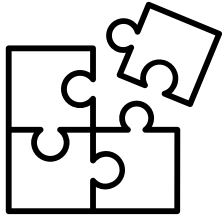


# State Water Board DPR Pathogen Research

Tools to Evaluate Microbial Risk, Plant Performance,  
and Reliability (DPR-1)

Raw Wastewater Pathogen Monitoring (DPR-2)

Brian Pecson, P.I. for DPR-1 and DPR-2, Trussell Technologies



# How Much Pathogen Treatment?

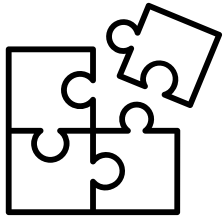


**Wastewater**

20-log virus  
14-log *Giardia*  
15-log *Crypto*



**Drinking Water**



# How Much Pathogen Treatment?

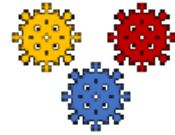


Wastewater

20-log virus  
14-log *Giardia*  
15-log *Crypto*



Drinking Water



Virus



*Giardia*



*Crypto*

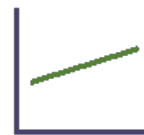
Pathogen



Method



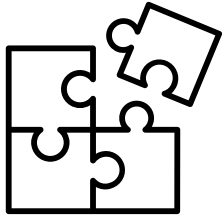
Volume



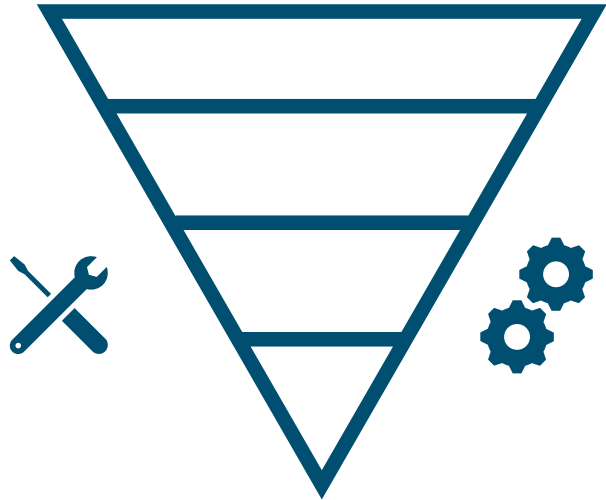
Dose-Response



Risk



# How Much Pathogen Treatment?



**DPR-1: Pathogen  
Treatment and Risk**



# DPR-1 Technical Work Group and Research Team



## Technical Work Group

**Brian Pecson (chair)**  
Trussell Technologies

**Nick Ashbolt**  
Southern Cross  
University

**Charles Haas**  
Drexel University

**Theresa Slifko**  
Metropolitan  
Water District

## Research Team



**Dan Gerrity**  
SNWA

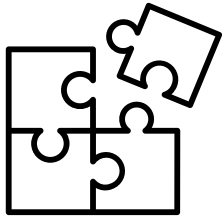
**Edmund Seto**  
University of Washington

## DPR-1 Staff

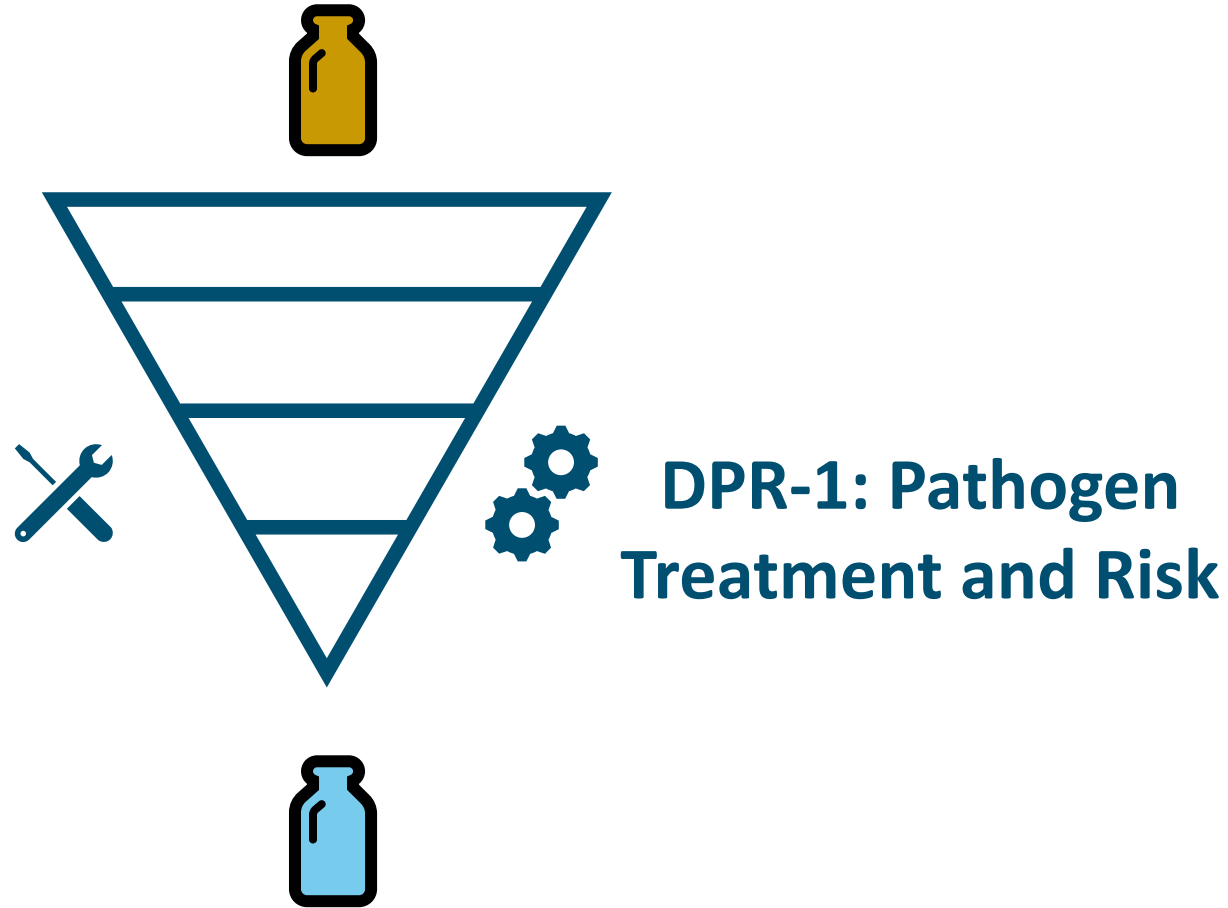


**Anya Kaufmann**  
Trussell Technologies

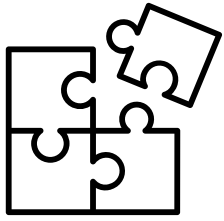
**Adam Olivieri**  
WRF/State Board Coordination



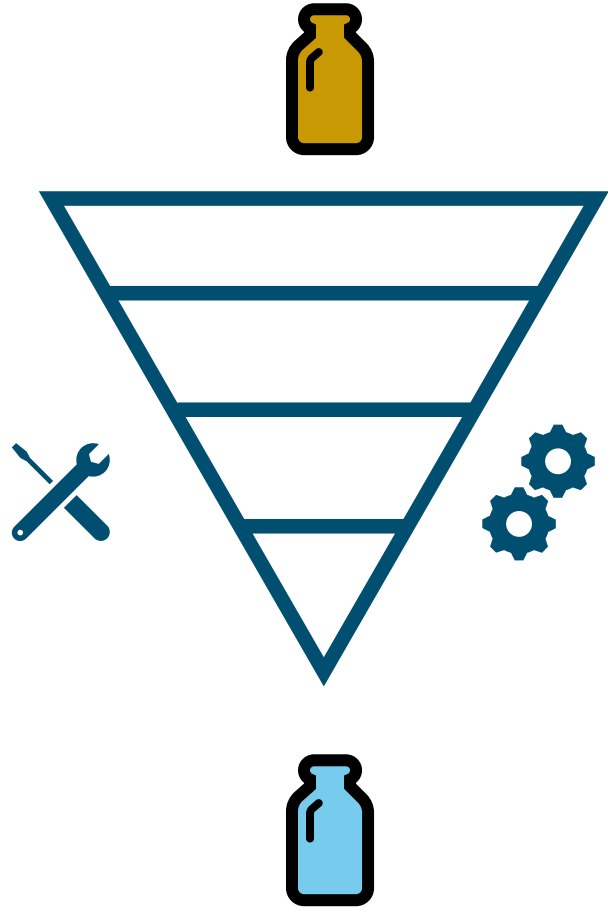
# How Much Pathogen Treatment?



			<b>Pathogen</b>
			<b>Method</b>
			<b>Volume</b>
			<b>Dose-Response</b>
			<b>Risk</b>

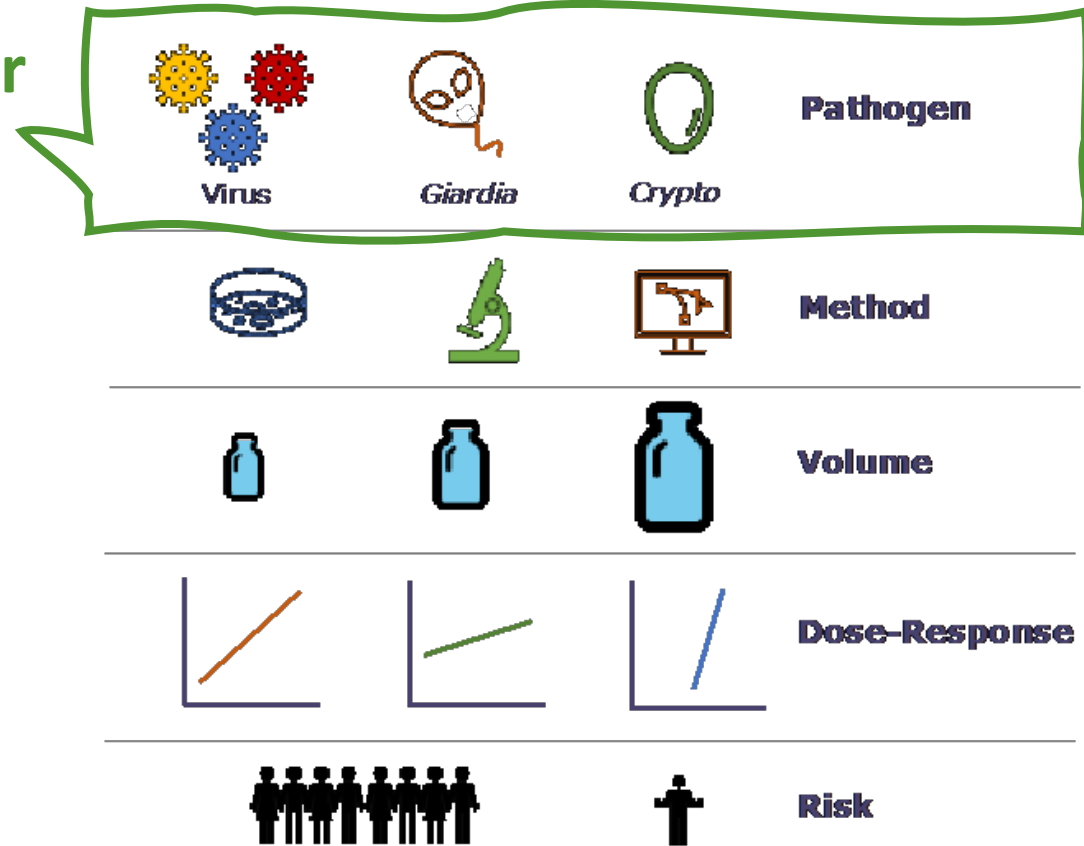


# How Much Pathogen Treatment?

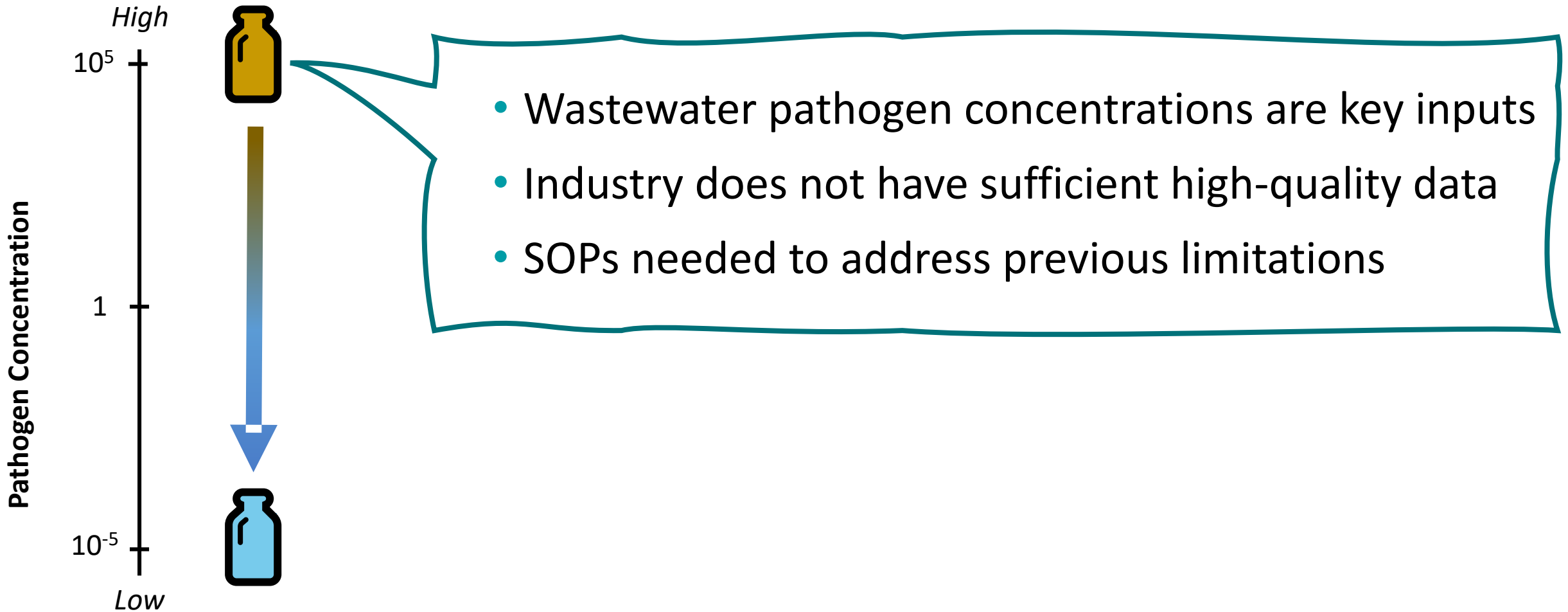


DPR-2: Raw Wastewater Pathogen Monitoring

DPR-1: Pathogen Treatment and Risk



# Motivation for Research





# DPR-2 Technical Work Group



**George Di Giovanni**  
Metropolitan Water  
District



**Menu Leddy**  
Essential  
Environmental &  
Engineering Systems



**Kara Nelson**  
UC, Berkeley



**Brian Pecson**  
Trussell Technologies



**Channah Rock**  
University of Arizona



**Theresa Slifko (chair)**  
Metropolitan Water  
District

## DPR-2 Staff:



**Emily Darby**  
Trussell Technologies

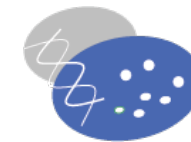


**Adam Olivieri**  
WRF/State Board  
Coordination



**Walt Jakubowski**  
QA/QC Officer

## DPR-2 Labs:



*cel analytical, inc.*  
water, wastewater, and soil laboratory services



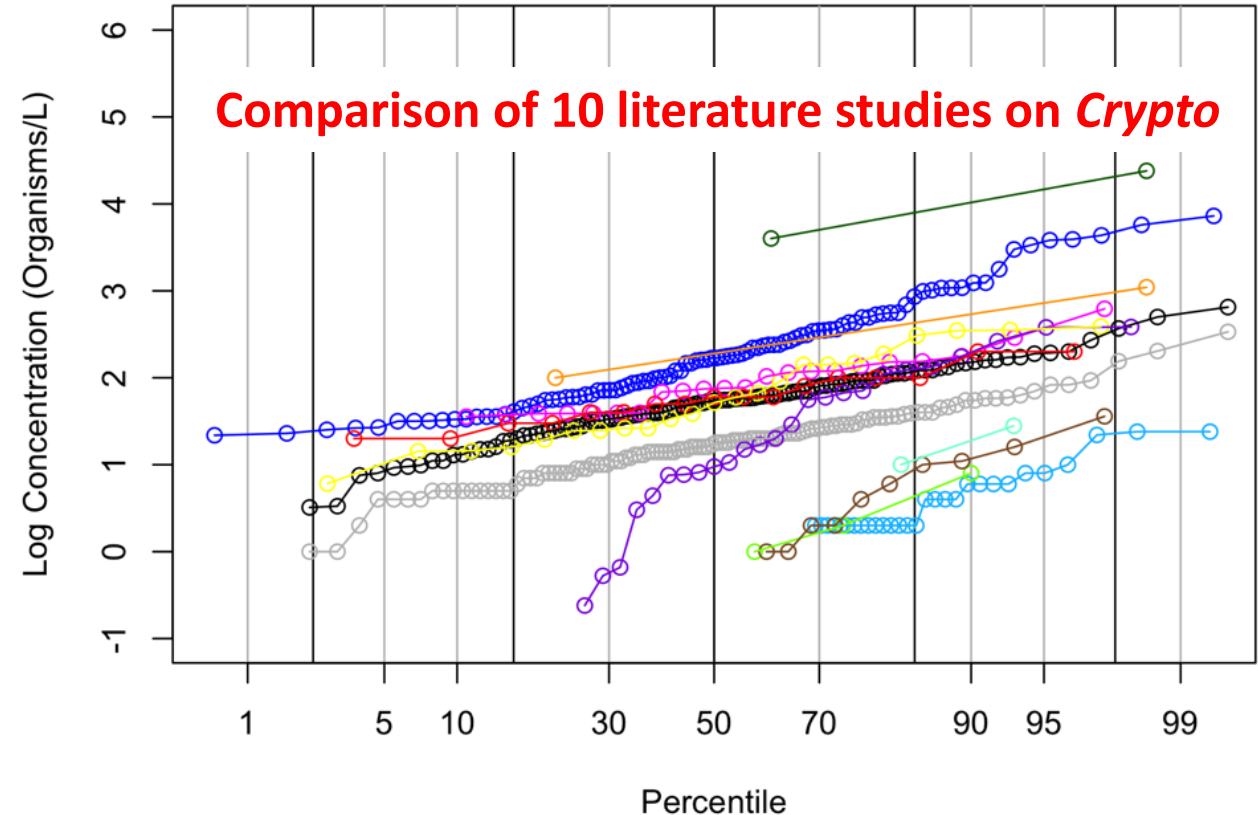
**BIOLOGICAL CONSULTING SERVICES  
OF NORTH FLORIDA, INC.**



**SCIENTIFIC  
METHODS**

# Literature Review

- Limited number of studies
- Low method sensitivity and high frequency of non-detects
- Recovery often not measured
- QA/QC often not strictly followed
- Conclusions
  - Possible to measure pathogens in raw WW
  - Amount and quality of data are insufficient



# Method Optimization

- Used to address limitations of past studies
  - Concentration method
  - Volume of sample to process
- Require strict QA/QC
  - Matrix spikes in 75% of all samples
  - Full set of controls
- Recommendation: use DPR-2 QAPP for future studies

QAPP Analytical Microbiology Supporting  
Version 4.0.

WRF Contract No: 4952  
Date: 05.06.20

## Quality Assurance Project Plan

Analytical Microbiology Services

Water Research Foundation  
Contract #4952

Prepared for:

The Water Research Foundation

Prepared by:



82 Mary Street Suite 2  
San Francisco, CA 94103  
Yeggie Dearborn Ph.D.  
Program Manager  
Email: [yeggie@celanalytical.com](mailto:yeggie@celanalytical.com)

August; October  
Version 1.0, Rev.01  
November  
Version 2.0, Rev.02  
Version 2.0, Rev.03  
Version 3.0  
Version 4.0

February 2021

# Sampling campaign

## Pathogens and Methods



Giardia



Crypto



Enterovirus



Adenovirus



Norovirus



SARS-CoV-2

Microscopy

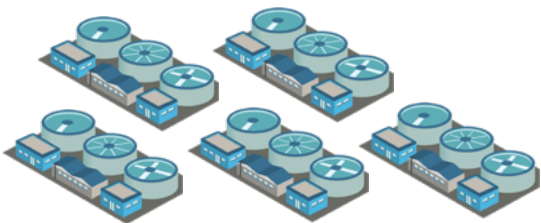
Culture

Molecular

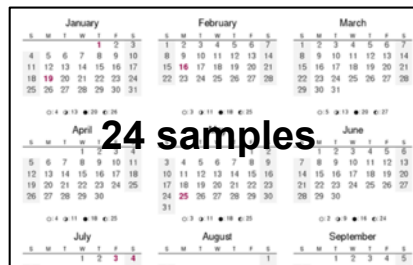
## Sampling Locations



## 14-month Monitoring Campaign

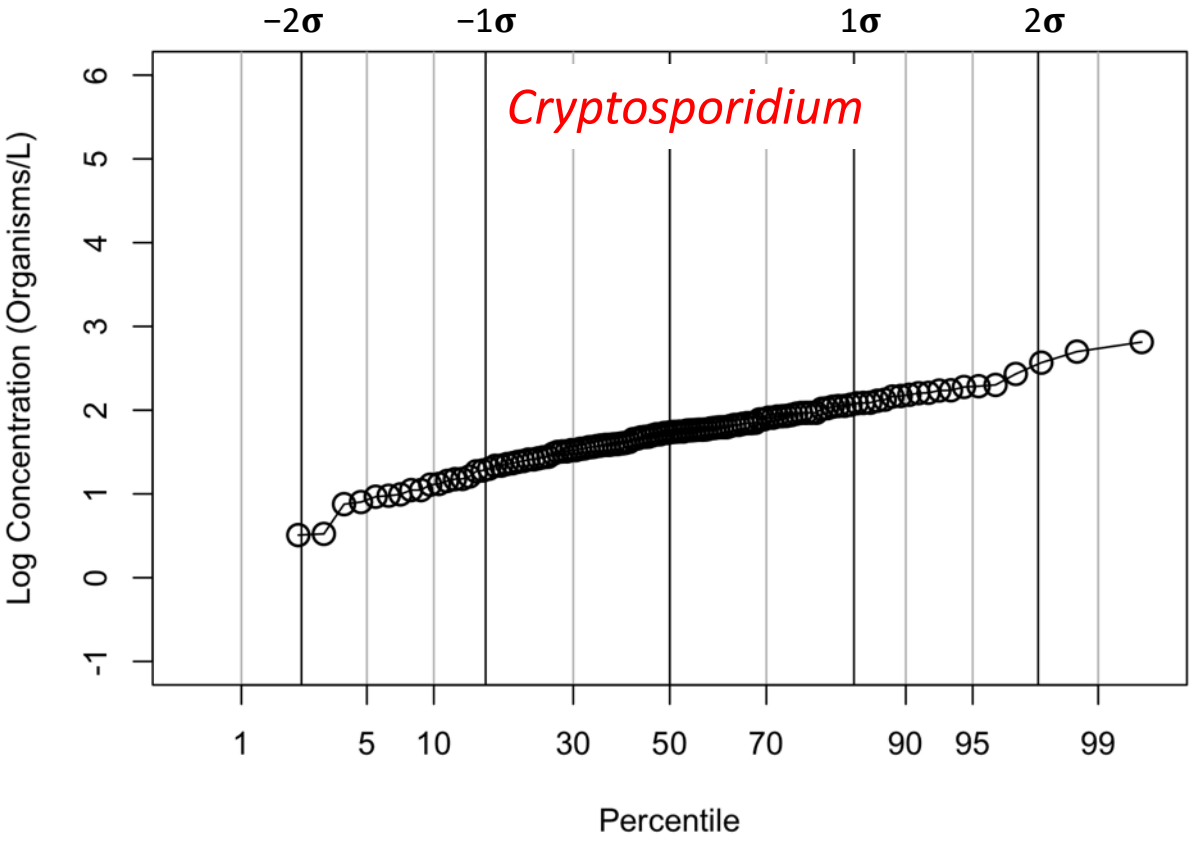


Five facilities

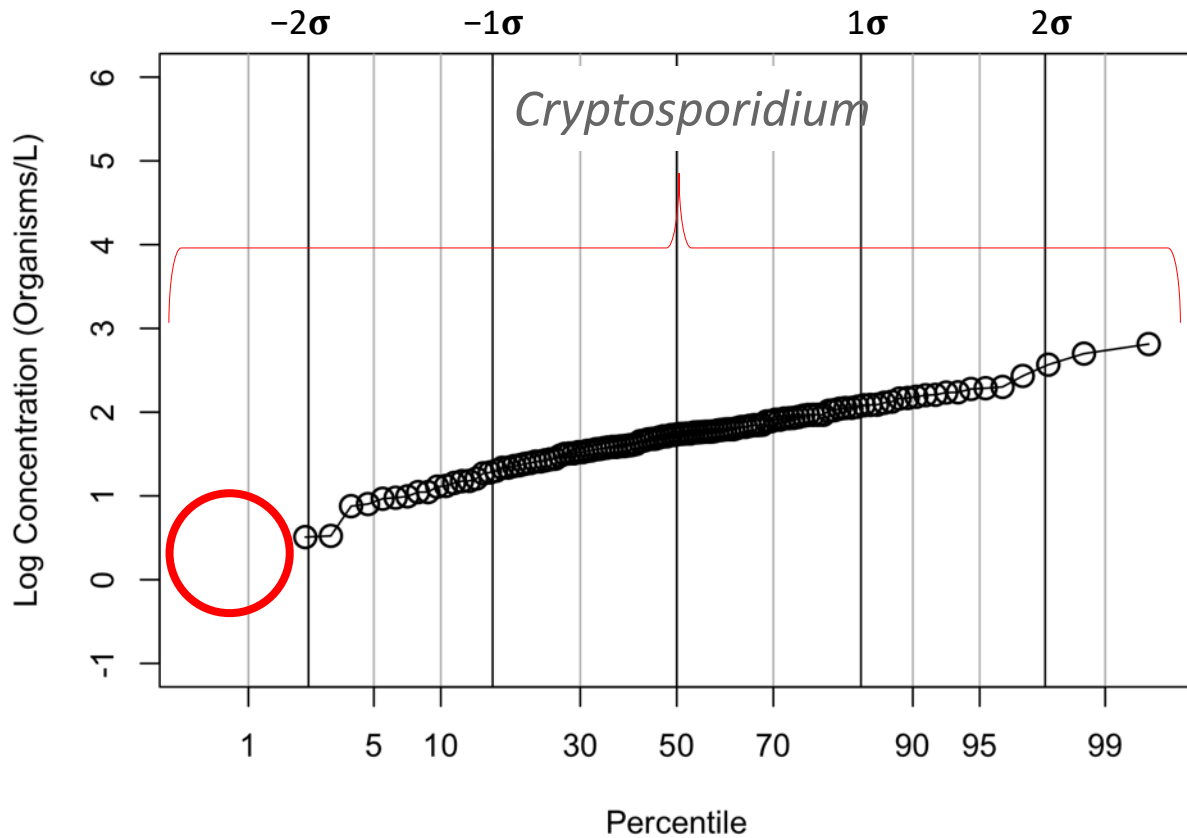


Range: 30 – 275 MGD

# A Closer Look: Pathogen Distributions

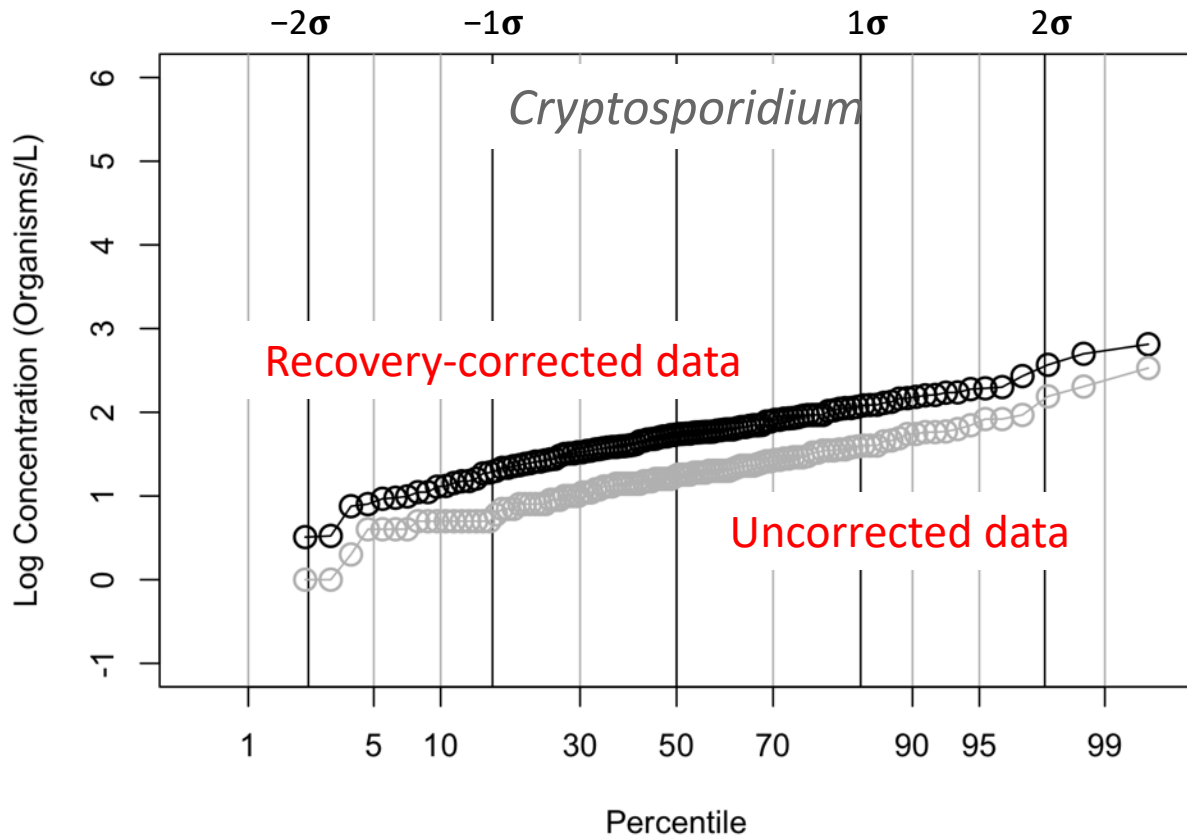


# A Closer Look: Pathogen Distributions

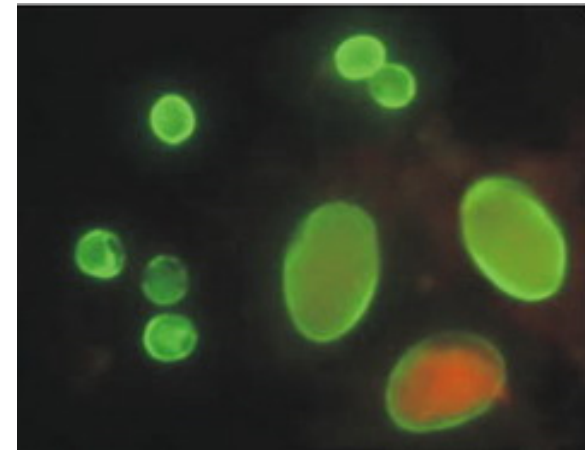


- High rate of detects across full range

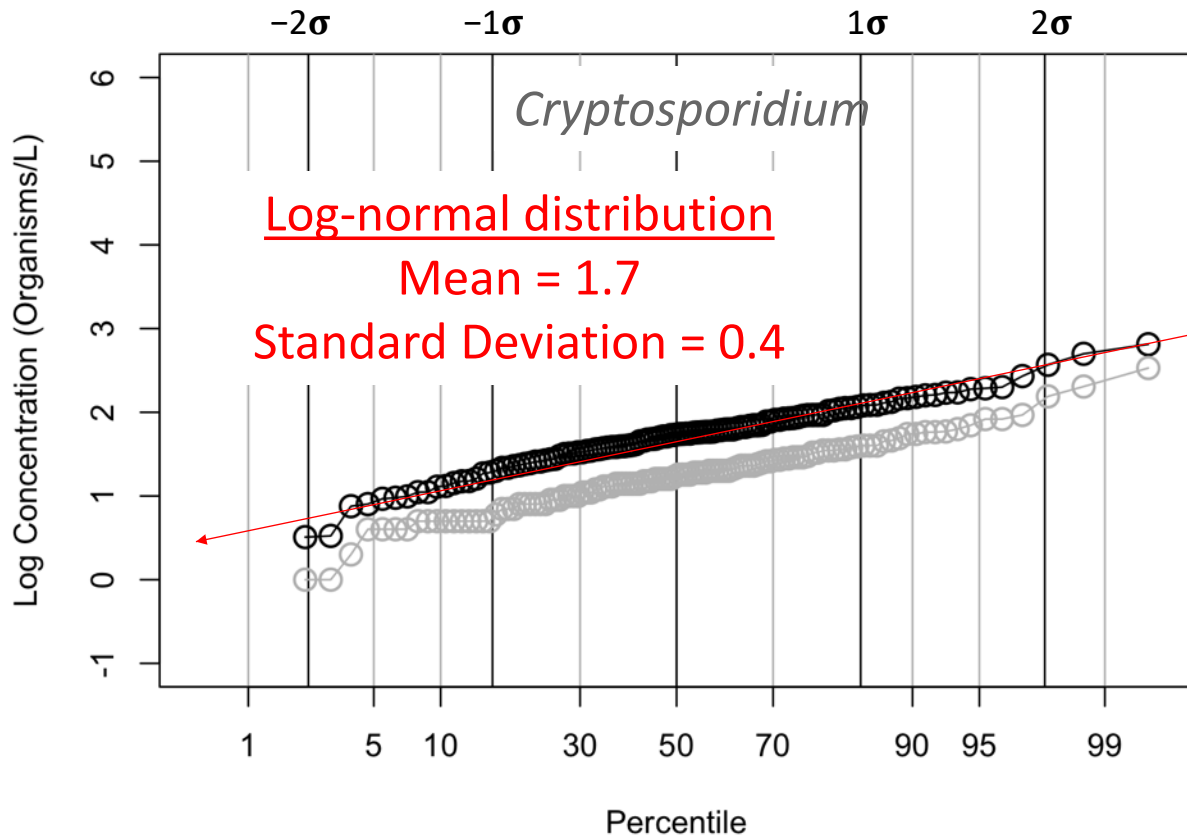
# A Closer Look: Pathogen Distributions



- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency



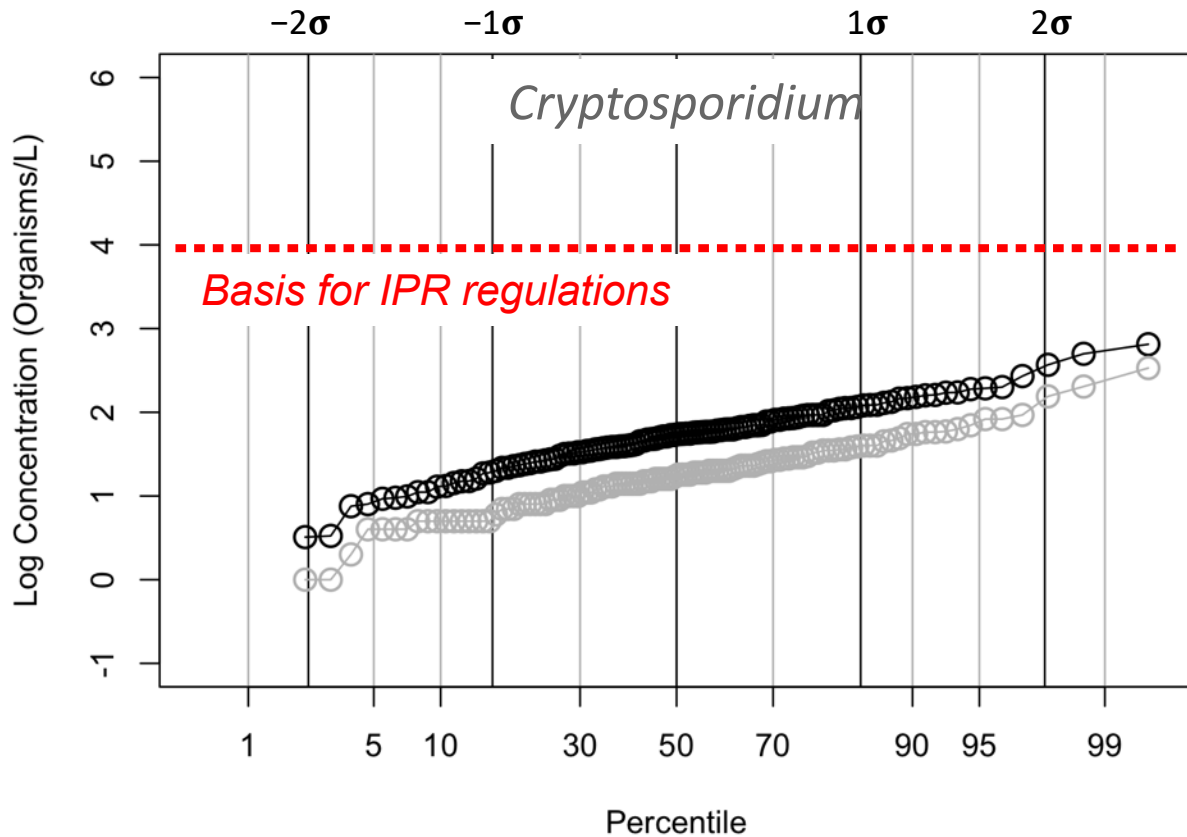
# A Closer Look: Pathogen Distributions



- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
- Models estimate past measured range

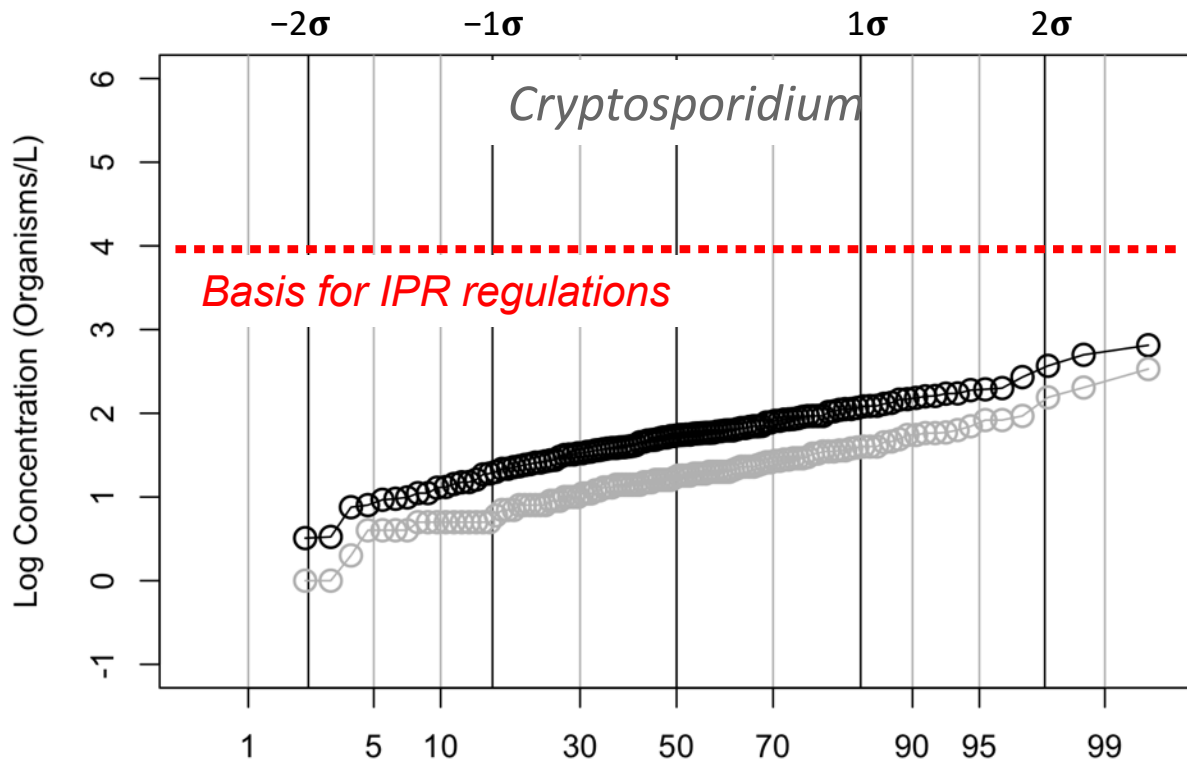


# A Closer Look: Pathogen Distributions



- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
- Models estimate past measured range
- Allows for comparison with IPR regs

# A Closer Look: Pathogen Distributions



- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
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## Recommendation:

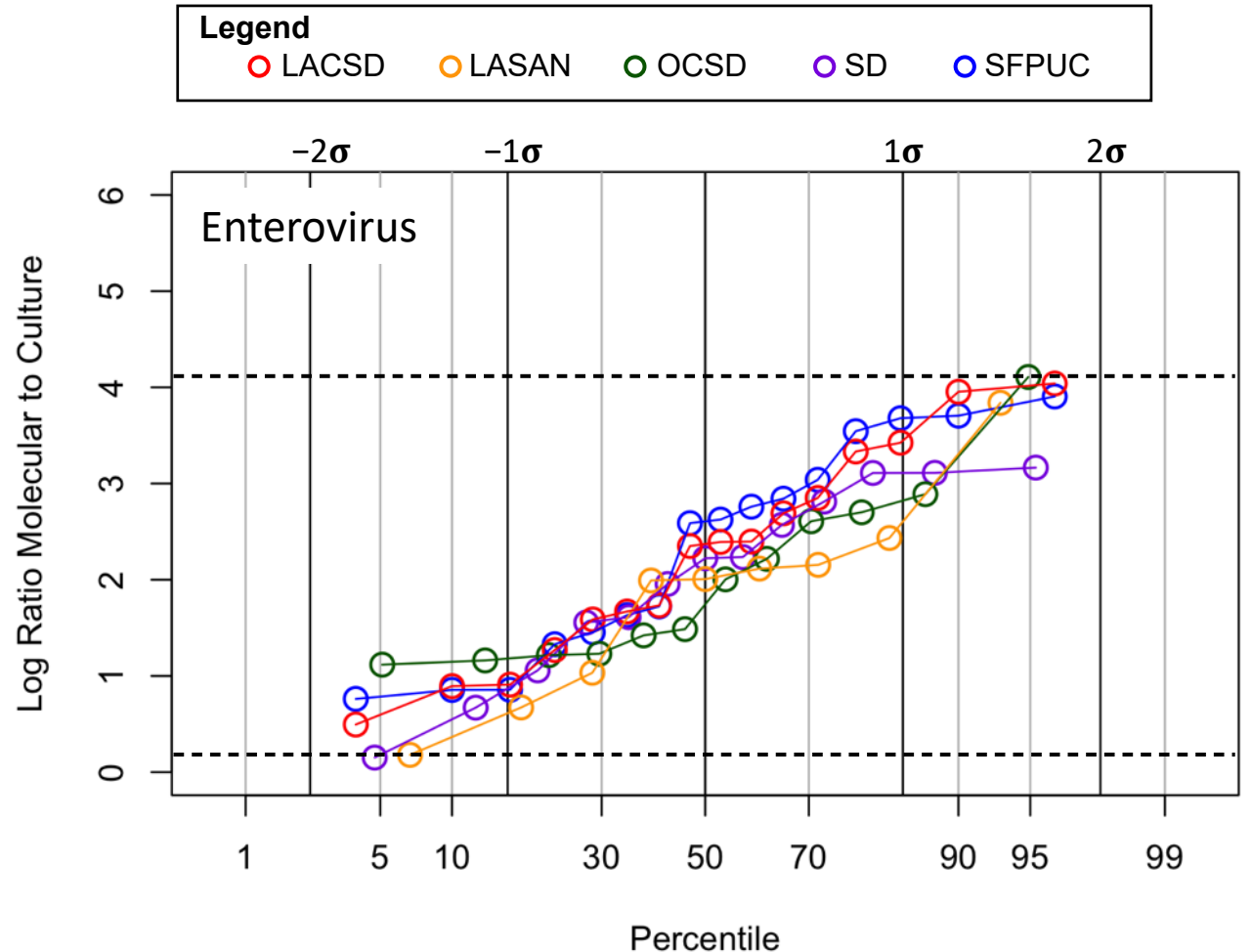
Use modeled distributions for probabilistic assessments of treatment targets

# Other Key Findings

- Pathogen distributions similar across treatment plants
  - 94% of comparisons had no significant differences between facilities
- Minimal level of seasonality observed
  - Enterovirus higher in summer / adenovirus higher in winter
- No clear impact of COVID-19 on concentrations
  - Data collected before and after Stay-at-Home order showed minimal change
- Uncertainties associated with the use of molecular data

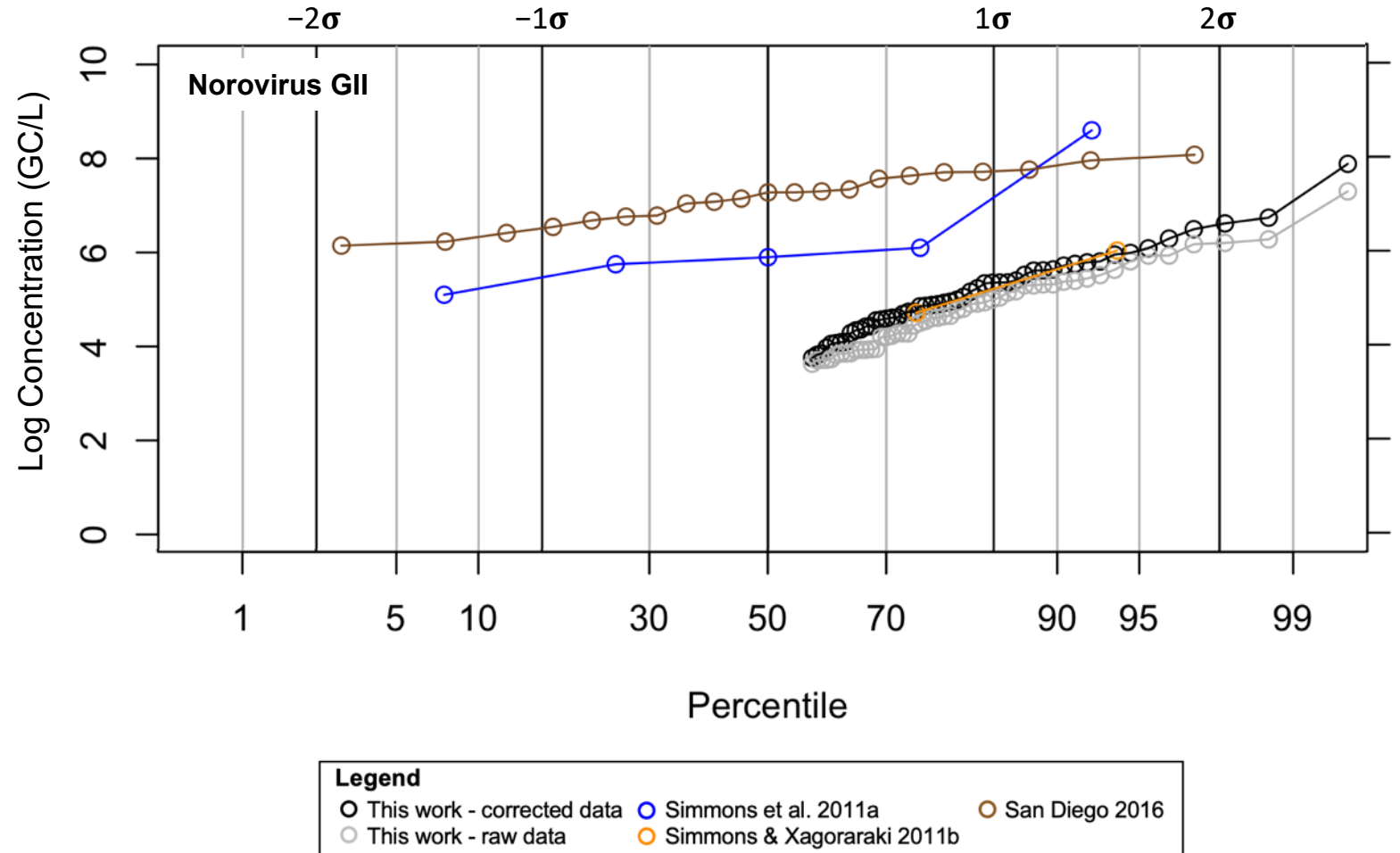
# Issues with the use of molecular data

- Genome copies (GC) not always associated with *infective* virus
- Difficult to link GC with infectivity
- DPR-2 ratios span orders of magnitude:
  - 10,000:1 to 1:1 (enterovirus)
  - 100,000:1 to 1:1 (adenovirus)



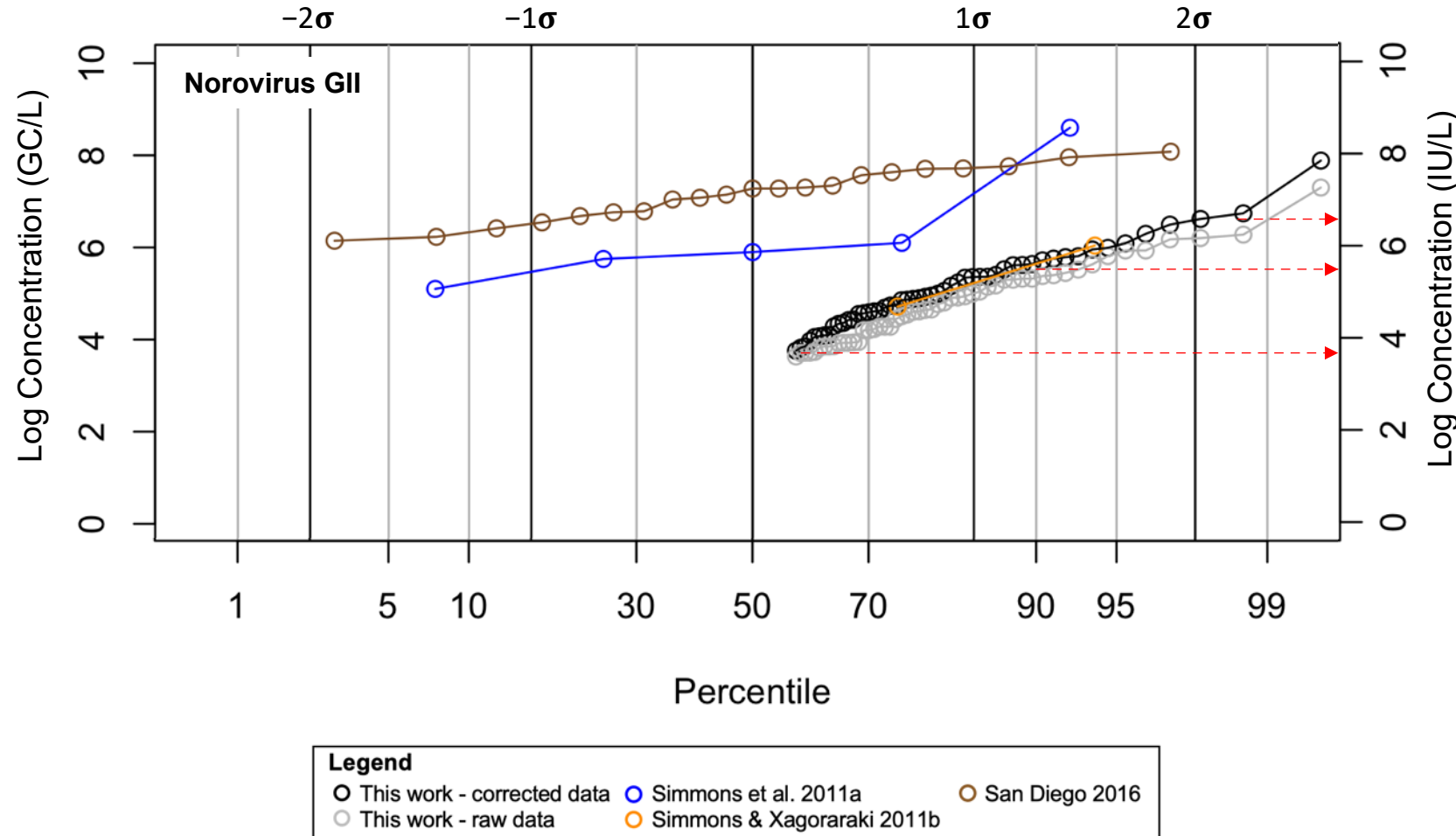
# When is this important?

- Norovirus not culturable
- Dose-response function makes assumptions about “infectivity” of genome copies
- If we assume 1:1, then each GC is an infectious unit (IU)



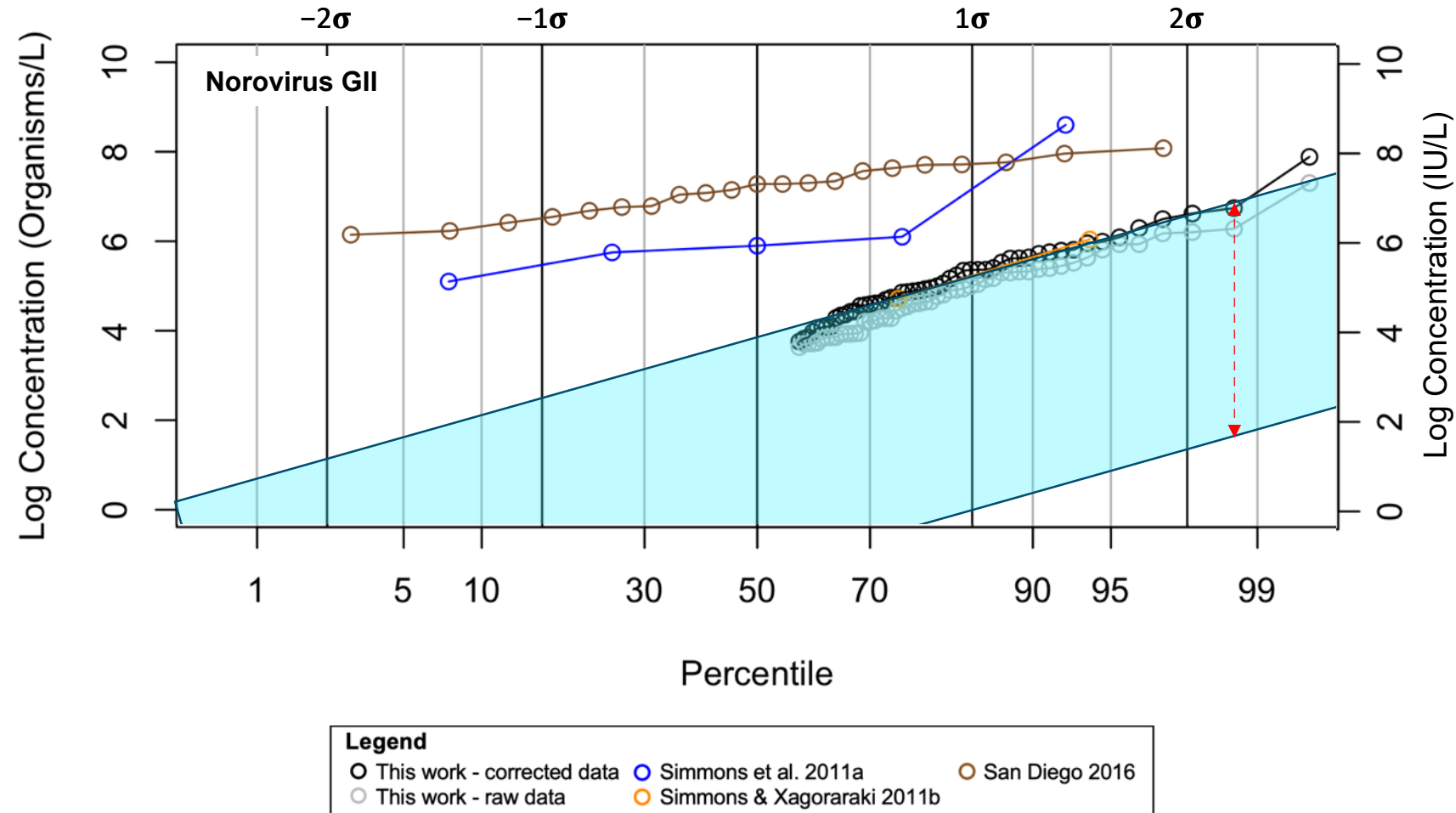
# When is this important?

- Norovirus not culturable
- Dose-response function makes assumptions about “infectivity” of genome copies
- If we assume 1:1, then each GC is an infectious unit (IU)



# Incorporate uncertainty in risk analyses

- DPR-1 Final Report shows how to incorporate molecular data into analysis
- Results in a “band” of potential values



# Recommendations for Regulatory Development

- Use DPR-2 datasets as the raw wastewater inputs for QMRA
- Correct pathogen data for recovery using matrix spikes
- Use culture data to reduce uncertainties with molecular interpretation; follow TWG recommendations for the use of molecular data
- Model the DPR-2 distributions (and relevant literature) for use in probabilistic assessments
- Require DPR-2 QAPP/SOPs for future pathogen monitoring studies



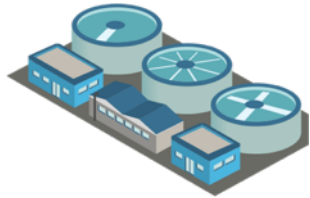
# How Much Pathogen Treatment?



Wastewater

What concentration of pathogens are we starting with?

**DPR-2: Raw Wastewater Pathogen Monitoring**



How much treatment is needed?

**DPR-1: Pathogen Treatment and Risk**



Drinking Water




Can we meet our risk goals?

# DPRisk Tool and Guidance Document

## DPRisk: QMRA Tool

### DPRisk

version 1.0.1 (11.05.2020)  
Sponsored by: The Water Research Foundation  
Copyright (C)2017 by The Water Research Foundation. ALL RIGHTS RESERVED



**Introduction**

**Background**

How to use the tool

License

**Model Specification**

Raw Wastewater Pathogen Concentrations

Treatment Train

Treatment Failure

Management Barriers

Exposure

Dose-Response

Results

PATTP Output

QMRA Output

Summary of PATTP and QMRA Output

Comparison of Risk Curves

### Quantitative Microbial Risk Assessment and Probabilistic Assessment of Treatment Train Performance for Direct Potable Reuse Scenarios

This tool is intended to facilitate quantitative microbial risk assessment (QMRA) and probabilistic assessment of treatment train performance (PATTP) for various direct potable reuse (DPR) scenarios. There are many possible analyses that you can conduct with this tool, including:

There are many possible analyses that you can conduct with this tool, including:

- Developing a distribution of treatment train performance for different potential DPR treatment trains.
- Evaluating daily and annual risks of infection for multiple microbial pathogens for different potential DPR treatment trains.
- Comparing different DPR treatment trains in terms of treatment performance and risk.
- Evaluating the impact of failures on treatment performance and risk.

The accompanying Guidance Document provides useful context for this tool, including:

- The background motivation for the creation of the tool.
- The historical context for the use of PATTP and QMRA in DPR.
- The project process that resulted in this tool.
- Detailed descriptions of each step of the tool, including references for default assumptions.
- Details on the computations implemented by the tool.
- Example case studies to help you get started with using the tool.

This tool was developed in the R statistical language.

## DPRisk: Guidance Document

### Guidance Document for DPRisk

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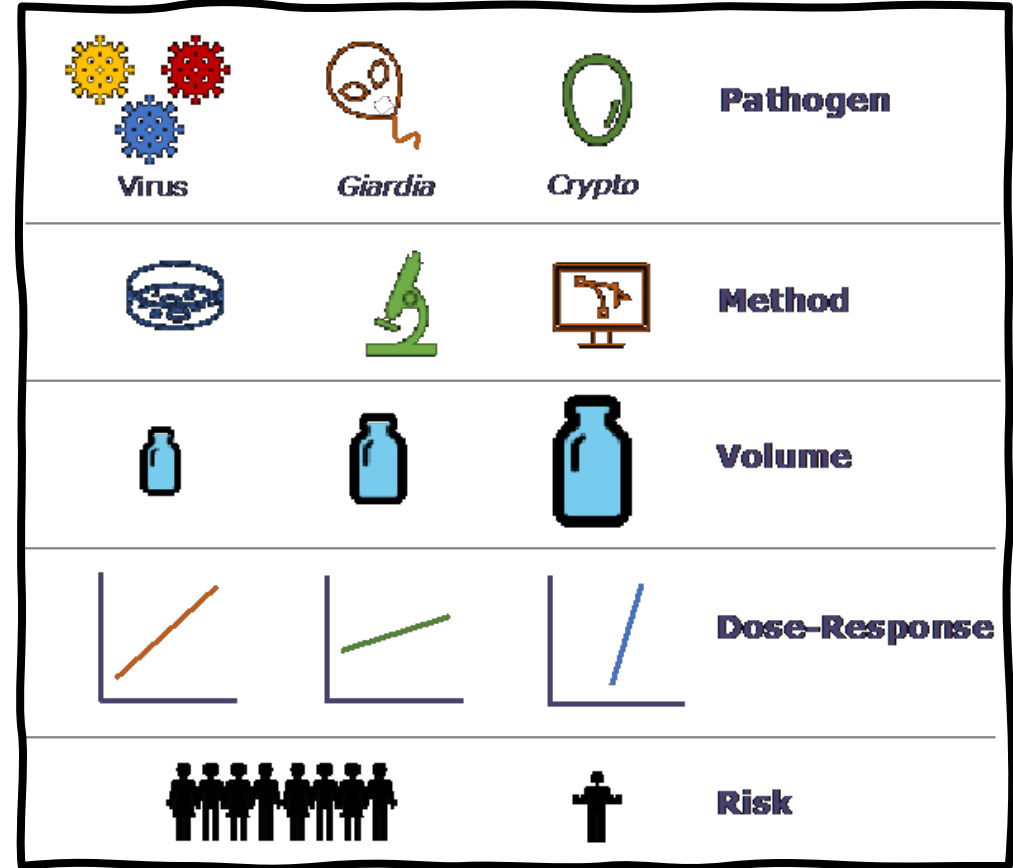
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**Also: User Input Files for 3 Case Studies**

# DPRisk Features

## INPUTS:

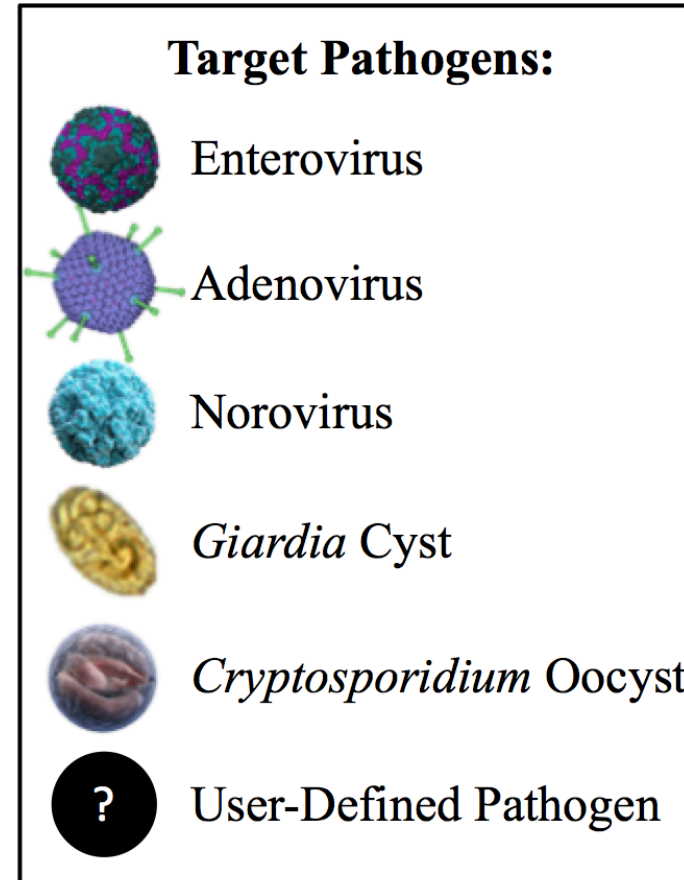
- Raw Wastewater Pathogen Concentrations
- Treatment Train
- Treatment Failure
- Exposure
- Dose Response



# DPRisk Features

## INPUTS:

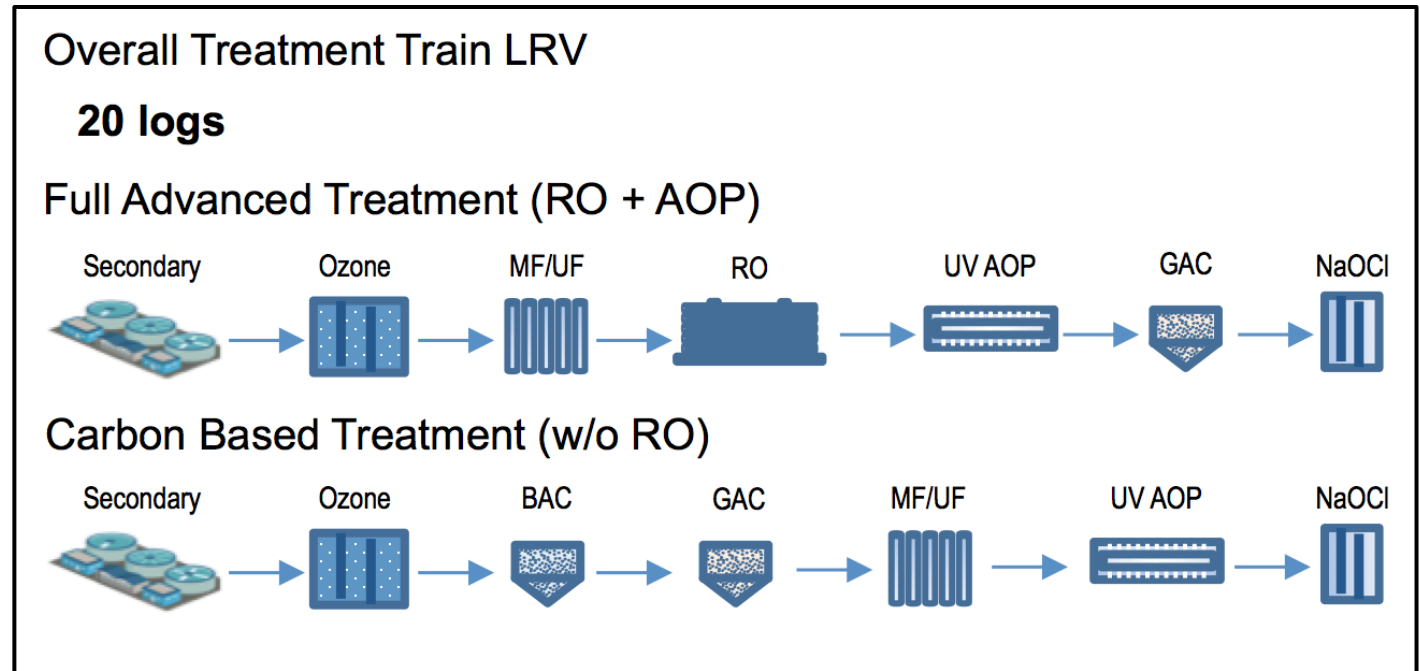
- Raw Wastewater Pathogen Concentrations
- Treatment Train
- Treatment Failure
- Exposure
- Dose Response



# DPRisk Features

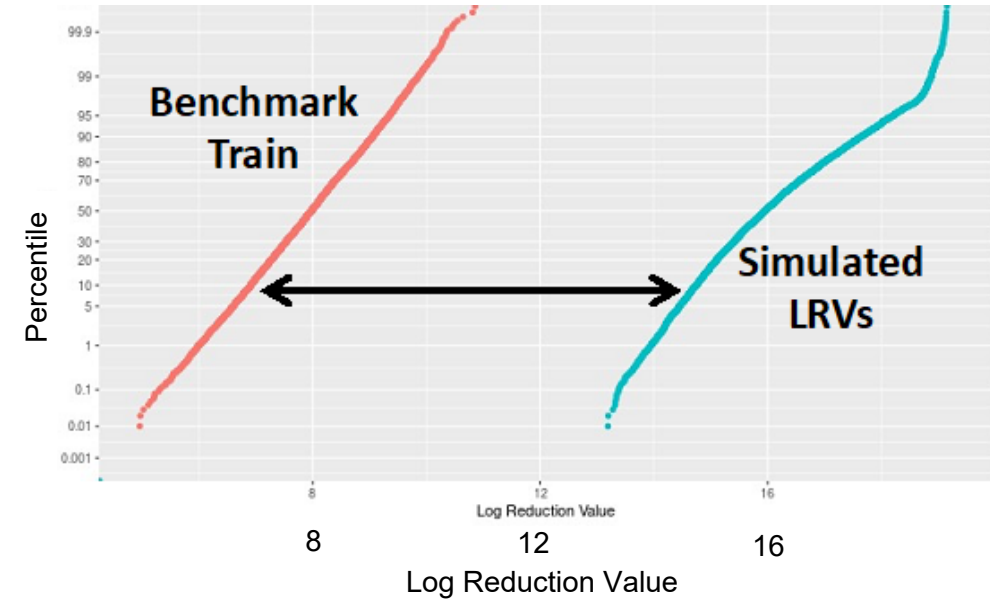
## INPUTS:

- Raw Wastewater Pathogen Concentrations
- **Treatment Train**
- Treatment Failure
- Exposure
- Dose Response

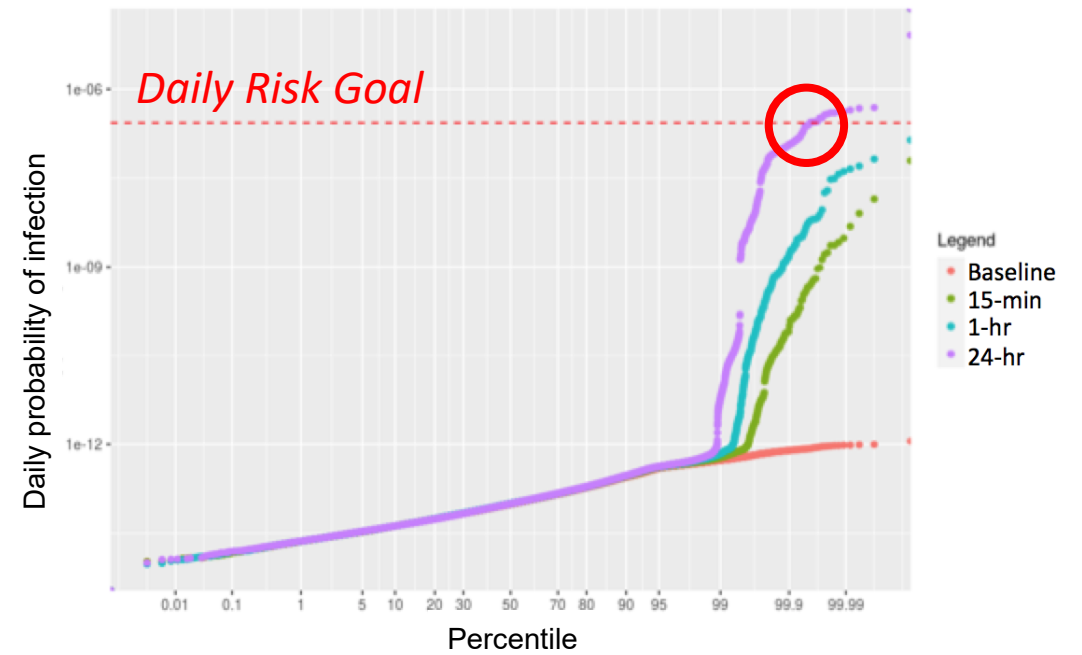


# DPRisk Outputs

- Probabilistic Assessment of Treatment Train Performance (PATTP)



- Quantitative Microbial Risk Assessment



# Not All DPR Projects Are Alike

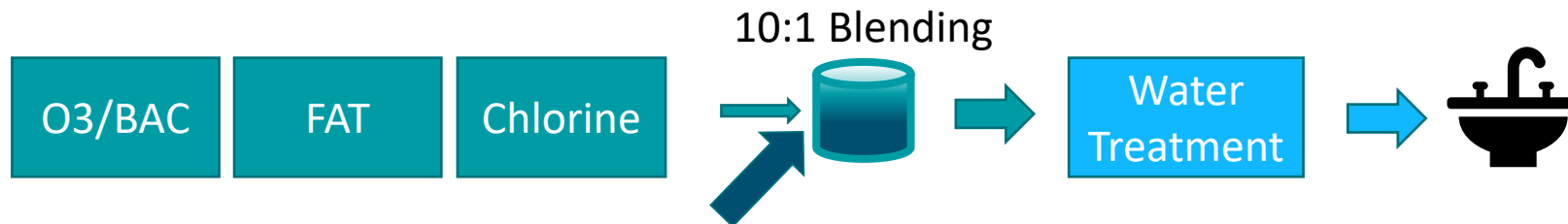
**TWA**



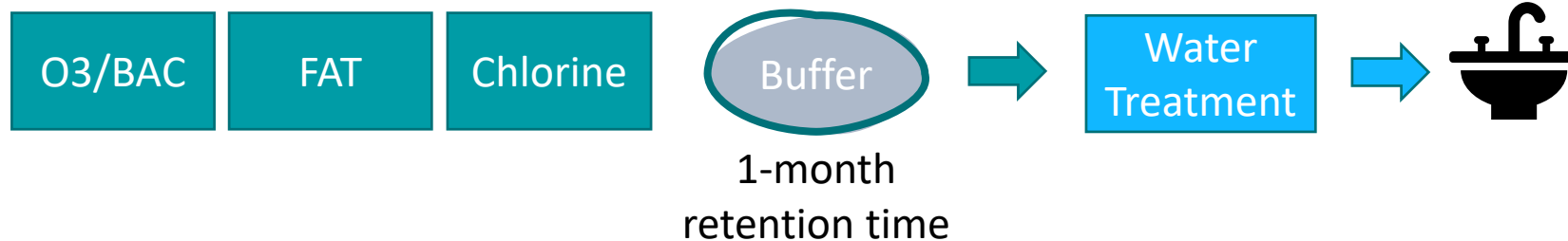
**RWA**



**RWA with Blending**

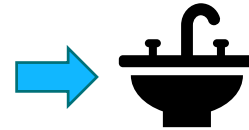
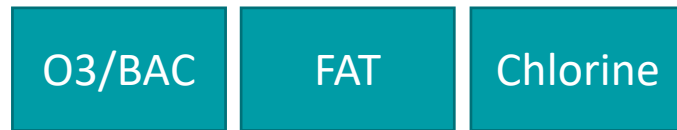


**RWA with Small Reservoir**



# Not All DPR Projects Are Alike

**TWA**



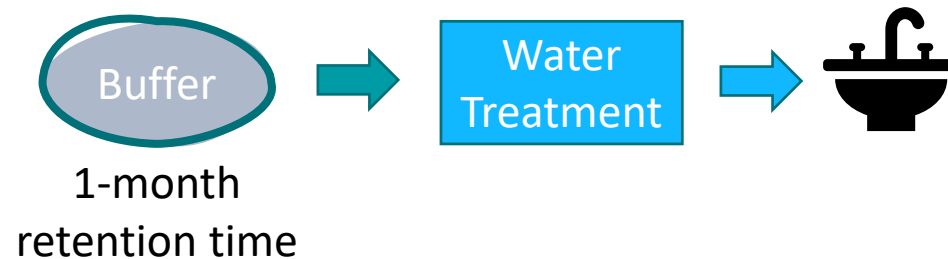
**RWA**



**RWA with Blending**



**RWA with Small Reservoir**



Do these projects have different risk profiles?



# DPRisk Includes Management Barriers

DPRisk Inputs

**Blending**

Specify the log removal associated with blending.

Specify log removal for blending as:

Point estimate ▼

Log Removal:

0

---

**Dilution**

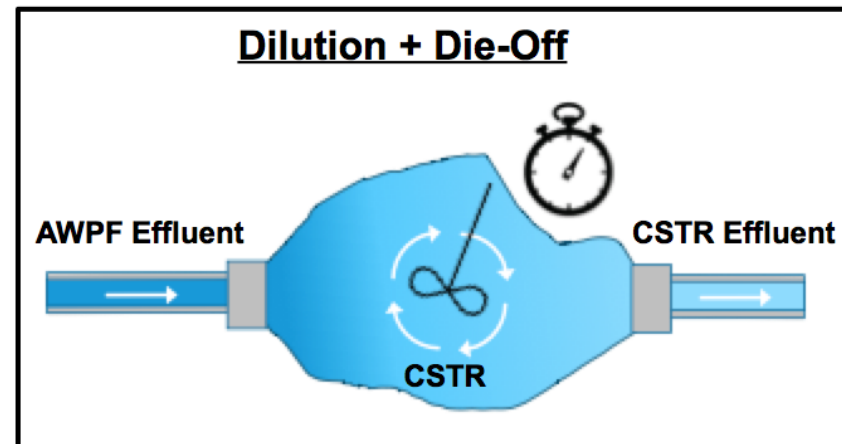
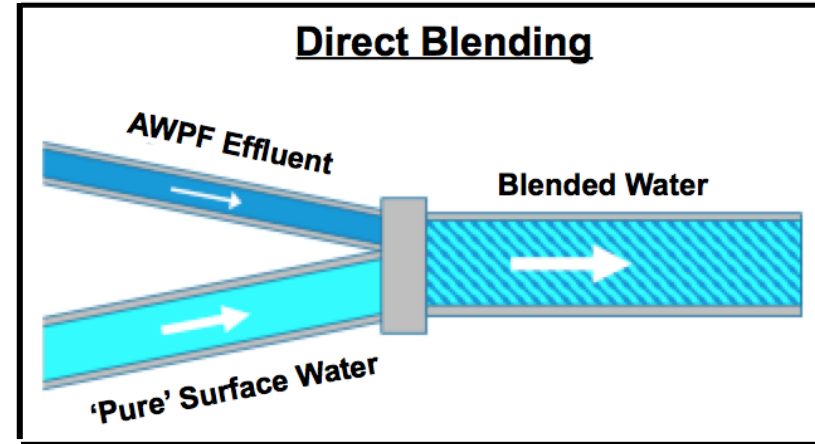
Specify the log removal associated with dilution.

Specify log removal for dilution as:

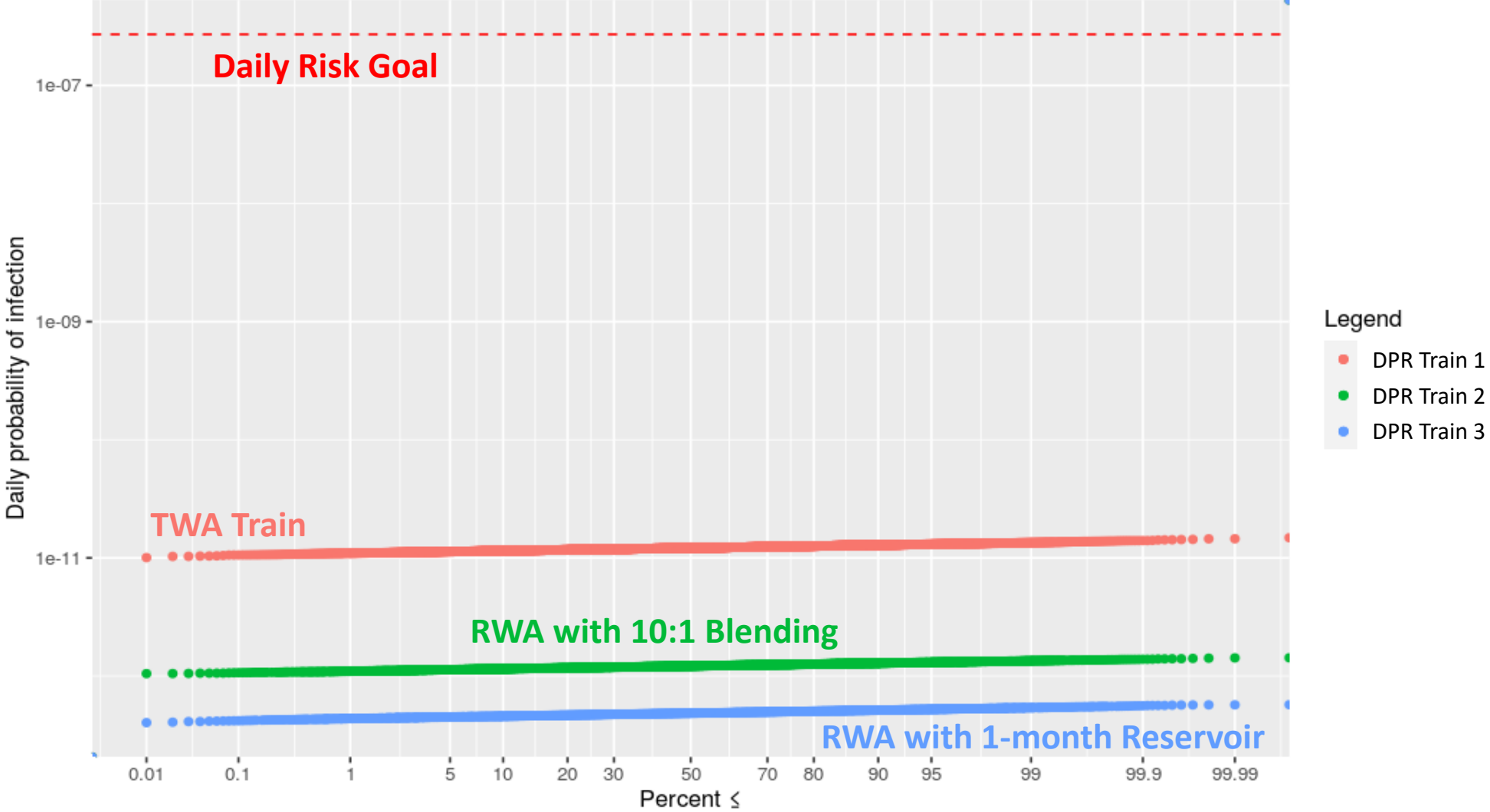
Point estimate ▼

Log Removal:

0



# Risk Profiles of RWA and TWA Trains (no failures)



# Risk Profiles of RWA and TWA with Failure Analysis



# Risk Profiles of RWA and TWA with Failure Analysis



Understanding differences in risk profiles...

...can allow for different DPR requirements.

# Recommendations

- Select modeled distributions from DPR-2 as raw wastewater inputs
- Use DPRisk for *probabilistic* assessments of performance and risk
- Develop frameworks to incorporate the benefits of non-treatment (management) barriers in RWA and TWA

# Acknowledgements

- Anya Kaufmann, Trussell Technologies (DPR-1)
- Dan Gerrity, Southern Nevada Water Authority (DPR-1)
- Emily Darby, Trussell Technologies (DPR-2)

# Questions?

Contact information: [brianp@trusselltech.com](mailto:brianp@trusselltech.com)