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Guidance for Assessing the Ecological Risks of Threatened and Endangered Species at Aqueous Film Forming Foam (AFFF)-Impacted Sites

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25 YEARS OF ESTCP
2019 | Enhancing DoD's Mission Effectiveness

Thank You Co-authors

- Geosyntec consultants
  - Jenn Arblaster, MS
  - Emily Larson, MS
- Colorado School of Mines
  - Chris Higgins, PhD (Co-PI)
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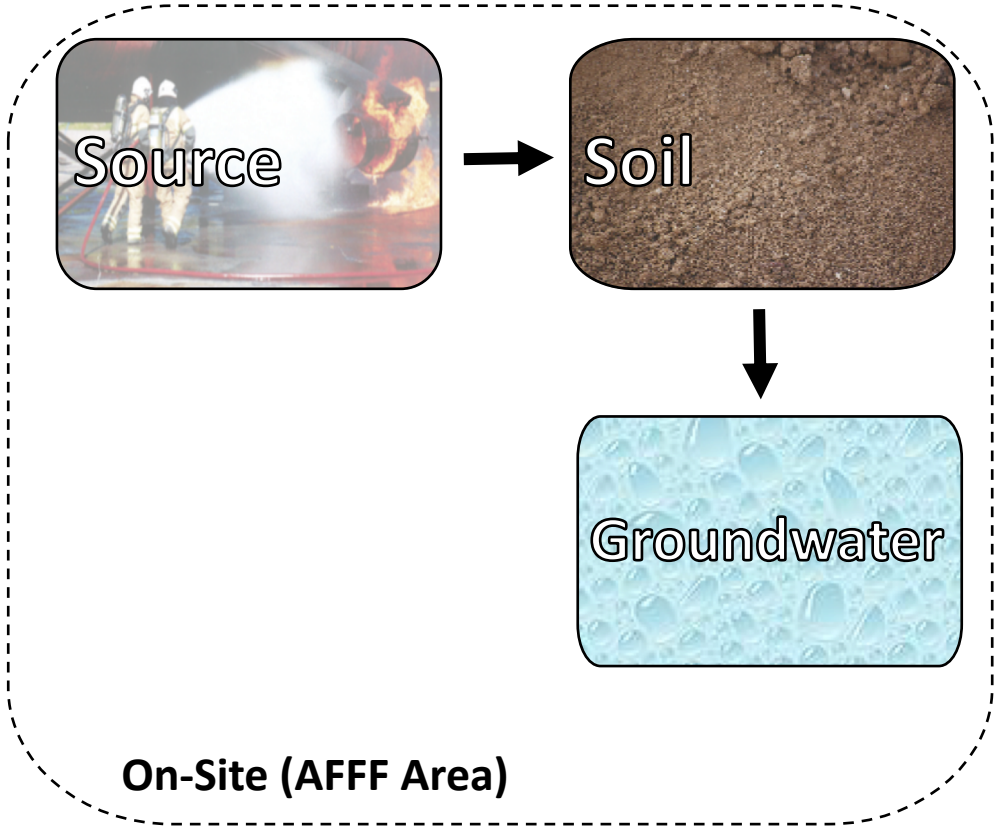
AFFF

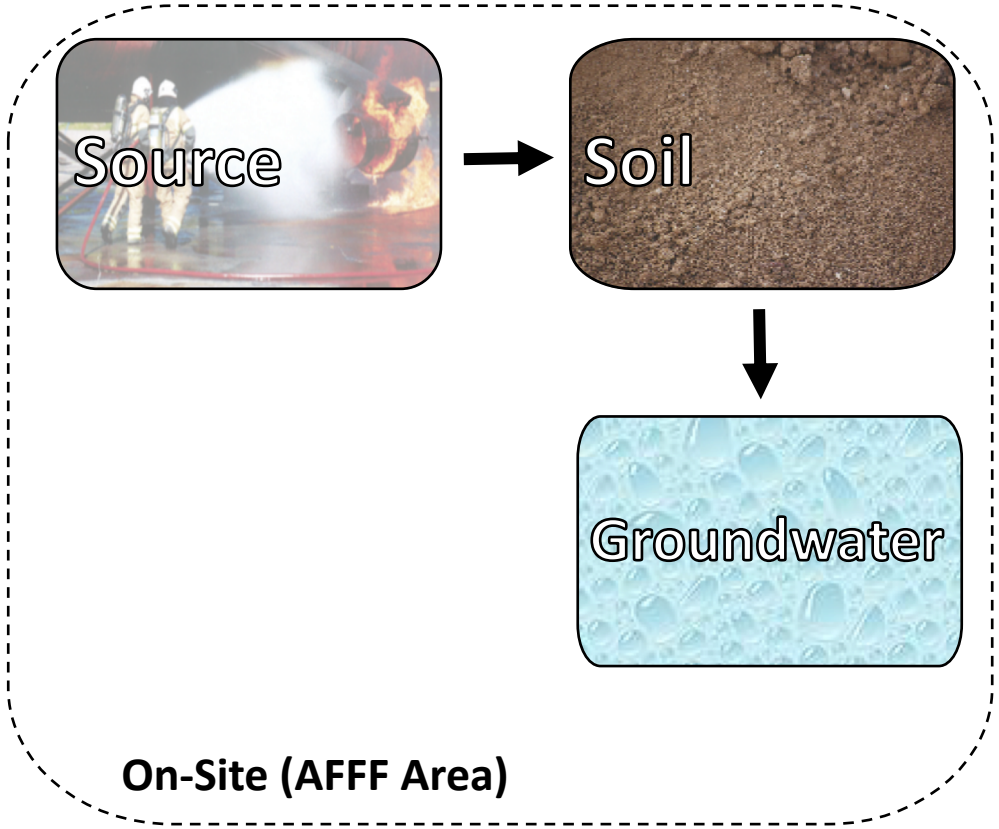
- AFFF = Aqueous Film Forming Foam
  - Complex, proprietary mixtures of fluorinated and hydrocarbon surfactants, water, corrosion inhibitors,
    solvent
  - ~1-10% PFAS by weight, 10s to 1000s of liters per use
- Hundreds to thousands of sites, some resulting in potential PFAS exposure to ecological receptors
  - Ecorisk driving decision making at sites in US, Australia, etc.

AFFF and Ecological Resources



- Wide range of behaviors
  - Some PFAS can sorb to soil and aquatic sediment
  - Some PFAS are more water soluble

AFFF and Ecological Resources



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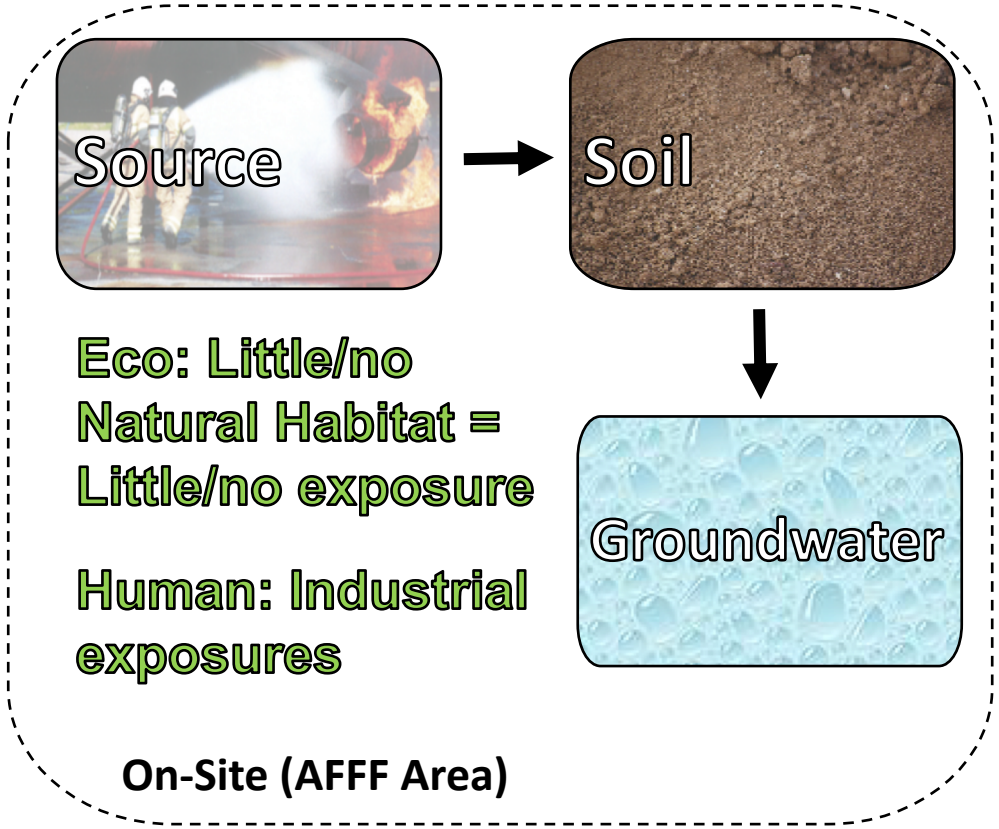
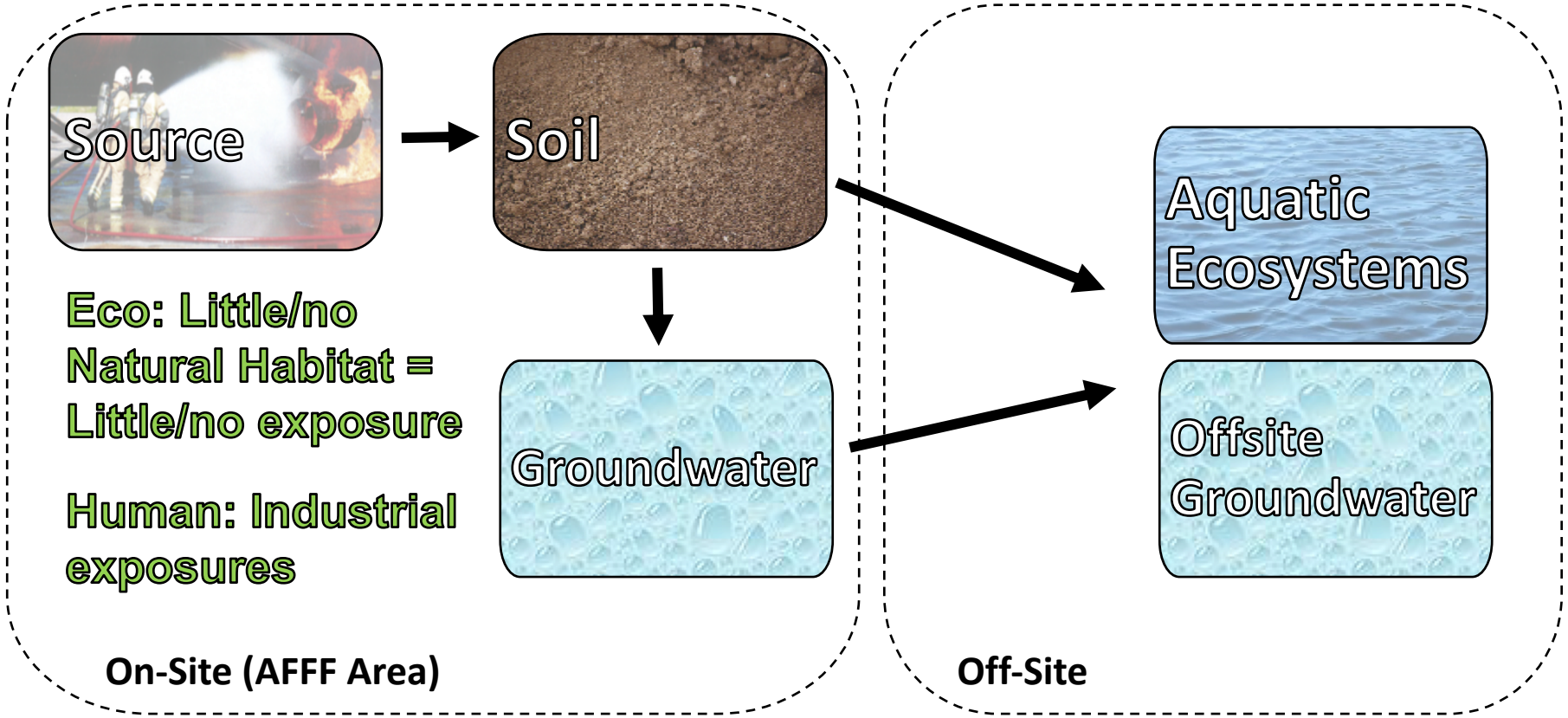
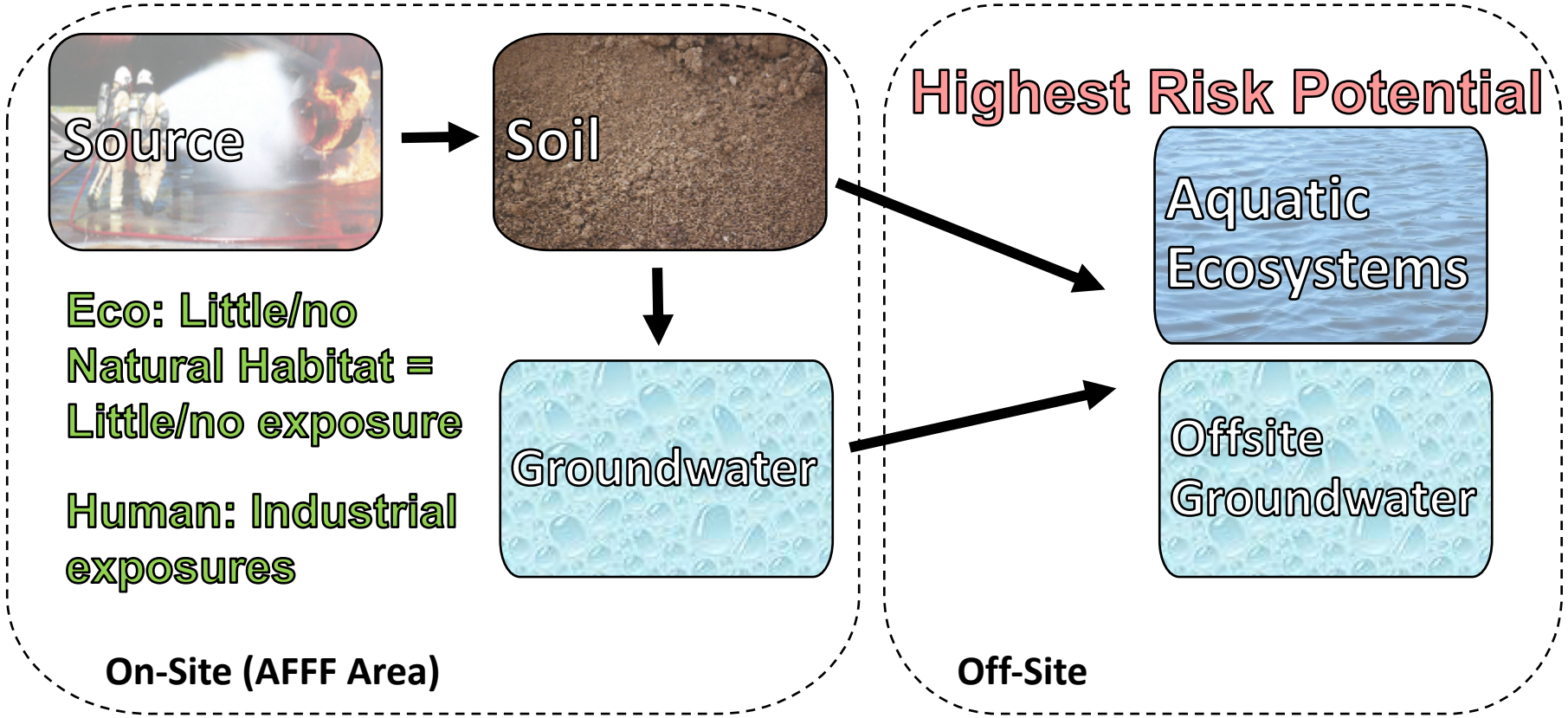


AFFF and Ecological Resources



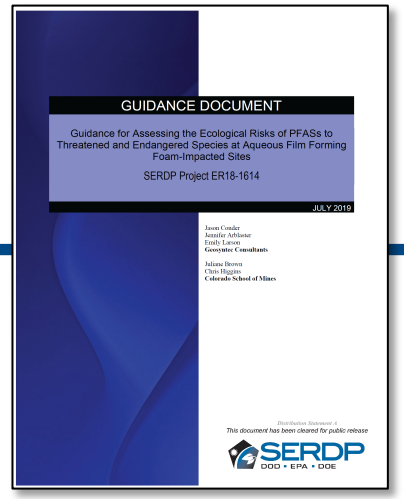
AFFF and Ecological Resources



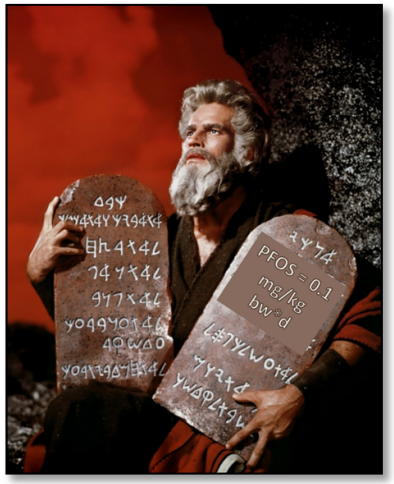
Technical Objective

- Strategic overview of state-of-the-practice for the ecological risk assessment (ERA) at AFFF sites (Threatened and Endangered (T&E) species focus, per SERDP Statement of Need ERSON-18-L2, 2017)
- Guidance for quantitatively assessing and managing ecological risks, targeting ecological risk assessors
  - What's the current best approach for ecological risk assessments?

Another Review/Catalogue of Research Papers

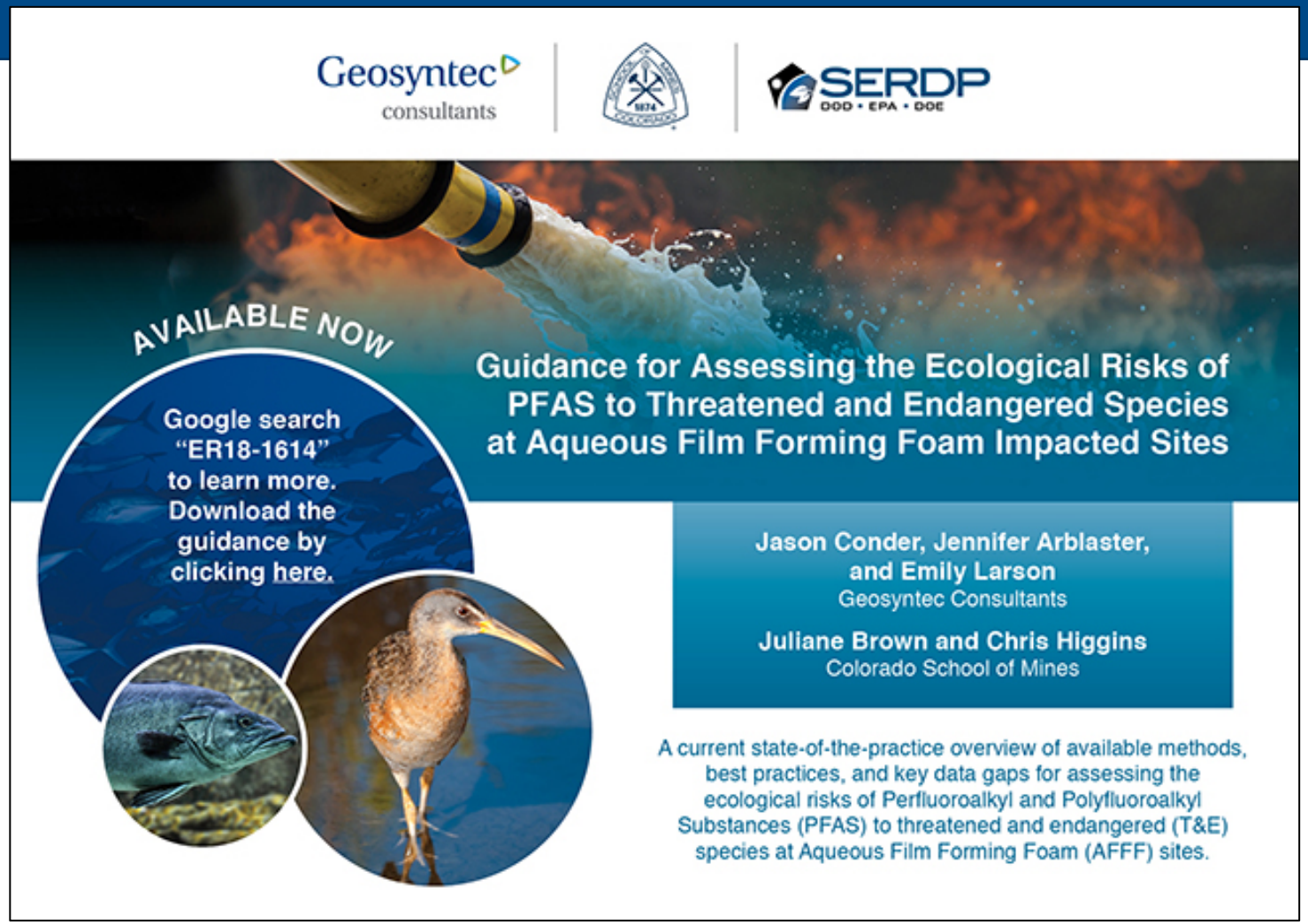


Our Project:
Current Best Practices Guidance



***Ten Commandments of* PFAS Ecorisk**

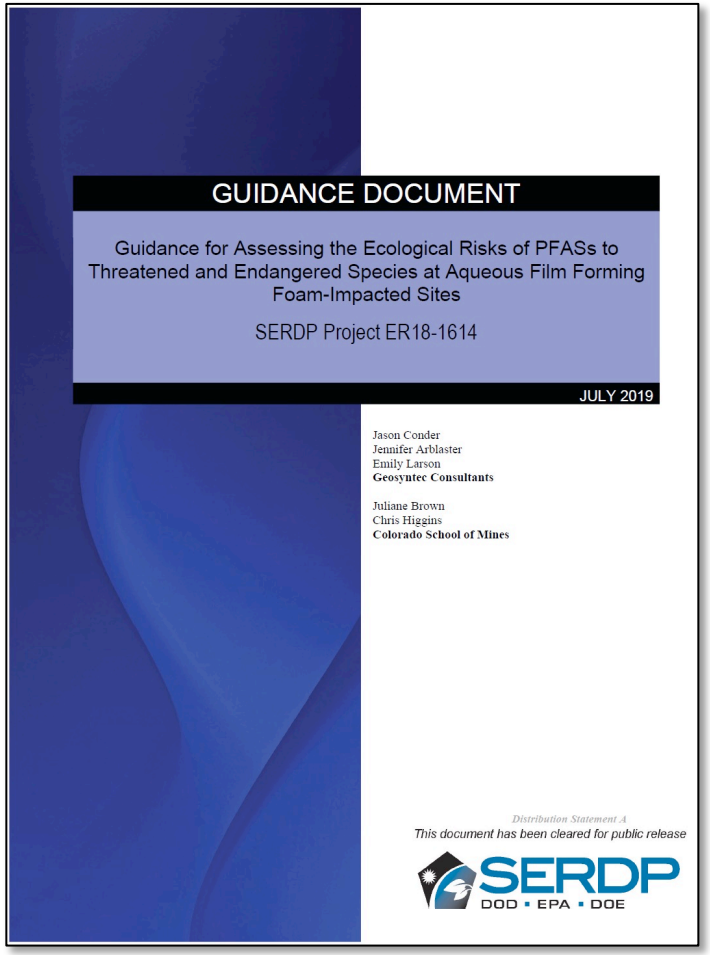
Guidance - Google “ER18-1614”



Conder, J., Arblaster, J., Larson, E., Brown, J., Higgins, C. 2019. Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites. SERDP Project ER18-1614. July. https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/ER18-1614

Guidance By the Numbers

- Guidance
  - 60-page main guidance text with 9 tables and 10 figures
  - 5 Appendices (62 pages total)
- Recommended values for use in ERAs for 18 target PFAS
  - 82 bioaccumulation values for predicting uptake by aquatic biota
  - 35 bioaccumulation values for predicting uptake by terrestrial biota
  - 23 Wildlife Toxicity Reference Values (TRVs)
  - 6 Aquatic Life Criteria
  - 4 plant/invertebrate soil criteria
- Based on a comprehensive and thorough review
  - Over 250 studies reviewed
  - Over 200 toxicity values and over 1300 bioaccumulation values considered


GUIDANCE DOCUMENT

Guidance for Assessing the Ecological Risks of PFASs to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites

SERDP Project ER18-1614

JULY 2019

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Chris Higgins
Colorado School of Mines

Distribution Statement A
This document has been cleared for public release

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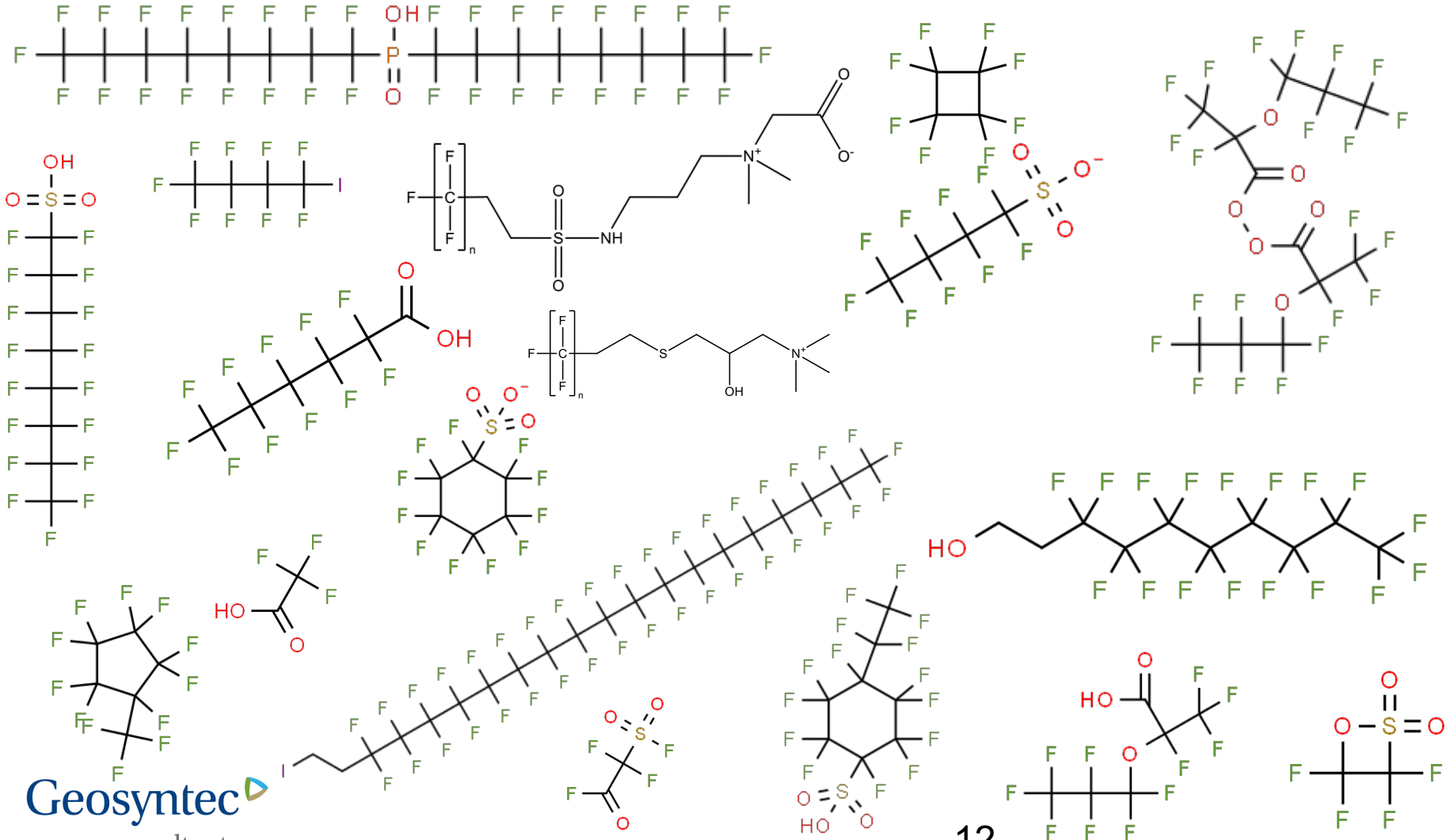
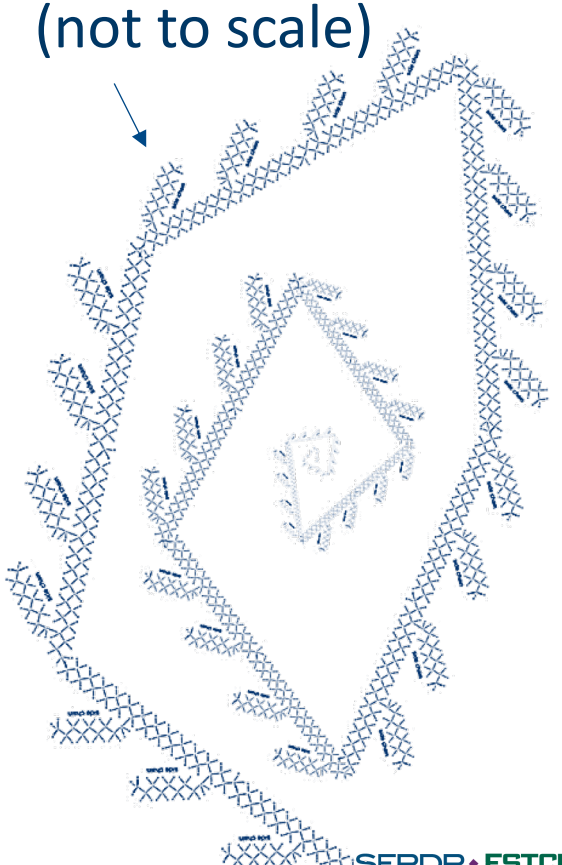
Which PFAS?



PFAS Polymer
(not to scale)



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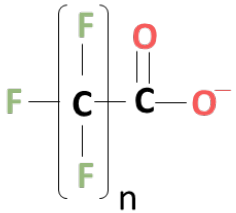
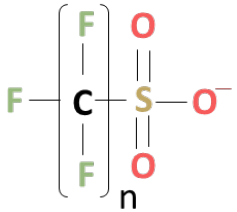
18 Target PFAS Included in the Guidance

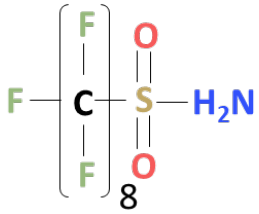
- 18 PFAS
  - Perfluoroalkyl carboxylic acids (PFCAs) (11)
    - E.g., PFOA
  - Perfluoroalkyl sulfonic acids (PFSAs) (4)
    - E.g., PFOS
  - PFOSA
  - N-EtFOSAA
  - N-MeFOSAA
- Based on
  - Method 537.1
  - EPA UCMR3
  - ATSDR Tox. Profile
  - PFAS with state guidance/standards
  - General data availability



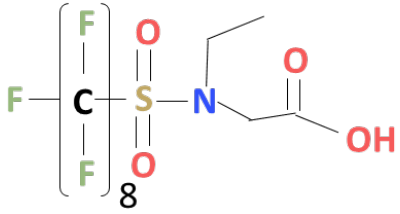
Perfluoroalkyl Carboxylates (n = 3-13)



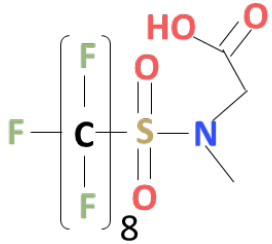
Perfluoroalkyl Sulfonates (n = 4, 6, 8, 10)



Perfluorooctane sulfonamide (PFOSA)

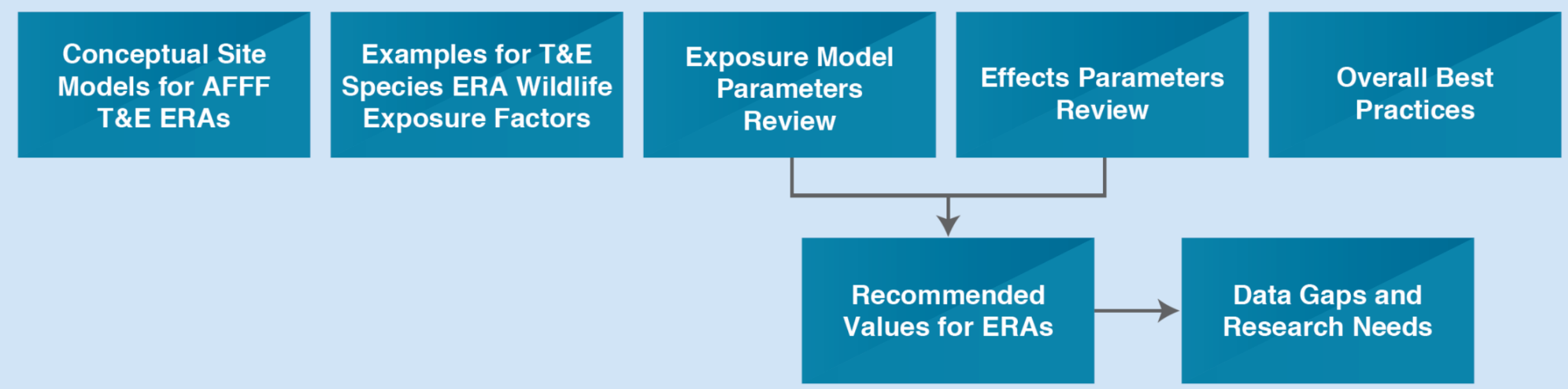


2-(N-Ethyl perfluorooctane sulfonamido) acetic acid (N-EtFOSAA)



2-(N-Methyl perfluorooctane sulfonamido) acetic acid (N-MeFOSAA)

Guidance Organization



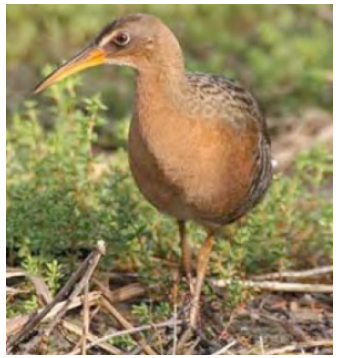
T&E Species Focus

- SERDP need specifically intended a focus on Threatened and Endangered (T&E) species ecorisk
- Portion of guidance provides example exposure factors (and sources of info) for T&E species
- Guidance is broadly applicable for ecological risk assessment with common species

Buena Vista Lake Ornate Shrew (*Sorex ornatus relictus*)

Western Pocket Gopher (*Thomomys mazama*)

California clapper rail (*Rallus obsoletus)*



Hawaiian stilt (*Himantopus mexicanus knudseni*)

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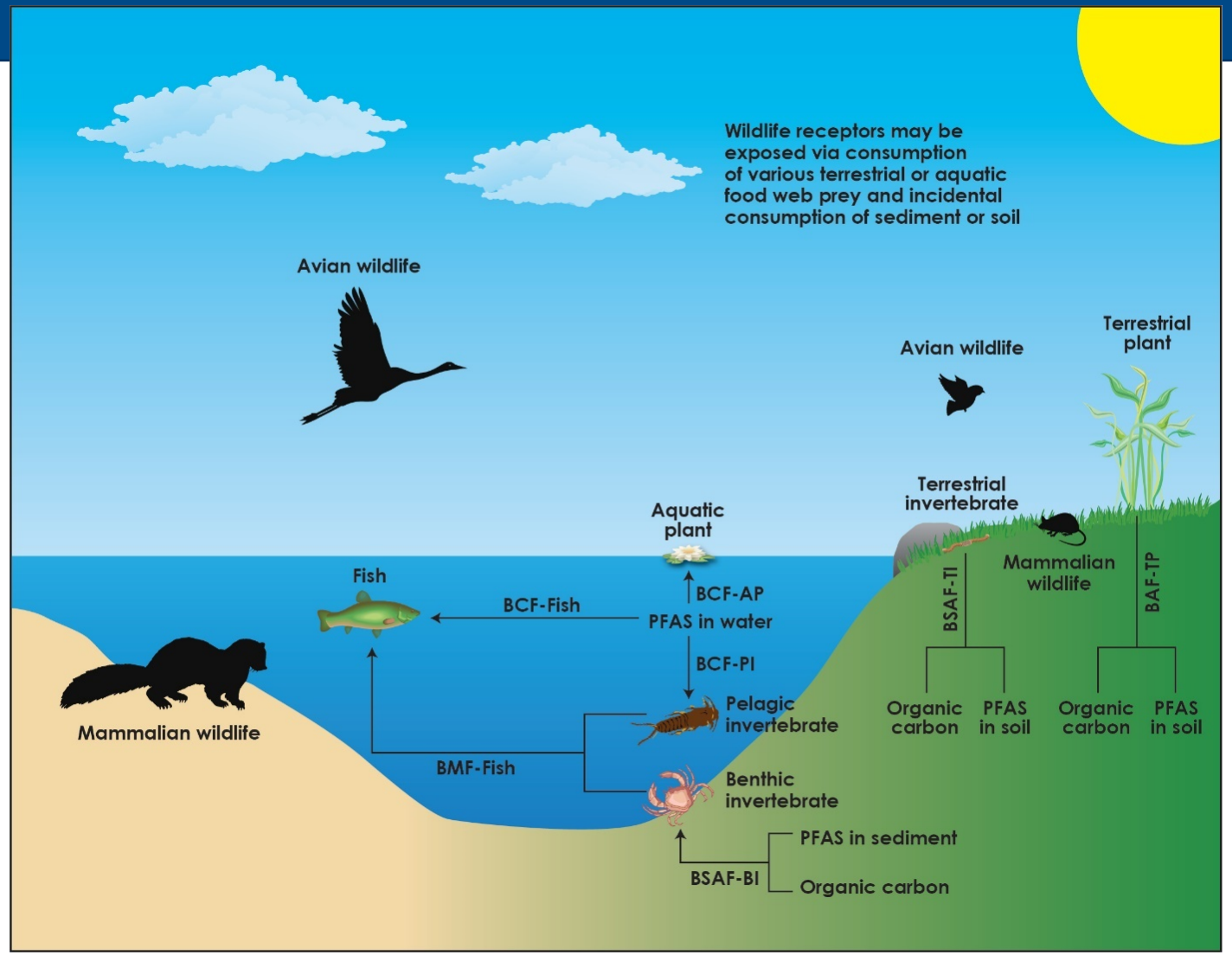
Conceptual Site Model



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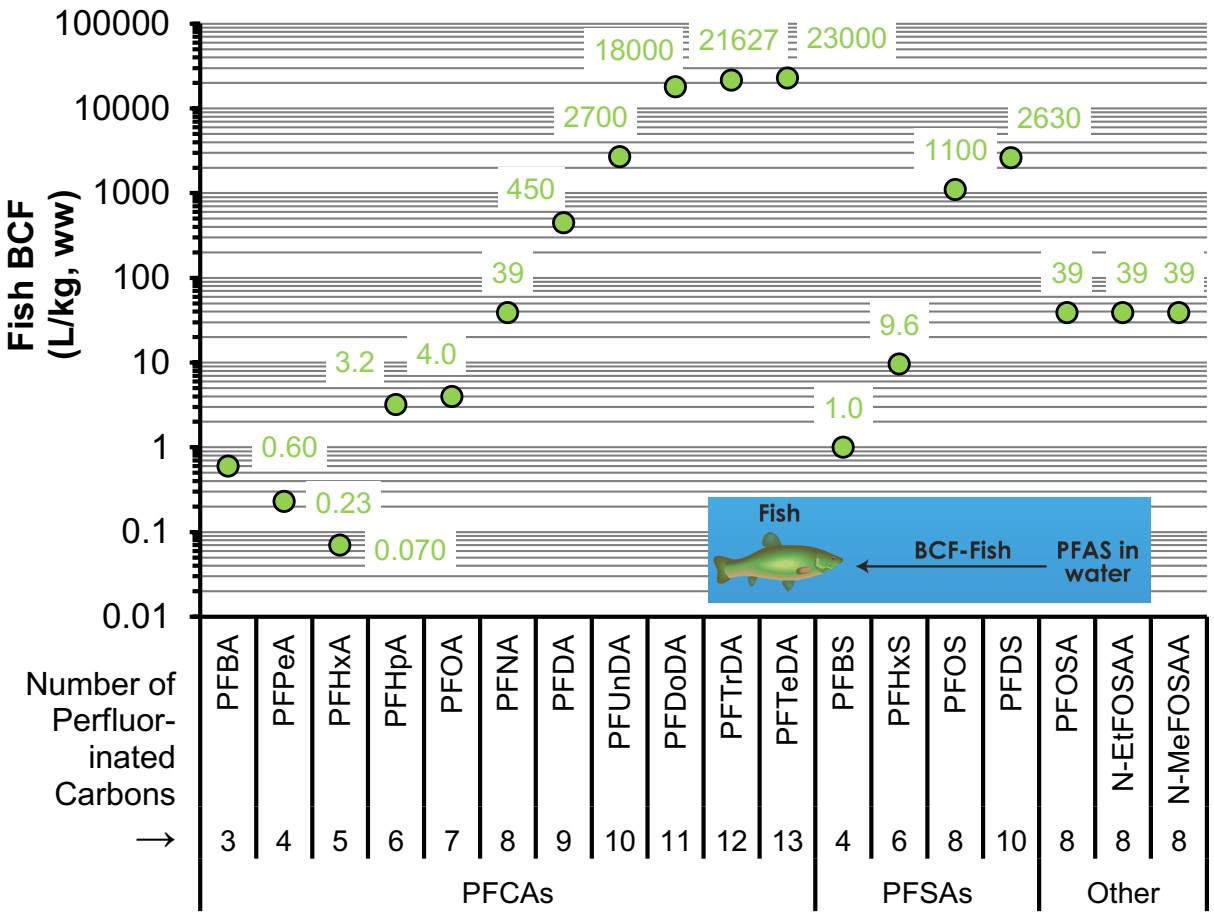
Exposure

- How can we predict accumulation of PFAS in the food web (diet items for wildlife)?
- Bibliography of studies reviewed included
- Process for selection of recommended values
- Tables and figures to present recommended values for bioaccumulation modeling:
  - Water to Pelagic Invertebrate Bioconcentration Factors
  - Sediment to Benthic Invertebrate Biota-sediment Accumulation Factors
  - Water to Aquatic Plant Bioconcentration Factors
  - Water to Fish Tissue Bioconcentration Factors
  - Diet to Fish Tissue Biomagnification Factors
  - Soil to Terrestrial Plant Bioaccumulation Factors
  - Soil to Terrestrial Invertebrate Biota-soil Accumulation Factors



Example: Fish BCFs

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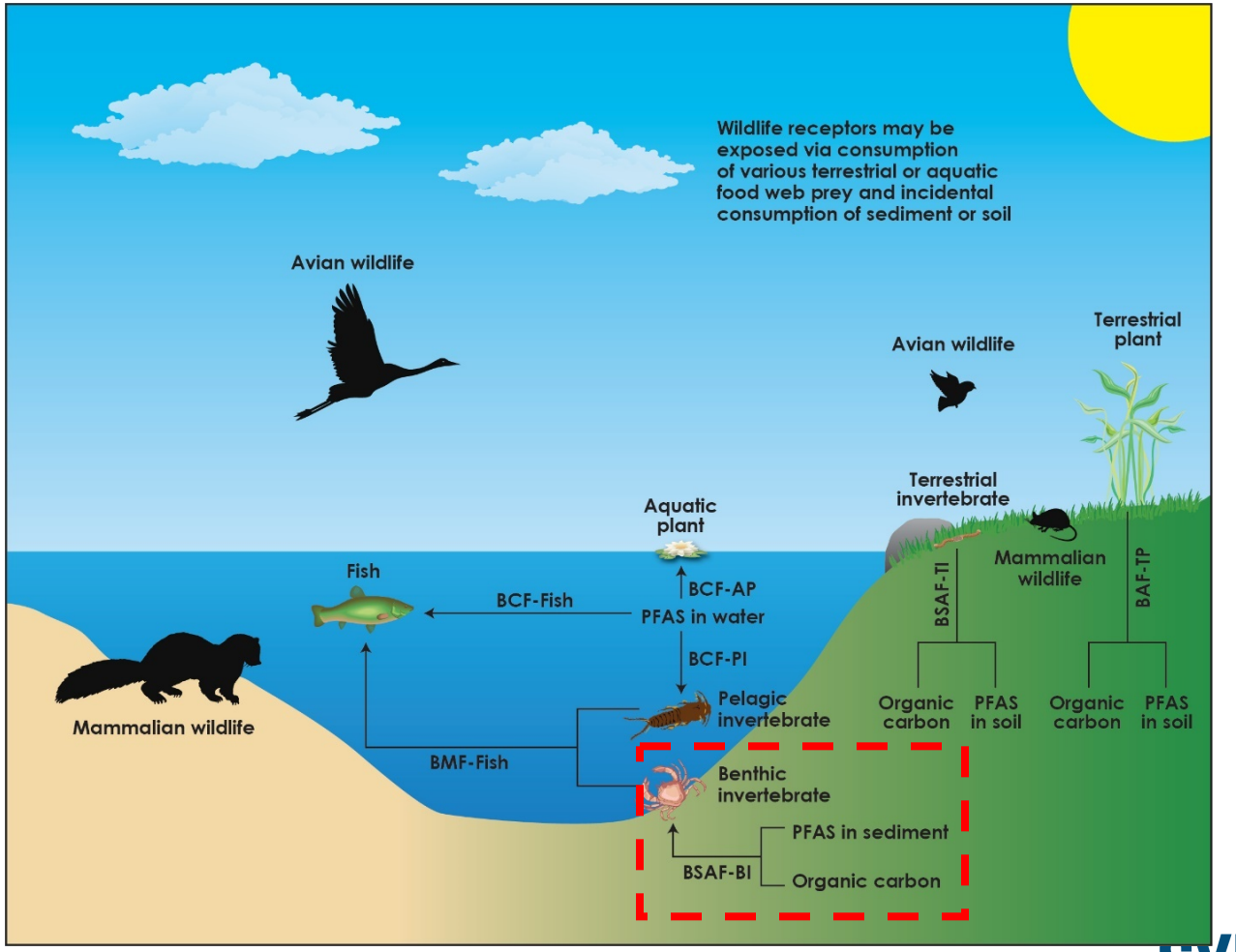
Bioaccumulation Model Framework

- Concentration in benthic invertebrate = measured concentration in sediment (organic carbon normalized) × BSAF-BI



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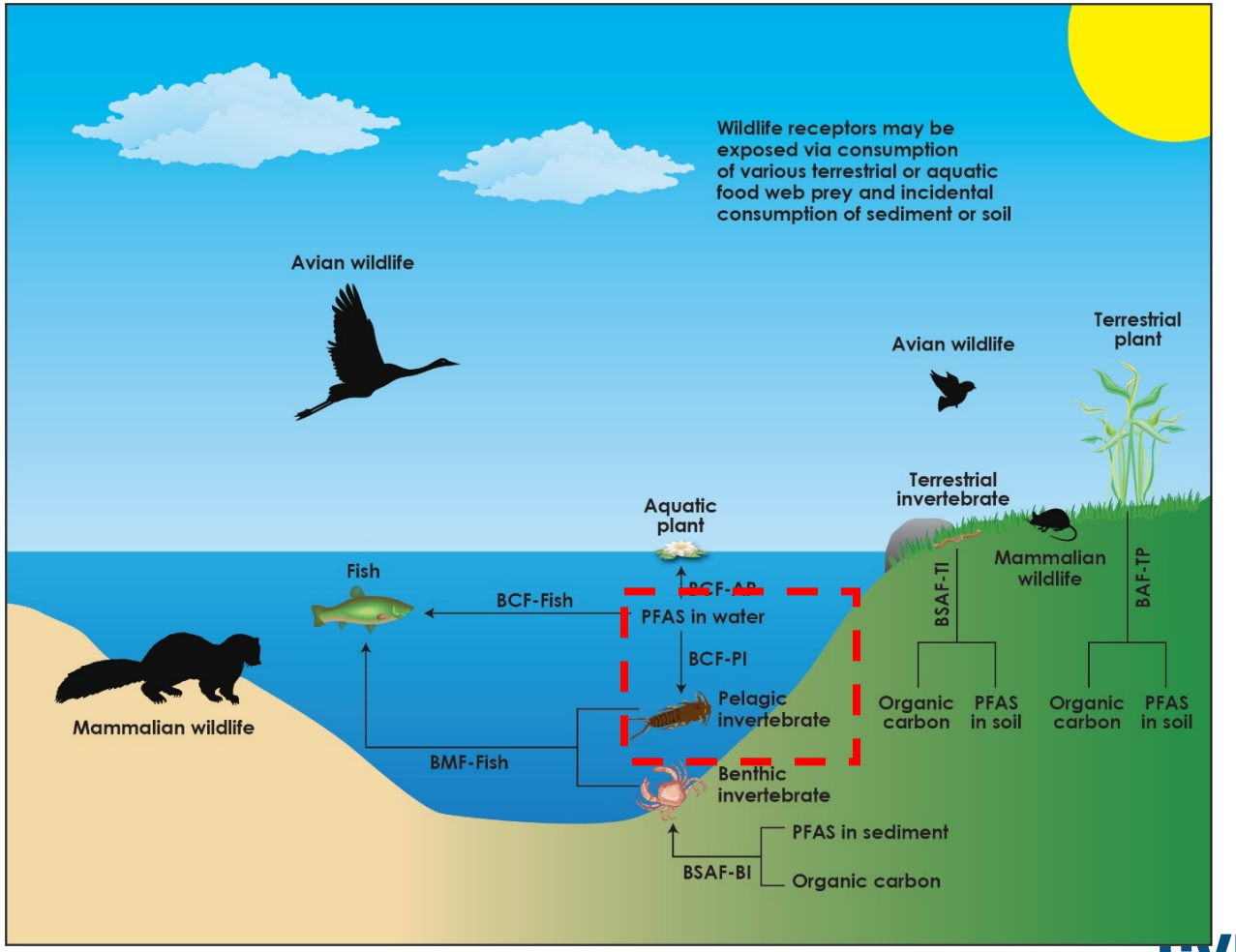
Bioaccumulation Model Framework

- Concentration in pelagic invertebrate = measured concentration in water × BCF-PI



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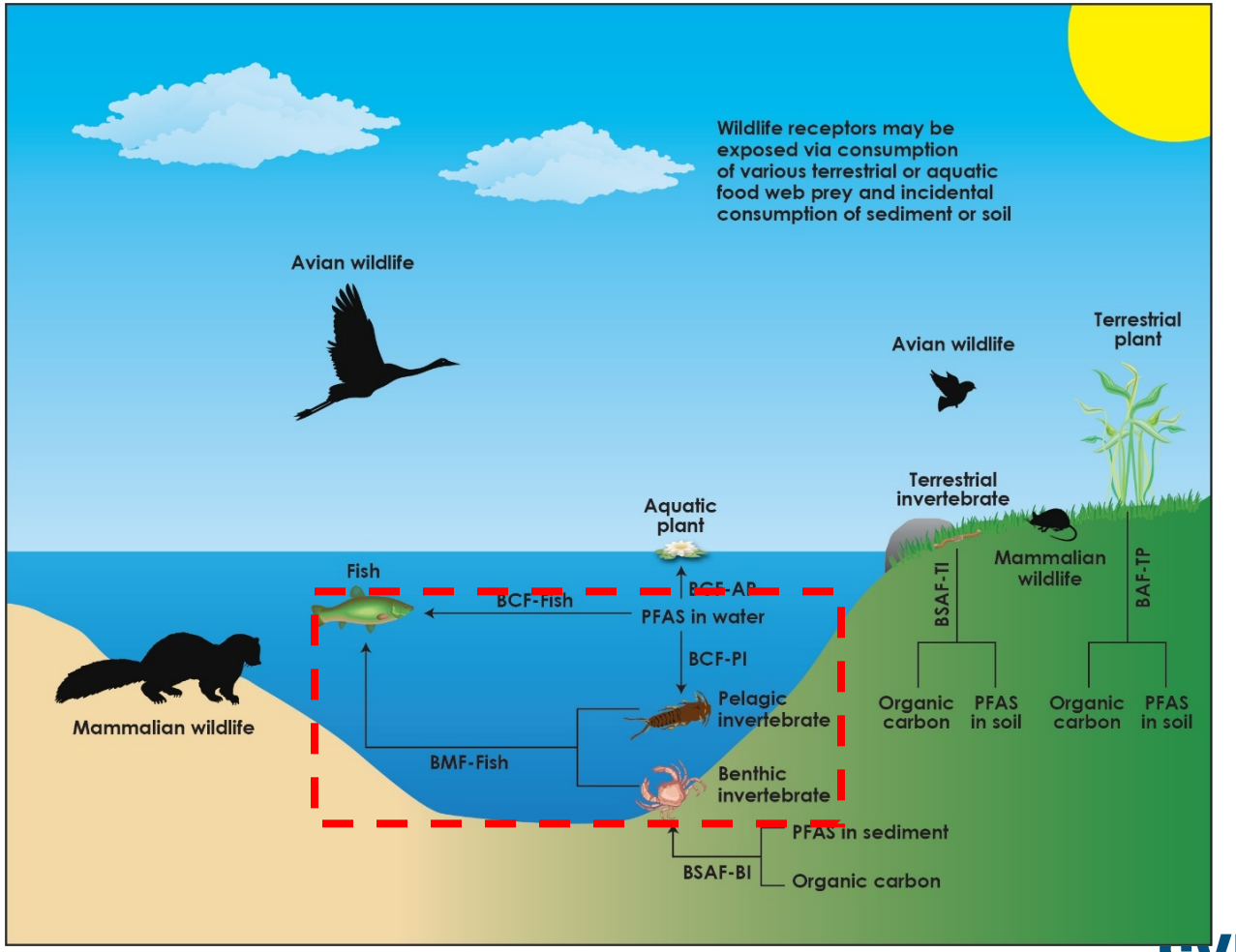
Bioaccumulation Model Framework

- Concentration in fish = sum of:
  - Concentration in benthic invertebrate × Proportion of benthic invertebrate in diet (e.g., 0.5 for forage fish) × BMF-Fish
  - Concentration in pelagic invertebrate × Proportion of pelagic invertebrate in diet (e.g., 0.5 for forage fish) × BMF-Fish
  - Measured concentration in water × BCF-Fish



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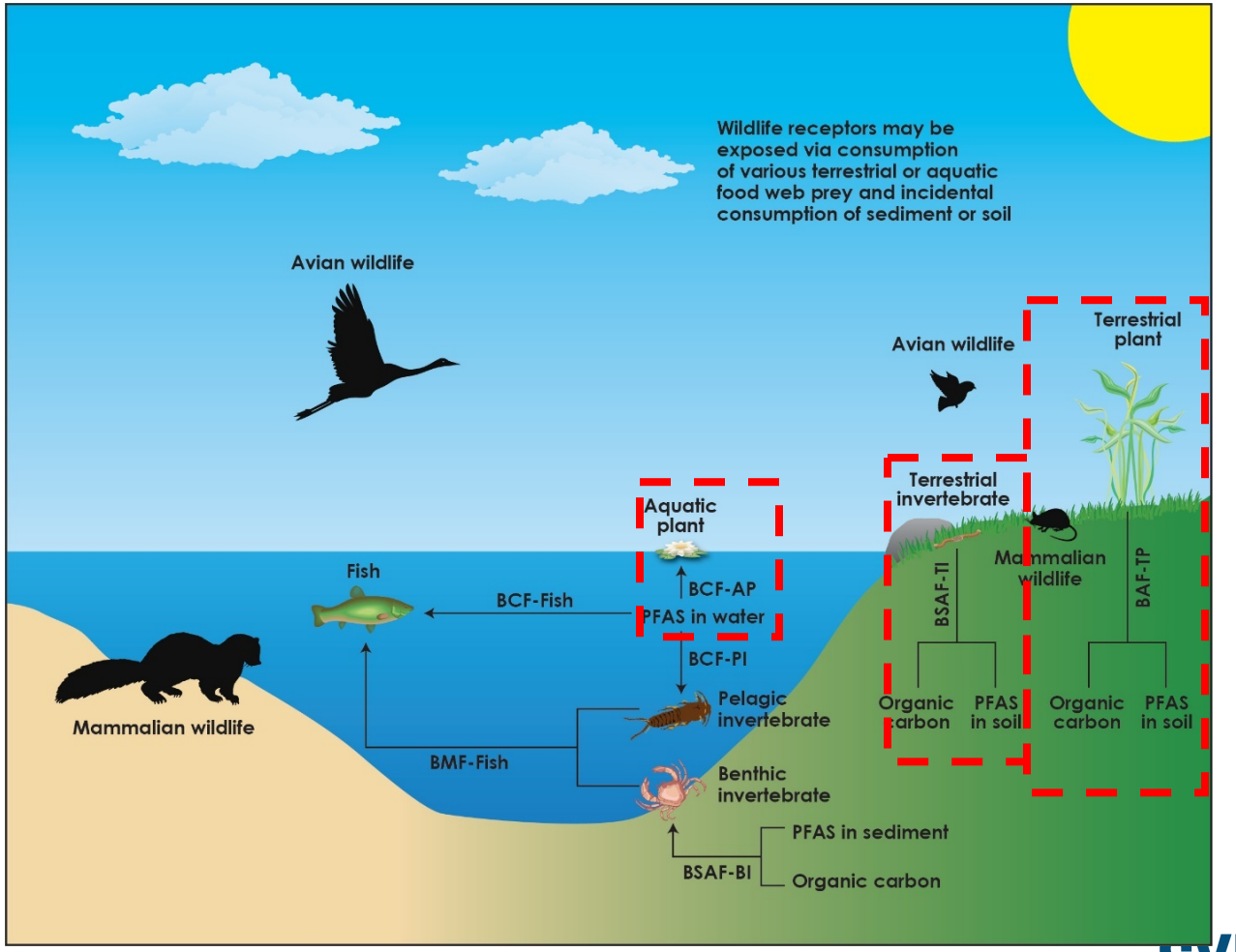
Bioaccumulation Model Framework

- Etc.
  - Concentration in aquatic plant = measured concentration in water × BCF-AP
  - Concentration in terrestrial invertebrate = measured concentration in soil (organic carbon normalized) × BSAF-TI
  - Concentration in terrestrial plant = Measured concentration in soil (organic carbon normalized) × BAF-TP



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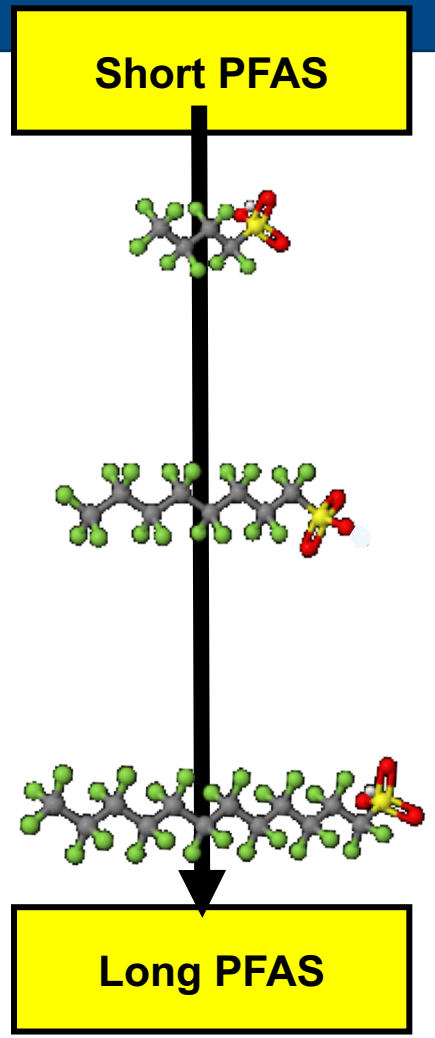
General Observations on Bioaccumulation

Chemical Size Affects Bioaccumulation



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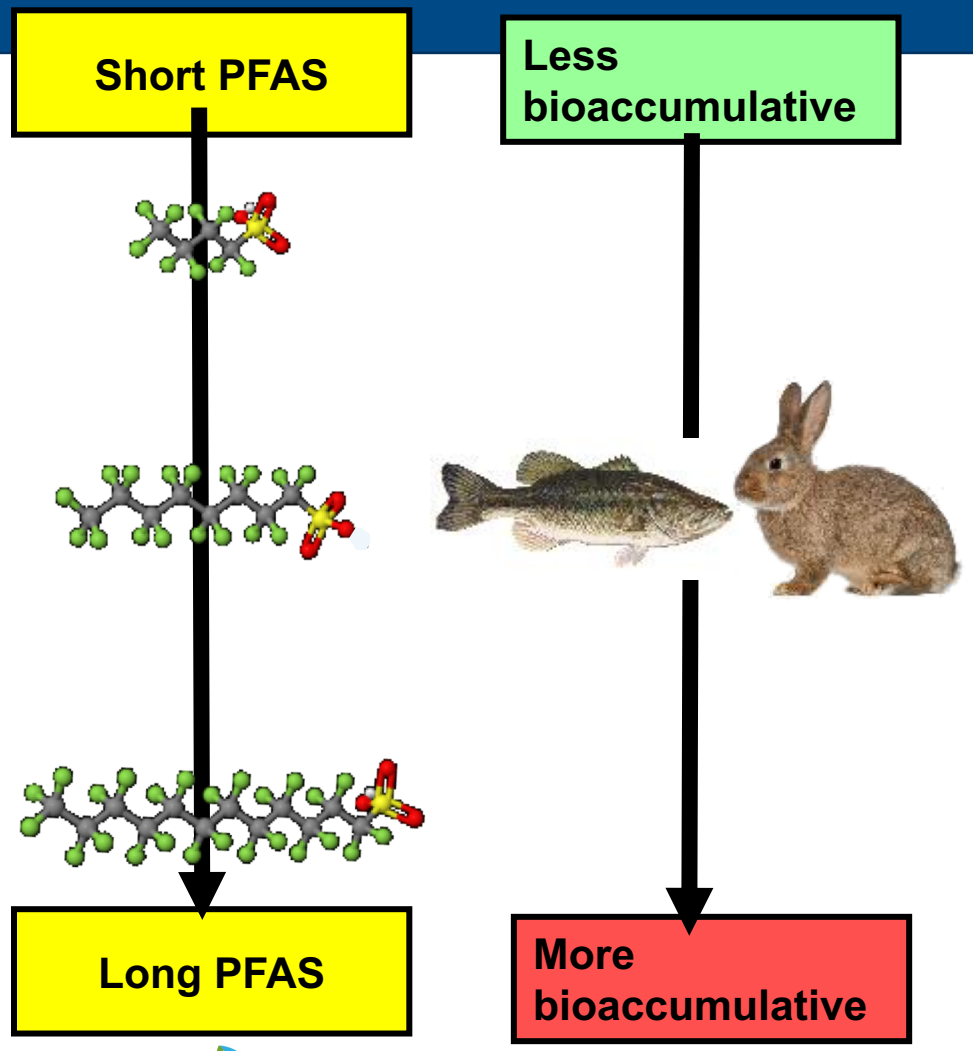

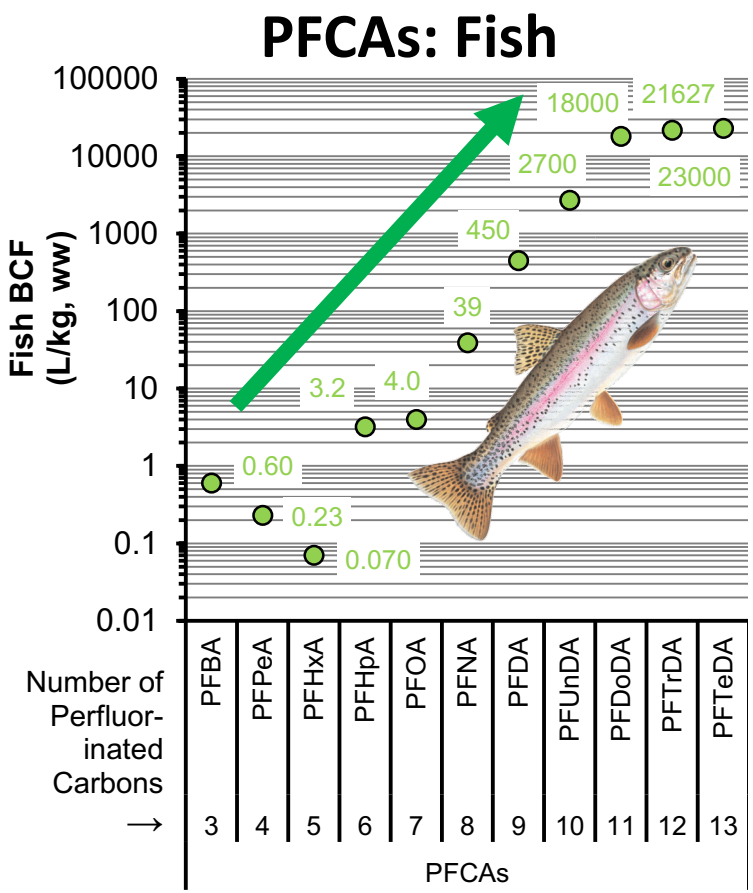

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General Observations on Bioaccumulation

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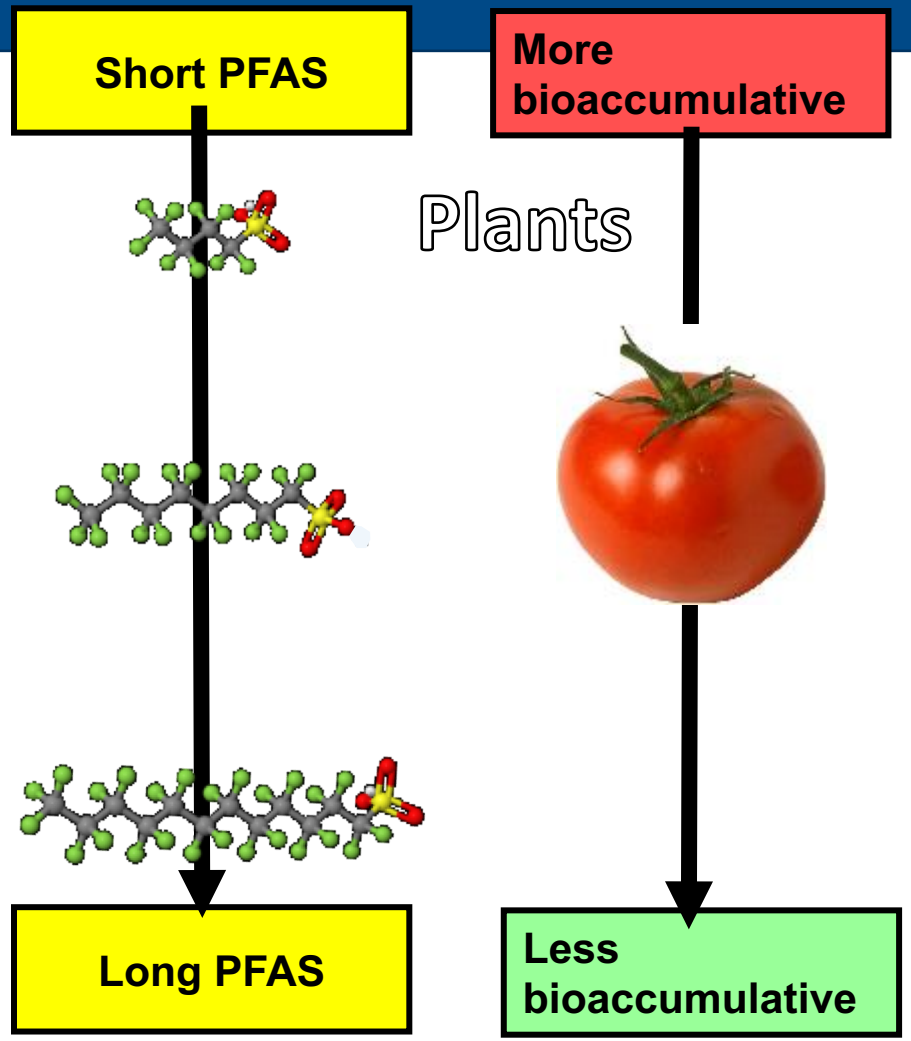

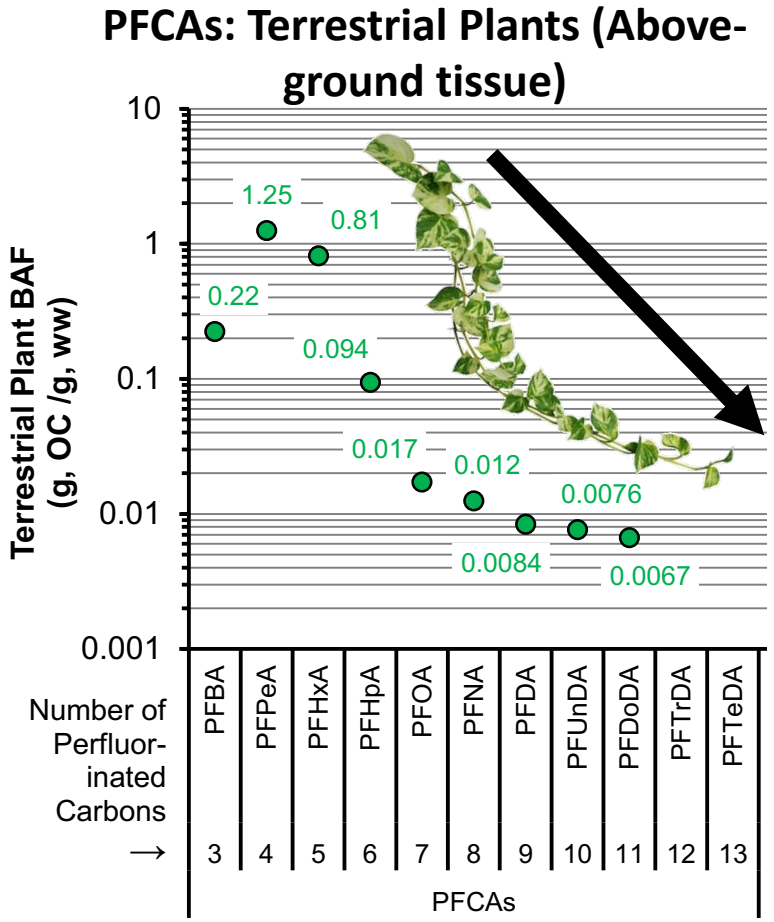

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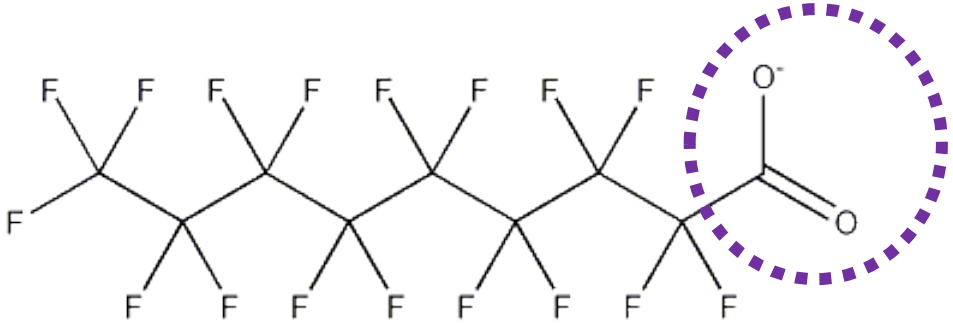
General Observations on Bioaccumulation
Functional Group Affects Bioaccumulation

Carboxylates PFCAs (e.g., PFOA, PFNA)

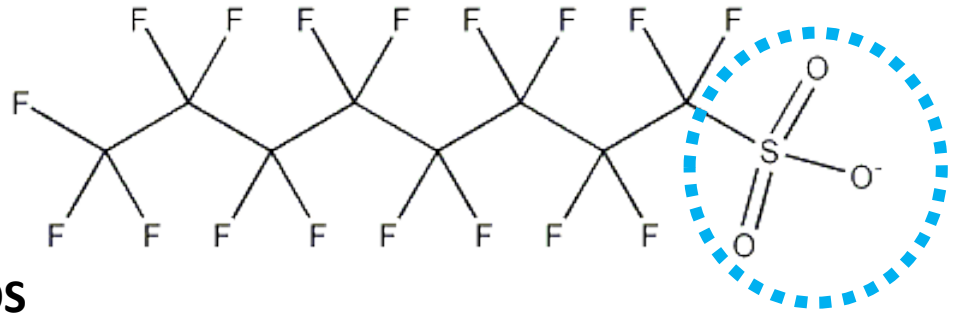
Carboxylate "head"

Sulfonate "head"

Sulfonate PFSAs (e.g., PFOS, PFDS)



PFNA
(a "tail" of 8 perfluorinated carbons, with a carboxylate "head")



PFOS
(a "tail" of 8 perfluorinated carbons, with a sulfonate "head")

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General Observations on Bioaccumulation

Functional Group Affects Bioaccumulation

Carboxylates PFCAs (e.g., PFOA, PFNA)

Carboxylate "head"

Sulfonate "head"

Sulfonate PFSAs (e.g., PFOS, PFDS)

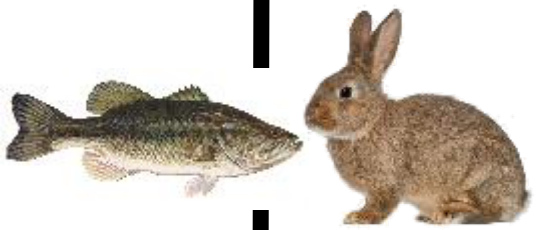
More bioaccumulative

Plants

Less bioaccumulative

Less bioaccumulative

Animals



More bioaccumulative

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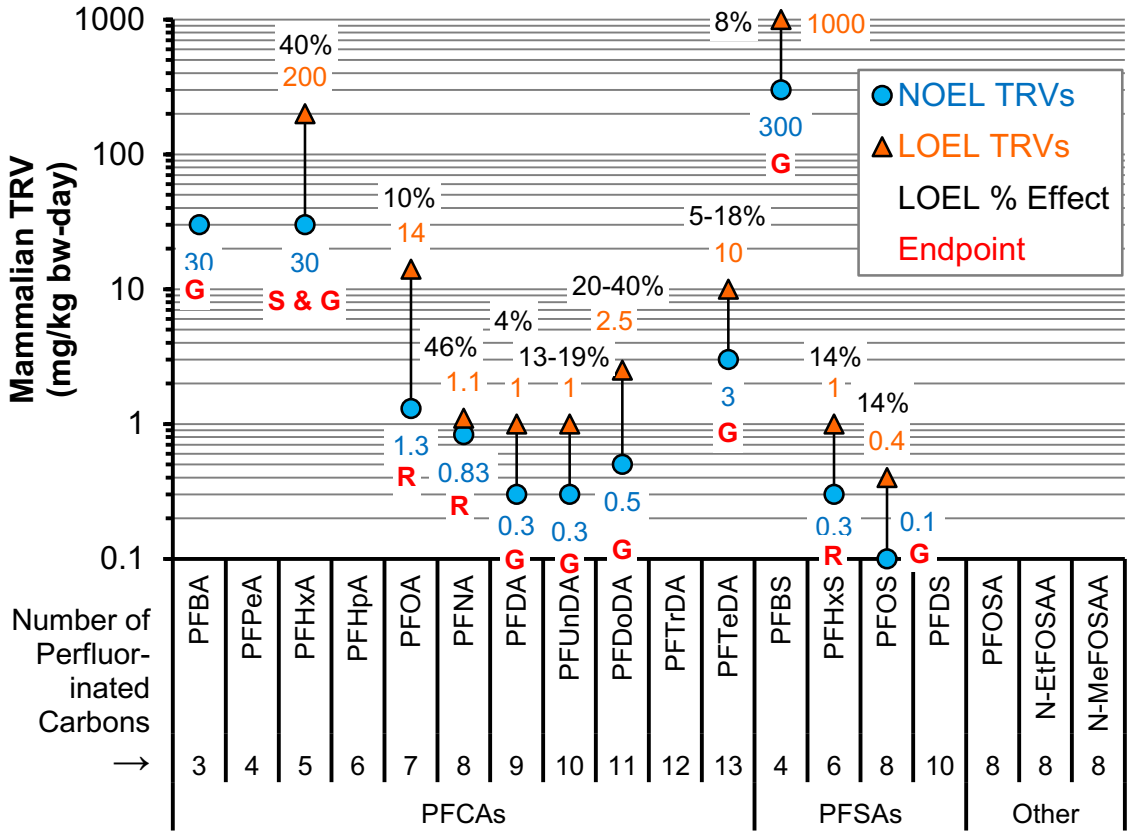
Effects

- How can we characterize the likelihood of adverse effects from site-specific PFAS exposures?
- Bibliography of studies reviewed included
- Used a process for selection of recommended values, with 10-point scoring system for wildlife Toxicity Reference Values (TRVs)
- Tables and figures to present recommended values for:
  - Mammalian TRVs
  - Avian TRVs
  - Aquatic life criteria (marine and freshwater), developed via EPA Species Sensitivity Distribution (SSD) approach
  - Criteria for soil invertebrates and terrestrial plants



Example: Mammalian TRVs

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General Observations on Effects

- Mammalian data suggest the shortest PFCAs and PFSAs are orders of magnitude less toxic than longer compounds
- For non-mammalian receptors, comparative lack of data beyond PFOA and PFOS
- PFOA and PFOS data suggest soil invertebrates and plants relatively insensitive (screening levels in the mg/kg range)

ERA Recommendations

- Selection of representative wildlife species and sources of information on species exposure factors
- Data needs and investigation
  - Environmental samples for PFAS analysis
  - Recommendations for a phased approach for ERA investigation
    - Evaluation abiotic samples, modeling, then tissue samples and ecological studies
- Characterizing risks
  - When more than one PFAS is detected
  - PFAS precursors/PFAS that are unable to be measured by current commercially-available techniques

Data Gaps and Critical Research Needs

- ERA bioaccumulation models for terrestrial ecosystems
- Biomagnification factors for higher trophic levels transfer (prey to predator)
- PFAS precursors exposures, particularly regarding invertebrate bioaccumulation and effects
- Mixture toxicity
- Derivation of toxicity benchmarks using lab toxicity studies with birds, benthic invertebrates, terrestrial plants, and terrestrial invertebrates
- Field ecology studies at AFFF sites to evaluate PFAS effects

PFAS	Carbon Chain Length	Number of Perfluor-inated Carbon Atoms	Summary	Key Data Gaps	Relative Importance of Data Gap
PFBA	C4	3	Moderate occurrence, low bioaccumulation	Avian Toxicity	Low
PFPeA	C5	4	Moderate occurrence, low bioaccumulation	Avian Toxicity	Low
PFHxA	C6	5	High occurrence, low bioaccumulation	Avian Toxicity	Moderate
PFHpA	C7	6	Moderate occurrence, low bioaccumulation	Avian Toxicity	Moderate
PFOA	C8	7	High occurrence, moderate bioaccumulation in benthic invertebrates	Avian Toxicity	Moderate
PFNA	C9	8	Low occurrence, high bioaccumulation in benthic invertebrates, moderate bioaccumulation in pelagic invertebrates	Avian Toxicity	Moderate
PFDA	C10	9	Moderate occurrence, high bioaccumulation in pelagic invertebrates	Avian Toxicity	High
PFUnDA	C11	10	Low occurrence, high bioaccumulation in pelagic invertebrates	Avian Toxicity	Moderate
PFDoDA	C12	11	Moderate occurrence, high bioaccumulation in pelagic invertebrates and fish	Avian Toxicity	High
PFTrDA	C13	12	Low occurrence, high bioaccumulation in fish	Avian Toxicity	Moderate
PFTeDA	C14	13	Low occurrence, high bioaccumulation in fish	Avian Toxicity	Moderate
PFBS	C4	4	Moderate occurrence, low bioaccumulation	Avian Toxicity	Low
PFHxS	C6	6	High occurrence, moderate bioaccumulation	Avian Toxicity	High
PFOS	C8	8	High occurrence, high bioaccumulation in pelagic invertebrates	None	Low
PFDS	C10	10	Moderate occurrence, moderate bioaccumulation in fish	Avian Toxicity	Moderate
PFOSA	C8	8	Moderate occurrence, low bioaccumulation	Avian Toxicity	Moderate
N-EtFOSAA	C8	8	Uncertain occurrence, likely low/uncertain bioaccumulation	Avian Toxicity	Moderate
N-MeFOSAA	C8	8	Uncertain occurrence, likely low/uncertain bioaccumulation	Avian Toxicity	Moderate

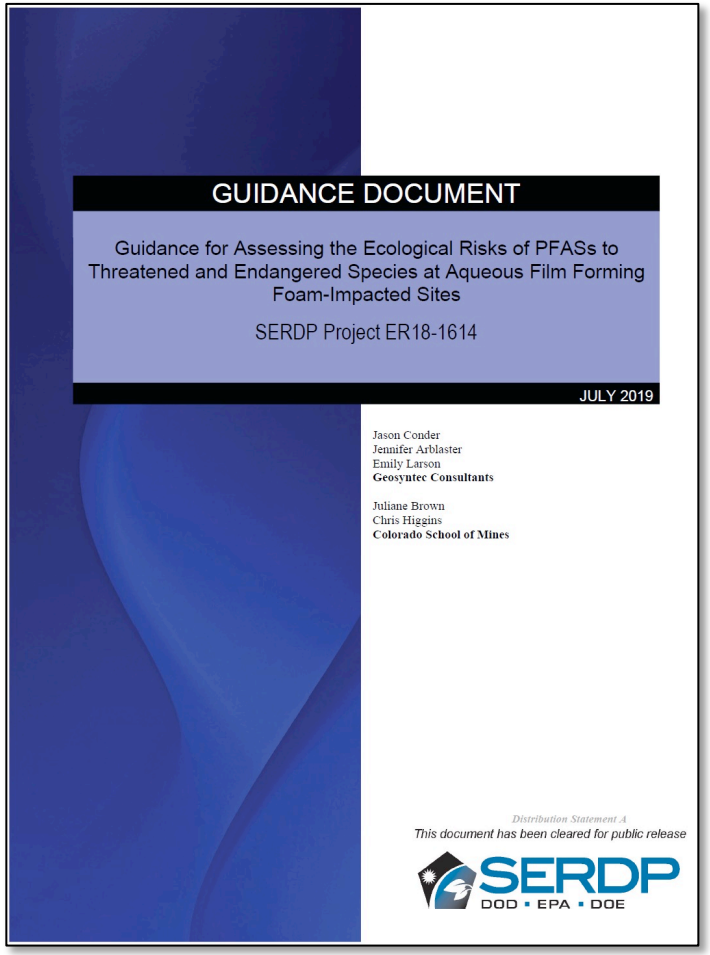
Prioritization of PFAS data needs by compound

Overall Conclusions

- Ecological Risk Assessment of AFFF-derived PFAS to T&E species is possible and ongoing now
  - Guidance is also useful for non T&E species
- Off-site habitats are most at risk
- Aquatic habitats are critical to address
- Terrestrial habitats may be important at some sites
- Risks from mixtures is uncertain
- Effects of many PFAS are unknown (precursors?)

Thanks For Listening

- Thanks to SERDP (ER18-1614) for funding
- Guidance document pdf download at: https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/ER18-1614)
  - Google "SERDP ER18-1614"
- Future efforts
  - Excel ERA model spreadsheet tool
  - Deep-dive training course (March 2020, Emerging Contaminants Summit, Denver, CO)
- Contact for more info/updates/questions
  - Jason Conder jconder@geosyntec.com


GUIDANCE DOCUMENT

Guidance for Assessing the Ecological Risks of PFASs to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites

SERDP Project ER18-1614

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