PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS – THE IMPORTANCE OF THE AIR QUALITY PATHWAY

Presented at the Fall Business Meeting
of the Association of Air Pollution Control Agencies (AAPCA)

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OVERVIEW

01 Background Air Quality Information on PFAS

02 PFAS Fate and Transport Case Study: Surface Coating Operation

03 A Closer Look at Some Key Air Quality Data

04 Key Findings and Takeaways

OVERVIEW

01

Background Air Quality Information on PFAS

- Why Is Dispersion and Deposition Important?
- State Efforts to Regulate PFAS
- Other Fate and Transport Studies

02

Case Study Involving PFAS Air Emissions

- Facility Setting
- Source Investigation Efforts
- Allocation Argument – Five Lines of Evidence Evaluated

03

Findings and Conclusions

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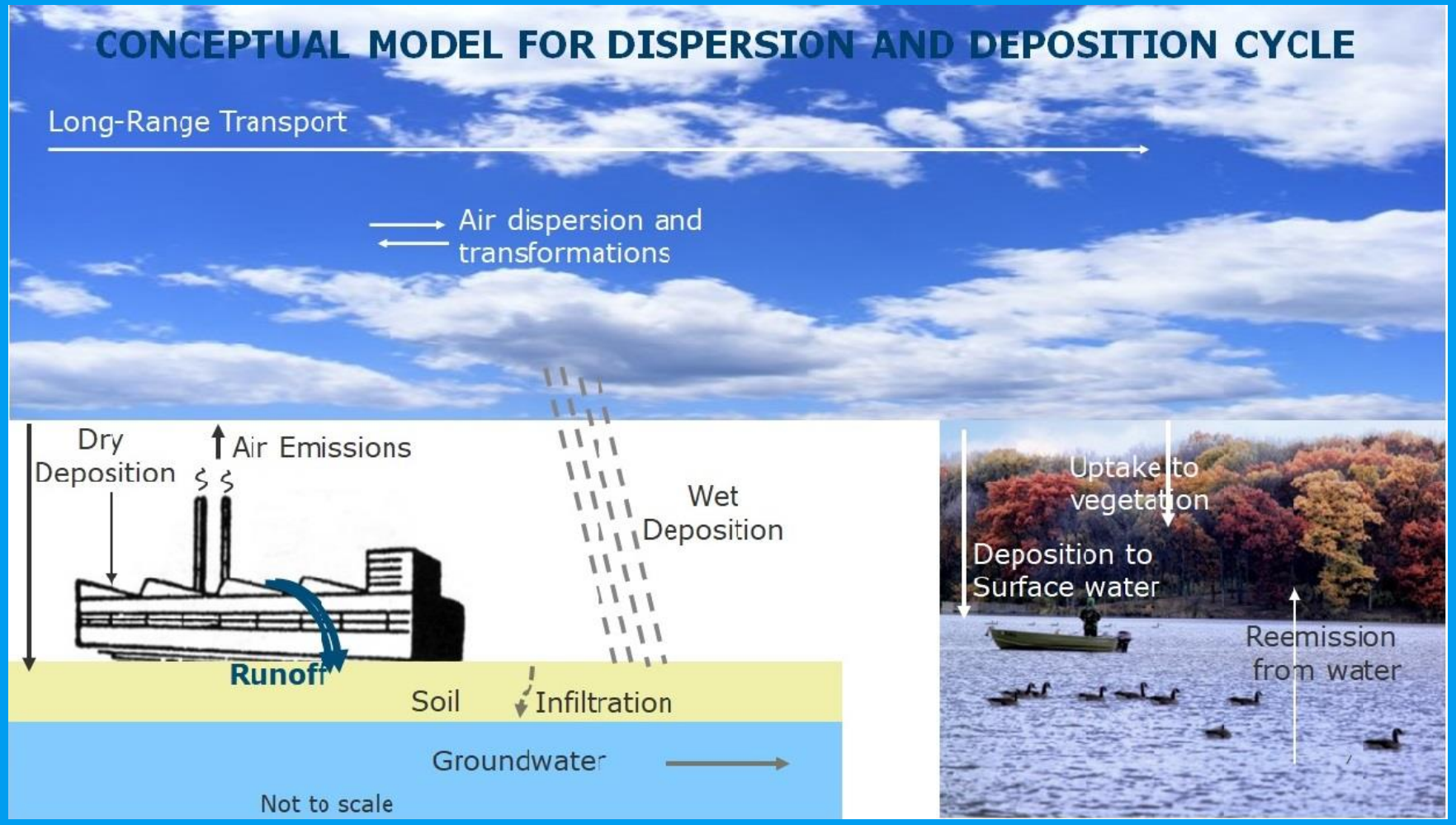
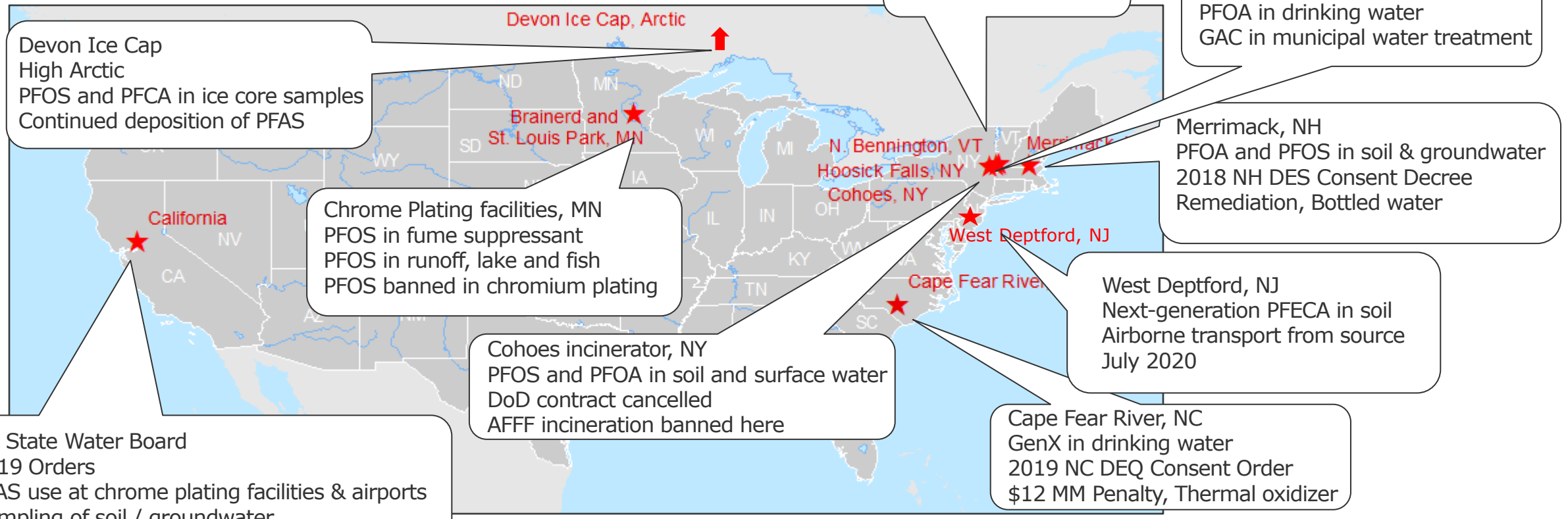
BACKGROUND AIR QUALITY INFORMATION ON PFAS



WHY DO WE CARE ABOUT PFAS AIR DISPERSION AND DEPOSITION?



Devon Ice Cap
High Arctic
PFOS and PFCA in ice core samples
Continued deposition of PFAS

North Bennington, VT
PFOA in groundwater
Legacy emissions

Hoosick Falls, NY
PFOA in drinking water
GAC in municipal water treatment

Merrimack, NH
PFOA and PFOS in soil & groundwater
2018 NH DES Consent Decree
Remediation, Bottled water

Chrome Plating facilities, MN
PFOS in fume suppressant
PFOS in runoff, lake and fish
PFOS banned in chromium plating

West Deptford, NJ
Next-generation PFECA in soil
Airborne transport from source
July 2020

Cohoes incinerator, NY
PFOS and PFOA in soil and surface water
DoD contract cancelled
AFFF incineration banned here

CA State Water Board
2019 Orders
PFAS use at chrome plating facilities & airports
Sampling of soil / groundwater

Cape Fear River, NC
GenX in drinking water
2019 NC DEQ Consent Order
$12 MM Penalty, Thermal oxidizer

Air emissions and aerial deposition responsible, in part, for observed contamination

STATE EFFORTS TO REGULATE PFAS IN AIR QUALITY

State	PFOA Concentration ($\mu g/m^3$)	Averaging Period
Michigan	0.07	24-hour
Minnesota	0.063	24-hour
New Hampshire*	0.05 0.024	24-hour Annual
New York	0.0053	Annual
Texas	0.005	Annual

* Denotes a value for ammonium perfluorooctanoate, a precursor to PFOA

Look for other states to begin regulating PFAS and for the list of regulated PFAS to increase.

WV MODELING ANALYSIS[1]

- Modeled PFO from a chemical manufacturing facility outside of Parkersburg, WV
  - Used AERMOD model to compare modeled results to measured environmental data (*i.e.,* air, surface soil/grass)
  - Modeled PFO as a gas-phase compound

Key Findings:

- Model was accurate in identifying maximum air concentrations and soil/grass impacts
- Attributed errors to meteorological input uncertainty and conservatism in the PRIME algorithm for evaluating building downwash
- Dry deposition was far more impactful than wet deposition, particularly with increasing distance from the source.

[1] Barton, C. et al. *A Site-Specific Screening Comparison of Modeled and Monitored Air Dispersion and Deposition for Perfluorooctanoate.* Journal of the Air & Waste Management Association, April 2010.

NC MODELING ANALYSIS[2]

- Chemical manufacturer that had reported 2017 emissions of 53 individual PFAS compounds, totaling more than 109,000 kg/yr
- Used the Community Multiscale Air Quality (CMAQ) model
    - Compared model results to measured environmental data (*i.e.,* precipitation)
    - Modeled all PFAS as gas-phase compounds

Key Findings:

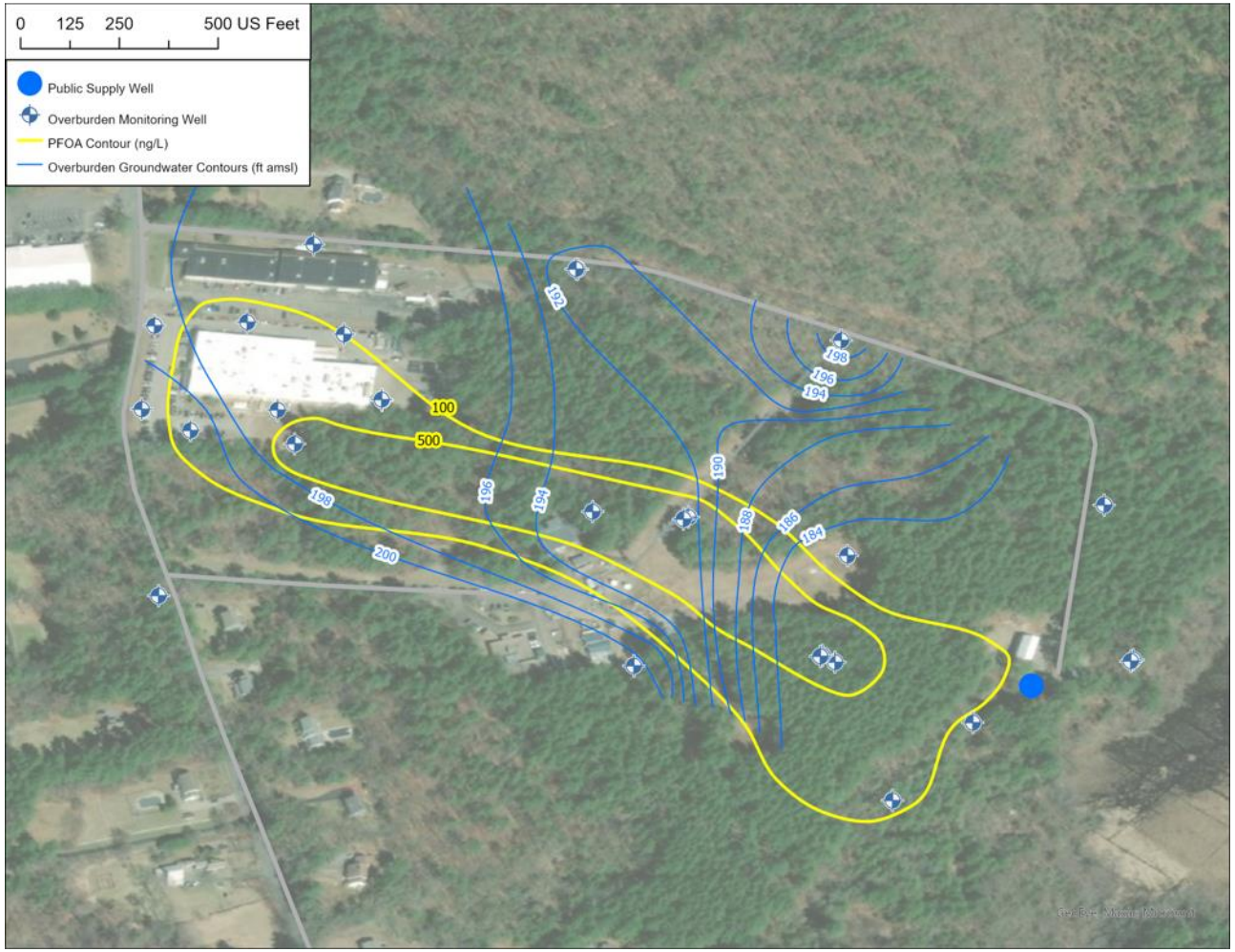
- Model captured spatial variability well, but predicted concentrations were approximately half what was observed in the field; meteorology, emissions, chemical properties and sample collection methods were identified as potential sources of error
- Compounds with acid functionality have higher deposition due to water solubility and pH partitioning
- Results indicated that only 5% of PFAS and 2.5% of GenX were deposited within 150 km of facility

[2] D'Ambro E.L. et al., *Characterizing the Air Emissions, Transport, and Deposition of Per- and Polyfluoroalkyl Substances from a Fluoropolymer Manufacturing Facility.* Int J Environ Sci Technol. January 2022.

CASE STUDY: SURFACE COATING FACILITY

PROBLEM STATEMENT

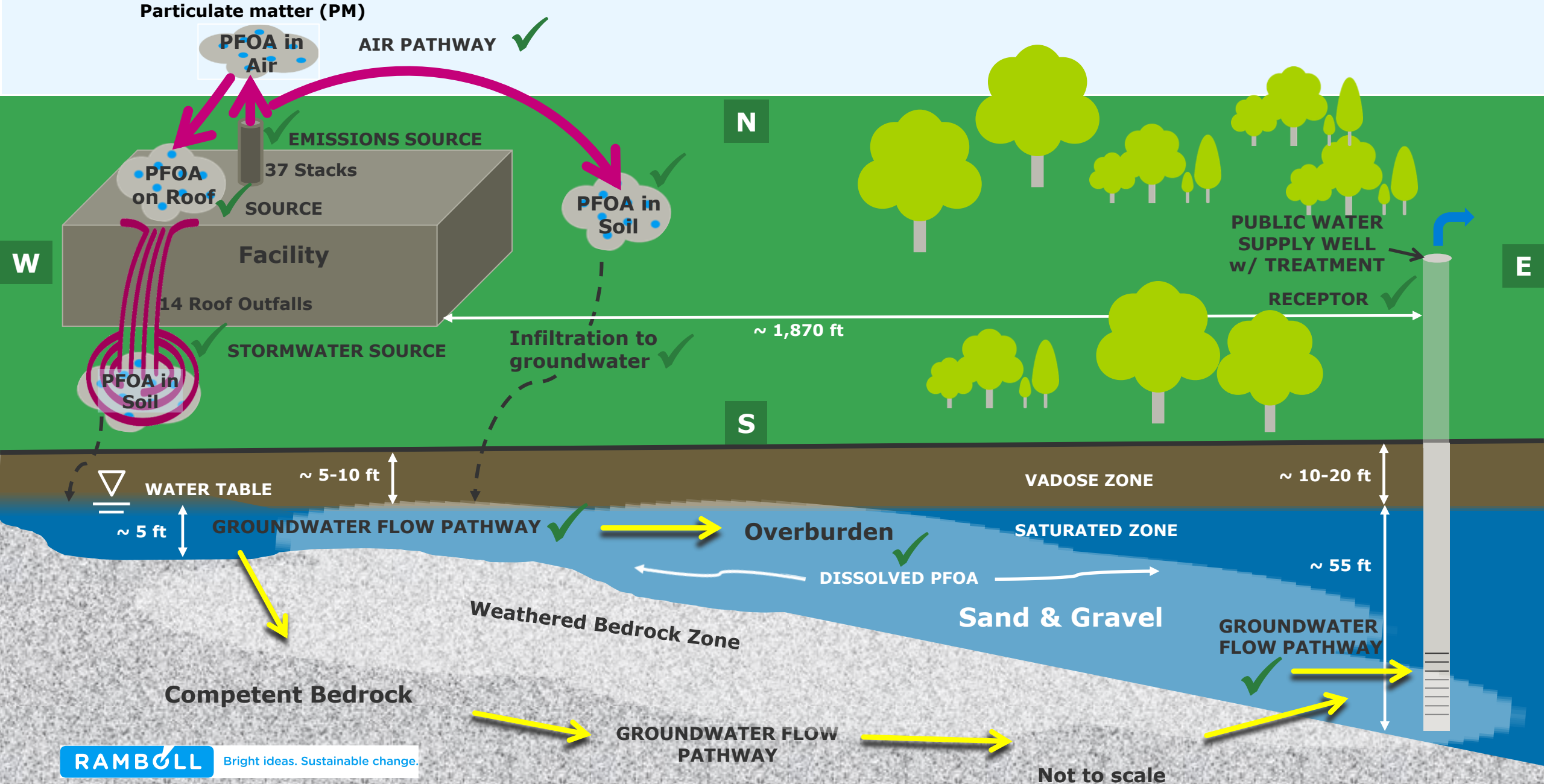
- PFAS found in public water supply well (UCMR3)
- PFAS in private drinking water wells
- Concentrations above regulatory thresholds
- State regulations triggered investigation
- Very complex and extensive site investigation



SURFACE COATING FACILITY - OVERVIEW

- Facility = ~45,000 sf
- 40+ years of same ops
- Manual and robotic spray application of coatings containing dispersions
- Solvent- and aqueous-based coatings
- Application in spray booths with HEPA filtration systems
- Vertical stack discharge
- Curing in IR and convection-type ovens with direct vent via stacks

CURRENT CONCEPTUAL SITE MODEL: OPS_{LEGACY}: ~37 YEARS; THEN $OPS_{CURRENT}$: ~4 YEARS



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INVESTIGATION SUMMARY

TASK	INVESTIGATION OBJECTIVE		
	Source Evaluation	Transport Pathway Evaluation	Receptor Evaluation
Materials Testing of $Ops_{Current}$ (Coatings, Residue)	X		
Roof Ballast and Roof Sediment Testing	X		
Air Emissions Testing of $Ops_{Current}$	X		
Aerial Deposition Modelling of $Ops_{Current}$		X	X
Roof Outfall Stormwater Sampling	X	X	
Soil Sampling	X	X	X
Overburden and Bedrock Groundwater Sampling	X	X	X
Public Water Supply Well Sampling			X

WHAT ARE THE CONTRIBUTIONS OF THE CURRENT AND FORMER FACILITY OPERATORS TO THE OBSERVED PFOA CONCENTRATIONS IN SITE MEDIA AND IN THE PUBLIC WATER SUPPLY WELL?

FIVE LINES OF EVIDENCE EVALUATED

01 **Purchase Inventory Records of Manufacturing Materials Used (Ops_{Legacy} and $Ops_{Current}$)**

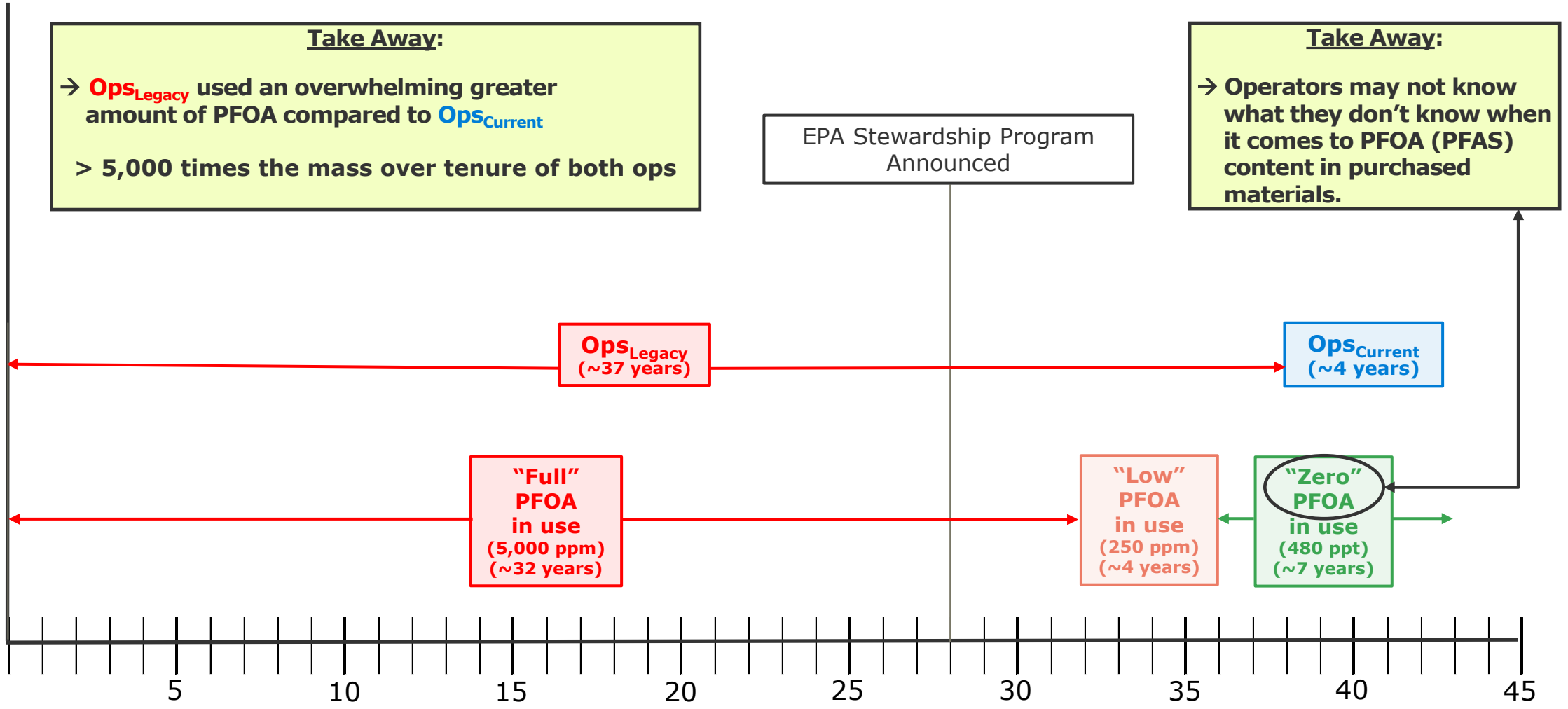
02 **Dispersion Testing of Manufacturing Materials Used ($Ops_{Current}$)**

03 **Environmental Sampling Results (Current Conditions)**

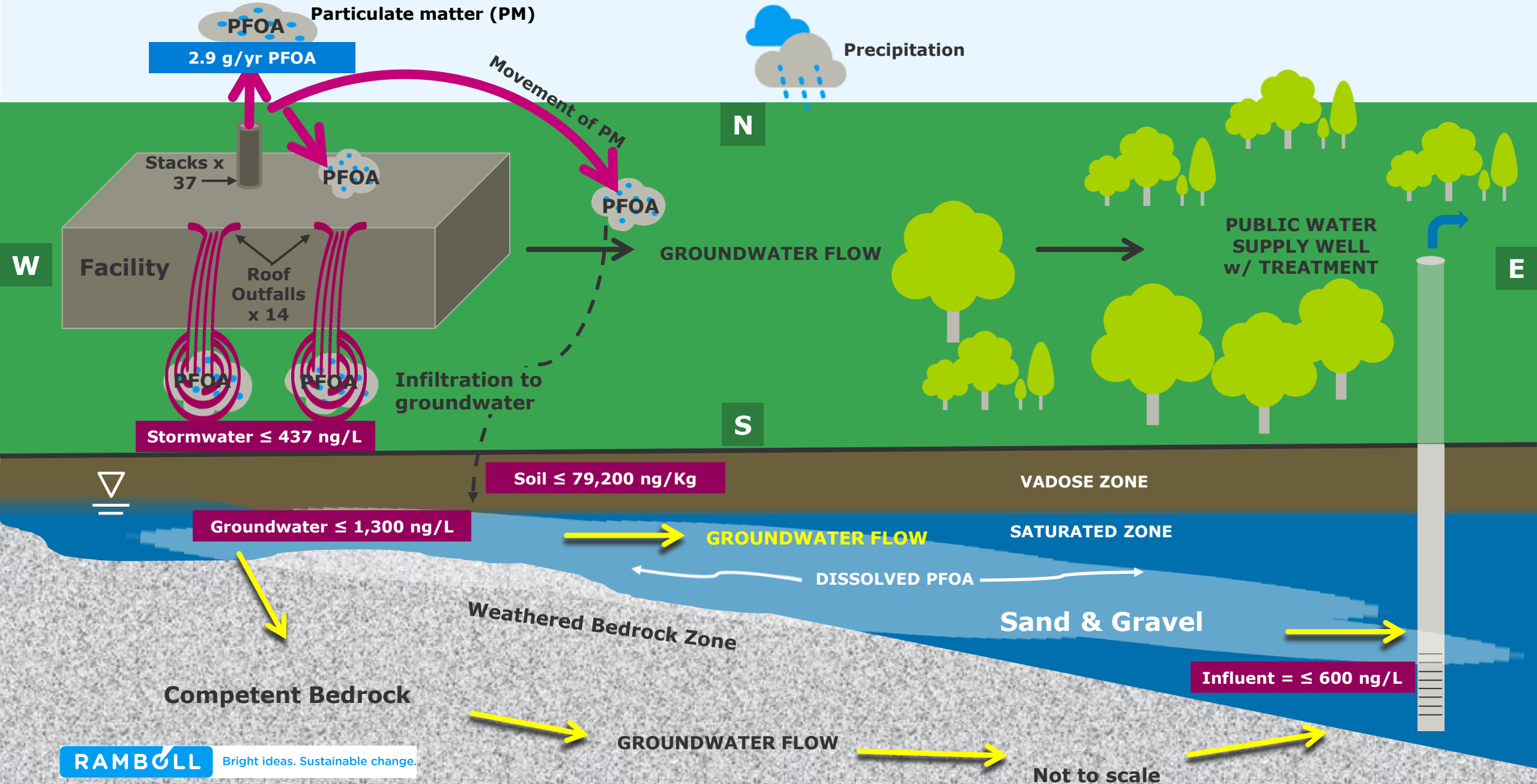
04 **Reconciliation of Environmental Sampling Results (Current Conditions) to Estimates from $Ops_{Current}$ Sources**

05 **PFOA Fate and Transport Calculations**

PURCHASE INVENTORY RECORDS AND DISPERSION TESTING DATA



ENVIRONMENTAL SAMPLING RESULTS: CURRENT CONDITIONS



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RECONCILIATION OF ENVIRONMENTAL SAMPLING RESULTS TO ESTIMATES FROM $OPS_{CURRENT}$

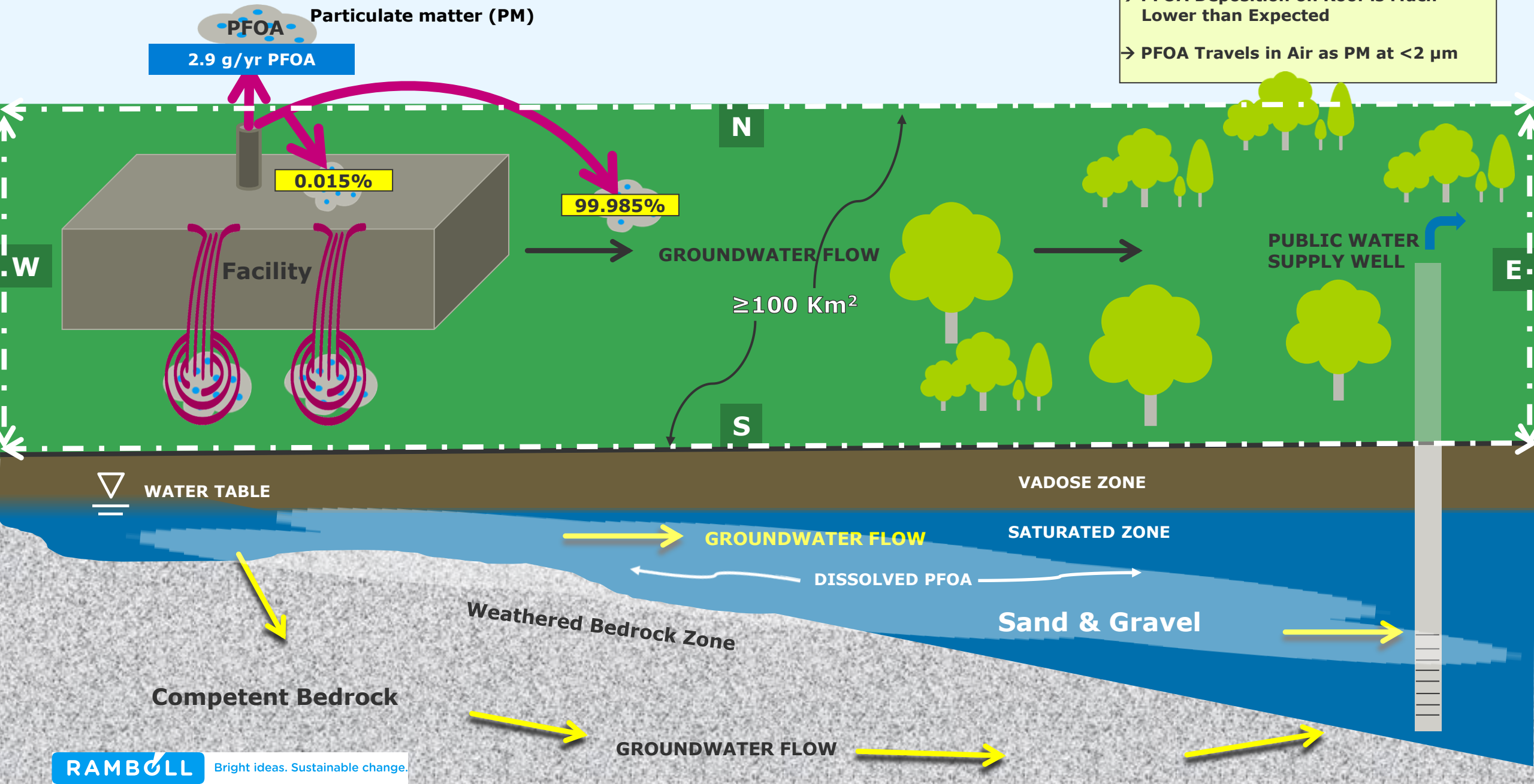
Can the emissions of 2.9 g/yr of PFOA from $Ops_{Current}$ create the sampling results measured in the various environmental media on the site?

AERIAL DEPOSITION MODELING RESULTS ($OPS_{CURRENT}$)

Take Aways:

→ PFOA Deposition on Roof is Much Lower than Expected

→ PFOA Travels in Air as PM at <2 µm



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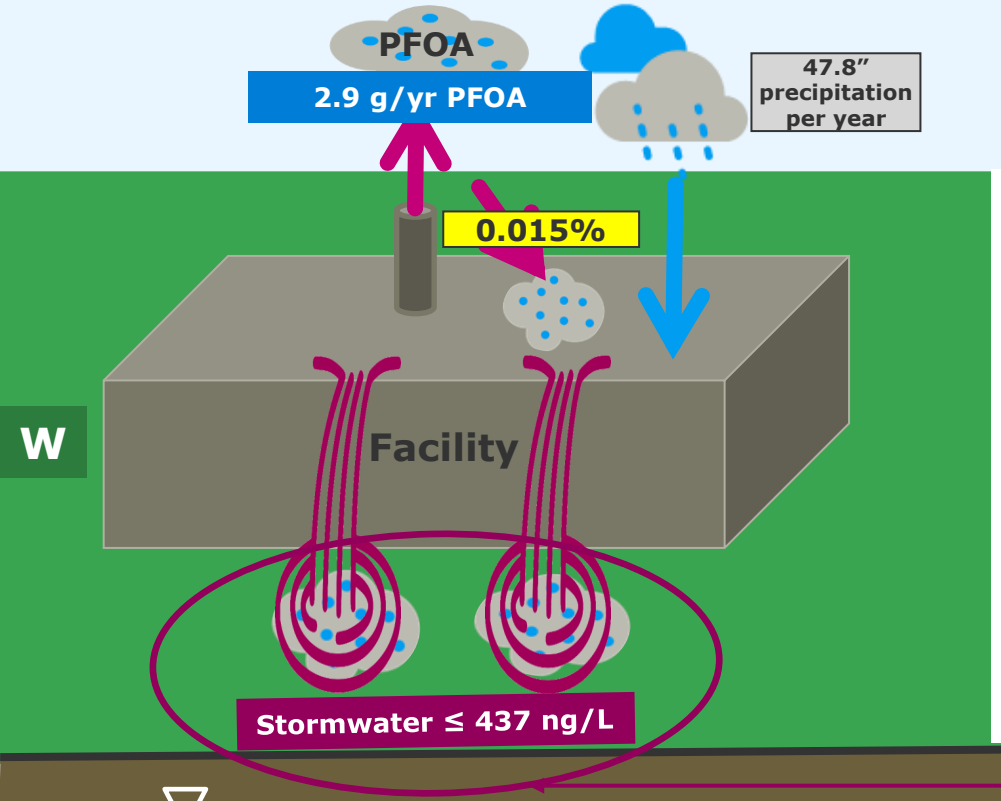
ESTIMATED AVERAGE STORMWATER CONCENTRATION



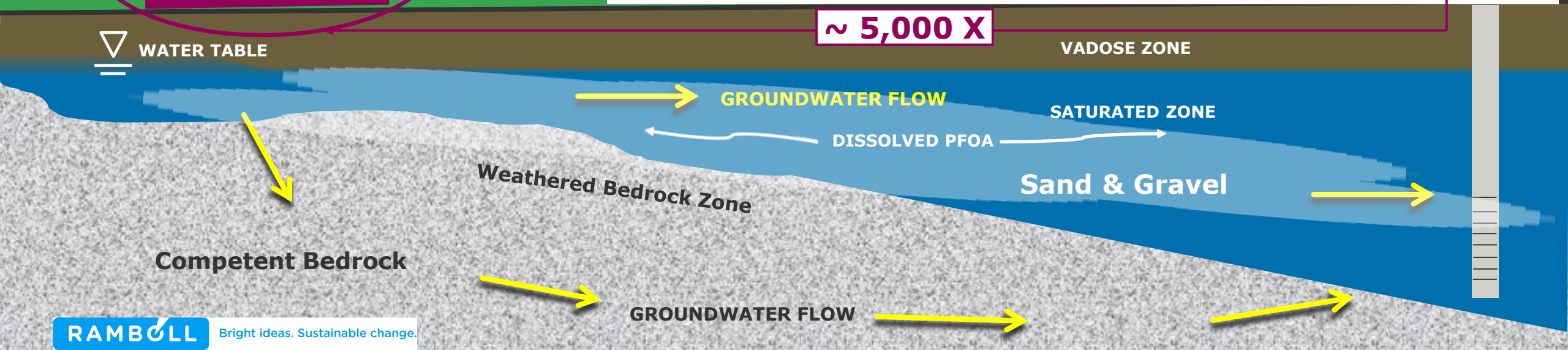
Take Away:

→ **Measured stormwater concentrations do not reconcile with estimated stormwater concentrations from $Ops_{Current}$.**

Estimated PFAS Concentrations in Stormwater from Facility Roof Runoff (Worst-Case)						
	Annual PFOA Emissions (g/yr)	% PFOA Deposited on Roof	Mass of PFOA Deposited on Roof (ng/yr)	Area of Roof (ft^2)	Annual Precipitation on Roof (L/yr)	Estimated Stormwater Concentration from Roof Runoff (ng/L)
PFOA	2.9	0.015%	4.4E+05	43,560	4.91E+06	**0.089**

Assumptions:

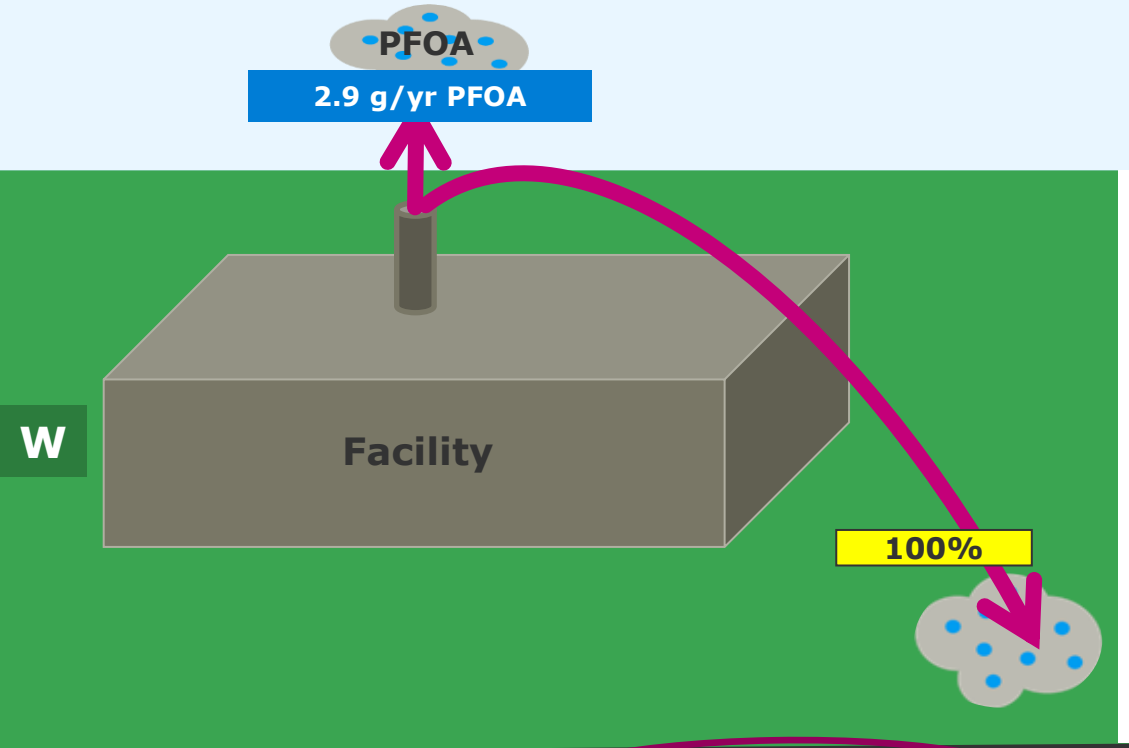
PFAS remains on roof with instantaneous and complete dilution.



ESTIMATED SOIL CONCENTRATIONS

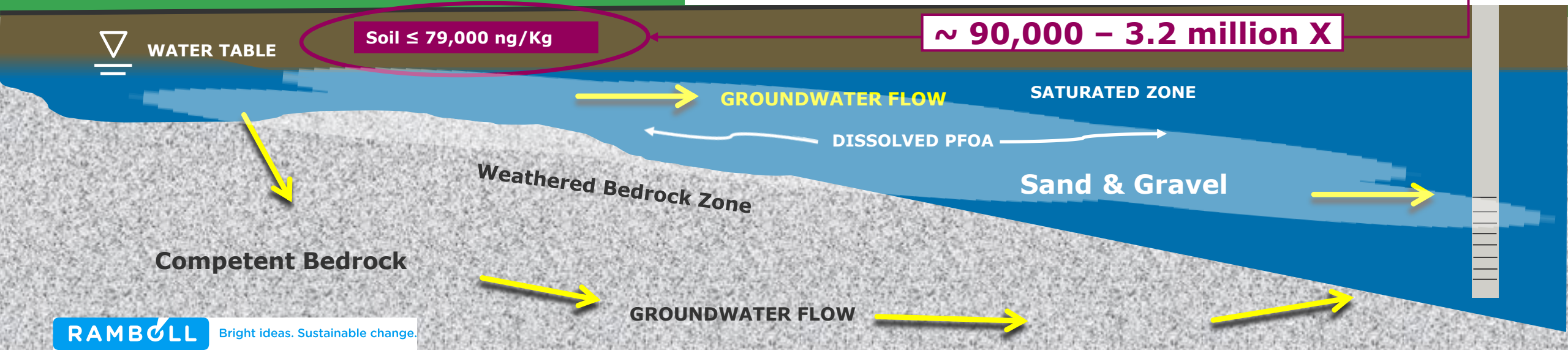
Take Away:

→ **Measured soil concentrations do not reconcile with estimated soil concentrations from $Ops_{Current}$.**



Estimated Soil Concentrations (Worst-Case)					
Soil Depth Interval (in)	Depth (m)	Volume in One m^2 (cm^3)	Mass of Soil in One m^2 (g)	grams of PFOA/gram of Soil	PFOA (ng/Kg)
0-1	0.03	25,400	33,020	1.97E-12	**8.78E-01**
0-6	0.15	152,400	198,120	3.28E-13	**1.46E-01**
0-12	0.30	304,800	396,240	1.64E-13	**7.32E-02**
0-36	0.91	914,400	1,188,720	5.47E-14	**2.44E-02**

Assumes all PFOA remains in soil (e.g., no dissolution into groundwater or other losses).



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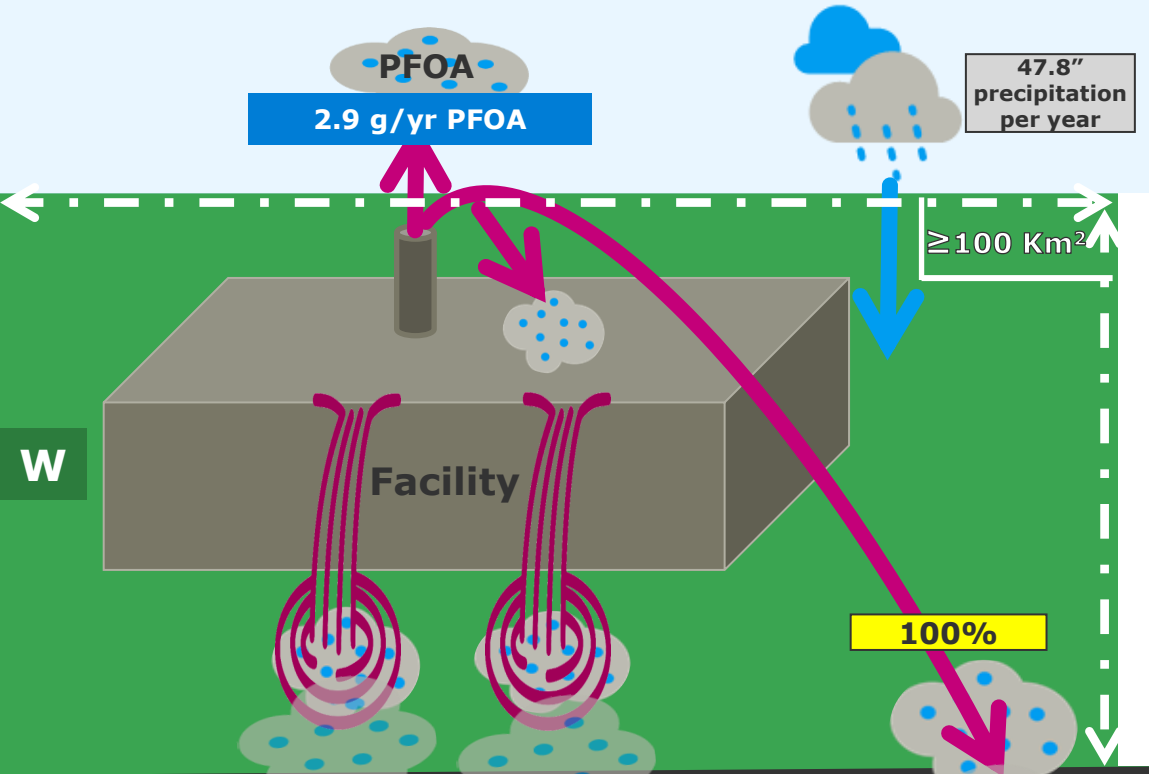
ESTIMATED AVERAGE GROUNDWATER CONCENTRATION

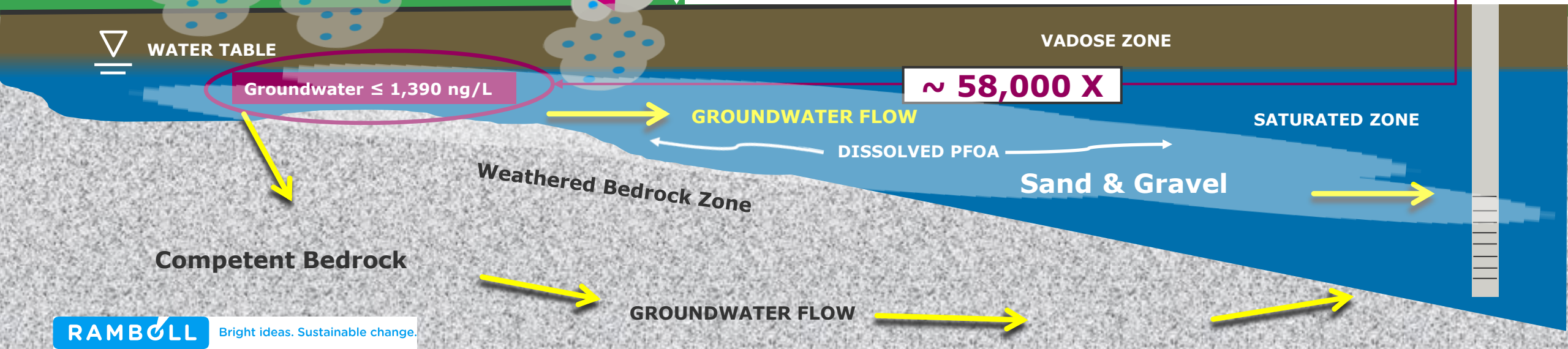


Take Away:

→ **Measured groundwater concentrations do not reconcile with estimated groundwater concentrations from $Ops_{Current}$.**

Estimated Groundwater Concentrations						
Annual PFOA Emissions (g/yr)		% PFOA Deposited on Roof and Ground	Mass of PFOA Deposited on Roof and Ground (ng/yr)	Deposition Area (km^2)	Annual Precipitation (L/yr)	Estimated Groundwater Concentration (ng/L)
PFOA	2.9	100%	2.9E+09	100	1.21E+11	**0.024**

Assumes all PFOA dissolves in groundwater (e.g., no vadose zone storage, dilution by upgradient groundwater, or other losses).



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RECONCILIATION OF ENVIRONMENTAL SAMPLING RESULTS TO ESTIMATES FROM $OPS_{CURRENT}$

01 The emissions of 2.9 g/yr of PFOA from $Ops_{Current}$ do not reconcile with any of the sampling results measured in the various environmental media on the site.

02 What are possible sources of the PFOA that could create the sampling results measured in the various environmental media on the site?

(Recall Ops_{Legacy} used > 5,000 times more PFOA mass vs. $Ops_{Current}$.)

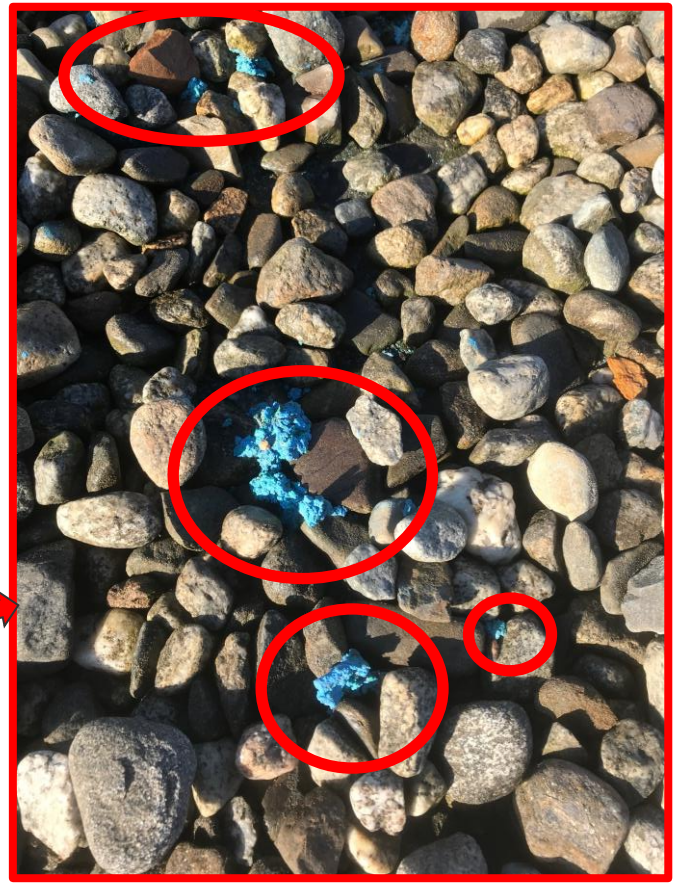
EXAMPLES OF COATING AGGLOMERATION AND CHUNKING

Coating Agglomeration on Inside of Stack Cap

≤17,200,000 ng/Kg PFOA

Roof Ballast and Roof Stack

Residue Under Roof Ballast

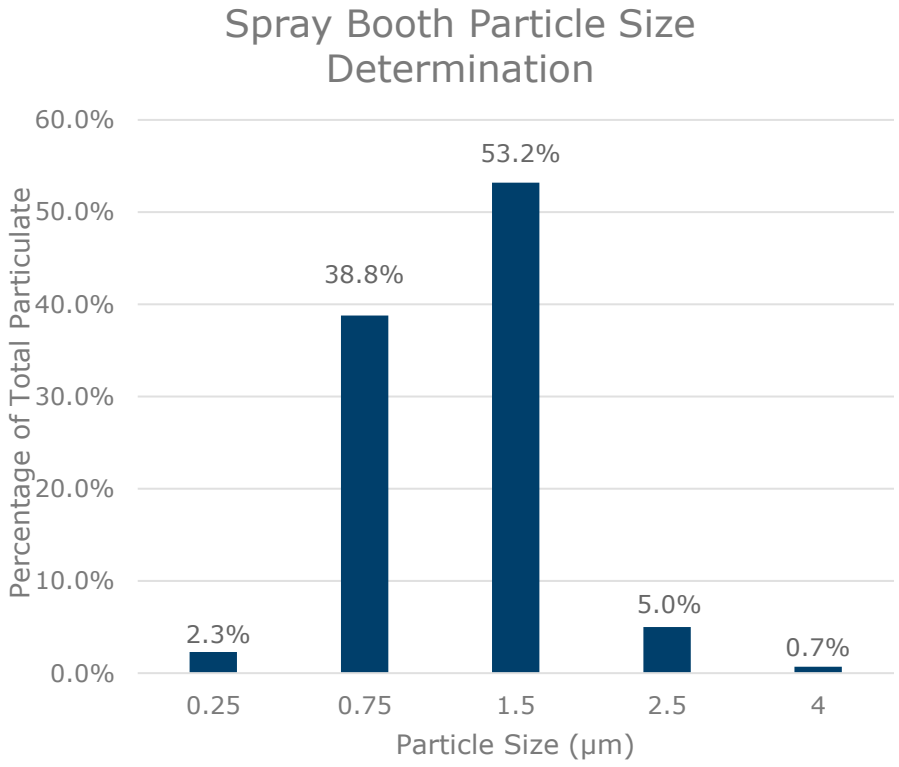


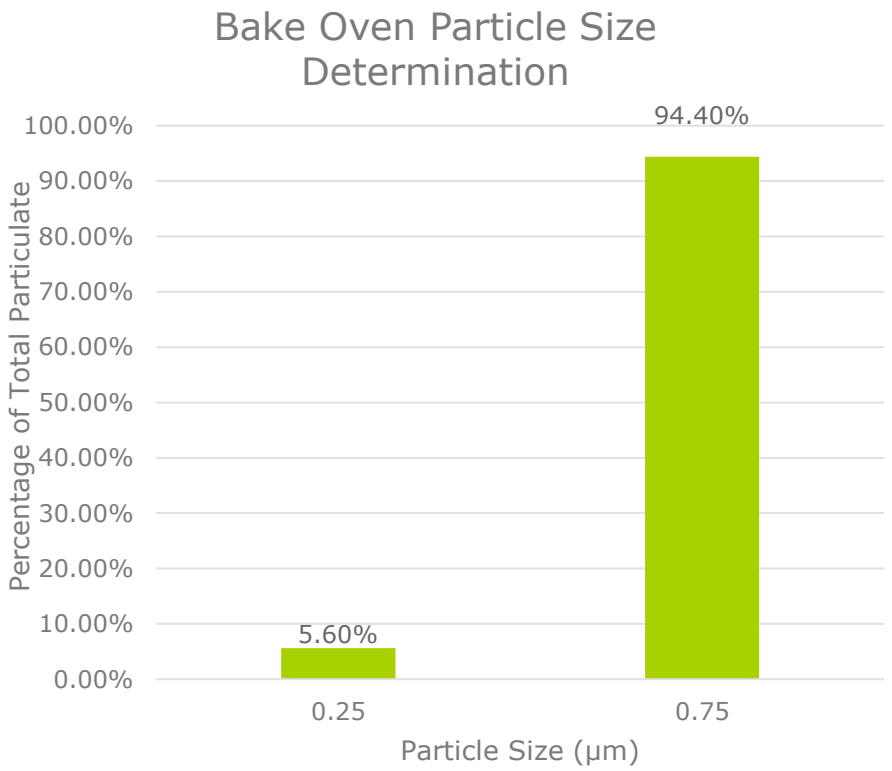
PFAS Residue in Roof Ballast from Chunking of Coating Agglomeration Occurring in Stacks

≤13,000,000 ng/Kg PFOA

A CLOSER LOOK AT SOME KEY AIR EMISSIONS DATA

Particle Size Distribution Results

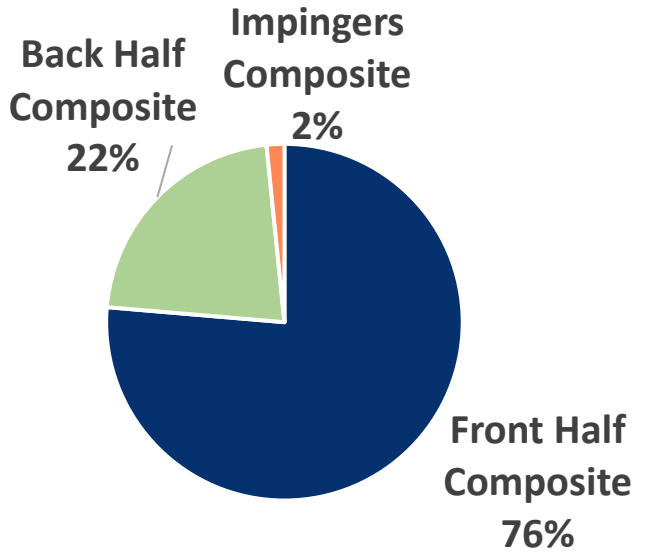




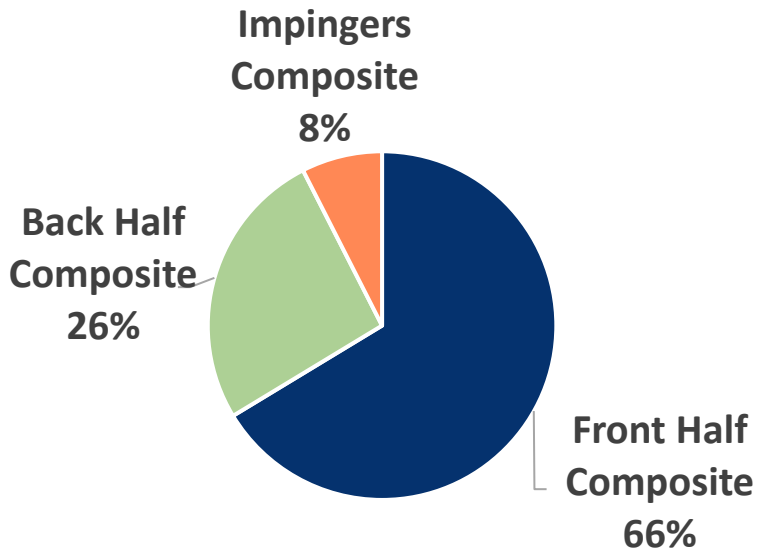
- ✓ > 98% of particles < 3 microns
- ✓ Majority between 0.5 – 2 microns.
- ✓ Enhanced filtration may have little benefit

PFOA Mass by Sample Fraction

Summary of Six Spray Booth Samples



Summary of Six Bake Oven Samples



- ✓ Sulfonated compounds were not filterable.
- ✓ ~66-76% present in filterable form
- ✓ Alternative PM controls could further reduce emissions, if needed.

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KEY FINDINGS AND TAKEAWAYS

FINDINGS AND CONCLUSIONS

01 Agglomeration of PFOA-containing coatings in stack components during $Ops_{Legacy's}$ tenure have resulted in the release of significant PFOA mass in residual coatings to the roof, which have served as a major source of PFOA for decades until recent roof and ductwork replacement.

02 Emissions and mass of PFOA released by Ops_{Legacy} were exponentially greater than $Ops_{Current}$, resulting in commensurate greater PFOA mass transport from Ops_{Legacy} compared to $Ops_{Current}$ via the pathways shown.

03 The measured concentrations in the environment on site and at the Public Water Supply Well cannot be reconciled to $Ops_{Current}$.

04 Multiple lines of evidence (at least 5) point to Ops_{Legacy} as the source of the PFOA observed in media around the facility and at the Public Water Supply Well with the potential for de minimis contributions from $Ops_{Current}$.

TAKE-AWAYS

01 **"PFOA Free" in process materials may not necessarily = 0 ppt PFOA**

- Can be significant at ppt thresholds

02 **Aerial deposition of PFAS emissions not concentrated around source**

03 **Agglomeration, chunking, and residue of PFAS from equipment can be significant**

04 **Vadose zone storage and retardation may also be significant factors, especially for longer term operations**

05 **More research on particle size data for PFAS from different industrial processes needs to be gathered and may shed further light on the importance of the air emissions pathway**

THANK YOU

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