source where the particulate air monitor was mounted for air sampling. Additionally, small potted evergreen plants, sp. Yucca (Yucca filamentosa 'Color Guard'), were placed adjacent to the soil plots.

At each collection date, see timeline (page 24), soil samples were collected from a different zone in the plot. These were collected using a decontaminated or dedicated plastic spoon, and from top 1" of soil section of the desired sample. The sample containers came from the testing laboratory and would be labeled as per the sample point.

TESTED CHEMICALS OF CONCERN

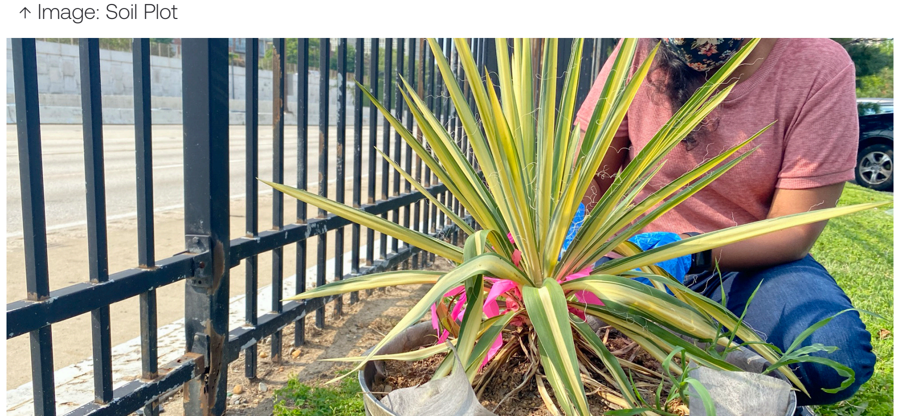
Metals:

Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu):
Lead (Pb)
Manganese (Mn)
Nickel (Ni)
Zinc (Zn)

PAHs:

Anthracene
Acenaphthene
Acenaphthylene
Benzo(a)anthrancene
Benzo(a)pyrene
Benson(b)fluoranthene
Benzo (g,h,i)perylene
Benzo(k)fluoranthene
Chrysene
Dibenz(a,h,)anthracene
Dibenzofuran
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Pyrene
1-Methylnaphthalene
2-Methylnaphthalene
2-Chloronapthalene

↑ Image: Soil Plot



↑ Image: Vegetation for Swabbing

↑ Image: Air Monitor next to soil plot and vegetation

Image →
Assembly of the soil sample box frame and drainage rock

← Image
Installing soil over filter fabric and drainage rock layers

Image →
Installing twine sampling grid on soil plot

Soil Sampling Methodology

SOIL PLOT MATERIALS

- Plan of the plot
- Wooden boxes (2 numbers, 2' x 3' x 1')
- Soil (2 cu. ft/box)
- Gravel
- Filter Fabric

SOIL SAMPLING MATERIALS

- Plastic/ Stainless steel spoon
- Bucket
- Stainless steel/ plastic spoons
- Tape measure
- Field data sheet and sample labels
- Log book
- Ziploc bags
- Decontamination supplies
- Distilled water
- Ice and Cooler
- Zip ties, Garbage bags, tape

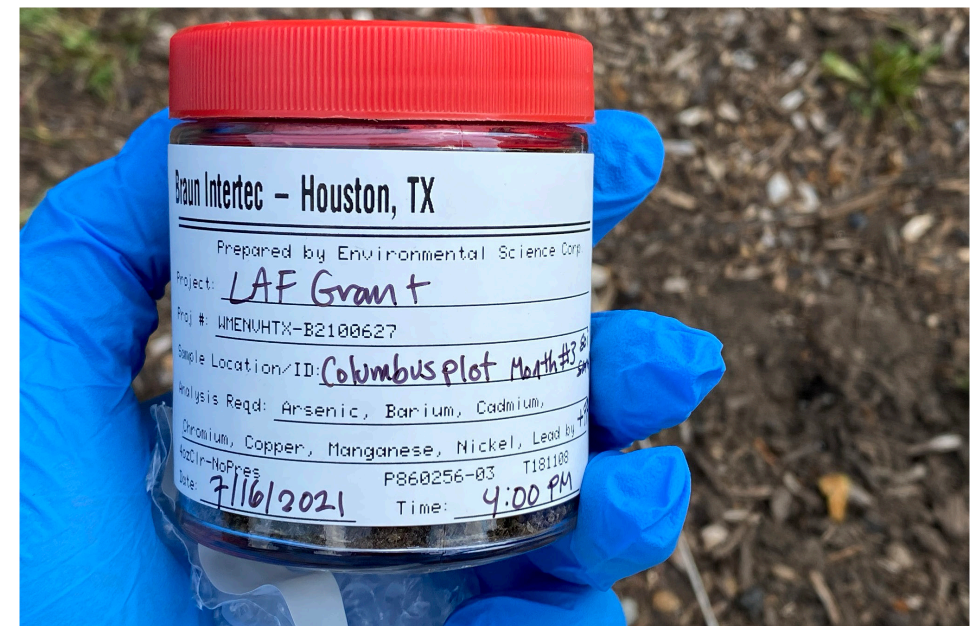
SOIL PLOT PREPARATION

1. Determine the types and amounts of equipment and supplies required.
2. Obtain sampling and testing equipment. Ensure that the equipment are in working order, decontaminated and ready to use.
3. Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.
4. Use different boxes or stakes or flagging, to split test plots into six distinct sampling zones (five sampling zones and one duplicate zone in each plot).
5. Monitor previous weather conditions like rain.

SOIL SAMPLE COLLECTION:

1. Near-Surface: Use spoons to remove large surface material and then use plastic or stainless steel scoop to collect the sample. Tools plated with chrome or other materials should not be used.
2. Surface Soil: Remove the large debris at the surface at the sampling square using a clean spoon. Using a pre-cleaned spoon, discard a thin layer of soil from the area which came in contact with the spade.
3. Transfer the soil sample into a labeled container with a spoon and secure the container tightly.
4. Label the containers with the correct name, date, time, analysis and sampler.
5. Seal the container and put the container in a zip lock bag. Put the ziplock bag into a garbage bag inside of a cooler.
6. Put ice outside the garbage bag.
7. Fill out the chain of custody and attach it to the top of cooler. Seal it with custody seal and tape.

Image →
Collection of
soil sample



← Image
Labeling
soil sample
containers with
date, time, and
site of sampling.

Image →
Sealing the
container and
filling chain of
custody.

Image → Marking leaves to be sampled with Flagging Tape

← Image Using Wipes to collect pollutant accumulation.

Image → Labeling containers with site name, date, and time of collection.

Surface Wipe Sampling Methodology

SURFACE SWAB MATERIALS

- An evergreen potted plant (such as Yucca)
- Flagging Tape
- Soil (2 cu. ft/box)
- Plant pots (2 nos.)
- Filter Fabric
- Gravel

SURFACE SAMPLING MATERIALS

- Wipes
- Sample containers (from lab)
- Labels (from lab)
- Ice and Cooler (from lab)
- Disposable gloves
- Log book
- Zip locks and Zip ties
- Trash bags
- Markers
- Ice and Cooler
- Zip ties, Garbage bags, tape

SURFACE WIPE SAMPLING PREPARATION

1. Determine the types and amounts of equipment and supplies required.
2. Obtain sampling and testing equipment. Ensure that the equipment are in working order, decontaminated and ready to use.
3. Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.
4. Identify if the Yucca has enough leaves to perform the study.
5. Monitor previous weather conditions like rain/snow.

*A new boxwood hedge was introduced on Columbus Boulevard site in May 2021. The hedge was planted along the sidewalk, between the road and the parking lot. The group took surface samples of the hedge using the same methodology as mentioned above.

SURFACE WIPE COLLECTION:

1. Wear gloves and use wipes to remove surface accumulation from the leaves, starting from the top leaves of the plant. Transfer the wipe into a labeled container and secure the container tightly. Mark the leaf for which the data has been collected using a flagging tape.
2. Label the containers with the correct name, date, time, analysis and sampler.
3. Repeat the above process with a different leaves, this time the sample would be used for testing PAHs.
4. Seal the containers and put the containers in different ziplock bags. Put the ziplock bags into a garbage bad inside of a cooler.
5. Fill out the chain of custody and attach it to the top of the cooler. Seal it with custody seal and tape.

Air Monitoring Methodology

AIR MONITORING / SAMPLING MATERIALS

- AirNote or Purple Air Monitor
- A light pole or any other mounting surface
- SD Cards
- Cable Ties
- Tweezers to access SD Cards
- Ladder

AIR MONITORING PREPARATION

1. Identify sites near the soil sampling plot to mount air monitors. Make sure the sites don't have barriers that may affect air flow such as walls, trees etc.
2. Make sure the monitors have access to continuous power.
3. Contact the site owner or the electrician to mount the monitor.
4. If possible, locate the monitor in a area which has access to Wi-Fi. If AirNote is used, access to Wi-Fi is not needed as it is inbuilt into the device and the data is transmitted wirelessly.

AIR SAMPLE COLLECTION:

1. Bi-weekly visit the site to collect data from the air monitor using Tweezers and replace the SD card with an empty SD card.
2. Make sure the air monitor still has access to power and has not been disturbed.
3. After collecting data, post process it using methodology suggested by the Clean Air Council or similar air quality experts.
4. For this pilot research, the air quality data was scrubbed to consolidate 15 minute interval data points for PM 2.5, Temperature and Humidity.

Image → Identification of needs for mounting an air quality monitor.

← Image Installation of PurpleAir at Columbus Boulevard site.

Image → Installation of PurpleAir at the I-95 site.

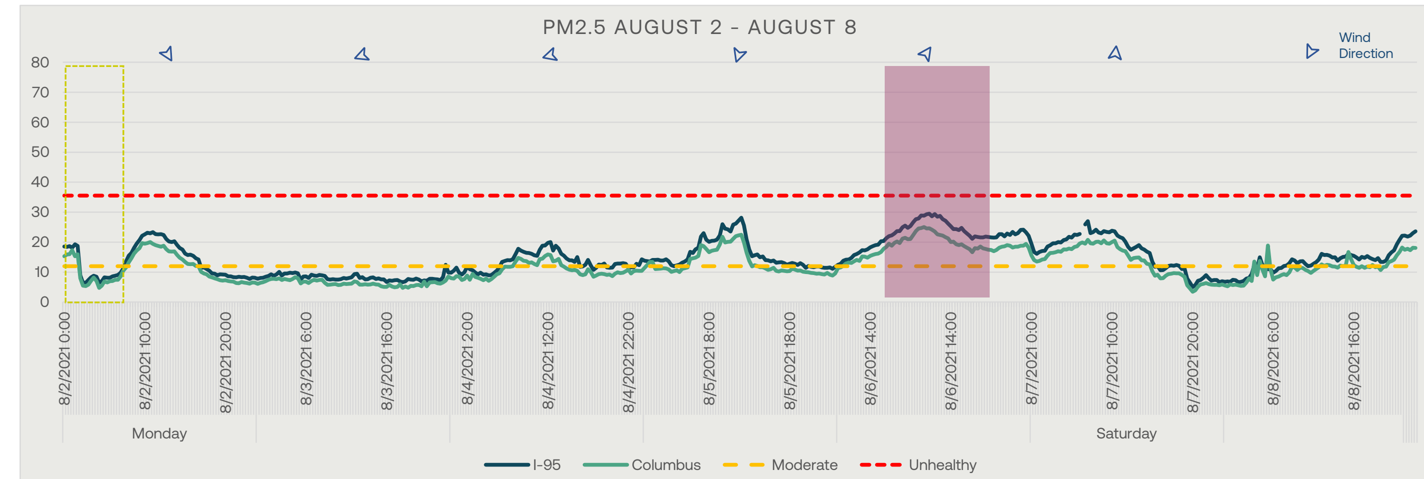
AIR QUALITY SAMPLING

The air quality data was collected on bi-weekly basis for both the sites. The methodology for cleaning up sampling data was advised by air quality experts. This included scrubbing data to just include data points at 15 minute intervals and removing outlier data. Each of the data points included temperature, humidity, and PM 2.5 information to make sure that the particulate matter information wasn't collected during an 'extreme' situation.

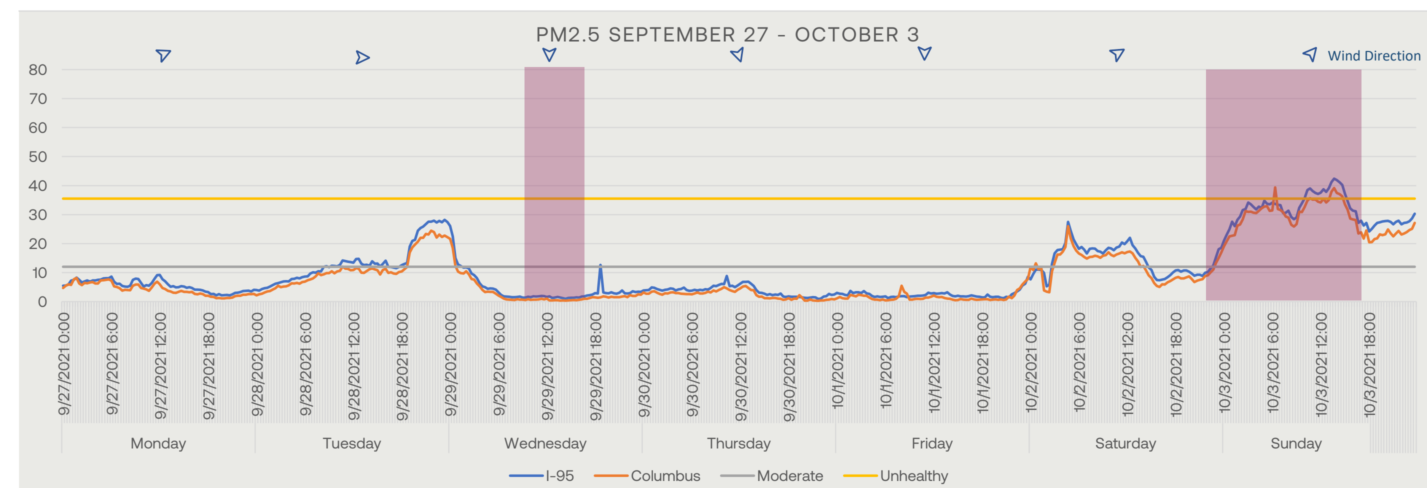
The data was then post-processed into weekly graphs to identify trends in PM 2.5 increase/reduction. This was combined with weather data such as wind speed and direction as well as traffic data to identify patterns.

FINDINGS - WIND GUSTS:

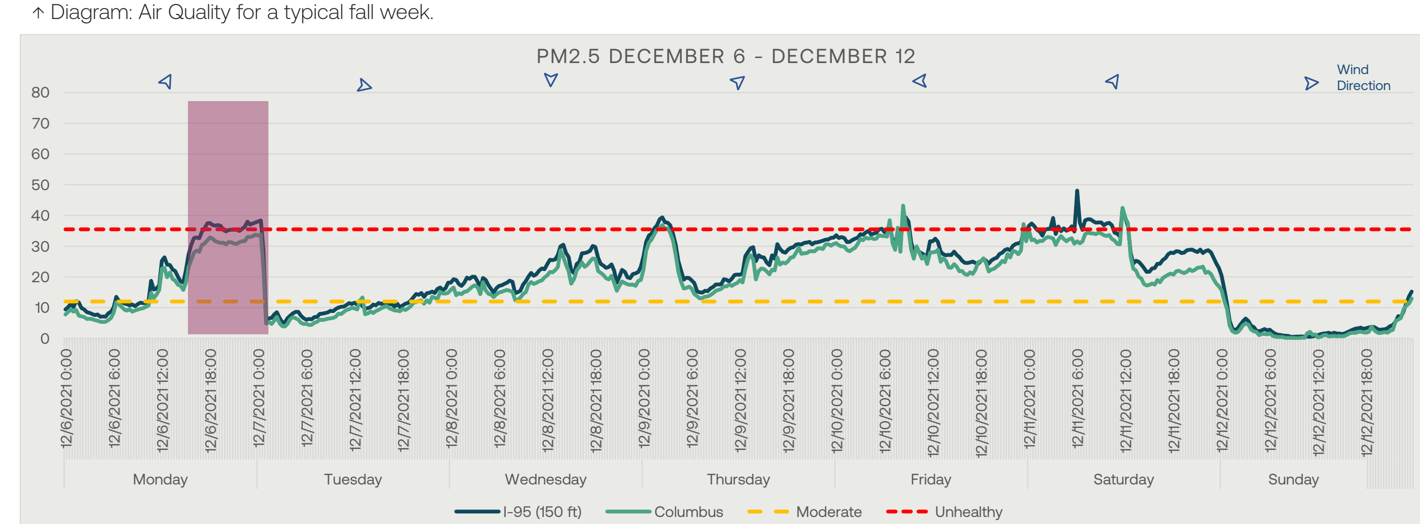
Spikes in PM 2.5 concentration were identified in case of predominant wind in windward direction as highway and wind gust. The following graphs show this trend during summer, fall, and winter. It was also observed that the concentrations weren't as high as in case of lower wind speeds and opposite wind directions. It can be derived that landscapes and weather should be monitored durid pre-design phaase to understand prevailing patterns on site. This will help one design barriers (if needed) as well as zoning of buffers to reduce pollution if the direction of predominant wind gusts are identified.



↑ Diagram: Air Quality for a typical summer week.



↑ Diagram: Air Quality for a typical fall week.

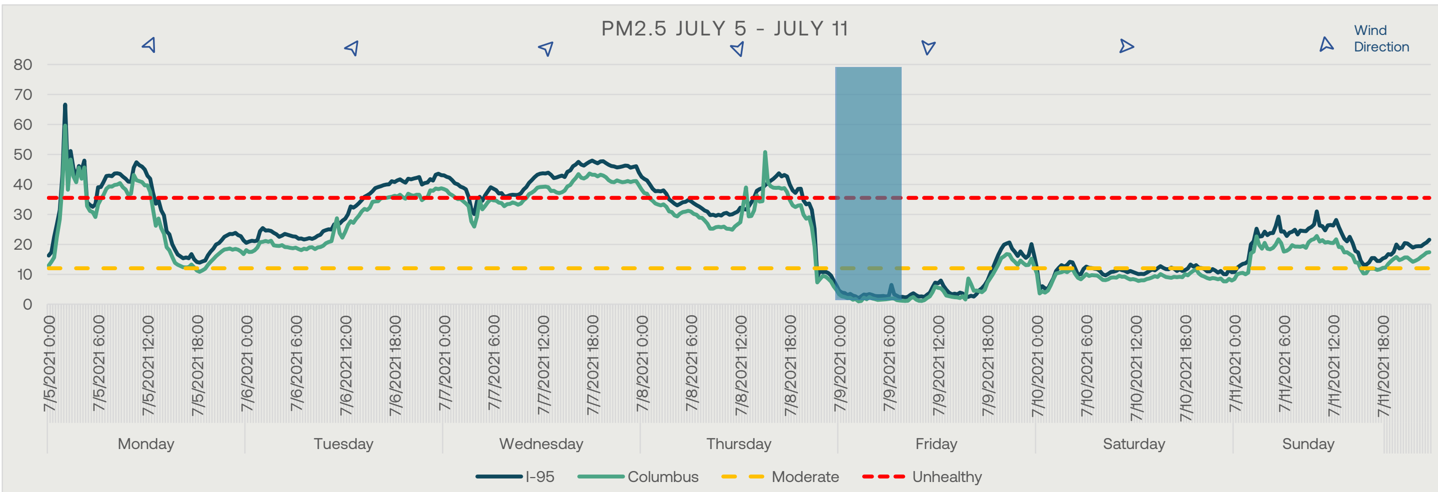


↑ Diagram: Air Quality for a typical winter week.

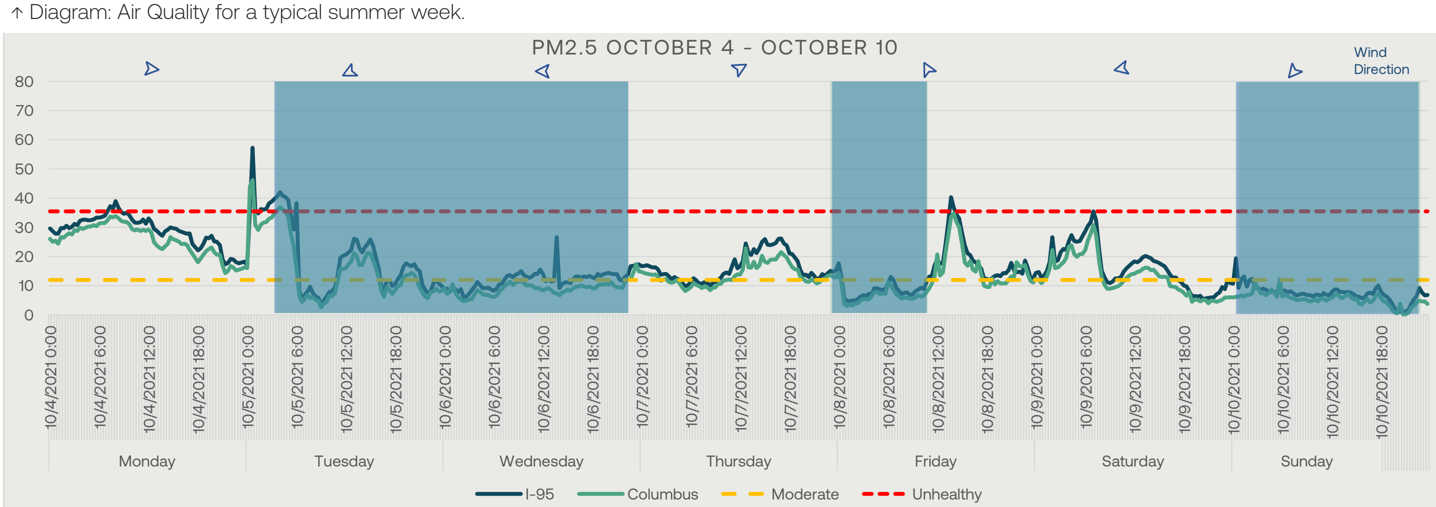
µg/m³ ■ Precipitation — Humidity >80% ■ Wind Gust

FINDINGS - PRECIPITATION:

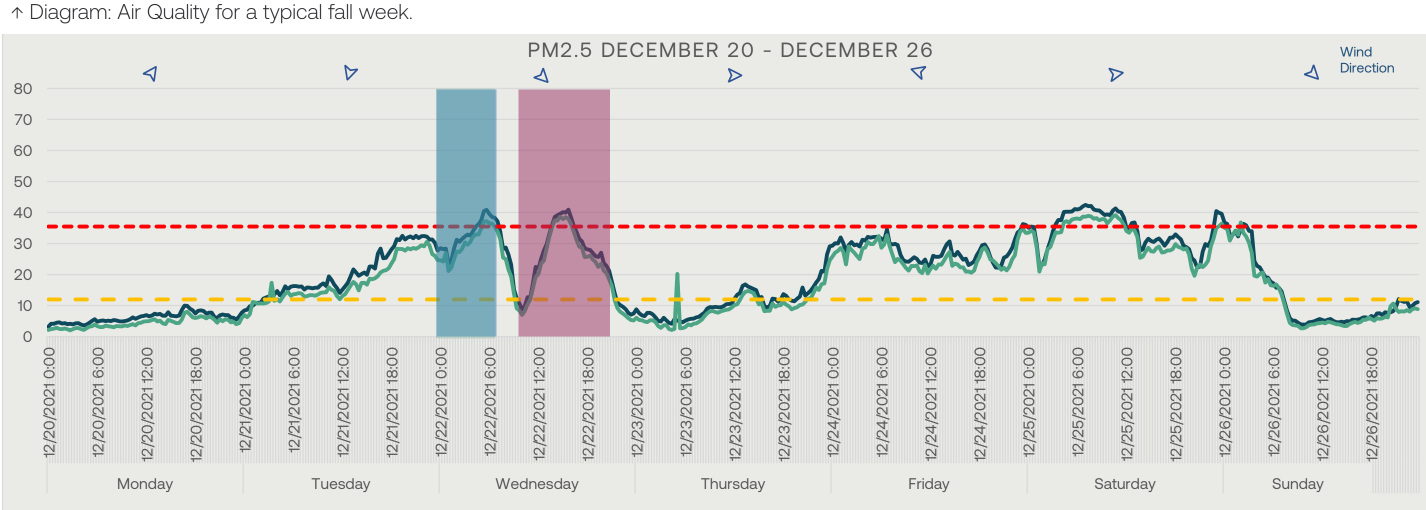
A dip in PM 2.5 concentration was observed right after a precipitation event. The following graphs show similar patterns through the seasons. One can also observe a spike in PM2.5 following a precipitation event as there was a case of wind gust following it. One may hypothesize that in areas that receive more rainfall events during certain seasons, park programming can be designed to activate them more during those seasons. Further, as a future opportunity, it can be investigated if water features such as spray parks can help improve air quality.



↑ Diagram: Air Quality for a typical summer week.



↑ Diagram: Air Quality for a typical fall week.

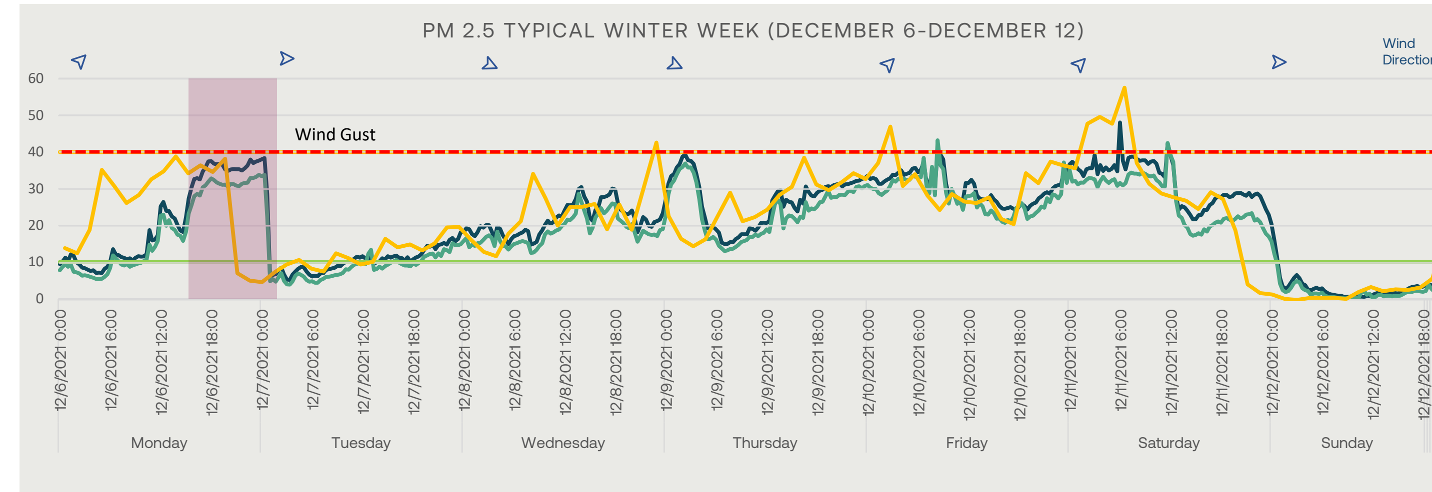


↑ Diagram: Air Quality for a typical winter week.

µg/m³ Precipitation Humidity >80% Wind Gust

FINDINGS - SITING:

Higher concentration of PM 2.5 was observed at I-95 site than Columbus Boulevard site. Further, it can be noted that with wind gust, all three sites saw an increase in PM 2.5 concentration. The decay of PM 2.5 with distance correlate with the study "Near-roadway air quality: synthesizing the findings from real-world data." authored by Karner, Alex A., D. Eisinger and D. Niemeier. At masterplan stage, landscape architects can work with planners to site parks and active programming such that they are away from the highways.

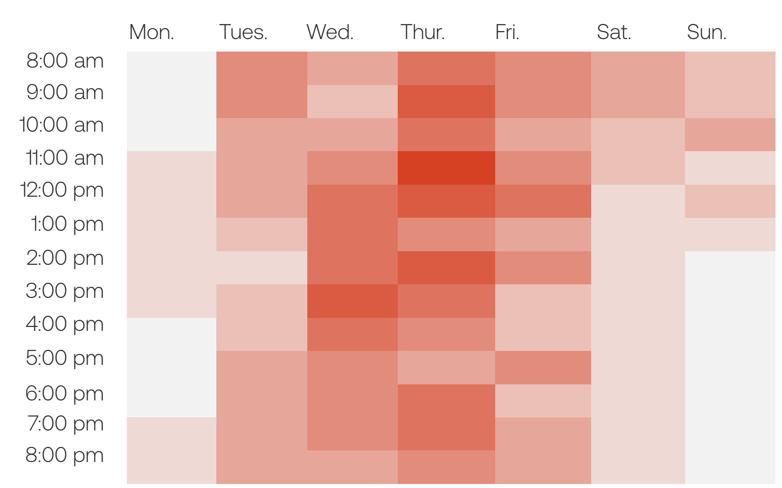


↑ Diagram: Air Quality for a typical winter week.

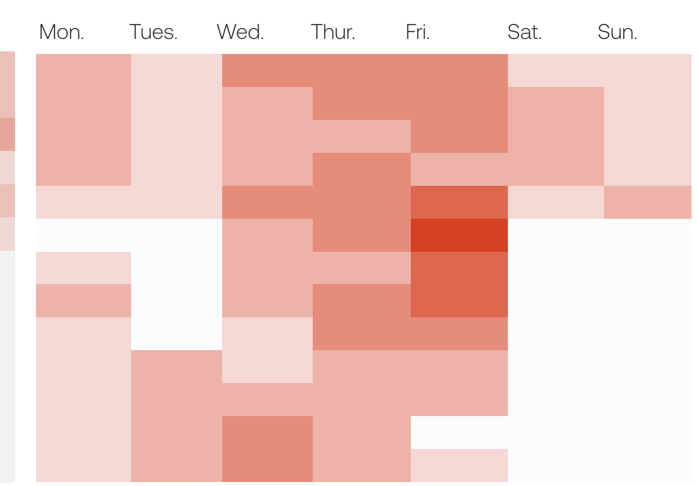
µg/m³ Precipitation Humidity >80% Wind Gust

FINDINGS- DAY OF THE WEEK:

EPA categorizes PM 2.5 concentrations above 35 as 'Unhealthy'. The following two graphs overlay PM 2.5 concentrations of a year long data collected by the monitor. Higher concentration of PM 2.5 was observed during mid week at each of the sites reduction in concentration during the weekends. The deduction is that the increase in concentration may be due to higher traffic volume or traffic patterns on certain days of the week. A research on investigating site specific reasons for increased pollutant levels could be interesting and helpful for designing programming.



↑ Diagram: Frequency of days above 'Unhealthy' level in a year at I-95.

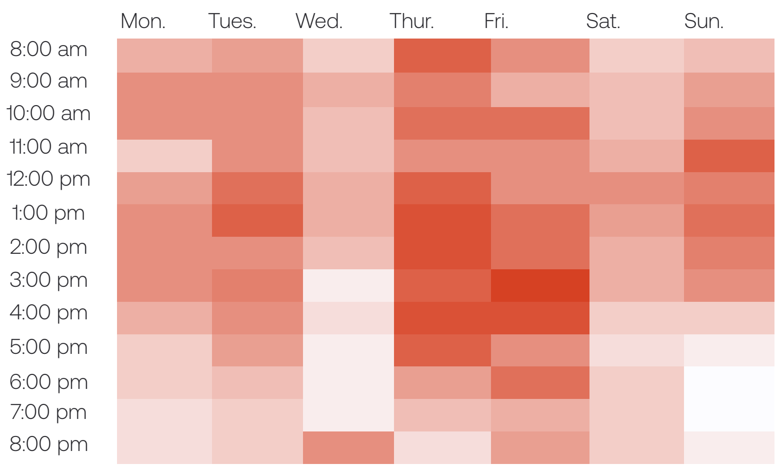


↑ Diagram: Frequency of days above 'Unhealthy' level in a year at Columbus Boulevard.

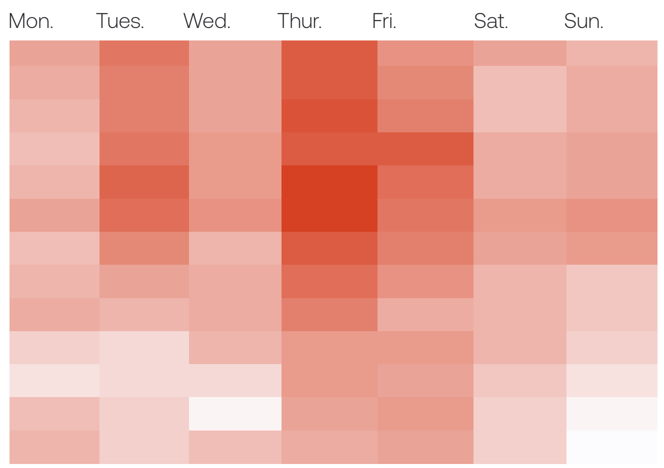
Days
30 0

FINDINGS- TRAFFIC VOLUME:

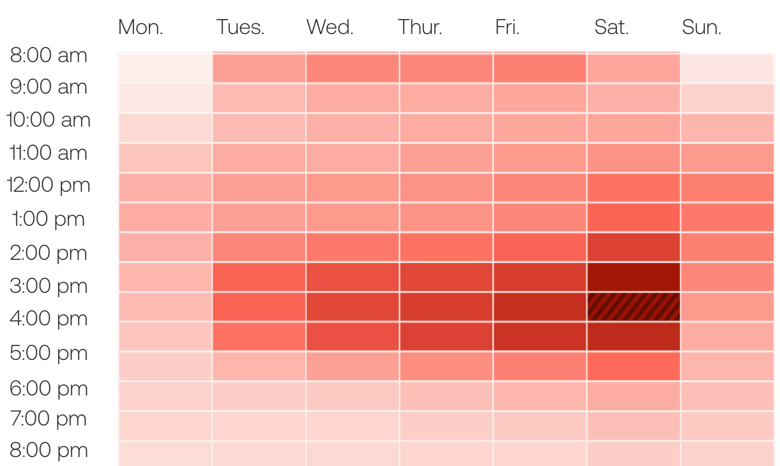
Higher concentration of PM 2.5 coincided with higher traffic volume. However, the traffic data is sourced at the City level and is not site specific. To be able to make correlations, site specific traffic volume is necessary. This would be helpful for designers to be able to design and site active landscapes along highway in zones which have lower traffic volume (assuming no barrier conditions) or activate these spaces during off-peak traffic hours.



↑ Diagram: Frequency of days above 'Moderate' level in a year at I-95.



↑ Diagram: Frequency of days above 'Moderate' level in a year at Columbus Boulevard.



↑ Philadelphia Traffic Report | TomTom Traffic Index." Accessed March 22, 2022.

SOIL SAMPLING

The soil sampling was done on a bi-weekly basis to observe accumulation of PM 2.5 over time. The samples were tested for heavy metals as well as PAHs.

The data was post-processed to identify trends in accumulation. Where available, the collected data was compared with EPA Regional Risk levels for the pollutants to identify if they were higher or lower than the standards.

FINDINGS- HEAVY METALS:

The initial hypothesis of quick but steady accumulation of heavy metals was not observed. It is suspected but not proven that this may be due to precipitation events and leaching. Another conclusion is that the period of study wasn't long enough and the testing period should be increased to observe trends. There may be opportunities to conduct this study for a longer period of time to study which heavy metals accumulate and if we continue to see patterns related to leaching. As designers, there may be some lessons that could be used in designing of open spaces such as washing down landscapes regularly to reduce accumulation in the soils. This may also effect irrigation patterns if necessary.

↑ Diagram: Accumulation of heavy metals on soil plots.

(mg/kg^2)

FINDINGS- PAHs:

Similar to heavy metals, the initial hypothesis of quick but steady accumulation was not observed in case of PAHs. The patterns of increase and decrease in accumulation is similar across most PAHs. Many of these are diesel derived PAHs, but can also come from coal and petroleum products. PAH loading initially appears to be increased at the Columbus Boulevard plot compared to the I-95 plot, which may have to do with increased acceleration and incomplete combustion. There are studies relating acceleration-deceleration pattern to pollutant accumulation and dispersion. There are opportunities to site landscapes such that the programming is not adjacent to traffic with incomplete combustion. Further, there is an opportunity for future pilot projects to monitor changes to the different substrate layers to understand how accumulation changes with soil depth, and if automated wash downs of landscapes can be a viable method to reduce human exposure.

(mg/kg^2)

↑ Diagram: Accumulation of PAHs on soil plots.

VEGETATION SURFACE WIPE SAMPLING

Similar to soil sampling, the vegetation sampling was also done on a bi-weekly basis. Many factors affected testing of accumulation of pollutants on vegetation. The initial proposal was to use boxwood for plant wipe sampling but on further discussion it was realized that Yuccas would be a better choice due to factors including leaf area, leafing pattern, branching pattern, and leaf count. The plants were replaced within a week to to include it in baseline sampling.

In May 2021, a new hedge was introduced at the site as part of sidewalk improvement project between road and the soil plot. This factor was taken into account while continuing to monitor the data at the same location. Additional sampling was done to ensure there were enough data points for the condition with the hedge. Further, the team also collected samples of the hedge to identify trends.

FINDINGS-HEAVY METALS:

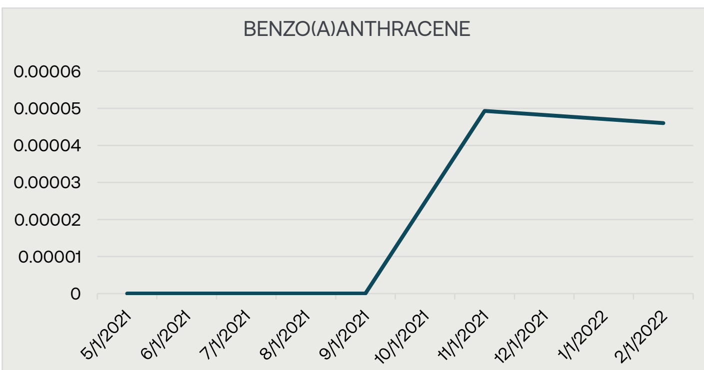
The amount of accumulation on leaves were lower in intensity than the soil samples. The plants on site were stolen multiple times which required the team test to alter the planned schedule. This included increaing the frequency of sampling on new plants obtain enough data points to observe trends. The following graphs show an increase in accumulation of heavy metals within the limited data sample. Drops in intensity potentially correspond to weather events such as rain. A tangential consideration would be to study the impacts of precipitation to intensity of pollutants on plant surfaces. This could translate to also studying impacts of irrigation systems in landscapes adjacent to highways and if there are merits to using sprinkler systems over drip in such conditions to remove or disperse pollutants away from high touch surfaces. Such a study can impact landscape maintenance and management regimes through simple interventions to improve health of public space users.

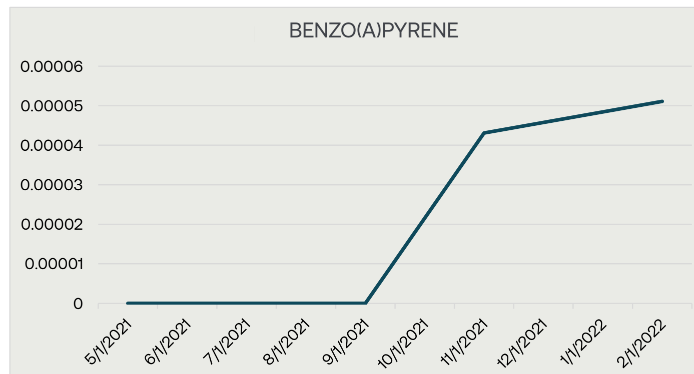
↑ Diagram: Accumulation of heavy metals on vegetation surface.

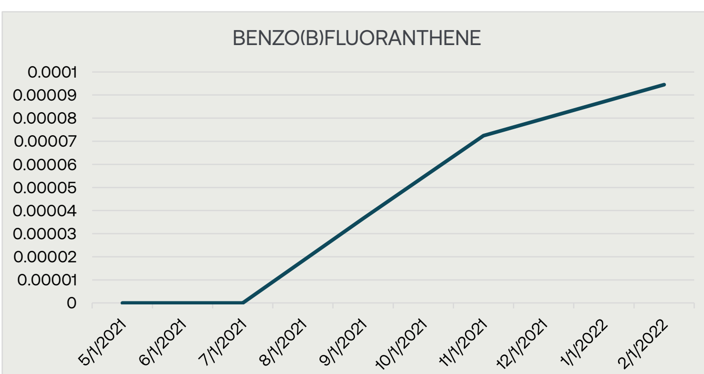
(μg/kg²)

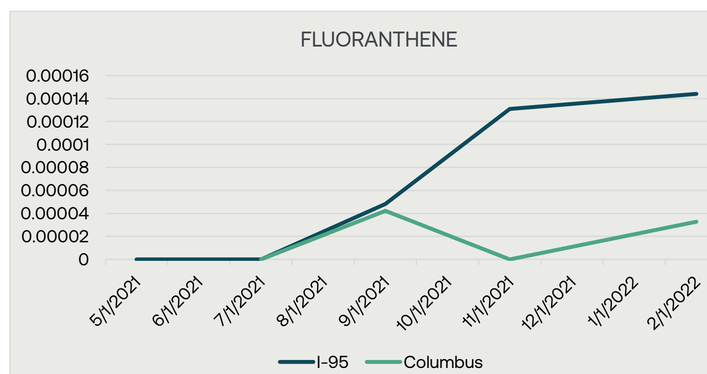
FINDINGS- PAHs:

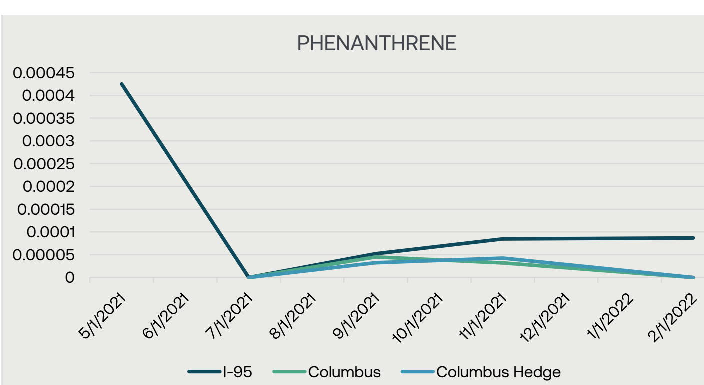
Similar to heavy metals, there was an increase observed in most PAHs at both the sites while the loading intensity is lower than the accumulation in soils. There are opportunities to increase period of research to identify if this trend persists for longer periods. This also leads to study around need for maintenance regimes that help with wash downs of landscapes that are in direct contact with humans.









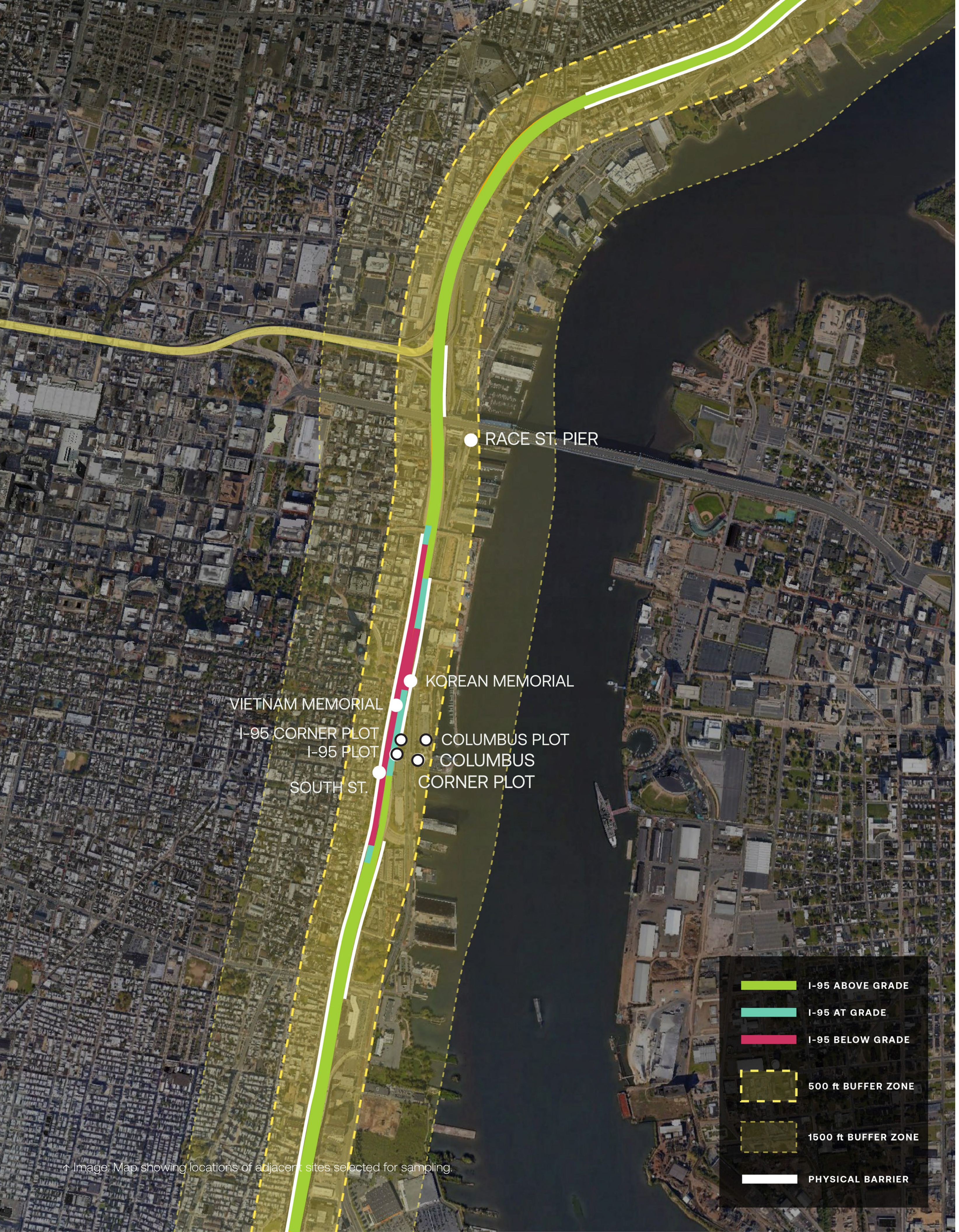


↑ Diagram: Accumulation of PAHs on vegetation surface.

(μg/kg²)

ADJACENT SITES SOIL + VEGETATION SAMPLING

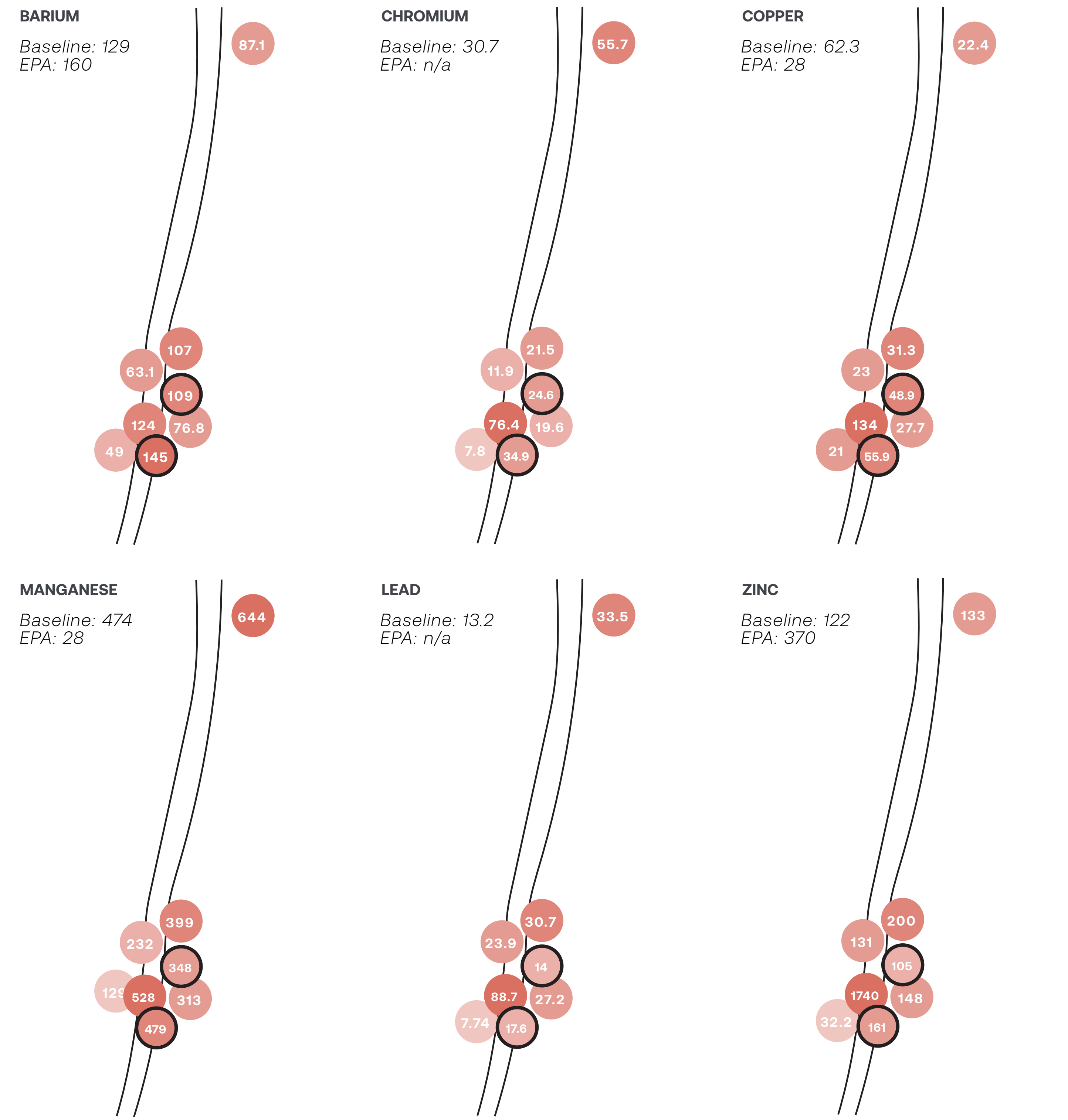
Multiple existing sites along I-95 were identified to study soil as well as vegetation health. The sites had different barrier or adjacency conditions such as elevated roof deck, fence, walls etc. The aim of the study was to understand how these sites were performing since these landscapes have been in place for a longer period of time and have collected higher concentrations of pollutants.



↑ Image: Map showing locations of adjacent sites selected for sampling.

SOIL HEAVY METALS - FINDINGS:

Looking at adjacent sites, the concentration of heavy metals were higher than the test plots for this pilot project. Some of the metals such as Lead at the pilot project site was low compared to trends seens in Philadelphia and this could suggest that lead accumulation may be due to legacy materials, lead paints, and road dust. Since the barrier conditions are different for each of the sites such as deck parks, walls, vegetation barrier etc., there is a future opportunity to study how each of these categories perform along a highway.



↑ Diagram: Levels of heavy metals in soils of adjacent sites.

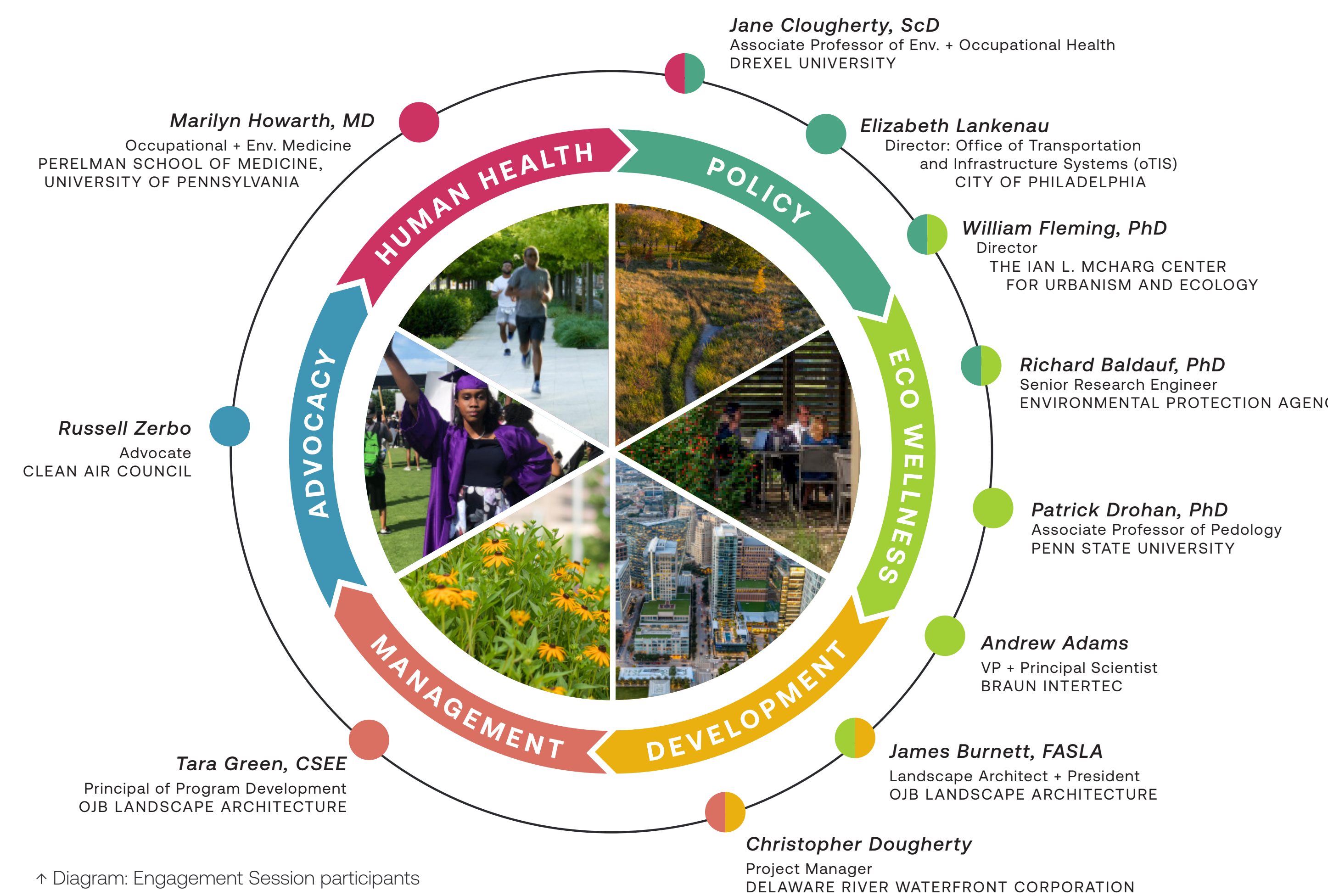
○ sites of pilot study (mg/kg^2)

The Engagement Study

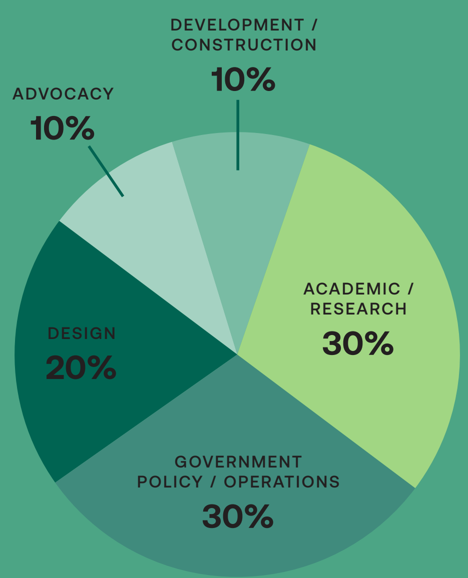
INTRODUCTION

As a companion to the field study pilot, this work piloted a trans-disciplinary engagement effort with the goal to identify areas for positive impact to the health and wellness of people in landscapes adjacent to highways. Engagement exercises were conducted with the Principal Investigators and the Advisory Group to capture a more holistic understanding from disperate viewpoints. This included specialists in human health, advocacy, land management, development, ecological/environmental wellness, and policy.

The following section outlines three separate engagement exercises that were conducted online, with the first being preceded with a digital survey. The exercise focused on the following goals: to (1) pinpoint shared research values and/or focus areas between industries, (2) identify how non-traditional industry engagement could shape and provide added value to the development process, and (3) discuss how to engage with different stakeholders of these landscapes. The engagement pilot was designed to fluidly integrate the ongoing field work to naturally foster conversation of how to catalyze positive change within all associated industries. It resulted in identification of potential collaborative initiatives as well as considerations for alterations to practices that would result in improvement to the wellbeing of people in these public landscapes.



↑ Diagram: Engagement Session participants



↑ Diagram: Current roles of survery participants

ATTENDEES	PRESENTERS	ENGAGEMENT SESSIONS
12	4	5

↑ Diagram: Engagement session 1 participants.

ENGAGEMENT SESSION 1 FINDINGS

+ Need for an empowerment toolkit.
+ Challenges one faces with the complexities of the urban environment.
+ Need for harder data to appeal to the sciences and academia.
+ Priority for human health and social justice was found throughout all the disciplines.
+ Need for hypothesis refinement and identifying what needs to be measured.
+ Redefining metrics of success of a project.

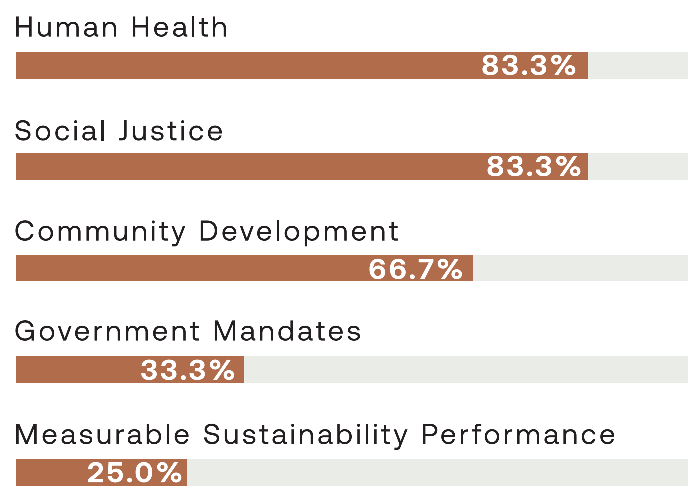
ENGAGEMENT SESSION 1 + SURVEY

The first advisory group engagement session explored the current state of highway-adjacent landscapes and discussed opportunities for emerging trends. A survey questionnaire was prepared to facilitate a conversation around industry perspectives; gaps and growing fields of interest that would impact landscapes adjacent to highways; and such sub-themes as design, human health, equity, policy, and research.

Focus area 1: Where is the focus of industry conversation?

The survey participants were asked to identify major discussion or trends related to air quality and public landscapes adjacent to roadways in their field of work.

The results showed that human health was the highest priority (see below) as the topic of conversation in the industries related to highways and air quality. During the engagement session, there was a remark on designing strategies that could be deployed for projects such as schools that are sited along highways and cater to sensitive groups such as children.



Focus area 2: What is meaningful to our work?

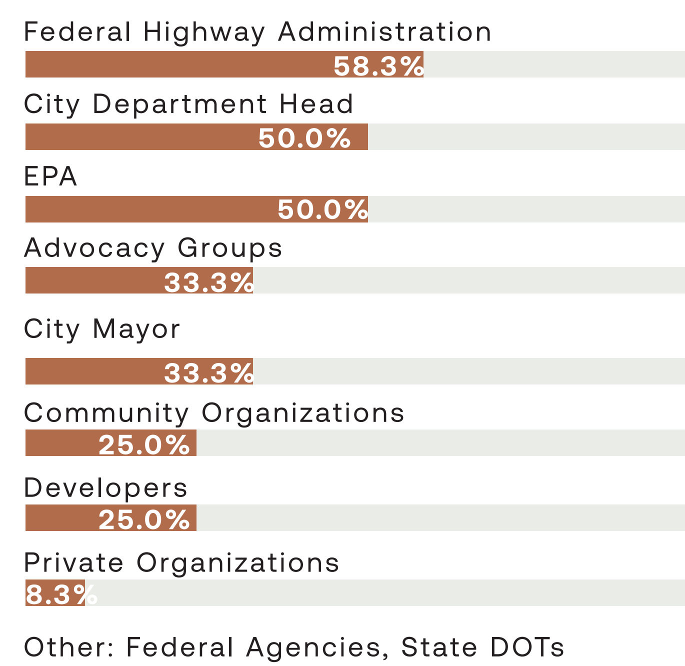
The participants were asked to rank impacts that would make for a meaningful research project focused on public landscapes adjacent to roadways.

It was found that social justice and human health had the highest ranking(see below) as research topics. Some of the suggested synergies included exploring federal restrictions on development types along roadways from air quality perspective. Another research topic included creating a communication framework that helps with advocacy of health concerns and risks along highways. There was an interest in conducting extensive data collection of air quality and noise levels to determine construction suitability of outdoor spaces adjacent to roadways. These topics could be explored in future research projects and would help designers with siting and designing these landscapes.

#1	Social Justice	#2.83 avg
#2	Human Health (mental, physical, community)	#2.92 avg
#3	Environmental Health (soil, water, air)	#3.25 avg
#4	Community Ownership/Place Making	#4.42 avg
#5	Habitat Health (flora & fauna)	#5.25 avg
#6	Economic Health	#6.08 avg
#7	Design Innovation	#6.17 avg
#8	Legacy (history of person or place)	#7.00 avg
#9	Longevity (next generation, futures)	#7.08 avg

Focus area 3: Who should we be working with to make positive change?

One of the questions included asking who the participants believe has the most influence to ensure research findings on roadside air quality in public landscapes have the biggest positive impact to human health. The results highlighted the role of federal highway administration and the city department heads to have the highest significance in bringing positive change. Some of the discussions included creating a standard for maintaining and managing these spaces from air quality and soil health perspective and how can the city agencies be involved in this process of creating these standards.



Focus area 4: Who needs to be at the table?

The survey participants were asked to identify groups that would be most interested in collaborating on roadside air quality issues. Landscape architects, material scientists, psychologists, medical doctors, health agencies, and Environmental Protection Agency were some of the groups that were highlighted. A multidisciplinary approach to research and design of highway adjacent spaces seemed as the suggested way to collaborate going forward.

Focus area 5: Where are our knowledge gaps?

There are knowledge gaps when it comes to understanding landscapes adjacent to roadways/air pollution sources. The following topics were identified related to the built environment, human health, and air quality.

Human Health + Behavior

The sonic impacts of roadway infrastructure on collective psychological health.

Why do people choose to live so close to a highway when given a choice?

Are deck parks or under-freeway parks safe for repeated and daily use?

Our Understanding of Air Quality

The complex chemistry among pollutants, deposition of pollutants on plants, soils, barriers

A systems analysis of air quality/pollutant cycles and how a series of potential interventions might upend those cycles/patterns

Data collection and meshing these data sets together

Localized, un-averaged, short term air quality

The Built Environment

Design to lessen long-term impacts to human health

How long will highways last given the evolving workplace and transportation/energy state

Quantifying the impacts

Designing innovative mitigation strategies for these complex locations and conditions

Is air quality improved by capping, do parks help?

Further, during the engagement session, the advisors remarked the need for hard data, correct selection of pollutants for studies, and correct methodology to analyze and process data these impact studies such as understanding of correlation between human health and air quality.

↑ Diagram: Engagement session 2 participants.

ENGAGEMENT SESSION 2 FINDINGS

- Need to collaborate with scientists and experts early on in the process.
- Integration of human health related testing/monitoring process at the planning stage. A pre-evaluation from human health perspective at project planning stage should include air and sound sampling.
- Understanding the full health-related impacts to the community when creating a new outdoor asset
- Importance of setting performative standards to adhere to evolving agency recommendations and innovations that address specific community risks
- Cost-benefit analysis to educate public about co-benefits designing for air quality.
- Need for communication toolkit to educate people of the air quality improvement after a landscape is constructed.
- Need for a design toolkit for air quality related interventions (like Philadelphia Water Department has on green stormwater infrastructure typologies). That is made in collaboration with leading research institutions.
- Need for integration of post-occupancy evaluation and monitoring system into design projects to evaluate air quality performance of a designed landscape. Determination of industry-relevant monitors and mythologies are needed as not all monitors are considered scientifically relevant.

ENGAGEMENT SESSION 2

The second engagement session focused on identifying new opportunities for multi-industry collaboration during the creation of near-roadway parks. The session was sub-divided into discussing three major phases of making a park such as Project planning, Project Design, and Project Operations. Due to the diverse expertise of the advisory group, a general level of knowledge of the design process was subsidized by team experts who provided short presentations outlining the phase processes, milestones, and major goals. Each presentation was followed by a digital brainstorm session that contained questions from the advisory group. Questions were presented to the group for a deeper discussion. The outcome of the engagement session resulted in highlighting gaps, needs, and tools to improve the process of creating and operating a park.

Focus area 1-Project Planning:

The first focus area was intended to identify potential collaborations and the questions that need to be answered at the project planning stage. Christopher Dougherty (DRWC) presented the masterplan for Delaware Waterfront site at Philadelphia (which is where the sampling sites were located). The presentation discussed the project planning process, suggesting that the project goals are set very early at this stage that are usually the outcomes of stakeholder engagement, economic viability and, planning committee's visions and desires for the site. The following questions could be discussed during the engagement studies and could be incorporated into the visioning and masterplanning process:

Siting + Analysis

- Is the planned park under, near, over or adjacent to a freeway or busy street?
- What types of experts can be involved in a site analysis of a space like this?
- Why is this space being considered for parkland now?
- Can adding new park space improve the daily air quality for those living and working around it?
- Should park planning involve assessments of the air shed, and local airflow patterns which may be influenced by highway infrastructure?

Setting Design Standards

- What air quality assessments are part of the project definition?
- Can adding a park lower road noise and improve sound quality for the residents or business around it?
- What are measurements for success?

Community Assets

- What needs can the new park serve for the community that are not currently being met?
- Are questions about human health addressed during community outreach?
- If the space exists now, how are people currently using it or have used it in the past?
- How do we get increased investment from community and from stakeholders?
- What needs can the new park serve for the community that are not currently being met?

Agency Impacts

- Setting higher regulatory standards
- How do you interface with roadways owners and goal set together?
- What other types of organizations are involved in developing sites like these?
- Linking funding to performative goals.

Focus area 2-Project Design:

The second focus area discussed the project design stage. It included presentation by OJB on key intent of each of the steps of the phase (such as winning a project, concept design, schematic design, design development, construction documentation, construction observation) and identified the collaborators at each stage for a conventional landscape project.

External Challenges:

What if the client doesn't care about air quality? What levers do you have?	Cost / benefit analysis to the AQ goals and monitoring	How can roadway owners be engaged in analysis?

The Design's Challenges:

Designers need design tools for AQ	What should and shouldn't people be doing in these spaces?	Where do landscape architects go for best practices information?
What are the demographics of potential users of the park? Who is using it now and who is not using but could with a new design?	How do you measure or confirm that the design, once it is built, meets or exceeds the goals that were set?	What are the adjacencies of the park and what program would support them or attract them to use the space?

Air Monitoring:

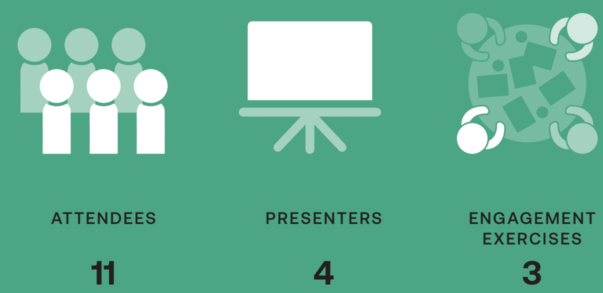
How can we integrate post occupancy evaluation of air quality and also impacts to soil?	What would an "air quality analysis report" of the site look like?	Should we integrate air monitors?
Design a sampling plan to use before and after	Type of deposition, volume, and particle size distribution	Know localized air monitoring vs regional modeling

Research Collaboration:

Do landscape architects know about EPA research on air quality mitigation?	EPA studies show the benefits of certain types of vegetation for screening - how to incorporate into planting design?	What experts or researchers can be included in the goal setting process for air quality?

Focus area 3-Project Operations: The third focus area discussed the programming and activation of space. It included presentation by Tara Green (OJB) on how a landscape architect thinks of park programming and how it might fit with health and wellness of the users. The advisory group collaboratively brainstormed on what information is needed and what actions one can take at project-operations stage after it's constructed to make it a better environment for people. The following were identified as actionable items that could affect this stage of design:

Financial partnerships with academic institutions in wellness	University research program partnerships	Pre-planning - engineering it so the highly active areas are protected
Air monitors with real-time data as part of an environmental education activation component?	Matrix of appropriate programmatic uses	Would university medical centers be interested in activation?
How does this fold into the program of innovation districts?	There is growing literature in greenspace and health in the academic world.	Understanding the demographics of the potential users? How is using it now and who is not using but could with a new design?



↑ Diagram: Engagement session 3 participants.

ENGAGEMENT SESSION 3 FINDINGS

- Importance of pre-evaluation of site from human health perspective at project planning stage. This should include air and sound sampling.
- Land development, zoning and programming based on risk assessment of the site.
- Need for development of community baseline for a site for both public as well as private projects.
- Need for a site based standard risk assessment.
- Educating community of the risks, and developing community benefits agreement including site cleanup and other ways of mitigating risks.
- Continued air quality as well as soil contamination monitoring of a site which further informs future baseline studies/standards.
- Need for non-traditional collaborations at different stages of a projects with experts.
- Need for regulations that ensure a site is assessed for any risks based on site history of contamination

ENGAGEMENT SESSION 3

The third session explored effective outreach to stakeholders and discussing engagement with communities affected by poor roadside air quality. Learnings from the first two engagement sessions were incorporated into determining the agenda for the last session. Questions included understanding what the risks are for different groups specific to development of a roadside landscape as well as what actions could be taken to mitigate the risks. These risk were categorized based on its intensity (high to low) as well as actions for each of the risks were discussed. Further, critical collaborators were identified within a lifetime of a project that could be beneficial in understanding and mitigating these risks.

Focus area 1:

What are the risks for different groups specific to developing a roadside landscape? How should the risk be mitigated?

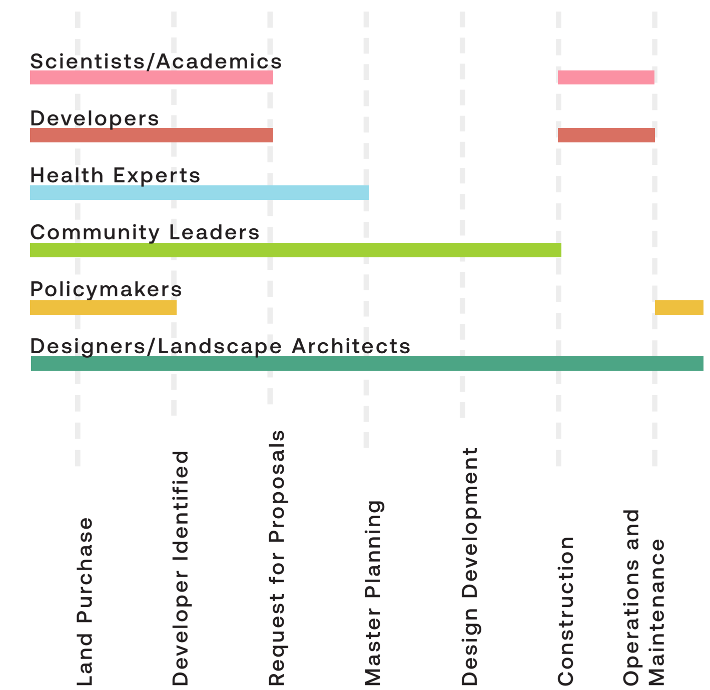
For each of the groups i.e. community, developer, designers and the city agencies, the advisory group suggested what could be considered high to low risk which developing a road.

- **Community:** The following were identified as the risk mitigation strategies as it relates to communities:

- **Designers:** The following were identified as the risks for designers as it relates to roadside landscape projects:

- **Cities/Agencies:** The following were identified as the risks as it relates to the the city or the local agencies with respect to roadside landscape projects. The cost of lawsuits were identified as the high risk. Others include:

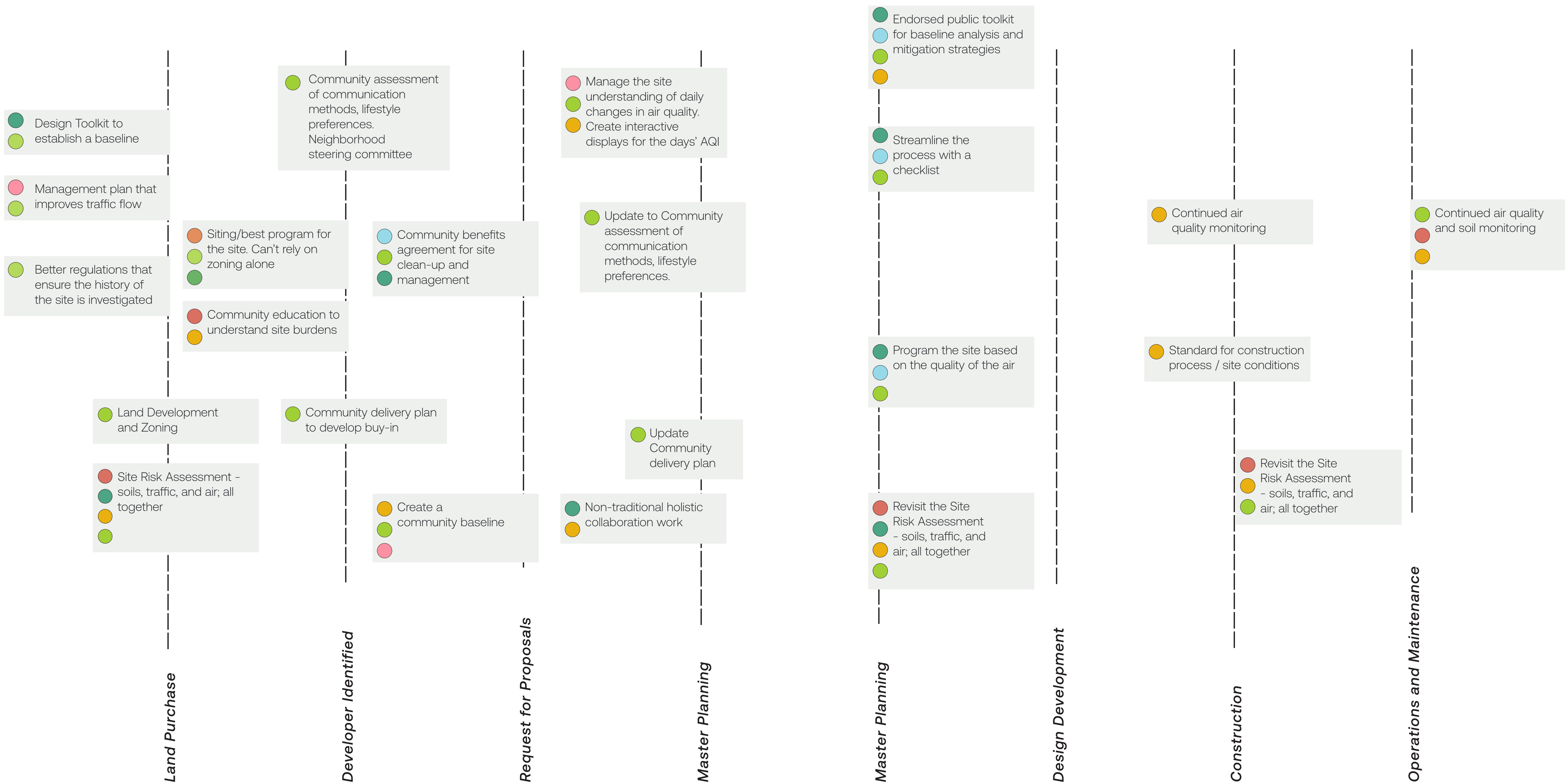
Focus area 2: The advisory group was asked about when during a development of a roadside landscape they see their industry getting engaged:



Focus area 3:

The advisory group brainstormed on creating a road map on when to engage with the experts and the topics of considerations at each stage of a roadside landscape project. Collaborations were also identified during the process on what industries should be included in the topics outlined below:

- Scientists/Academics
- Developers
- Health Experts
- Community Leaders
- Policy Makers
- Designers / Landscape Architects



Conclusion

This study was an important step for interdisciplinary research surrounding human health, wellness, and happiness in landscapes affected by polluted air. Collaboration with experts across various disciplines highlighted widespread concern regarding poor outdoor air quality while illuminating how difficult it is to control, measure, and legislate the air we breathe. It was heartening to discover the efficacy landscape architects have in the continued study of these fields. Both the soil and air monitoring conducted by the project team proved to be straightforward and accessible to non-academics. Furthermore, many of the key collaborators in the collection and interpretation of data are professionals that landscape architects regularly collaborate with, such as soil scientists and geotechnical experts.

The study also highlighted how beneficial it is for landscape architects to collaborate with individuals in fields outside of those they would typically encounter on a design project. Academics, government officials, and leaders of community groups all offered invaluable insight into angles of the problem that the team had not fully considered. Policymakers are uniquely qualified to enforce standards of public health that are so often cast aside in the name of efficiency and profit in the development world. Landscape architects and urban designers, likewise, are perfectly positioned to drive research and implementation of best practices in soil, air, and plant surface monitoring in new roadside landscapes.

Literature review, expert interviews, and ongoing expert engagement sessions were a vital part of the team's research and clarified many of the team's future goals for this research after the completion of the grant period. Toolkits were widely supported as an effective method for the implementation of outdoor air quality best practices. Project risk assessment, design strategies, community engagement and education were all areas in which the team felt a published guide from experts could be a helpful tool. One area that was highlighted for deeper collaboration and exploration was the physics of air movement in complex urban environments and how that impacts the movement of pollutants in the air.

The project engagement sessions illuminated how the expansion of a collaborative group to individuals with greater decision-making power could have a positive impact on the implementation of healthy air practices. Developing a policy matrix at the city and state levels would be a huge step towards actionable change. These sessions also showed the importance of having charrettes in both academic research and with local communities to address specific air quality issues within neighborhoods, communities, and project site locations.

The team also gained a much better understanding of where landscape architecture as a profession can be impactful in the research and implementation process. The team learned that a site analysis process that incorporates air quality monitoring is an achievable goal for designers with client buy in. There were also many exciting ideas raised around the role of programming and maintenance of built landscapes, and how that can lower the risk of air pollution to all site users.

In conclusion, landscape architects are uniquely positioned to listen and learn from communities that will live, play and breathe in the spaces they design. Promoting community health and wellness requires a diversified approach, including metric based analysis, multi-industry collaboration, and goal setting. Air quality is a relatively new and critical piece of complex design puzzles. Further research, data collection and collaboration on air quality can improve our urban spaces, creating a healthier future for all.

Appendix

Soil Sampling Data: The soils were sampled on a bi-monthly basis and was compared with baseline data as well as EPA Regional Risk standards.

Plot ID	Sample Schedule	Date Collected	Total Metals (mg/kg)2								
			Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Manganese	Nickel	Zinc
I-95	Baseline	2/10/2021	1.23 J	129	0.295 J	30.7	62.3	13.2	474	24.4	122
	Month 1	3/10/2021	3	135	<0.500	35.2	70	14.6	489	48.6	129
	Month 3	5/12/2021	<2.00	120	<0.500	31.4	73.3	12.2	685	26.5	113
	Month 5	7/16/2021	<10.0	135	<2.50	33.9	64.9	16.8	543	24.9	150
	Month 7	9/14/2021	<2.00	105	<0.500	23.9	46.7	8.71	330	21	78.6
	Month 10	11/16/2021	2.58 O1	145 J5 O1	<1	34.9 O1	55.9 O1	17.6 O1	479 O1 V	43.2 O1	161 J3 J5 O1
	Month 12	2/13/2022	<1.00	68.6	<1.00	13.6	35	10.6	275	10.3	82.3
Columbus	Baseline	2/10/2021	1.69 J	110	0.236 J	23.1	55.2	10.2	417	22.3	92.5
	Month 1	3/10/2021	3.29	129	<0.500	37.2	61.2	13.5	441	49.5	105
	Month 3	5/12/2021	<2.00	104	<0.500	21.8	55.3	9.87	426	18	96.5
	Month 5	7/16/2021	<10.0	141	<2.50	30.9	70.4	17	515	25	131
	Month 7	9/14/2021	2.29	128	<0.500	32.1	61.5	13.3	418	25.7	104
	Month 10	11/16/2021	2.11	109	<1.00	24.6	48.9	14	348	20.3	105
	Month 12	2/13/2022	<1.52	63.1	<1.52	12.8	36.2	7.88	269	12.8	63.5
EPA Regional Risk-based SSLs3			0.0015	160	0.69	NE	28	NE	28	26	370

↑ Table: Heavy metals accumulation in soils

Plot ID	Sample Schedule1	Date Collected	Total Polycyclic Aromatic Hydrocarbons (PAHs) (mg/kg)2									
			Anthracene	Acenaph-thene	Acenaphth-ylene	Benzo(a) anthracene	Benzo(a) pyrene	Benzo(b) fluoran-thene	Benzo(g,h,i) perylene	Benzo(k) fluoran-thene	Chrysene	Dibenz(a,h) anthracene
I-95	Baseline	2/10/2021	0.0313	0.0104 J	0.00821 J	0.125	0.1	0.135	0.0726	0.0512	0.127	0.018
	Month 1	3/10/2021	0.0117	<0.00600	0.00976	0.0836	0.0791	0.126	0.057	0.0389	0.0931	0.0124
	Month 3	5/12/2021	0.0189	0.00873	0.00969	0.0952	0.0921	0.154	0.0804	0.0536	0.134	0.0174
	Month 5	7/16/2021	<0.00600	<0.00600	<0.00600	0.024	0.0288	0.0453	0.0283	0.0163	0.0374	<0.00600
	Month 7	9/14/2021	0.00713	<0.00600	0.00822	0.0467	0.0491	0.0806	0.0456	0.025	0.063	0.00946
	Month 10	11/16/2021	0.0138	<0.00600	0.00867	0.0724	0.0714	0.116	0.0644	0.041	0.0833	0.0146
	Month 12	2/13/2022	0.0147	0.00714	<0.00600	0.0503	0.0583	0.0826	0.0519	0.0303	0.0587	0.0097
Columbus	Baseline	2/10/2021	<0.00579	<0.00526	<0.00543	0.0101 J	0.00946 J	0.0139 J	0.00878 J	<0.00541	0.00918 J	<0.00433
	Month 1	3/10/2021	0.00933	<0.00600	0.00858	0.0484	0.0501	0.0733	0.0333	0.0249	0.0452	0.00716
	Month 3	5/12/2021	0.0101	<0.00600	0.00824	0.0563	0.051	0.08	0.0427	0.0282	0.0709	0.0098
	Month 5	7/16/2021	<0.00600	<0.00600	<0.00600	0.0141	0.0171	0.0277	0.0175	0.0108	0.0168	<0.00600
	Month 7	9/14/2021	0.0261	<0.00600	0.0077	0.164	0.183	0.26	0.151	0.088	0.142	0.0327
	Month 10	11/16/2021	0.0153	<0.00600	0.0284	0.0728	0.096	0.13	0.0806	0.0445	0.0783	0.0167
	Month 12	2/13/2022	<0.00600	<0.00600	<0.00600	0.0214	0.0284	0.04	0.0251	0.0142	0.0262	<0.00600
EPA Regional Risk-based SSLs3			58	5.5	NE	0.011	0.0029	0.3	NE	2.9	9	0.096

↑ Table: PAHs accumulation in soils

Plot ID	Sample Schedule1	Date Collected	Total Polycyclic Aromatic Hydrocarbons (PAHs) (mg/kg)2									
			Dibenzo-furan	Fluoran-thene	Fluorene	Inde-no(1,2,3-cd) pyrene	Naphtha-lene	Phenan-threne	Pyrene	1-Methyl-naphtha-lene	2-Methyl-naphtha-lene	2-Chloro-napthalene
I-95	Baseline	2/10/2021	0.00844 J	0.261	0.0152	0.0921	0.0176 J	0.12	0.177	0.0169 J	0.0270 J	<0.00966
	Month 1	3/10/2021	<0.00600	0.224	0.00741	0.0673	0.0211	0.0875	0.174	0.021	0.0392	<0.0200
	Month 3	5/12/2021	0.00785	0.251	0.0113	0.0778	<0.0200	0.139	0.192	0.0214	0.0357	<0.0200
	Month 5	7/16/2021	<0.00600	0.055	<0.00600	0.0246	<0.0200	0.0218	0.0481	<0.0200	<0.0200	<0.0200
	Month 7	9/14/2021	<0.00600	0.00824	<0.00600	0.0448	<0.0200	0.0338	0.069	<0.0200	0.0274	<0.0200
	Month 10	11/16/2021	<0.00600	0.162	<0.00600	0.0685	<0.0200	0.0628	0.141	<0.0200	0.0297	<0.0200
	Month 12	2/13/2022	<0.00600	0.12	0.00642	0.0484	<0.0200	0.0726	0.0995	<0.0200	<0.0200	<0.0200
Columbus	Baseline	2/10/2021	<0.00536	0.0175	<0.00516	0.0105 J	<0.0103	0.00687 J	0.0144 J	<0.0113	<0.0107	<0.0117
	Month 1	3/10/2021	0.00604	0.0971	0.0092	0.0376	<0.0200	0.0487	0.0747	0.0212	0.0358	<0.0200
	Month 3	5/12/2021	0.006	0.124	0.00683	0.0434	0.0234	0.0514	0.0969	0.026	0.0535	<0.0200
	Month 5	7/16/2021	<0.00600	0.0282	<0.00600	0.0152	<0.0200	0.00909	0.0243	<0.0200	<0.0200	<0.0200
	Month 7	9/14/2021	<0.00600	0.296	<0.00600	0.163	<0.0200	0.0761	0.245	<0.0200	0.0231	<0.0200
	Month 10	11/16/2021	<0.00600	0.152	<0.00600	0.0765	0.0233	0.0481	0.125	0.0259	0.0474	<0.0200
	Month 12	2/13/2022	<0.00600	0.0387	<0.00600	0.0235	<0.0200	0.0128	0.0352	<0.0200	<0.0200	<0.0200
EPA Regional Risk-based SSLs3			NE	89	5.4	0.98	0.00038	NE	13	0.006	0.19	NE

↑ Table: PAHs accumulation in soils (contd.)

Vegetation Surface Sampling Data: The vegetation surface was sampled on a bi-monthly monthly basis

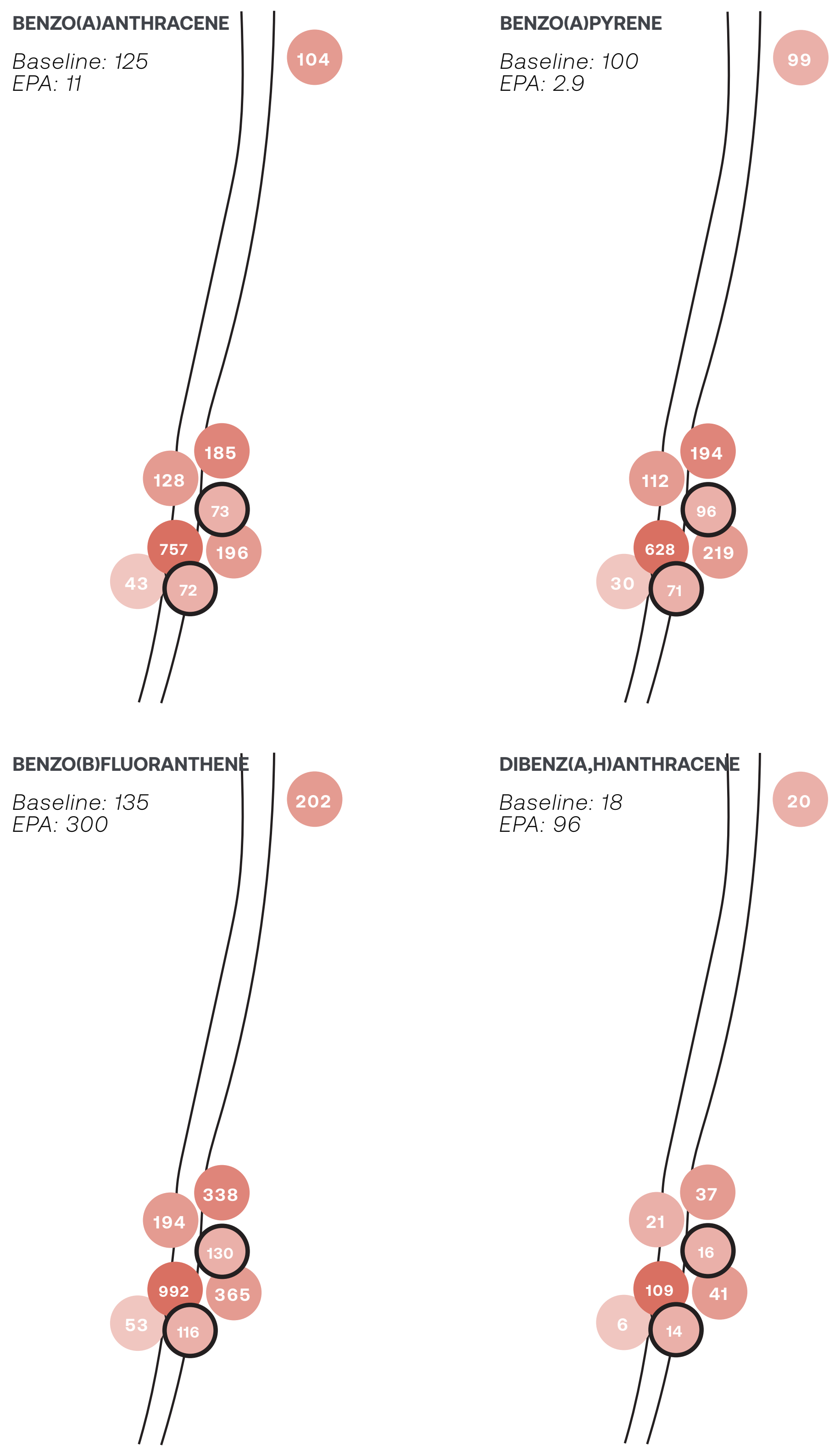
Plot ID	Sample Schedule	Date Collected	Total Metals (mg/kg)2								
			Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Manganese	Nickel	Zinc
I-95	Baseline	2/10/2021	1.23 J	129	0.295 J	30.7	62.3	13.2	474	24.4	122
	Month 1	3/10/2021	3	135	<0.500	35.2	70	14.6	489	48.6	129
	Month 3	5/12/2021	<2.00	120	<0.500	31.4	73.3	12.2	685	26.5	113
	Month 5	7/16/2021	<10.0	135	<2.50	33.9	64.9	16.8	543	24.9	150
	Month 7	9/14/2021	<2.00	105	<0.500	23.9	46.7	8.71	330	21	78.6
	Month 10	11/16/2021	2.58 O1	145 J5 O1	<1	34.9 O1	55.9 O1	17.6 O1	479 O1 V	43.2 O1	161 J3 J5 O1
	Month 12	2/13/2022	<1.00	68.6	<1.00	13.6	35	10.6	275	10.3	82.3
Columbus	Baseline	2/10/2021	1.69 J	110	0.236 J	23.1	55.2	10.2	417	22.3	92.5
	Month 1	3/10/2021	3.29	129	<0.500	37.2	61.2	13.5	441	49.5	105
	Month 3	5/12/2021	<2.00	104	<0.500	21.8	55.3	9.87	426	18	96.5
	Month 5	7/16/2021	<10.0	141	<2.50	30.9	70.4	17	515	25	131
	Month 7	9/14/2021	2.29	128	<0.500	32.1	61.5	13.3	418	25.7	104
	Month 10	11/16/2021	2.11	109	<1.00	24.6	48.9	14	348	20.3	105
	Month 12	2/13/2022	<1.52	63.1	<1.52	12.8	36.2	7.88	269	12.8	63.5
EPA Regional Risk-based SSLs3			0.0015	160	0.69	NE	28	NE	28	26	370

↑ Table: Heavy Metals accumulation in Vegetation Surface (contd.)

[1]Samples were collected by Braun Intertec Corporation (Braun Intertec) and analyzed by Pace Analytical in Mt. Juliet, Tennessee.
[2]Metals analyzed by U.S. Environmental Protection Agency (EPA) Methods 6010B and 6020.
(J) The identification of the analyte is acceptable; the reported value is an estimate.
All values reported in milligrams per kilogram (mg/kg).

ADJACENT SITES SOIL SAMPLING- PAHS

Adjacent sites were tested for PAHs to understand how they are performing compared to pilot study sites.

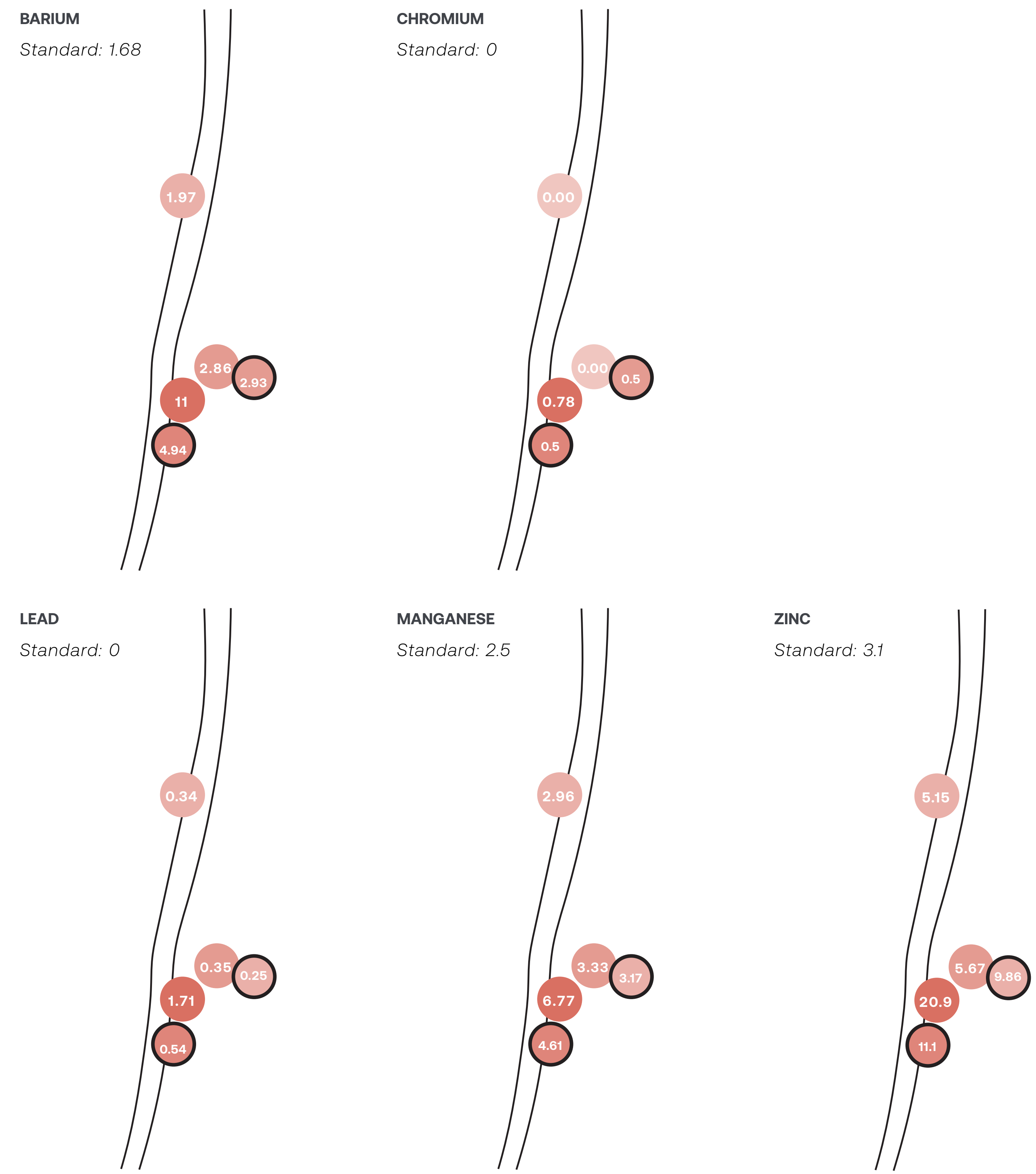


↑ Diagram: Levels of PAHs in soils of adjacent sites.

○ sites of pilot study (µg/kg²)

ADJACENT SITES VEGETATION SURFACE SAMPLING- HEAVY METALS

The vegetation surface were sampled at the adjacent sites and in general it was observed that the occumulation was higher at site adjacent to I-95 on grade with the highway.



↑ Diagram: Levels of heavy metals in swabs of vegetation in adjacent sites.

○ sites of pilot study (µg/kg²)