Moss and Air Quality

Patti Bakker
Amanda Bidwell

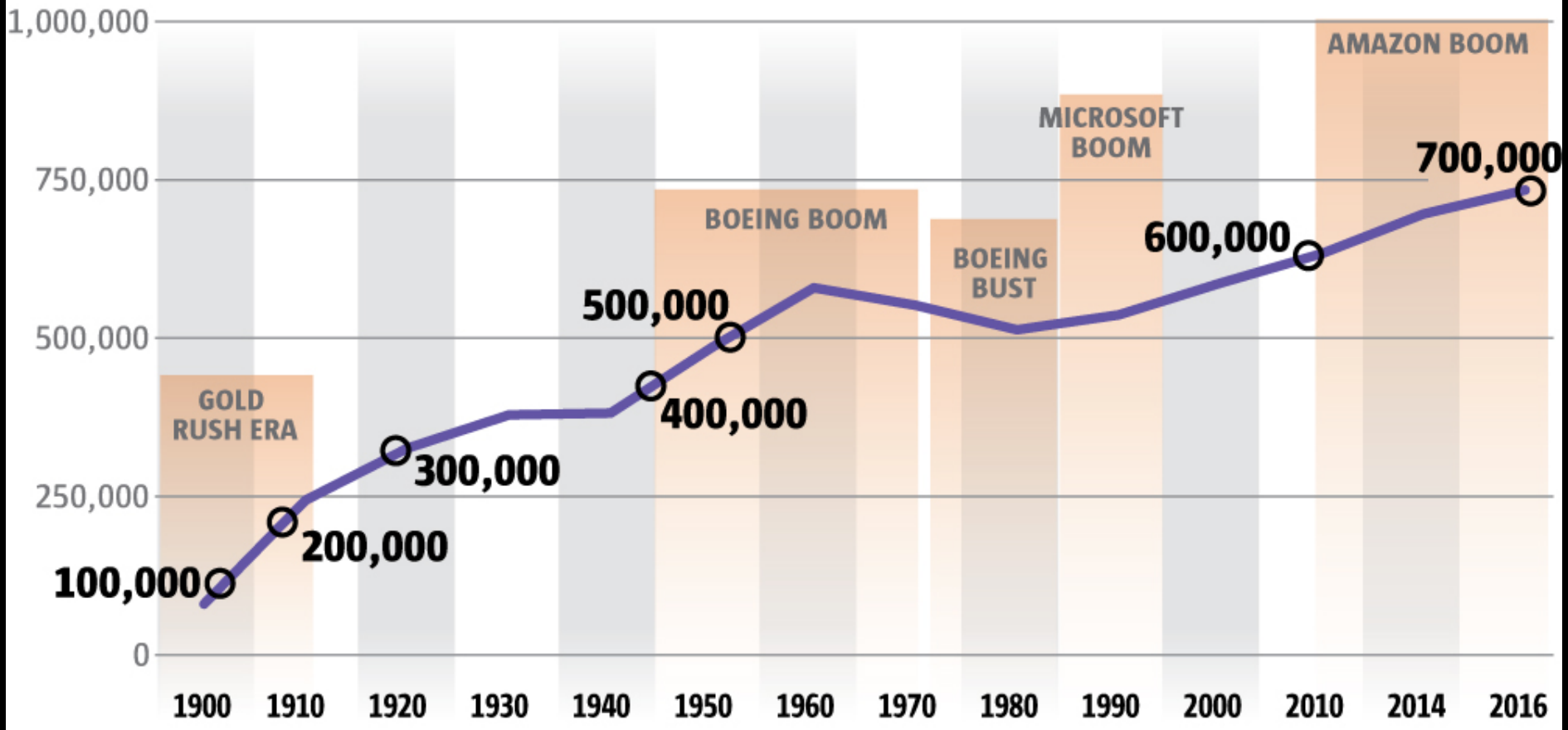
Seattle Urban Forestry Commission
July 11, 2018

Moss & Soil Monitoring to Measure Forest Health Implications in Seattle, WA

Report prepared for GSP // Seattle Parks & Recreation by:
Amanda L Bidwell LLC

Seattle population milestones

Last year, Seattle passed the 700,000 mark for the first time. New census data estimate the city's 2016 population at 704,352.



Source: U.S. Census Bureau

THE SEATTLE TIMES

SOURCES OF URBAN POLLUTION

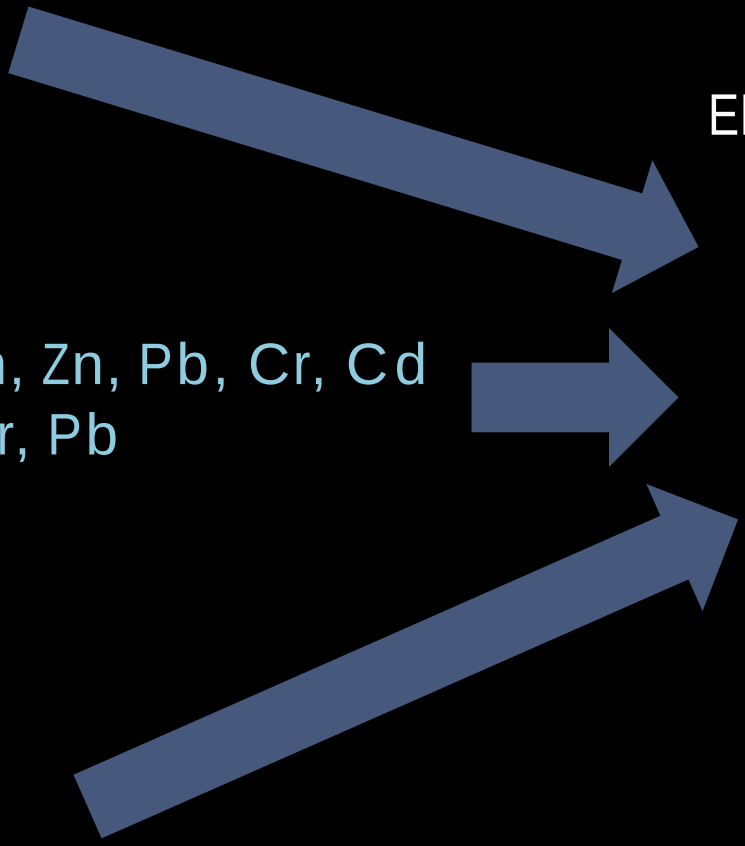
Exhaust emissions

Exhaust: NOx, PM_{10}, $PM_{2.5}$
Diesel Fuel/Soot: Ni, Sr

Brake & Tire Attrition

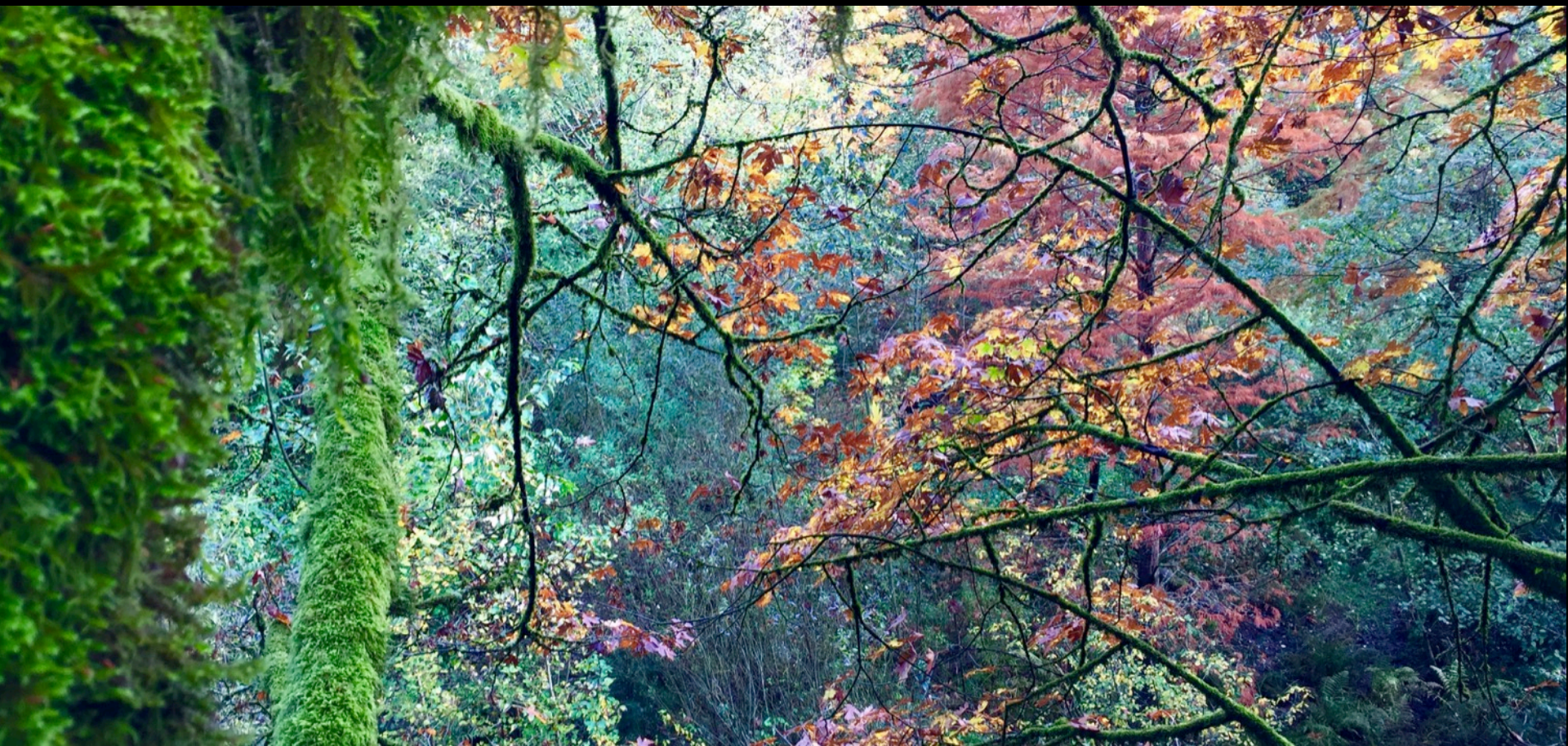
Brakes: Fe, Ti, Cu, Sr, Mn, Zn, Pb, Cr, Cd
Tires: Zn, Fe, Ti, Cr, Cu, Sr, Pb

Lubricant Degradation
Cd, Fe, Pb, Ti



EPA Urban Toxins:
Cd
Cr
Pb
Mn
Ni

How will Seattle's urban forests tolerate and adapt to changes in urban pollution throughout the area?

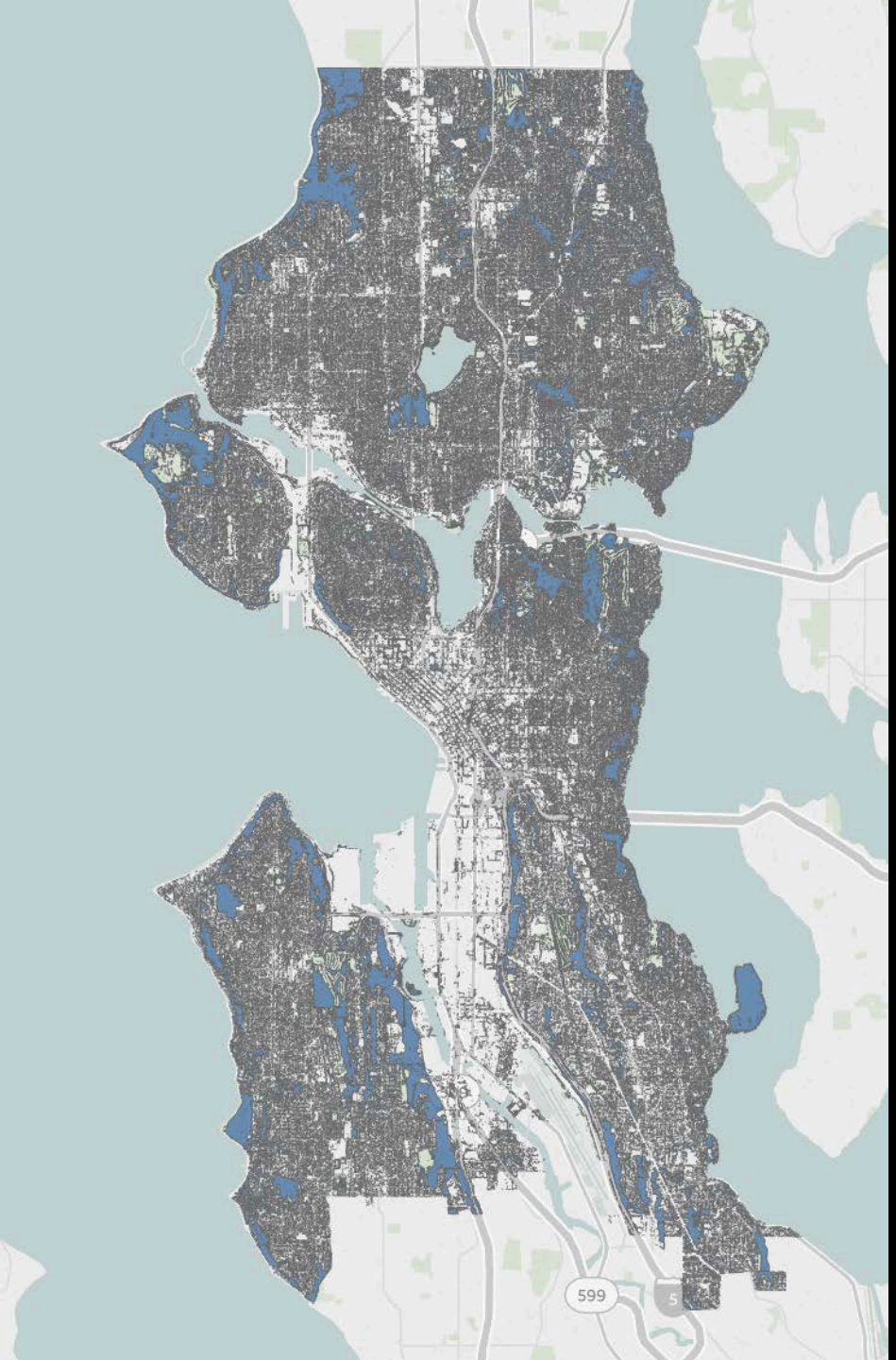


WHY USE MOSS?

- Nonvascular
- Lack protective epidermis
- Absorb organic compounds & inorganic ions deposited on surface
- Undergo significant natural drying & re-wetting cycles
- Provide snapshot of wet and dry deposition (1-3 yrs)
- History of use as bioindicators in Europe & PNW
- Inexpensive analysis costs

WHY USE SOIL?

- Metals, in their various forms, can exist in pore-water as soluble species or precipitate out of solution.
- Metals can stunt plant growth and reduce native survivorship in urban forests
- WA Dept. of Ecology measured 'naturally-occurring' background levels for Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn for PSR
- 'Naturally-occurring' background levels = concentration of hazardous substance not influenced by anthropogenic activities
- Strategies can be implemented to 'tie-up' metals reducing potential for plant uptake if staff has an understanding of current soil conditions



Seattle's Urban Canopy Coverage

28% of land is covered by tree canopy

72% deciduous

28% coniferous

Source: City of Seattle 2016 Canopy Cover Study

Common mosses on maples

- *Isothecium stoloniferum (Brid.)*
- *Homalothecium lutescens (Hedw.)*
- *Orthotrichum lyelli* Hook. & Taylor

Map of Green Seattle Partnership Sampling Locations

Conifer Broadleaf Evergreen Mixed Forest:

Northacres Park

Dry-Mesic Conifer and Conifer Deciduous Forest:

Camp Long, Discovery Park 1/2, East Duwamish Greenbelt 1/2, Frink Park, Golden Gardens, Harrison Ridge Greenbelt, Kingfisher Natural Area #1, Kinnear Park, Kubota Gardens Natural Area 1, Lakeridge Park, Magnolia Park, Magnuson South Park, Mt Baker Park, Northeast Queen Anne Greenbelt, St. Mark's Greenbelt, Westcrest Park, West Duwamish Greenbelt 1, Woodland Park

Mesic-Moist Conifer and Conifer Deciduous Mixed Forest:

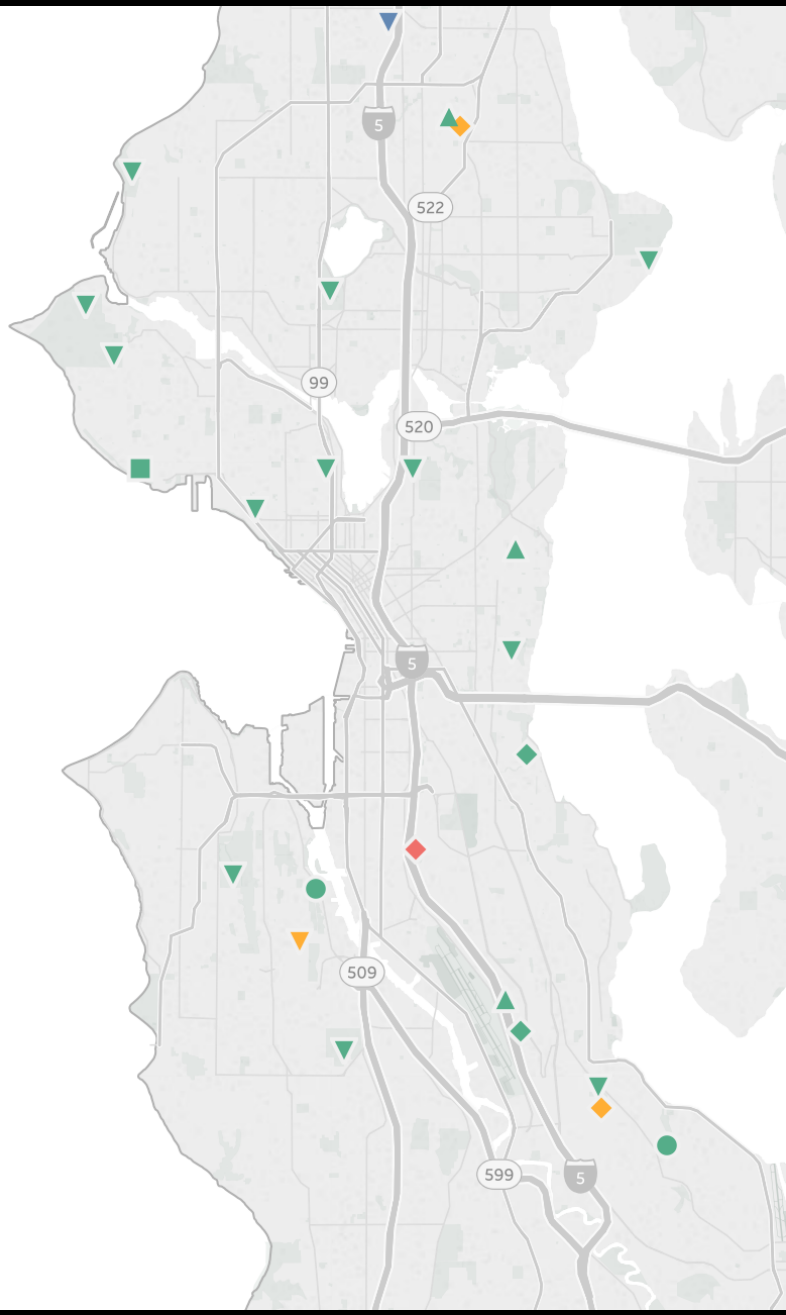
Kingfisher Natural Area 2, Kubota Gardens Natural Area 2, West Duwamish Greenbelt 2

Riparian Forest and Shrubland:

Maplewood Playfield

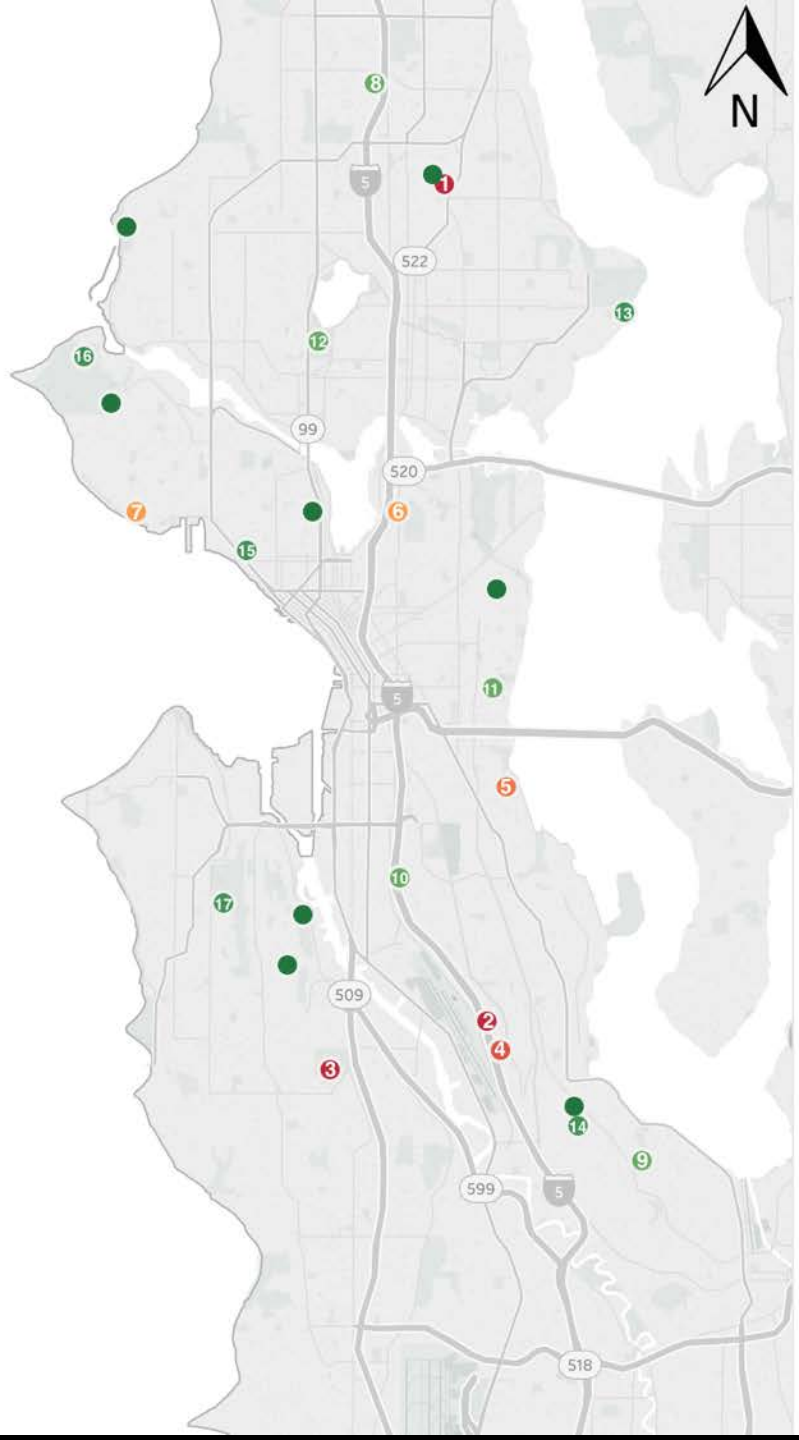
GSP restoration phases:

- ■ 0
- ▲ 1
- ◆ 2
- ▼ 3
- ● 4



As, Al, Cd, Co, Cr, Cu, Fe, Mo, Ni, Pb

Dot map indicates sample locations with elevated moss tissue concentrations for several of the ten most toxic metals in the dataset. Numbers in filled circles link locations to the element list below.



Element list (selected locations):

1. Al, As, Cr, Cu, Fe, Ni, Co, Pb (Kingfisher 2)
2. Mo, Al, Fe, Co, Cr, Cu, As, Cd (East Duwamish Greenbelt 1)
3. As, Pb , Mo, Al, Co, Cr, Cu, Ni(Westcrest)
4. Cr, Al, Co, As, Ni, Mo (East Duwamish Greenbelt 2)
5. Ni, Cr, Cu, Al, Fe (Mt. Baker)
6. Pb, Mo, Ni, Cu (St. Marks Greenbelt)
7. Al, Fe, Co, Pb (Magnolia)
8. Co, Cd (Northacres)
9. As, Mo (Lakeridge)
10. Cu, Pb (Maywood Playfield)
11. Ni, Cu (Frink)
12. Cr, Cd (Woodland)
13. Cd (Magnuson South)
14. Mo (Kubota Gardens 2)
15. Pb (Kinnear)
16. Cd (Discovery Park 1)
17. As (Camp Long)

*Dark green circles indicate that none the concentrations were among the top 6 concentrations.

Dot map indicates the top 7 air pollution 'Hotspots' identified from moss samples with multiple high priority metals

Orange = Moist-Mesic Conifer and Conifer Decidious Mixed Forest type
Green = Dry-Mesic Conifer and Conifer Decidious Mixed Forest type

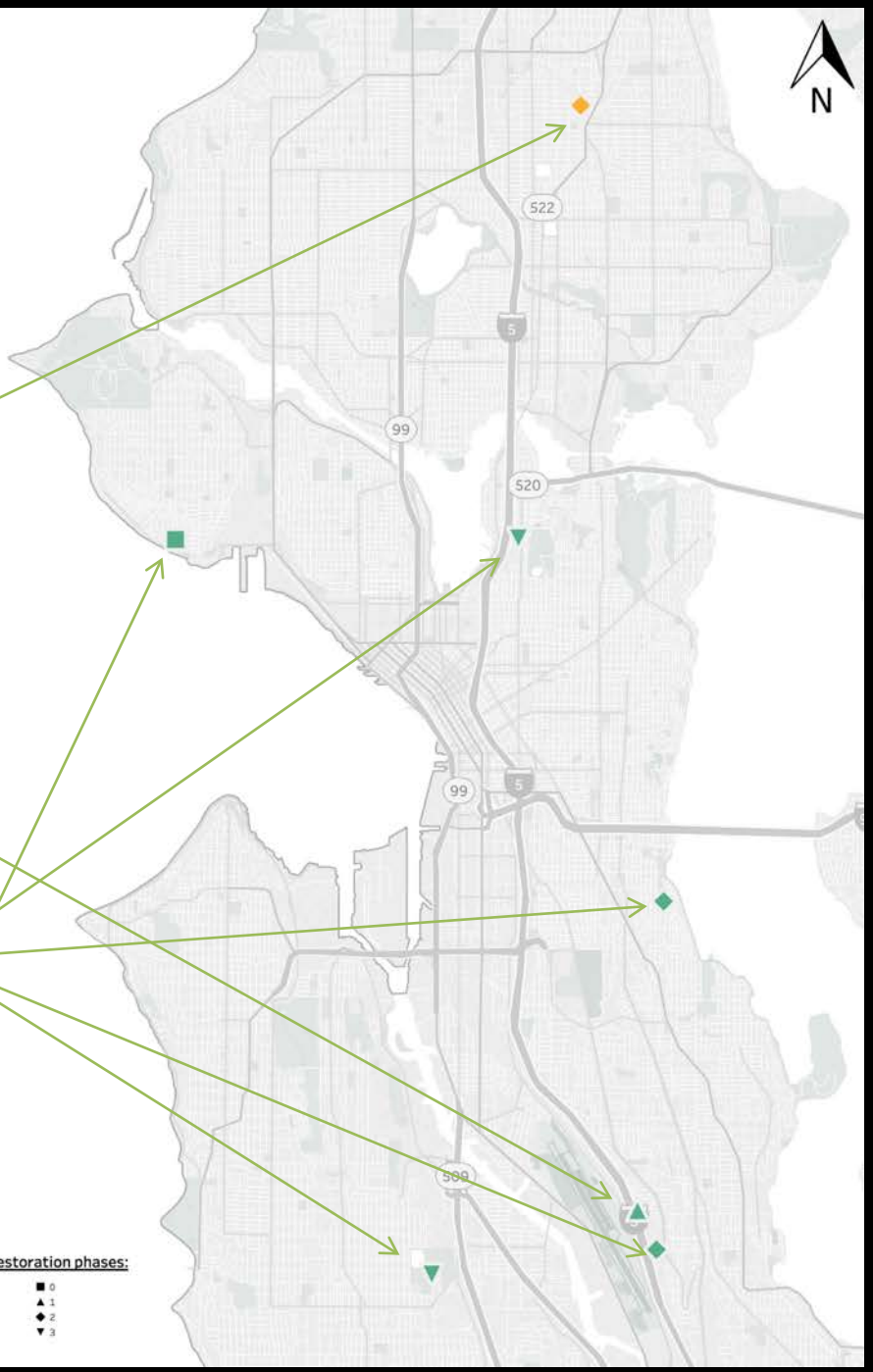
Recommendations:

•Kingfisher NA #2 - 98th St Slope:
-Minimal canopy cover, so establish ground cover ASAP to help 'tie-up' metal deposition influences.
-Install resin lysimeters to measure seasonal/annual wet metal deposition rates as moss had higher concentrations of As, Cr, Pb, and Ni.

•EDGB #1 - Chicago:
-In phase 2 of restoration, so establish ground cover (mulching/compost additions) and native plantings should help mitigate metal concentrations.

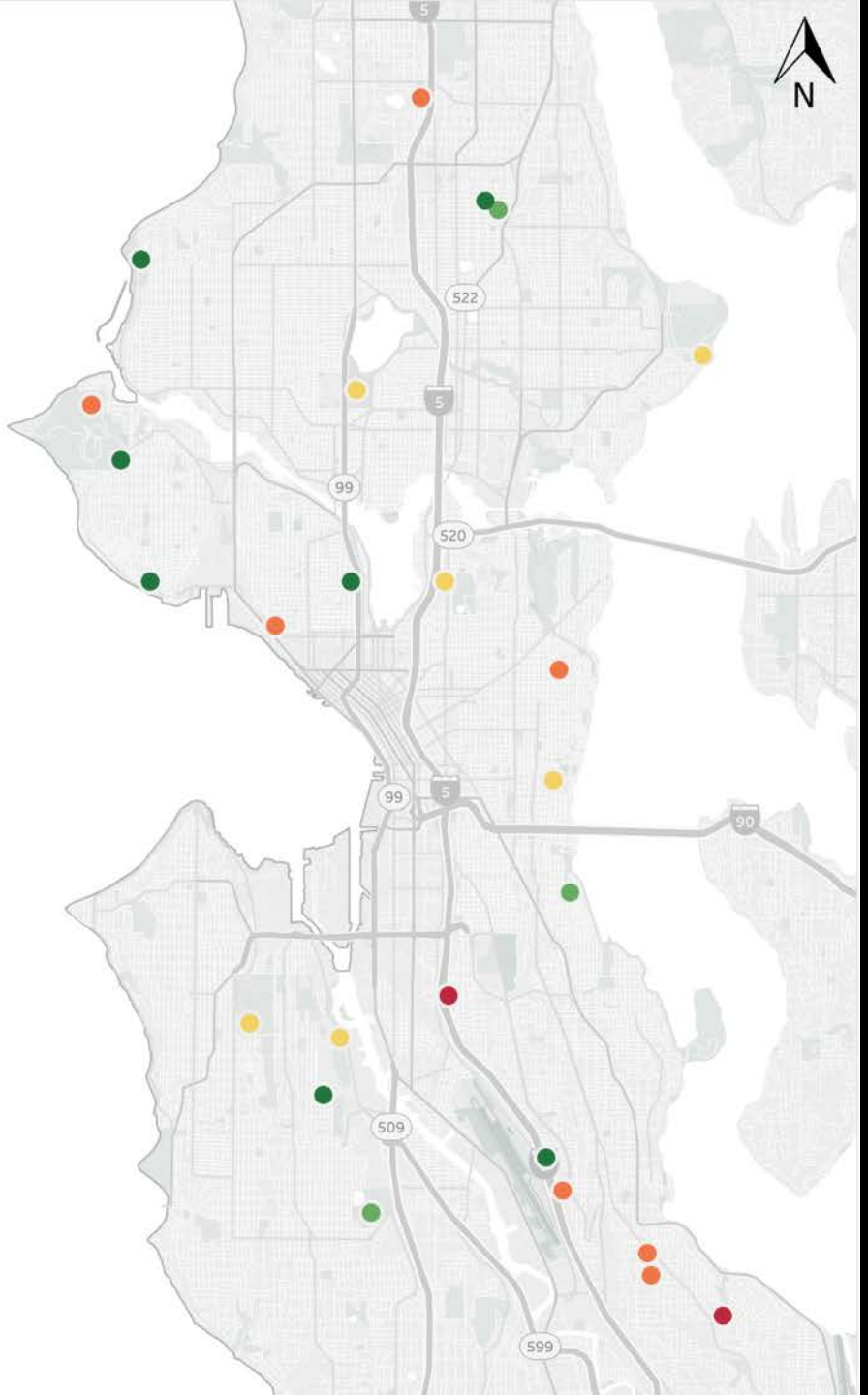
•EDGB #2 - Cloverdale, Westcrest Park, Mt. Baker Park, & St. Marks GB:
-Continuing mulching and adding Cedar Grove compost amendments.

•Magnolia Park:
-No currently in active restoration, considering adding to GSP items for 2018/2019 activites.



Soil Metals Levels Above Background Concentrations

Dot map indicates sample locations with elevated soil concentrations above naturally occuring background values for the Puget Sound region determined by WA's Department of Ecology report (1994) . Samples are color-coded as Dark red, orange, yellow, light green, and dark green based on # of elements above background soil concentrations.



<u>1 value above background soil concentrations:</u>
Pb: Discovery Park 2, East Duwamish Greenbelt 1, Golden Gardens Park, Kingfisher Natural Area 1, Magnolia, Northeast Queen Anne Greenbelt, West Duwamish Greenbelt 2

<u>2 value above background soil concentrations:</u>
As, Pb: Westcrest Park
Cr, Ni: Kingfisher Natural Area 2
Cr, Ni: Mt Baker Park

<u>3 value above background soil concentrations:</u>
As, Pb, Zn: Camp Long
Cr, Ni, Pb: Frink Park, Magnuson Park South, St. Mark's Greenbelt,
Cr, Ni, Zn: West Duwamish Greenbelt 1
Cu, Pb, Zn: Woodland Park

<u>4 value above background soil concentrations:</u>
Cr, Cu, Ni, Pb: Kubota Gardens Natural Area 2
Cr, Ni, Pb, Zn: Kubota Garndes Natural Area 1
Cd, Cr, Ni, Pb: East Duwamish Greenbelt 2, Northacres Park
Cr, Ni, Pb, Zn: Discovery Park 1, Harrison Ridge Greenbelt, Kinnear Park

<u>5 value above background soil concentrations:</u>
Cd, Cr, Cu, Ni, Pb: Lakeridge Park
Cr, Cu, Ni, Pb, Zn: Maplewood Playfield

SOIL RECOMMENDATIONS:

- Soil at these locations also above ‘naturally-occurring’ background values for suite of metals – continue mulching and composting at these sites to ‘tie-up’ metals & reduce ability for plant uptake

- Tillage and soil mixing 8-12” in depth during phase1-2 activities

- Continue to incorporate mycorrhizal inoculates (both endomycorrhizae and ectomycorrhizae species) into bare-root and potted soil mixtures to increase likelihood of native plant survivorship

ADDITIONAL RECOMMENDATIONS:

- Regular soil testing for suite of metals including Al, As, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Ni, P, Pb, Si, Sr, Ti, Zn
- Soil analysis for pH, organic matter content, and cation exchange capacity
- Installation of resin lysimeters to measure seasonal and annual wet-deposition rates across priority GSP restoration sites

Moss & Soil Monitoring to Measure Forest Health Implications in Seattle, WA

Report prepared by:
Amanda L Bidwell LLC
Amanda.Bidwell7@gmail.com // AmandaBidwell.com

Forest planting strategies for GSP:

Phytoremediation is a cost-effective green alternative to traditional soil remediation strategies. Below is a list of PNW plant species that are known to tolerate heavy metals common in urban areas (table 7):

Scientific name	Common name	Notes	Sources
Carex obnupta	Slough Sedge	Commonly used in bioswales to treat runoff-based pollutants	Giraldo et al., 2010
Carex densa	dense sedge	Commonly used in bioswales to treat runoff-based pollutants	Giraldo et al., 2010
Pteridium aquilinum	Bracken fern	Literature shows some success for Cu, Cr	Olaifa et al., 2014; García et al., 2010
Pteris vittata	Brake fern	Literature shows effectiveness with As, Pb	Ma et al., 2001
Acer circinatum	Vine maple	Literature shows effectiveness with leachates	McCutcheon & Schnoor, 2003
Salix lucida	Pacific willow	Literature shows effectiveness with Cr and Zn	McCutcheon & Schnoor, 2003
Salix scouleriana	Scouler's willow	Study on Vashon Island indicated uptake/accumulation of Cd	Institute of Env. Research & Ed., 2003
Achillea millefolium	Yarrow	Study on Vashon Island indicated uptake and accumulation of Cd	Institute of Env. Research & Ed., 2003
Pseudotsuga menziesii	Douglas fir	Literature shows effectiveness for As, Cd, Pb	Astier et al., 2014; Bonet et al., 2016

Most of these plant species are already incorporated into GSP planting strategy. In areas where soils are significantly above background concentrations for metals, we recommend incorporating more of these plants.

Below is a list of parks that are significantly above background levels for a variety of metals that should be looked into for additional plantings (table 8):

Elements significantly above background soil levels	Location
As, Pb	Westcrest Park
As, Pb, Zn	Camp Long
Cd, Cr, Ni, Pb	East Duwamish Greenbelt #2
Cd, Pb	Lakeridge Park
Cr, Cu, Ni, Pb	Kubota Gardens Natural Area #2
Cr, Cu, Ni, Pb, Zn	Maple Wood Playfield
Cr, Ni	West Duwamish Greenbelt #1
Cr, Ni, Pb	Magnuson South, Northacres Park, St. Mark's Greenbelt
Cr, Ni, Pb, Zn	Harrison Ridge Greenbelt, Kinnear Park
Cr, Pb, Zn	Discovery Park #1, Kubota Gardens Natural Area #1, Woodland Park
Ni	Kingfisher Natural Area #2
Ni, Pb	Frink Park
Pb	East Duwamish Greenbelt #1, Golden Gardens, Kingfisher Natural Area #1, Magnolia Park, Northeast Queen Anne Greenbelt, West Duwamish Greenbelt #2

Questions?