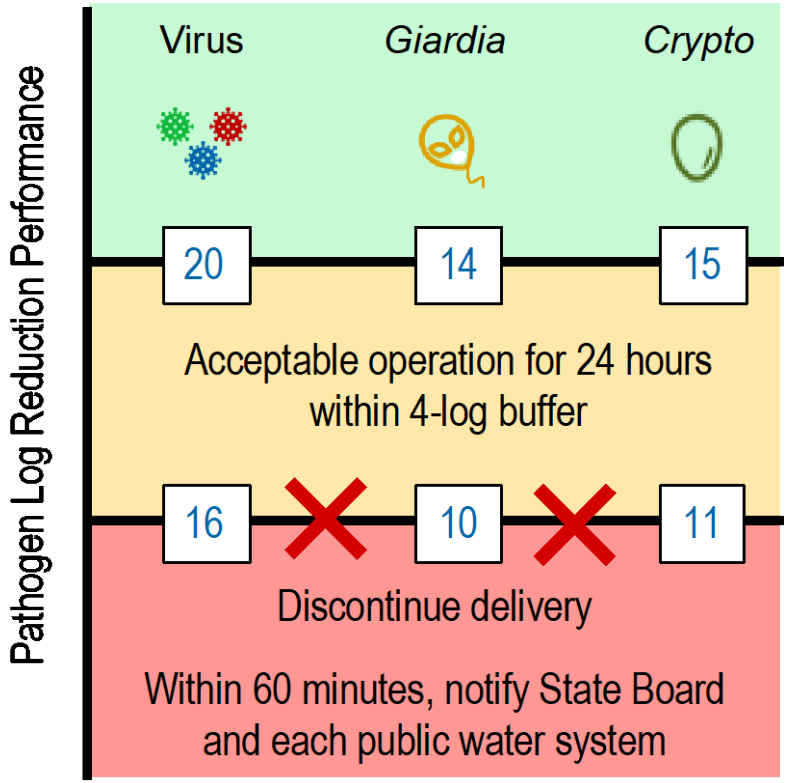
NWRI DPR Expert Panel – Pathogen Control

October 27, 2021

Review of Regulations

- What is in the criteria?
- What is the basis for the pathogen log reduction requirements?
- How does one judge compliance with the LRT criteria?
  - Do we need to be compliant 100% of the time? 95% of the time?

What are the criteria?



DDW LRV Derivation

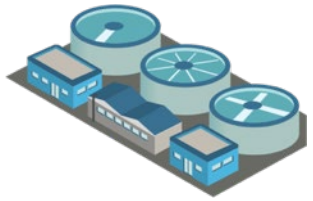
Calculating Risk

- Previous regulations are based on an annual risk goal of 10^{-4} infections per person per year
- For DPR, DDW said they wanted to ensure more *consistent* treatment by establishing a daily risk goal of 2.7×10^{-7} ($10^{-4}/365$days)

Calculating Risk

1. Exposure Assessment

Raw wastewater



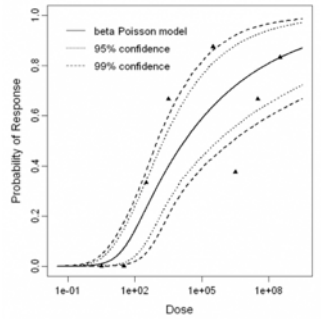
Treatment

Drinking water levels

Drinking water consumption

Exposure

2. Dose-Response



Dose-response

Risk

There are a lot of decisions to consider when calculating risk…

What data should we use?

What about molecular data?

Should we use a point estimate or distribution?

Is treatment constant or does it vary?

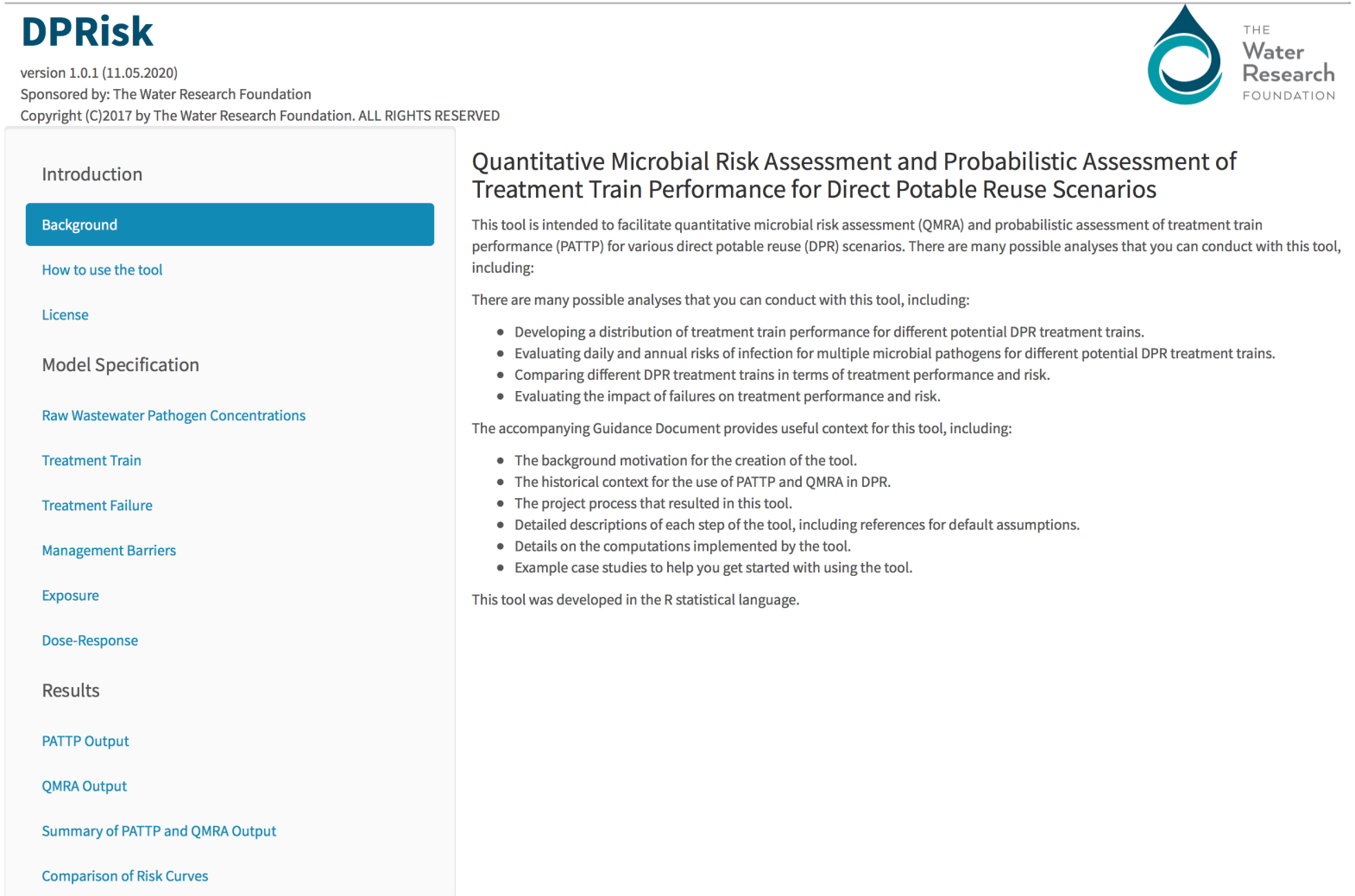
How do you account for failures?

How much water do people drink?

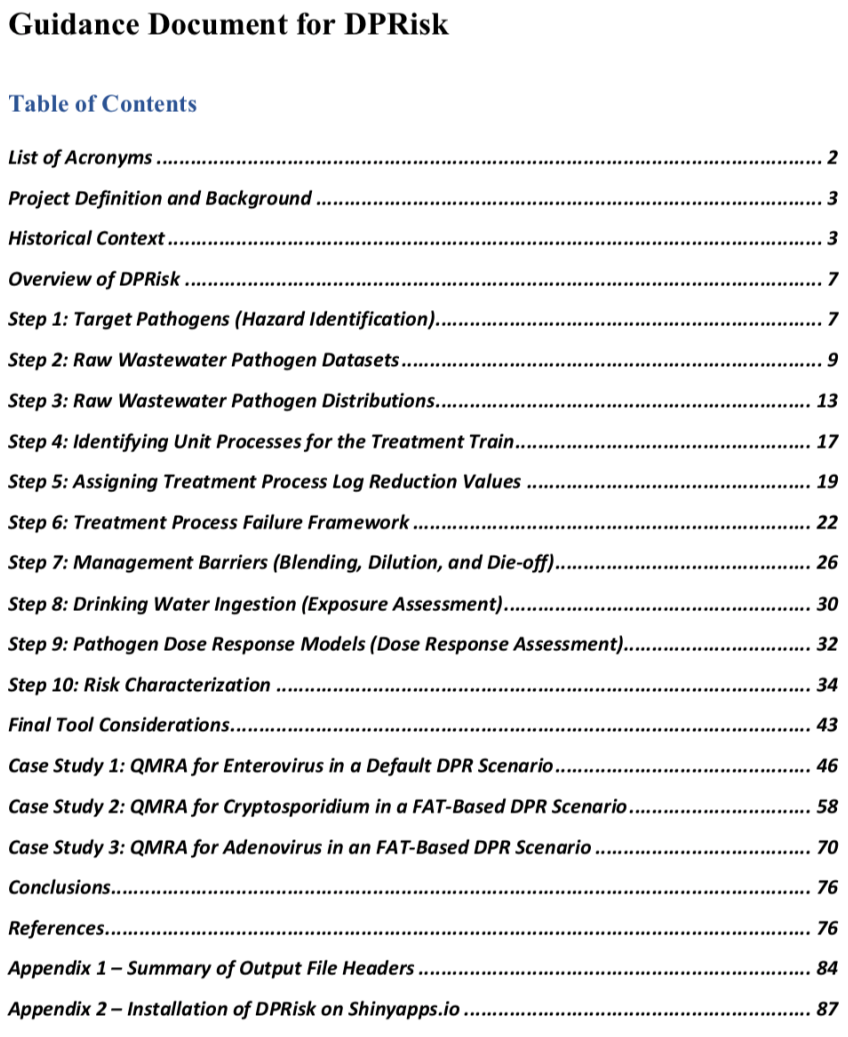
Which D-R functions to use?

DPRisk Tool and Guidance Document

DPRisk: QMRA Tool



DPRisk: Guidance Document


Guidance Document for DPRisk

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2. Dose-Response

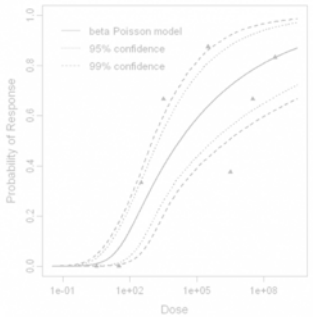
Raw wastewater

Treatment

Drinking water levels

Drinking water consumption

Exposure



Dose-response

Risk

DDW used this same approach, but went backwards to determine the appropriate level of treatment for DPR

Calculating the Benchmark Treatment

1. Exposure Assessment

2. Dose-Response

Raw wastewater

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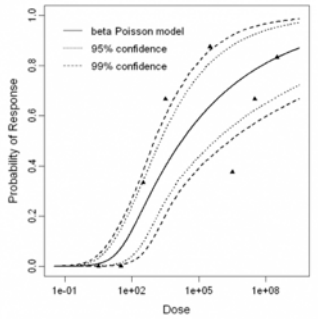
Drinking water levels

Drinking water consumption

Exposure



Dose-response

Risk

DDW used this same approach, but went backwards to determine the appropriate level of treatment for DPR

But they had to make assumptions about each of these steps…

Virus

Calculating the Benchmark Treatment – Virus

1. Exposure Assessment

2. Dose-Response

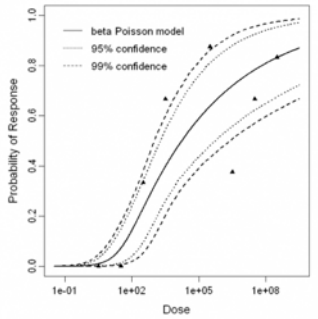
Raw wastewater

Treatment

Drinking water levels

Drinking water consumption

Exposure



Dose-response

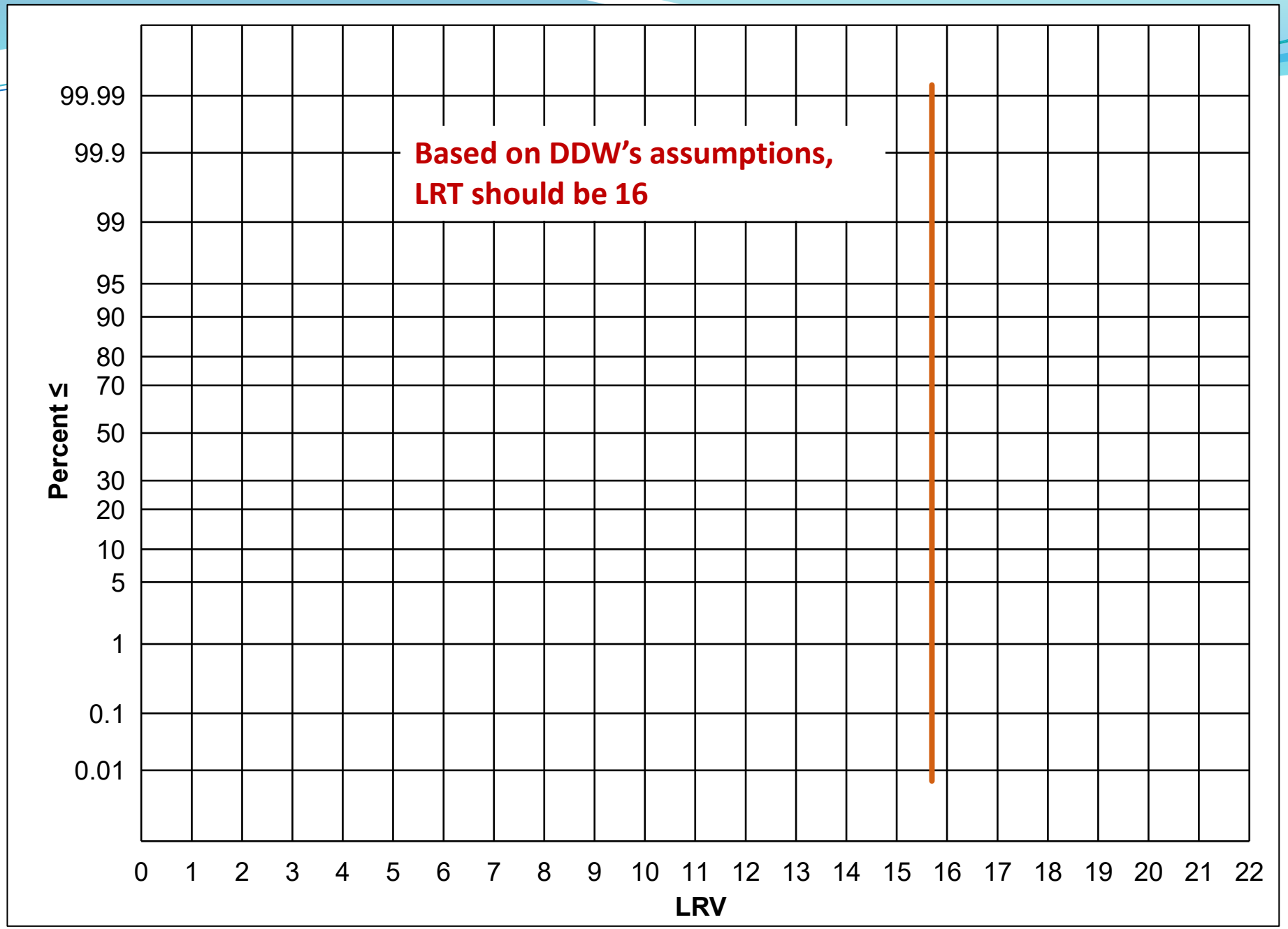
Risk

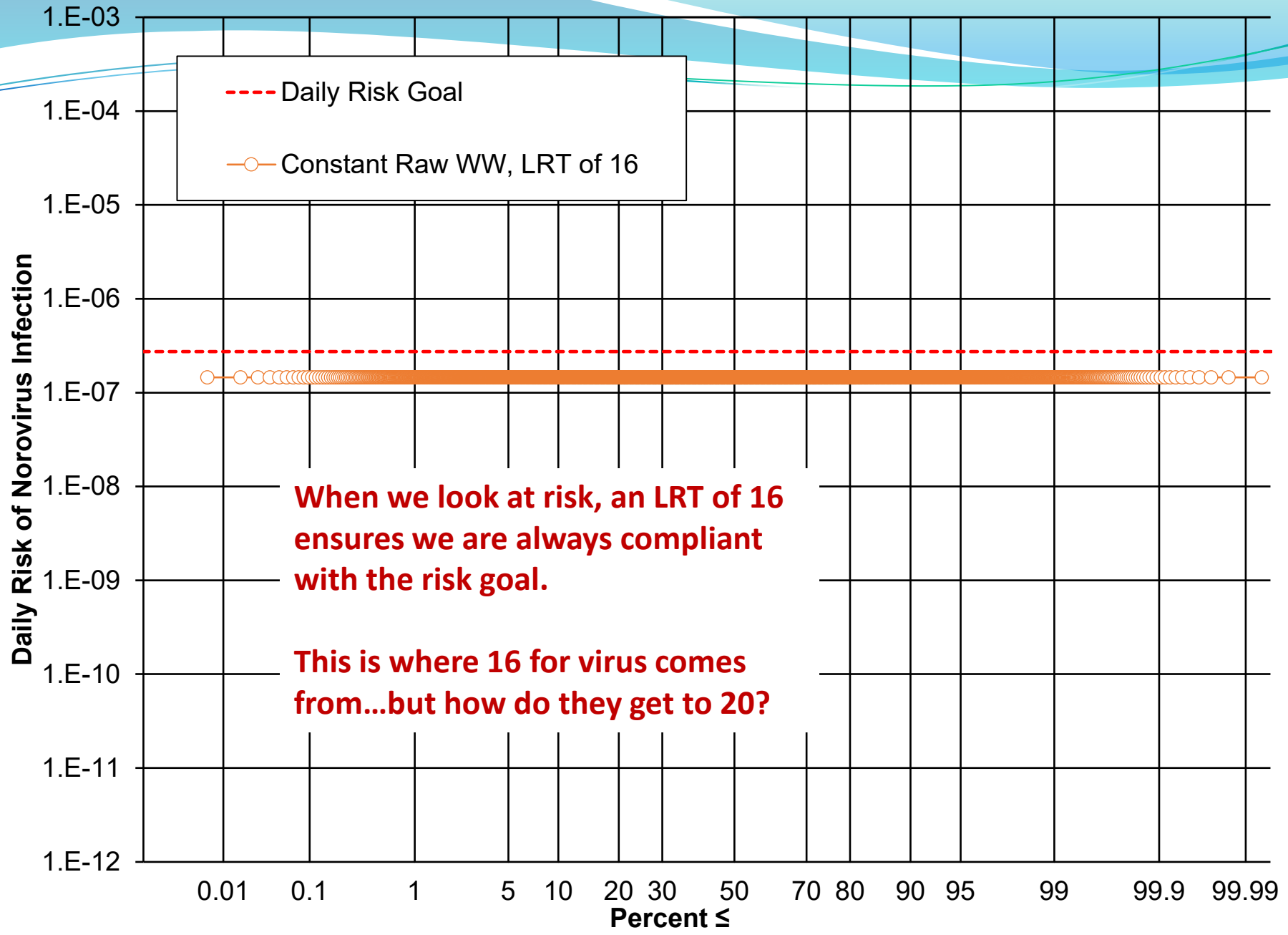
DDW used point estimate of highest concentration of norovirus recorded (1E9 GC/L)

DDW assumed consumption of 2 L/day

DDW used the hypergeometric dose-response (Teunis et al. 2008; alpha = 0.04; beta = 0.055)

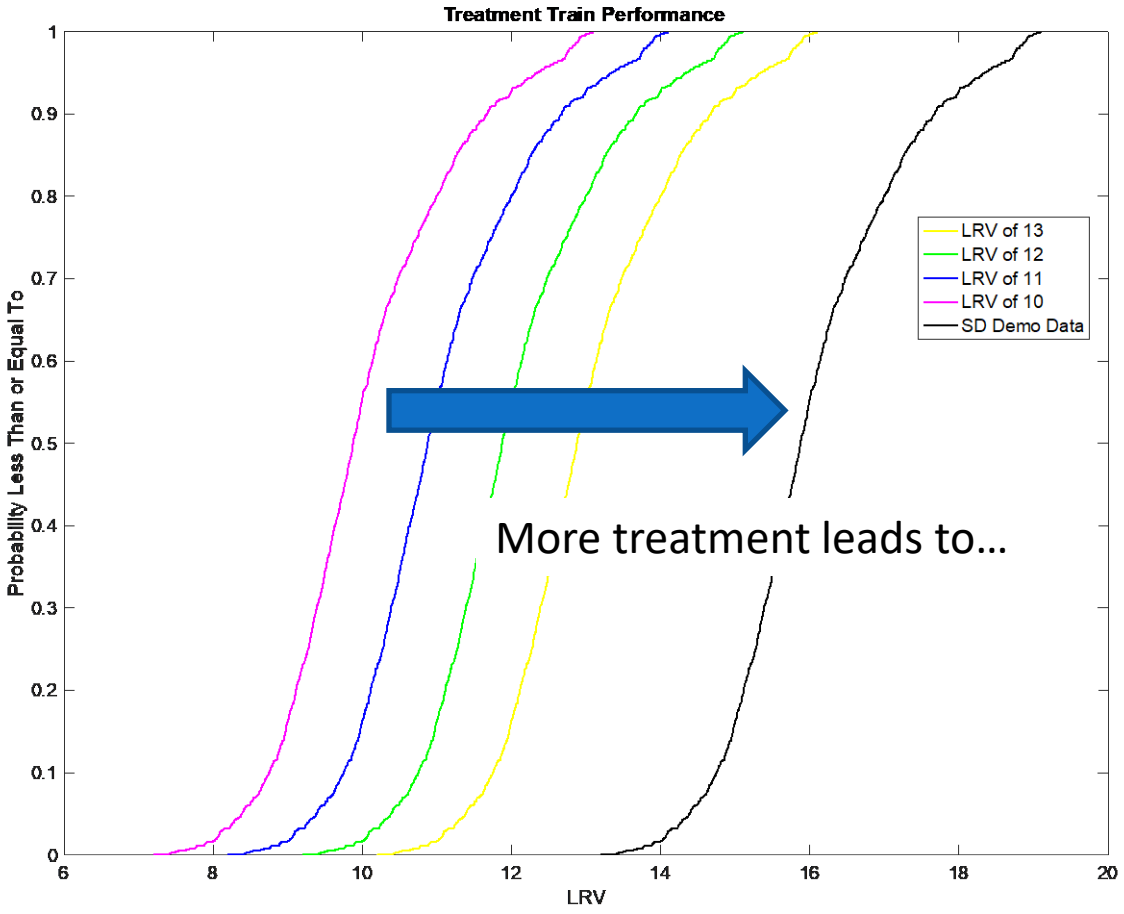
Daily risk of 2.7×10^{-7}

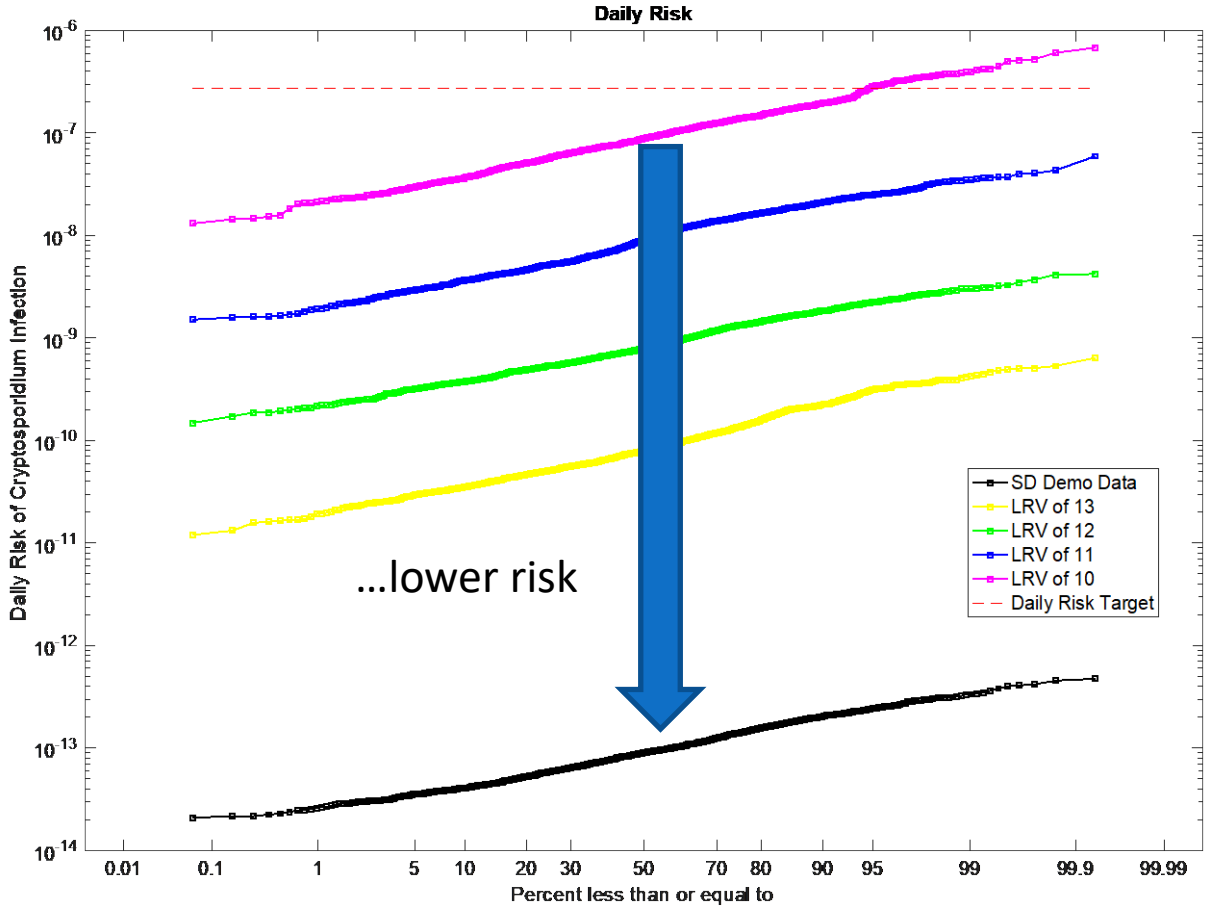

Based on DDW's assumptions,
LRT should be 16
Percent ≤
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
0.1
0.01
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
LRV


Daily Risk Goal
Constant Raw WW, LRT of 16
Daily Risk of Norovirus Infection
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤
When we look at risk, an LRT of 16 ensures we are always compliant with the risk goal.
This is where 16 for virus comes from…but how do they get to 20?

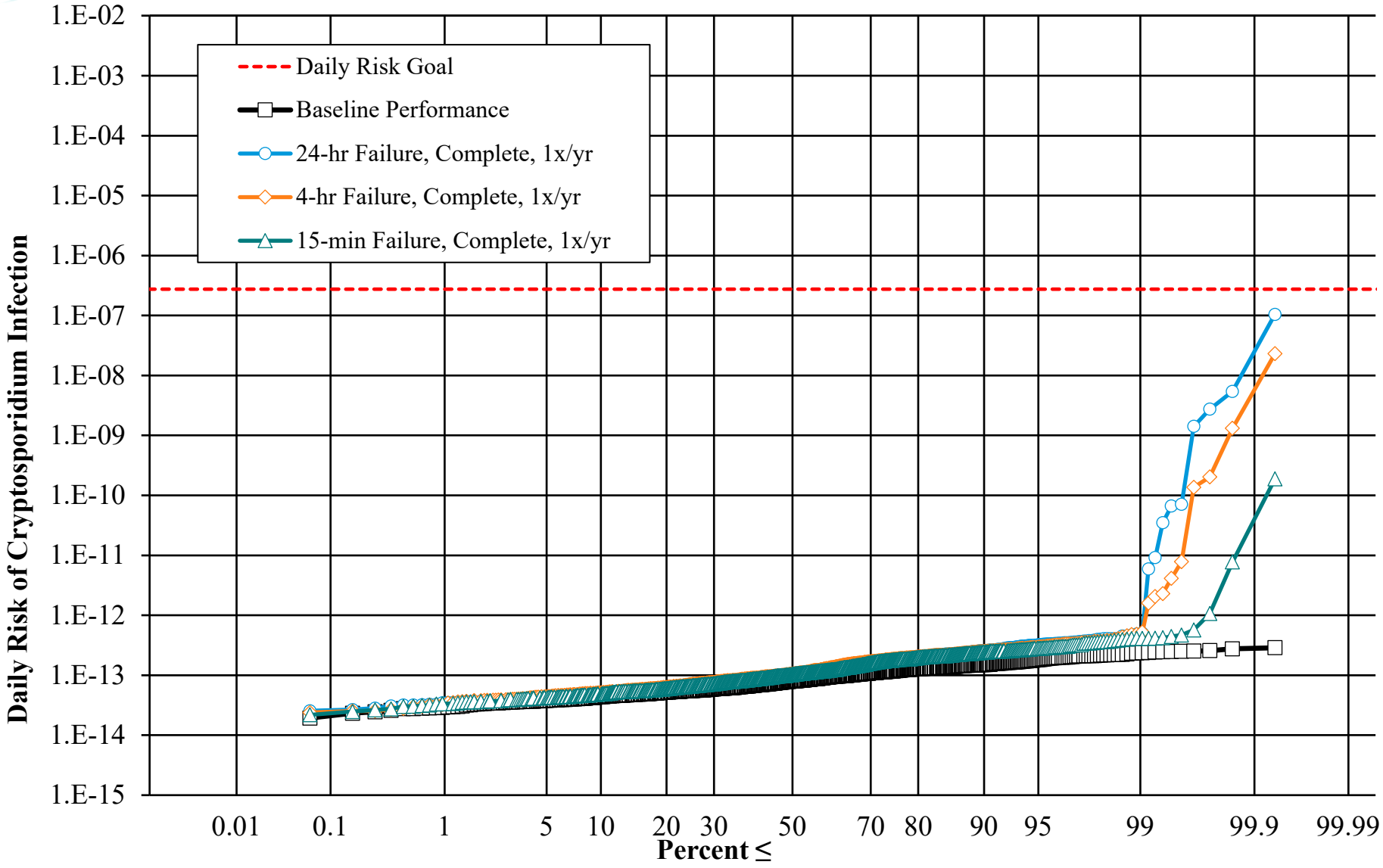
Redundancy and Risk

"To minimize the chance that the required log reductions necessary to meet the health objective are not consistently met, DPR projects must provide log reduction capacity in excess of the basic LRVs (redundant LRV treatment)."





Failures and Risk

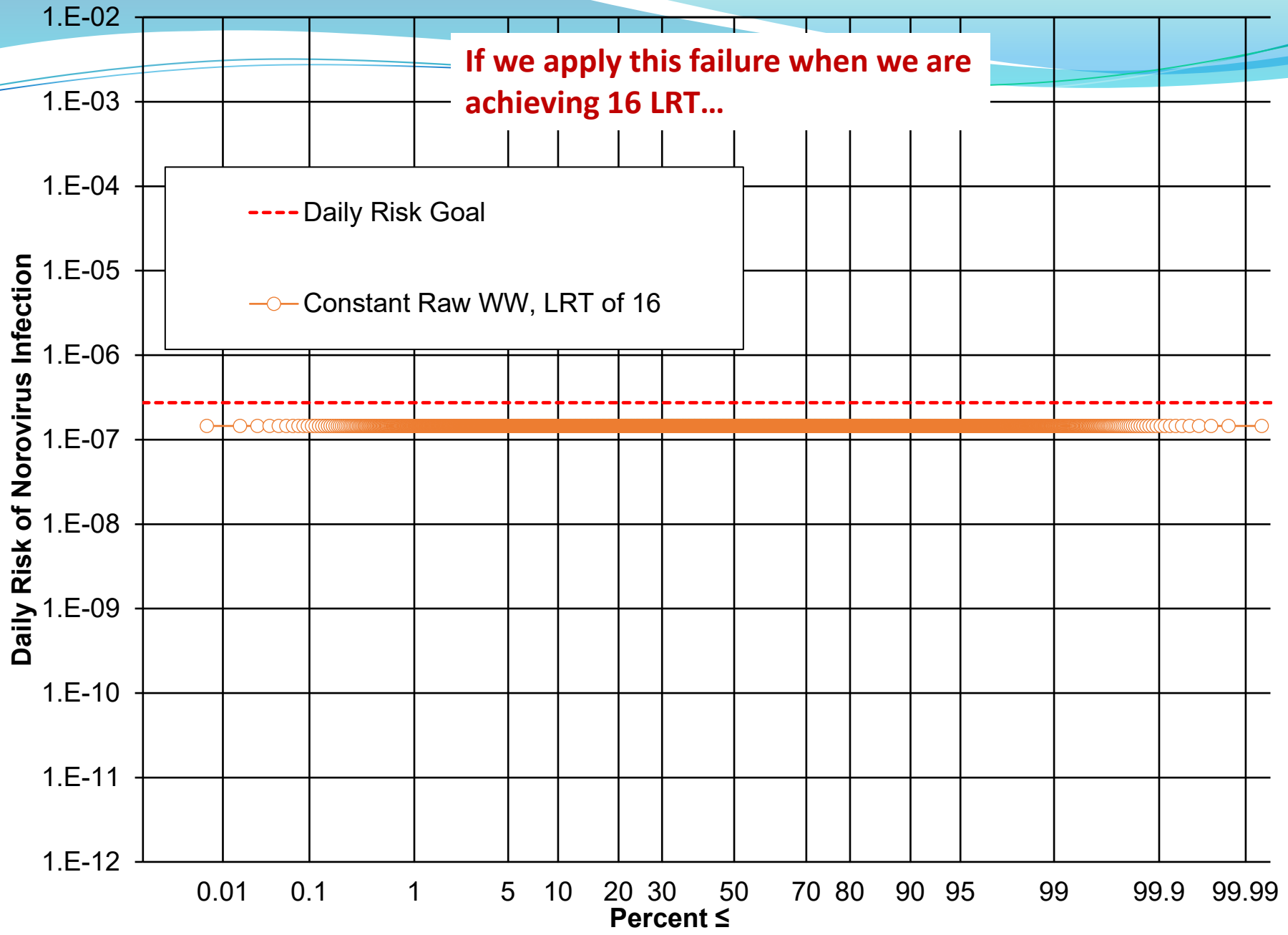


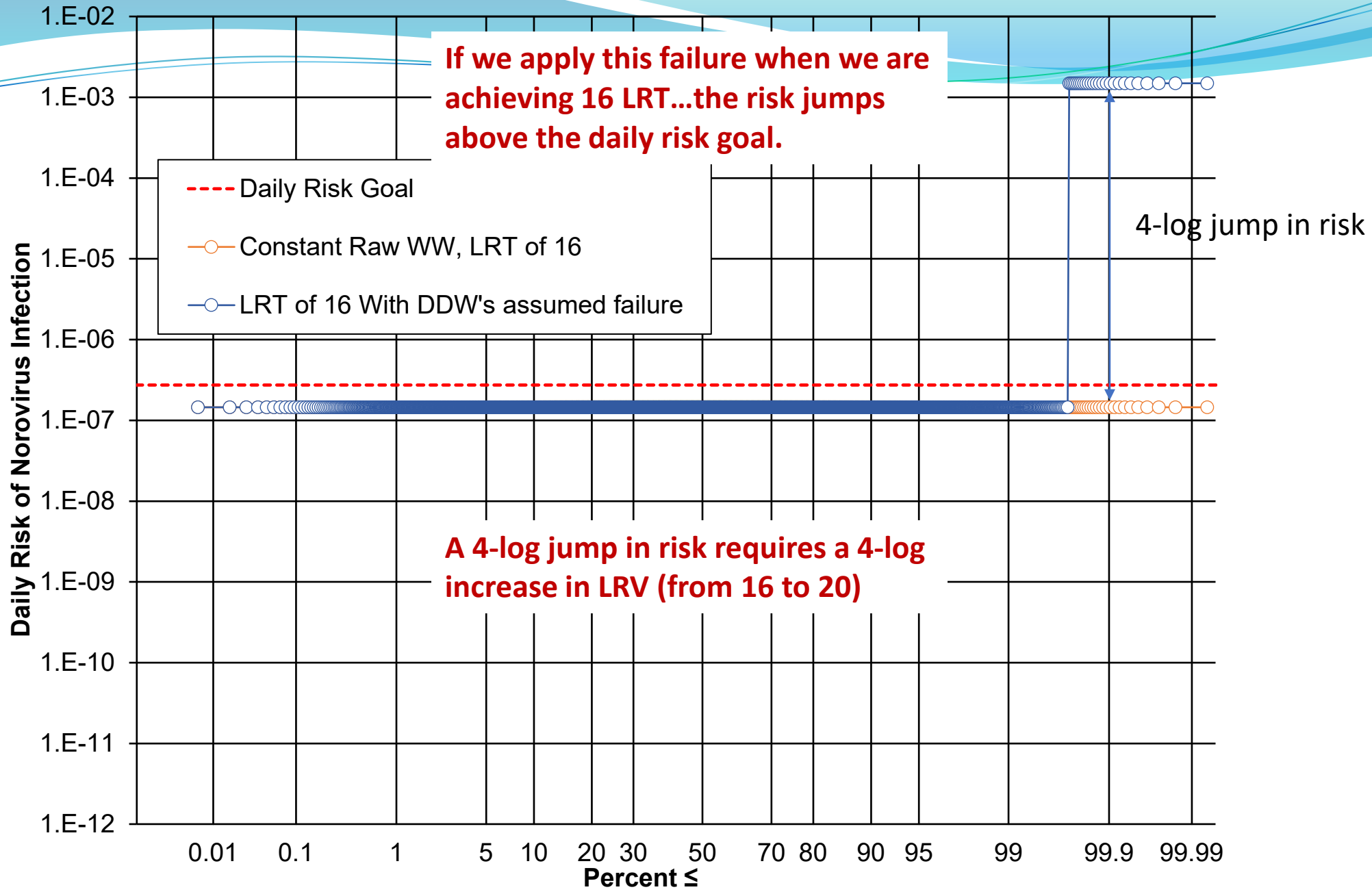
We also know that <u>failures</u> lead to <u>higher risk</u> levels.

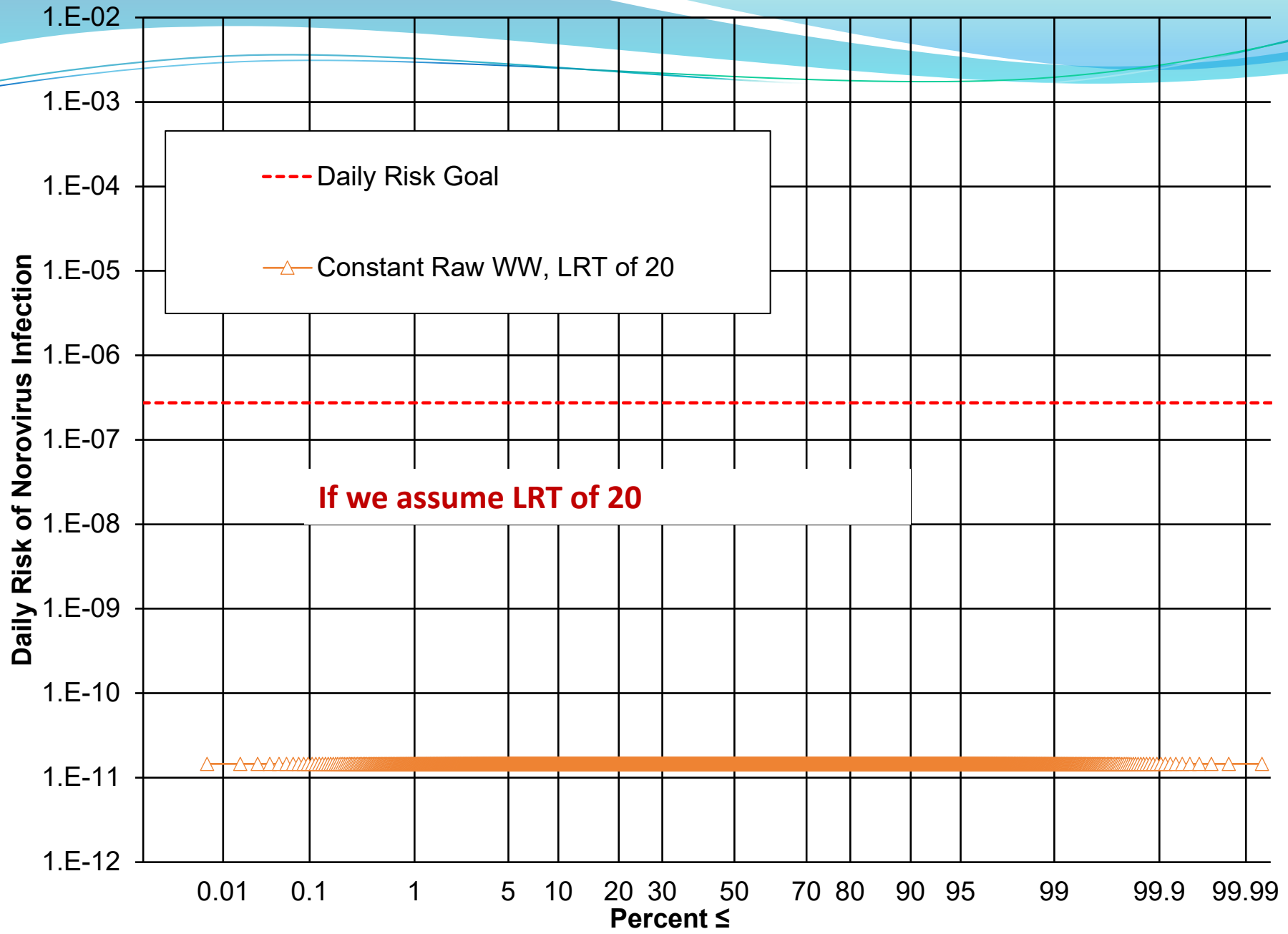
DDW Failure Assumption

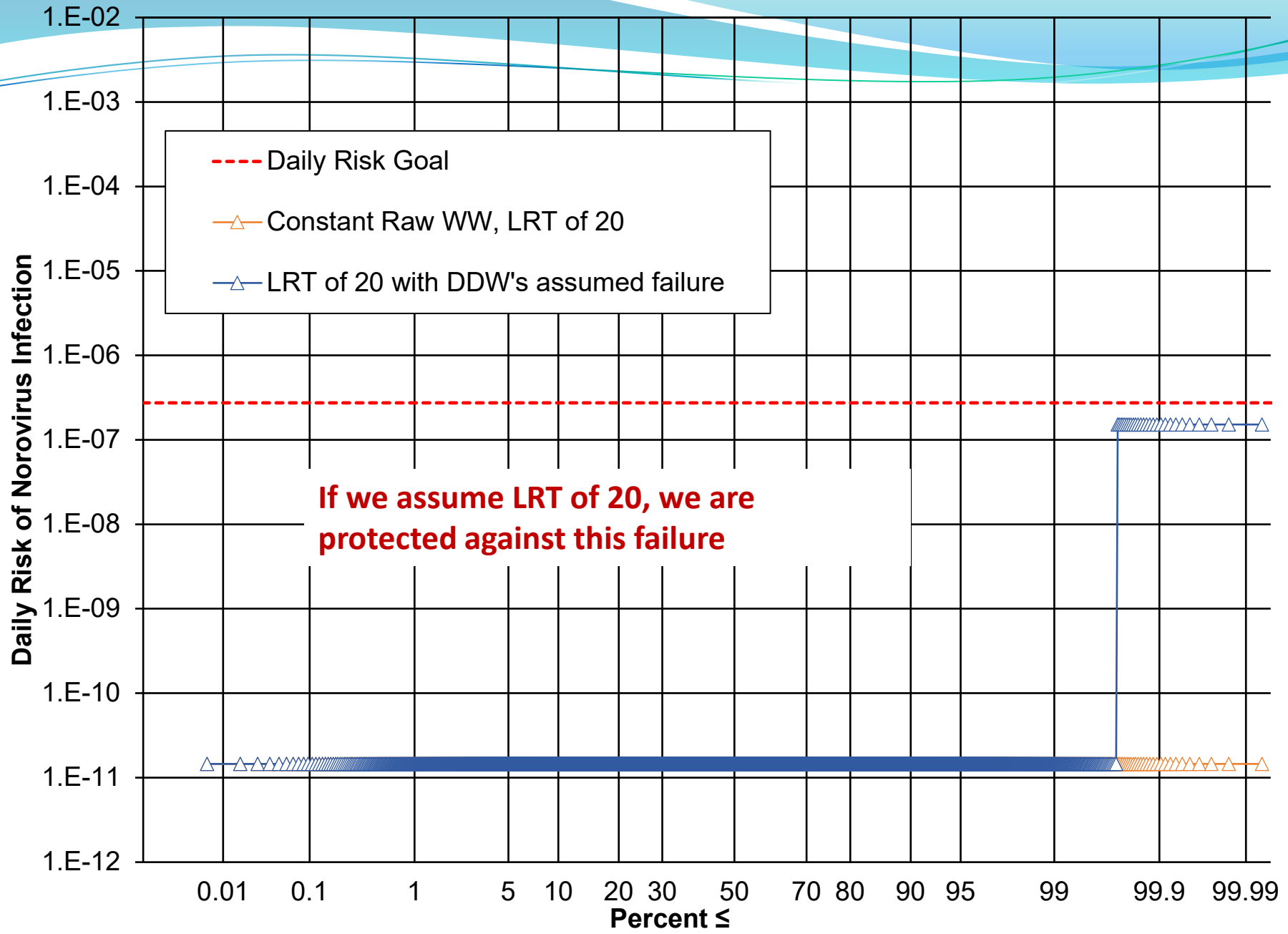
- UV/AOP failure (6-log reduction)
- Duration: 15-minutes
- Frequency: 1x/year

If we apply this failure when we are achieving 16 LRT…




If we apply this failure when we are achieving 16 LRT…the risk jumps above the daily risk goal.
Daily Risk Goal
Constant Raw WW, LRT of 16
LRT of 16 With DDW's assumed failure
4-log jump in risk
A 4-log jump in risk requires a 4-log increase in LRV (from 16 to 20)
Daily Risk of Norovirus Infection
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤

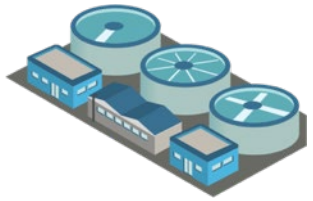

1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
Daily Risk of Norovirus Infection
Daily Risk Goal
Constant Raw WW, LRT of 20
If we assume LRT of 20
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤


1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
Daily Risk of Norovirus Infection
Daily Risk Goal
Constant Raw WW, LRT of 20
LRT of 20 with DDW's assumed failure
If we assume LRT of 20, we are protected against this failure
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤

Calculating Risk

1. Exposure Assessment

Raw wastewater



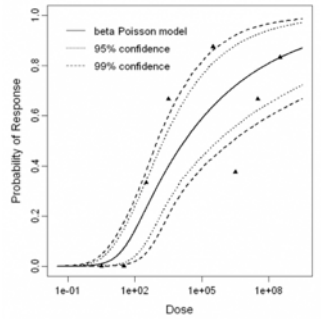
Treatment

Drinking water levels

Drinking water consumption

Exposure

2. Dose-Response



Dose-response

Risk

There are a lot of decisions to consider when calculating risk…

What data should we use?

What about molecular data?

Should we use a point estimate or distribution?

Is treatment constant or does it vary?

How do you account for failures?

How much water do people drink?

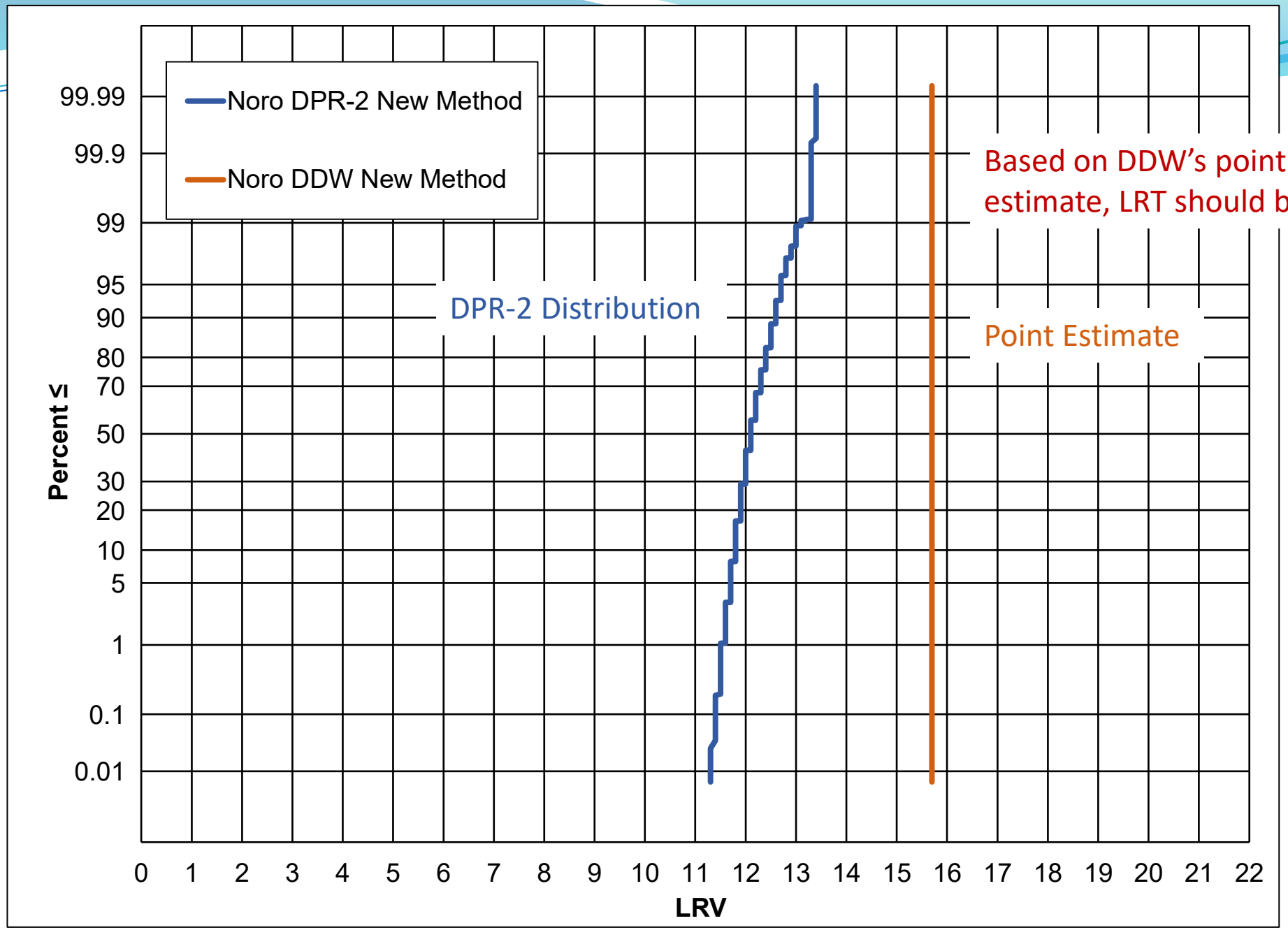
Which D-R functions to use?

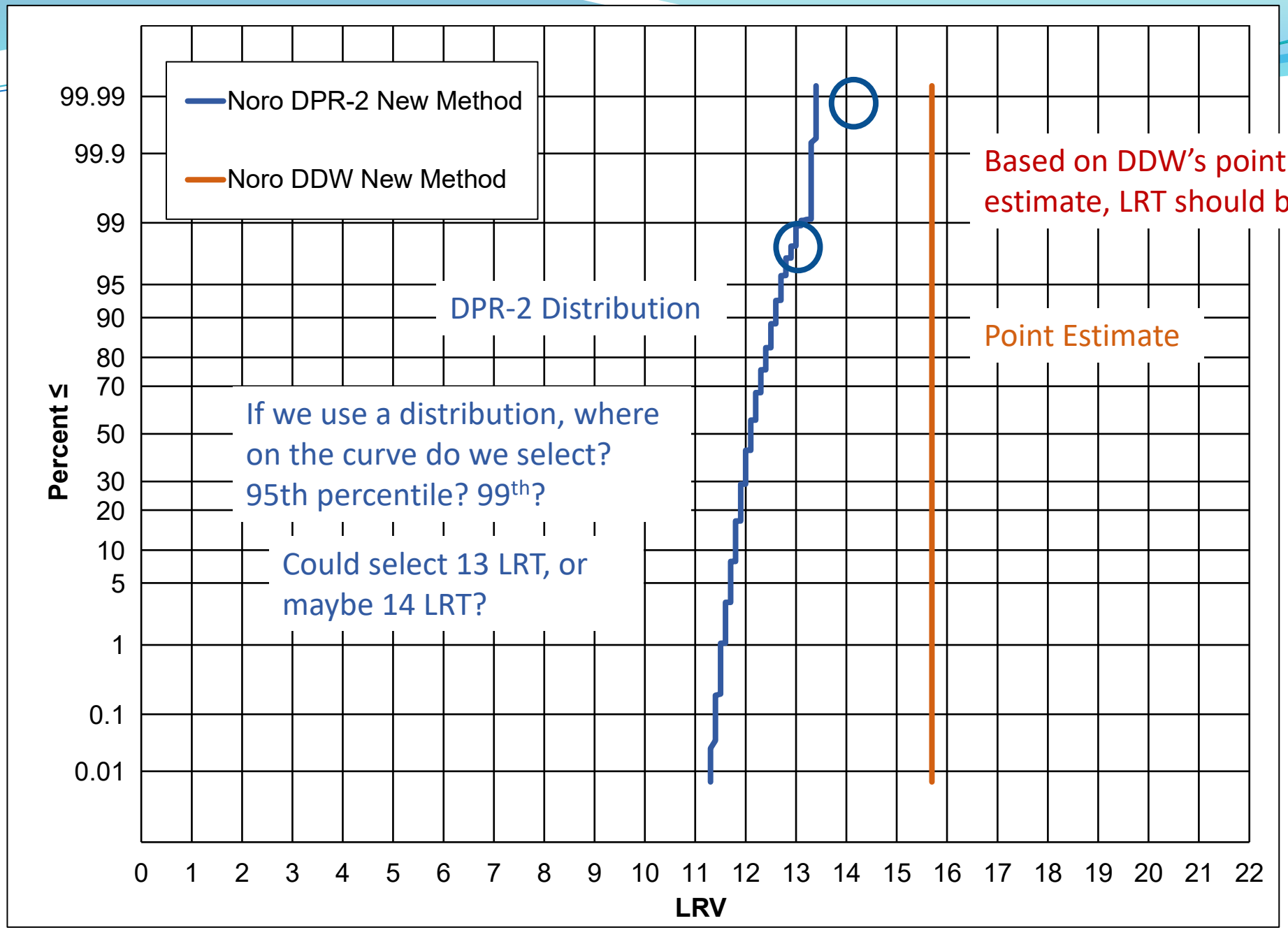
Norovirus

Raw Wastewater Pathogen Concentrations

- Point Estimate vs Distribution
  - DDW used point estimate of highest concentration recorded
    - 1E9 GC/L
  - DPR-2 data has been modeled as a lognormal distribution
    - 4.0 ± 1.2 log 10 GC/L
- How does this impact LRT required for compliance with daily risk?
- Let's look at the "benchmark" LRT curve and risk curves

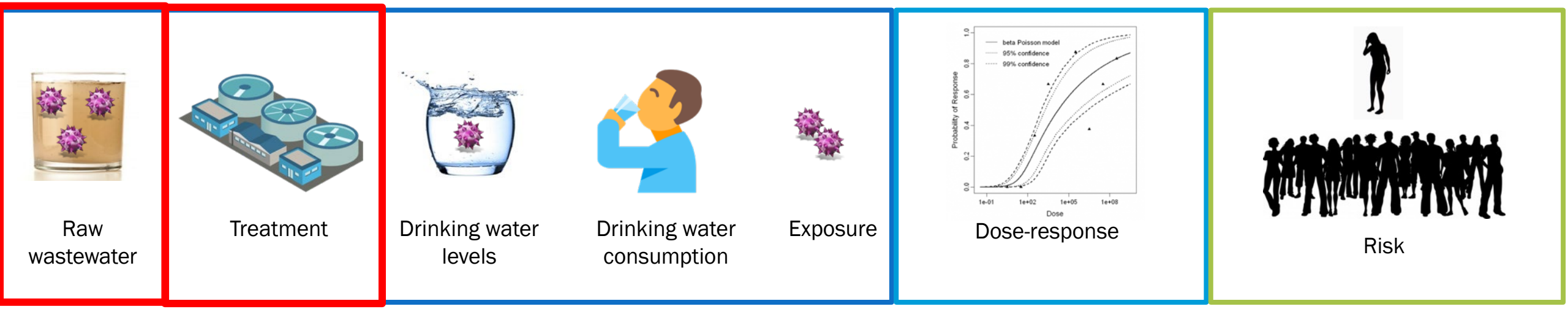
Volume consumed = 2L/day; Dose response is hypergeometric (unless otherwise noted)


Noro DPR-2 New Method
Noro DDW New Method
Based on DDW's point estimate, LRT should be 16
DPR-2 Distribution
Point Estimate
Percent ≤
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
0.1
0.01
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
LRV


Noro DPR-2 New Method
Noro DDW New Method
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
0.1
0.01
Percent ≤
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
LRV
DPR-2 Distribution
If we use a distribution, where on the curve do we select? 95th percentile? 99th?
Could select 13 LRT, or maybe 14 LRT?
Based on DDW's point estimate, LRT should be 16
Point Estimate

PATTP to Risk

- We can look at the benchmark curves, but risk will give us a better sense of conservatism.
- What happens when we take these different LRTs forward to risk?



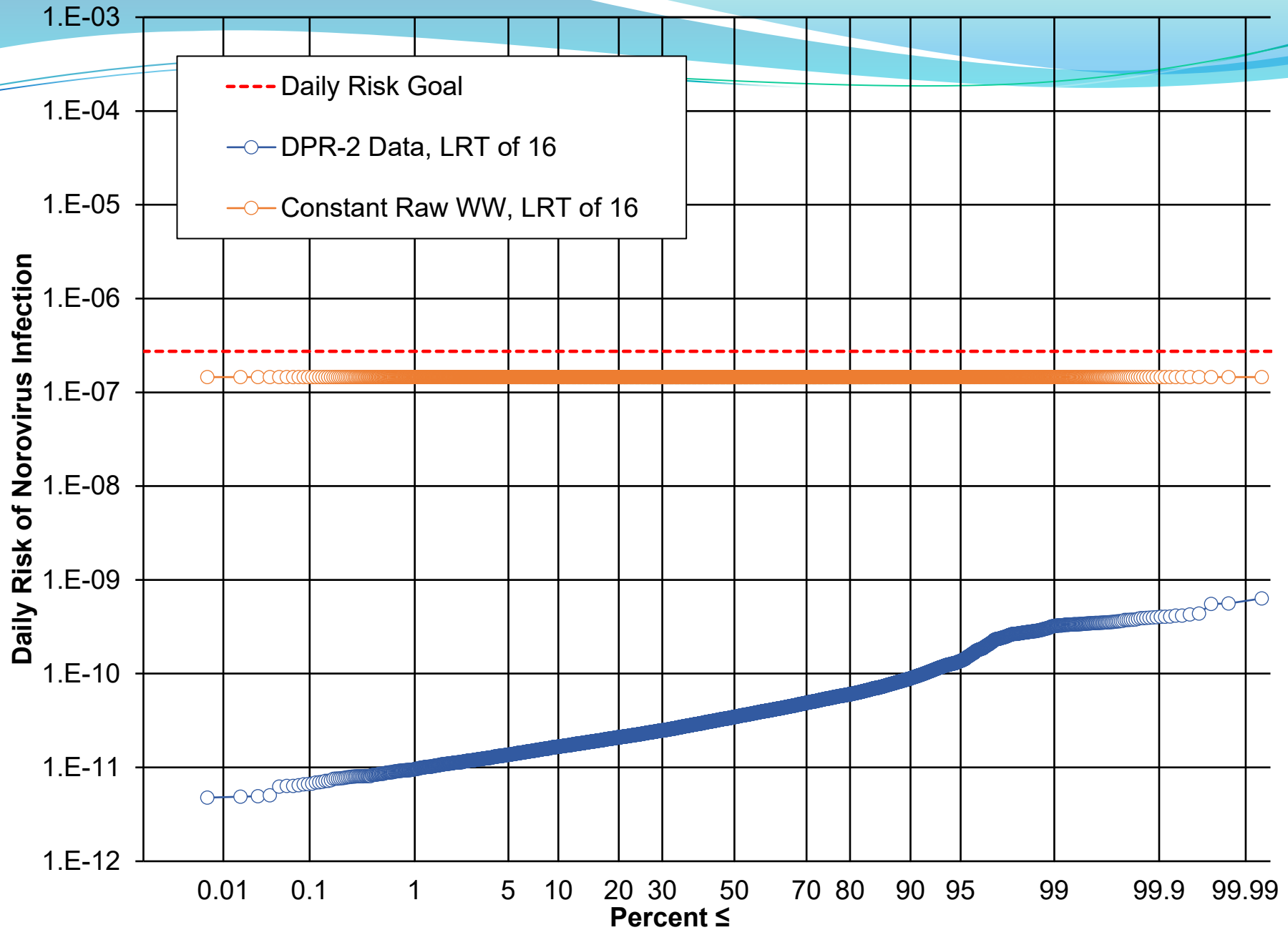
Point estimate vs. distribution

LRT 16
LRT 14
LRT 13

Constant at 2L/day

Hypergeometric

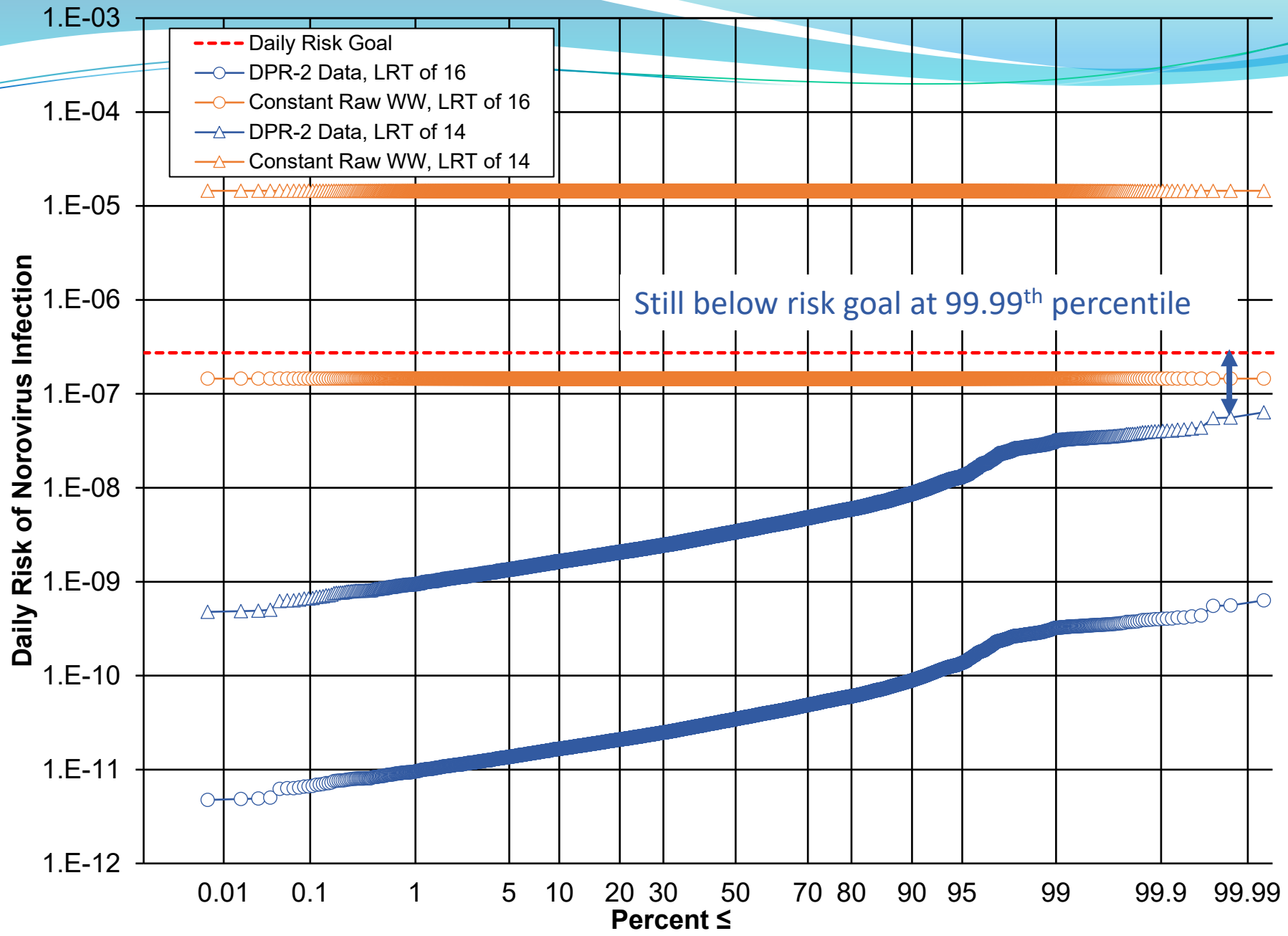
LRT 16



Point estimate
LRT 16

Distribution
LRT 16

LRT 16 vs LRT 14



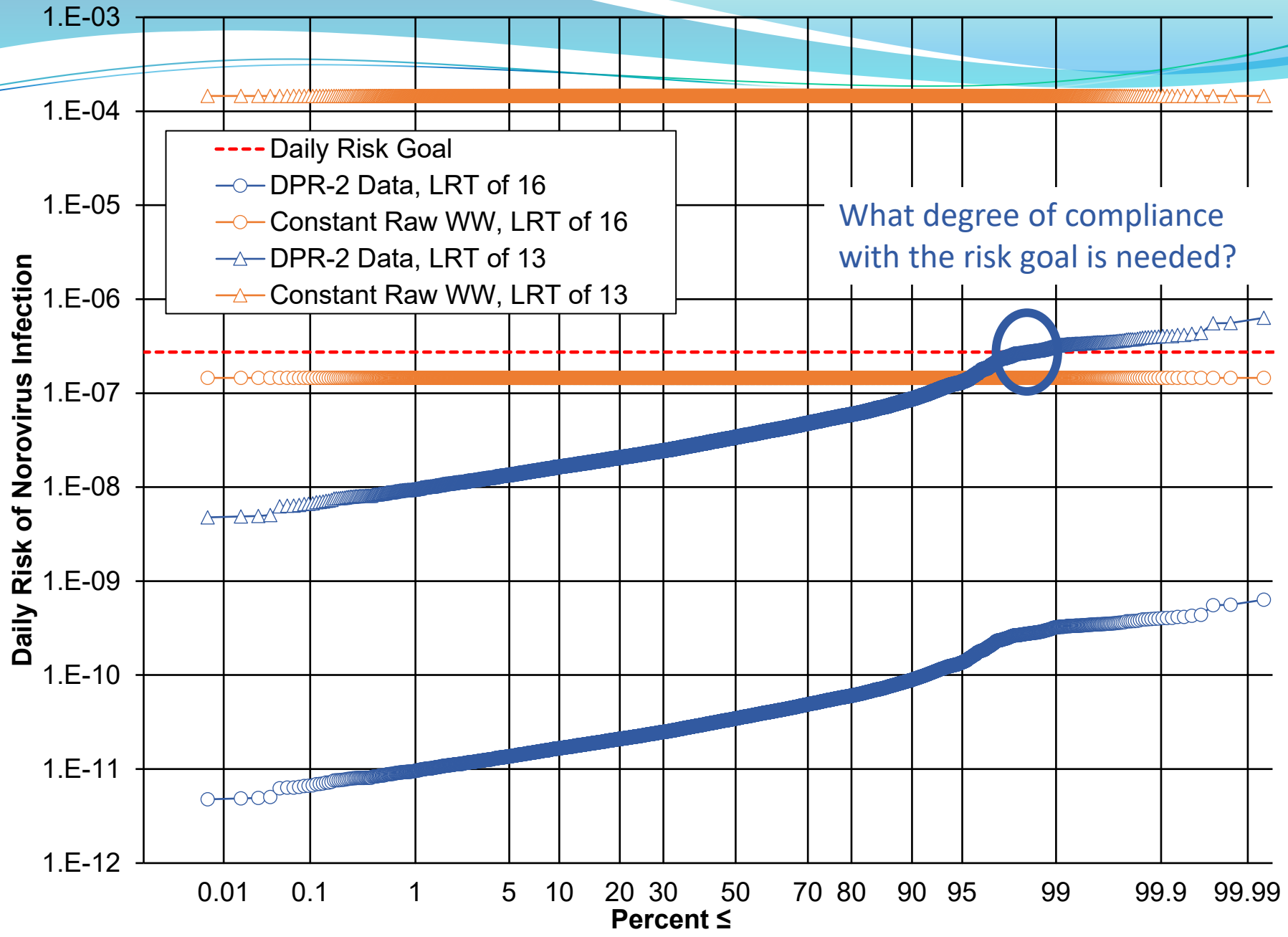
Point estimate LRT 14

Point estimate LRT 16

Distribution LRT 14

Distribution LRT 16

LRT 16 vs LRT 13



What degree of compliance with the risk goal is needed?

Point estimate LRT 13

Distribution LRT 13

Point estimate LRT 16

Distribution LRT 16

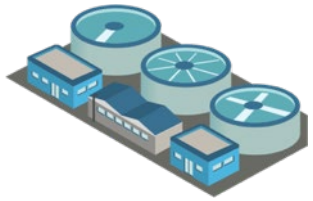
Point Estimate vs. Distribution

- Using a high point estimate for the raw wastewater concentration requires a higher LRT
- Using a distribution for the raw wastewater concentration requires a lower LRT
- DDW's assumption to use a high point estimate for the raw wastewater concentration is conservative

Molecular Data Assumptions

- When we use molecular data, we have to make assumptions about the infectivity of a genome copy. How many GCs are actually infective?
- DDW assumed a 1:1 ratio – every GC is infectious
- DPR-2 showed that this ratio can range from 1:1 to 10,000:1 or higher
- What happens if we make a different assumption about GC:IU?

Raw wastewater

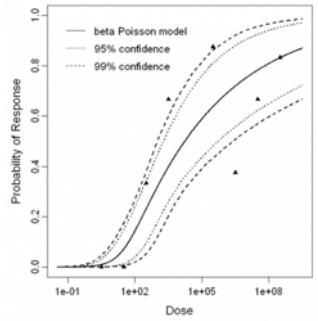


Treatment

Drinking water levels

Drinking water consumption

Exposure



Dose-response

Risk

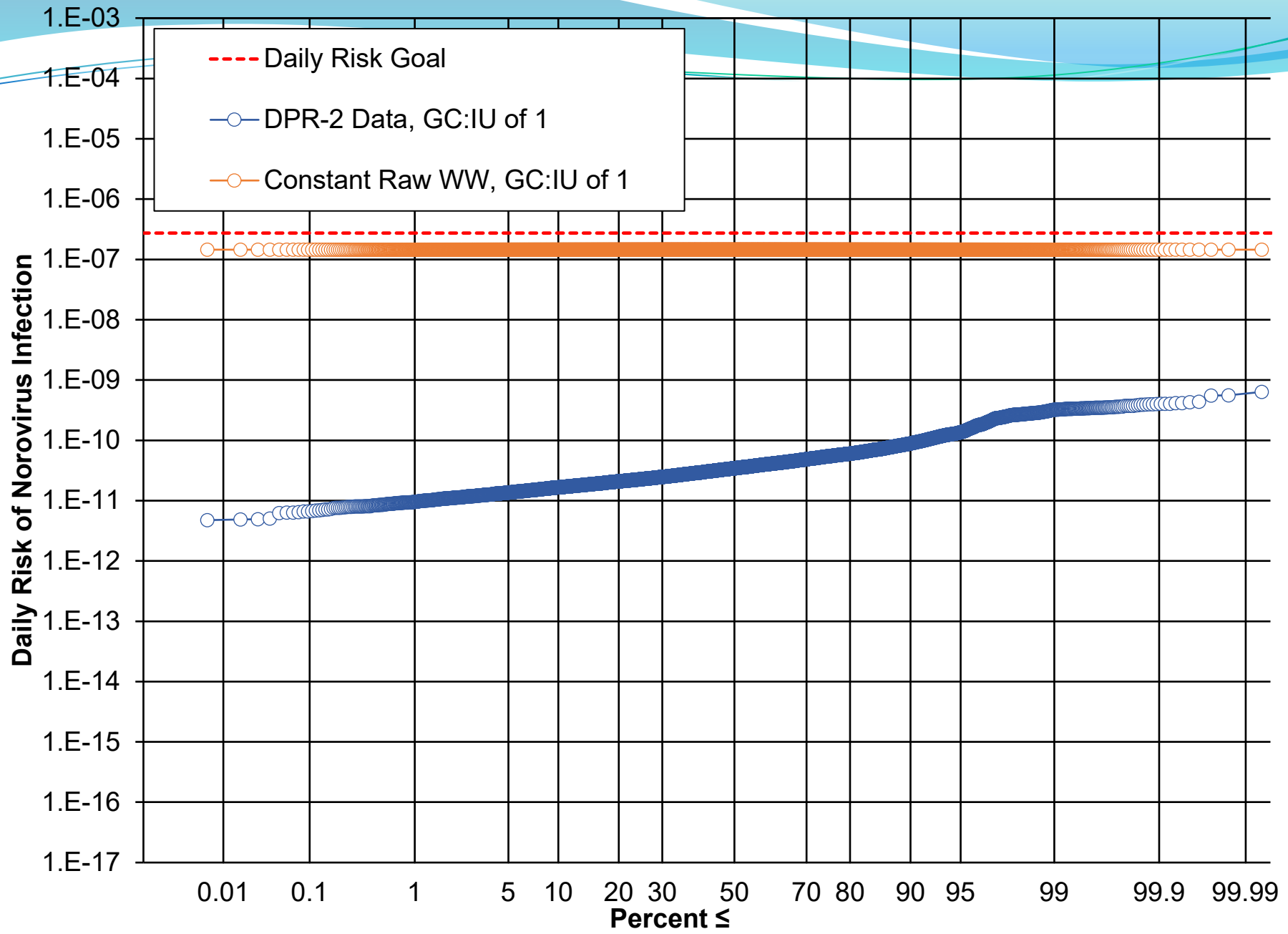
Point estimate vs. distribution & GC:IU varies

LRT 16

Constant at 2L/day

Hypergeometric

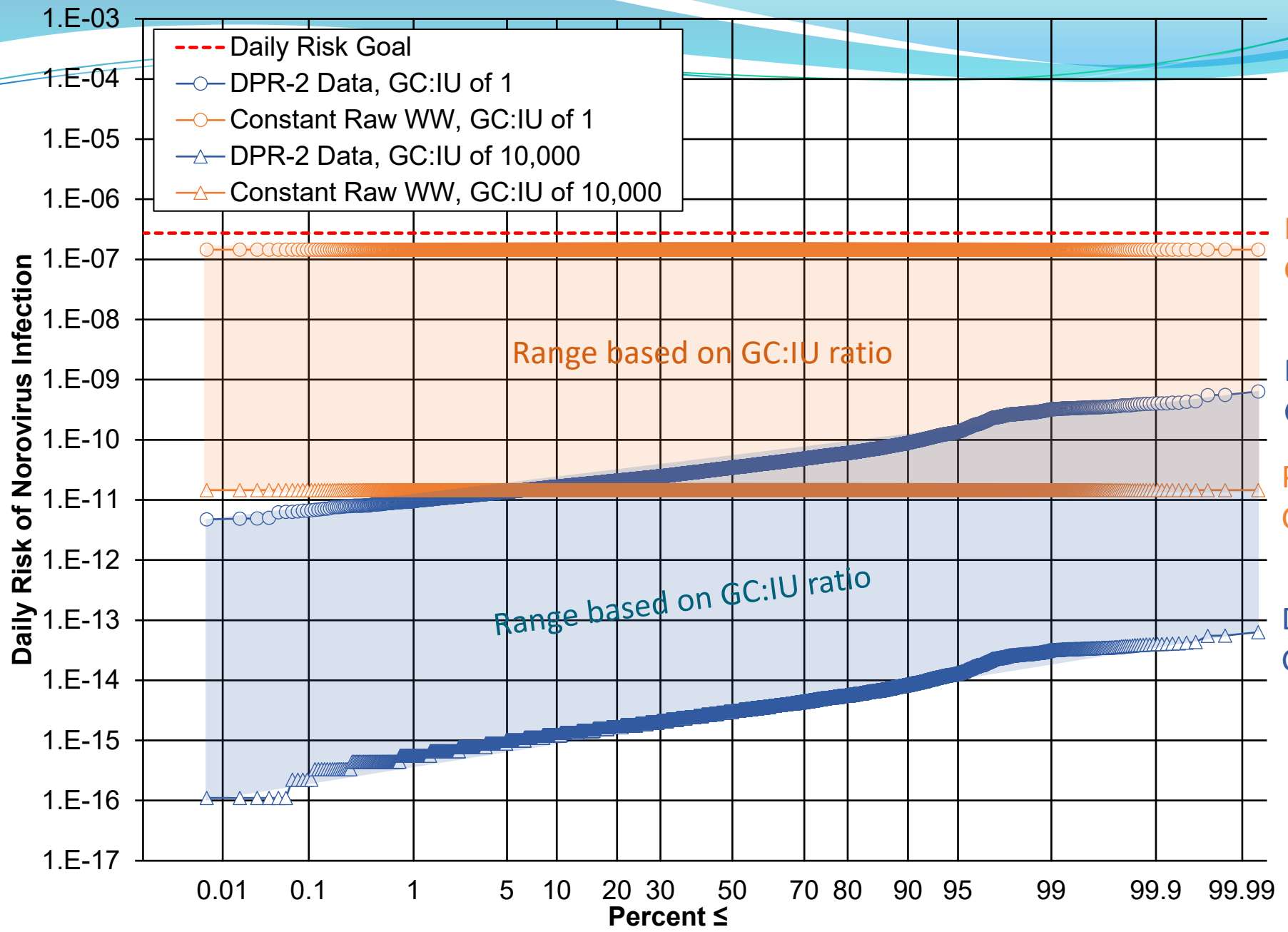
GC:IU range
Assumes LRT is 16



Point estimate
GC:IU = 1:1

Distribution
GC:IU = 1:1

GC:IU range
Assumes LRT is 16

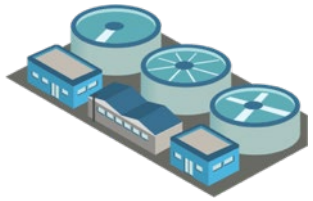


Dose Response Functions

- We also have to decide which dose-response function(s) to use.
- Norovirus has two dose-response functions to choose from:
  - Hypergeometric
    - Teunis et al. 2008; alpha = 0.04; beta = 0.055
  - Fractional Poisson
    - Messner et al. 2014; P = 0.72; alpha = 1106
- For Norovirus, DDW selected the hypergeometric dose-response.
  - DPR-1 recommended bounding with both functions (Van Abel et al. 2017)

Dose Response Functions

Raw wastewater

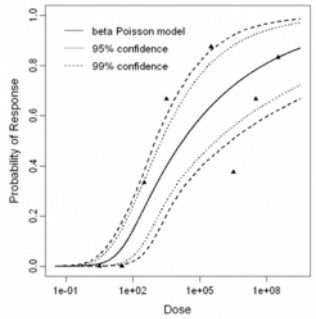


Treatment

Drinking water levels

Drinking water consumption

Exposure



Dose-response

Risk

Point estimate vs. distribution

GC:IU = 1:1

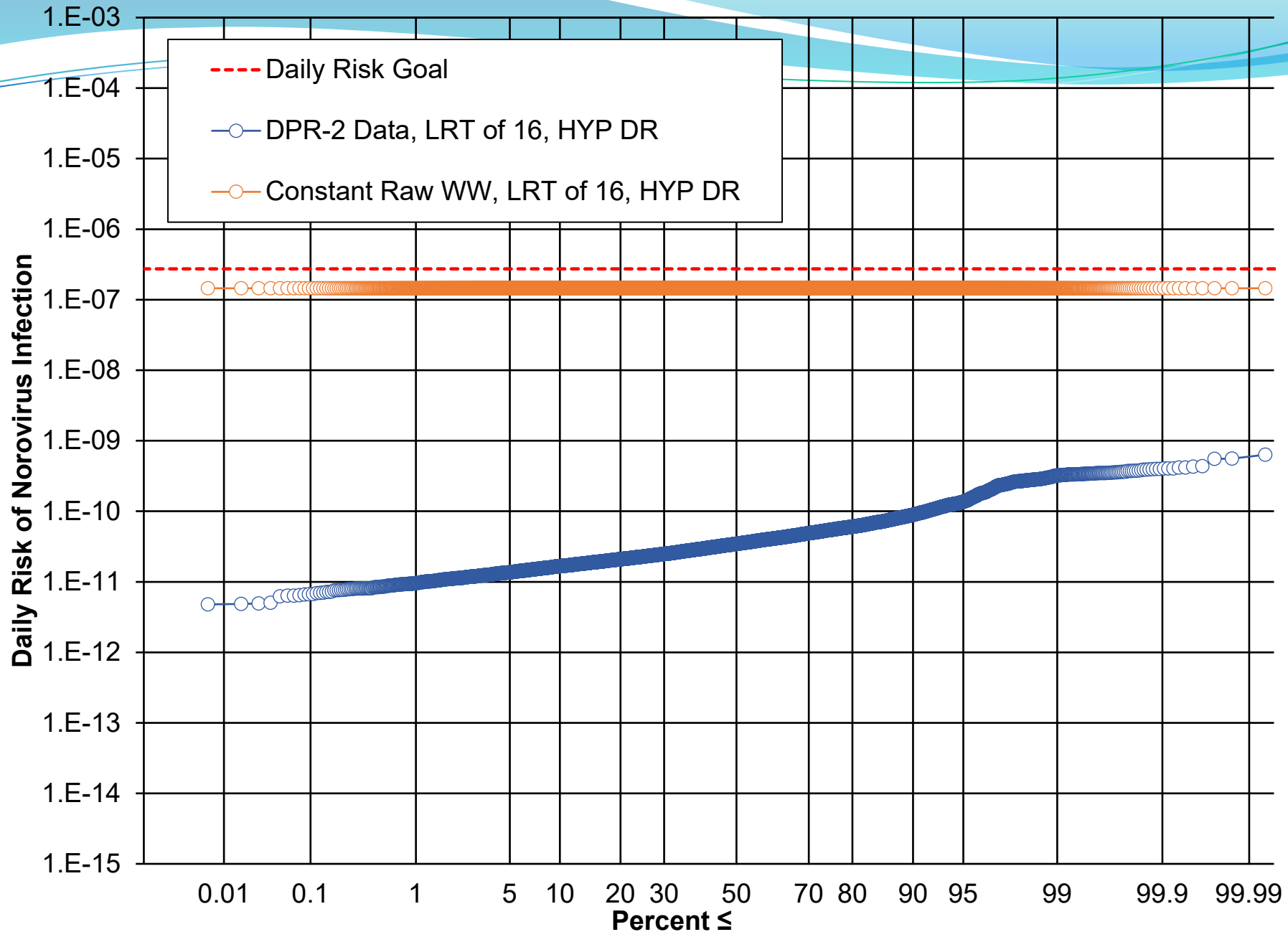
LRT 16

Constant at 2L/day

Hypergeometric vs. Fractional Poisson

Dose-response comparison

LRT of 16
HYP DR
GC:IU of 1

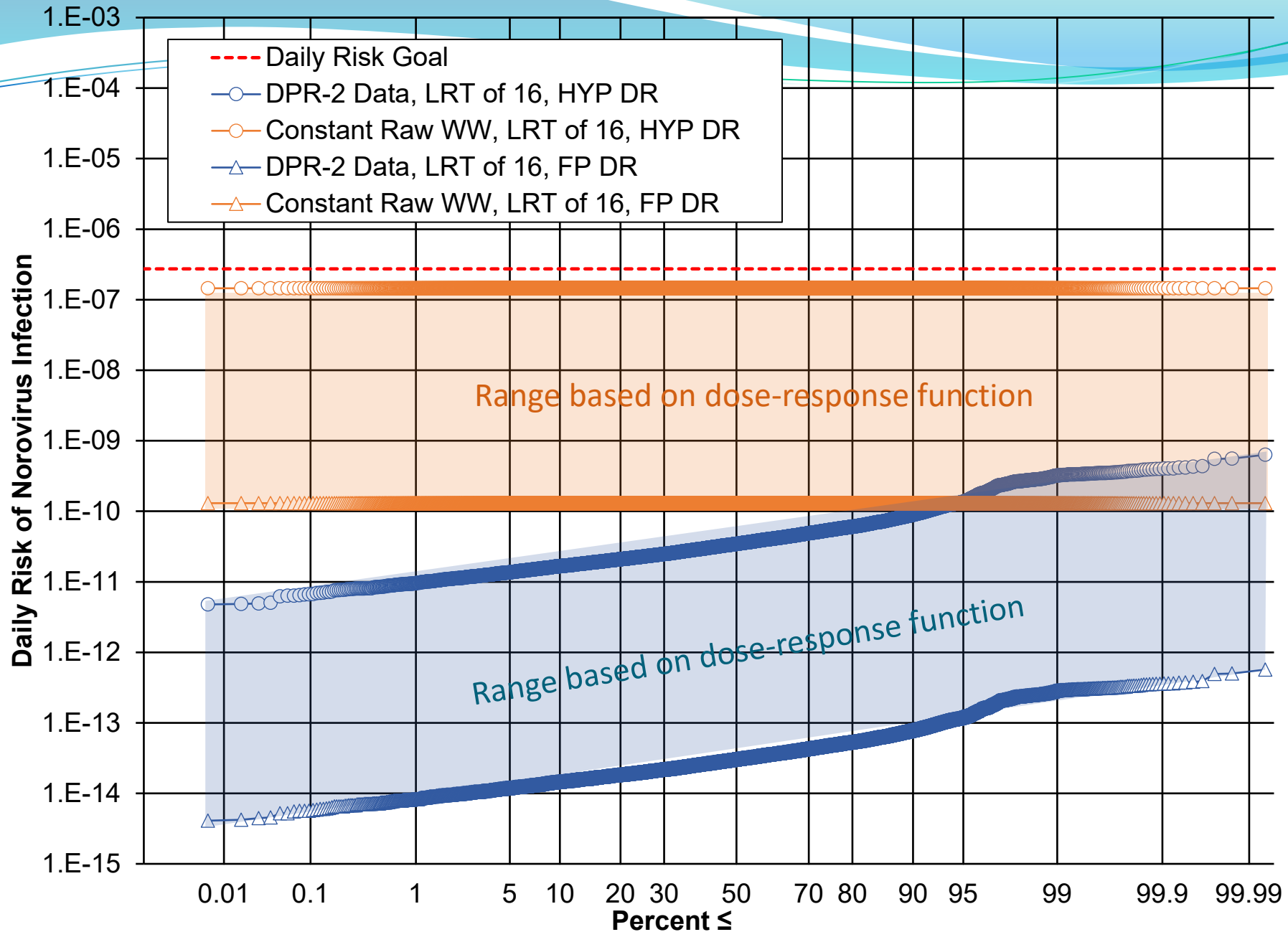


Point estimate HYP DR

Distribution HYP DR

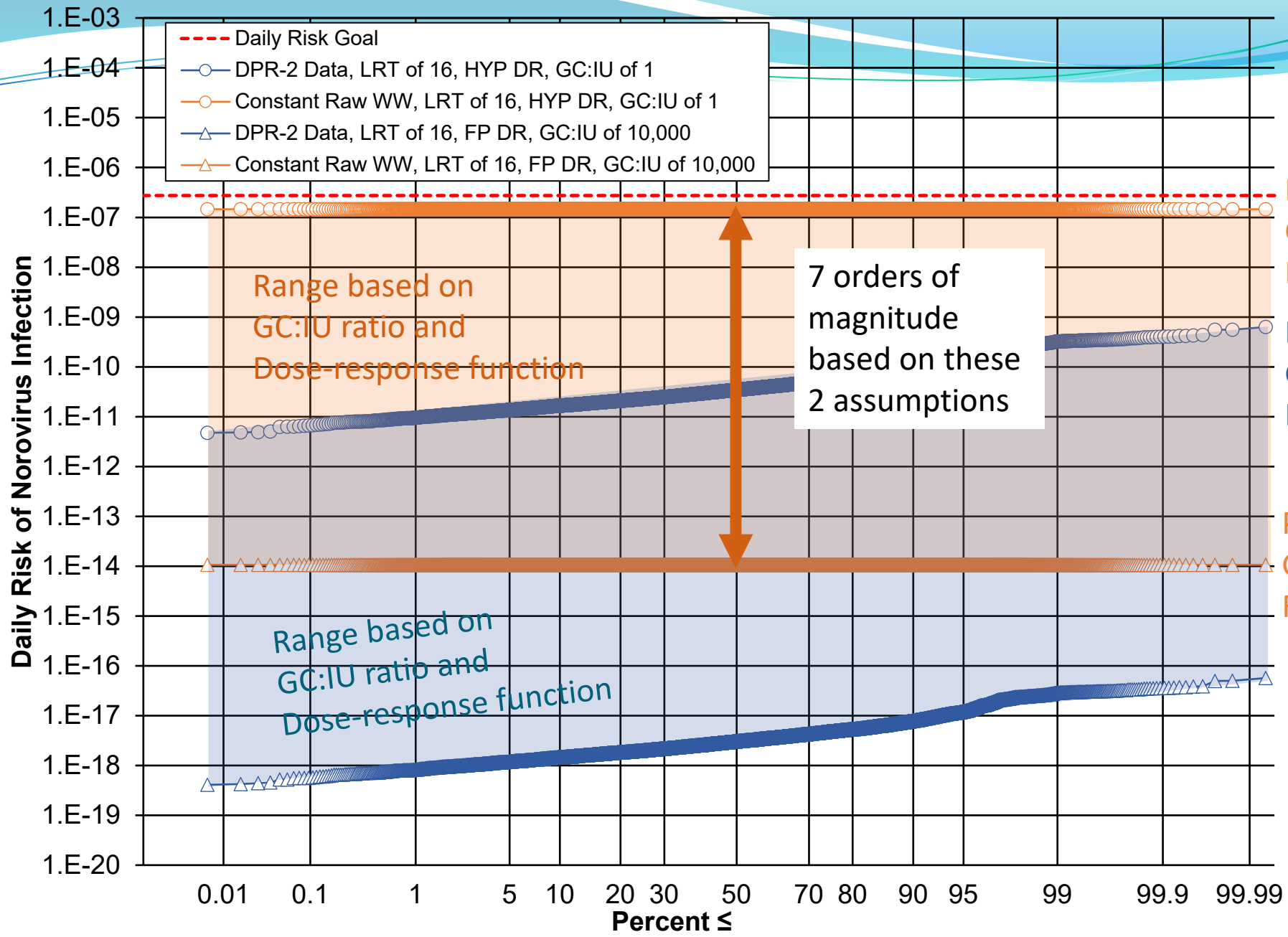
Dose-response comparison

LRT of 16
HYP DR vs FP DR
GC:IU of 1



Dose-response comparison

LRV of 16
HYP DR vs FP DR
GC:IU of 10,000:1

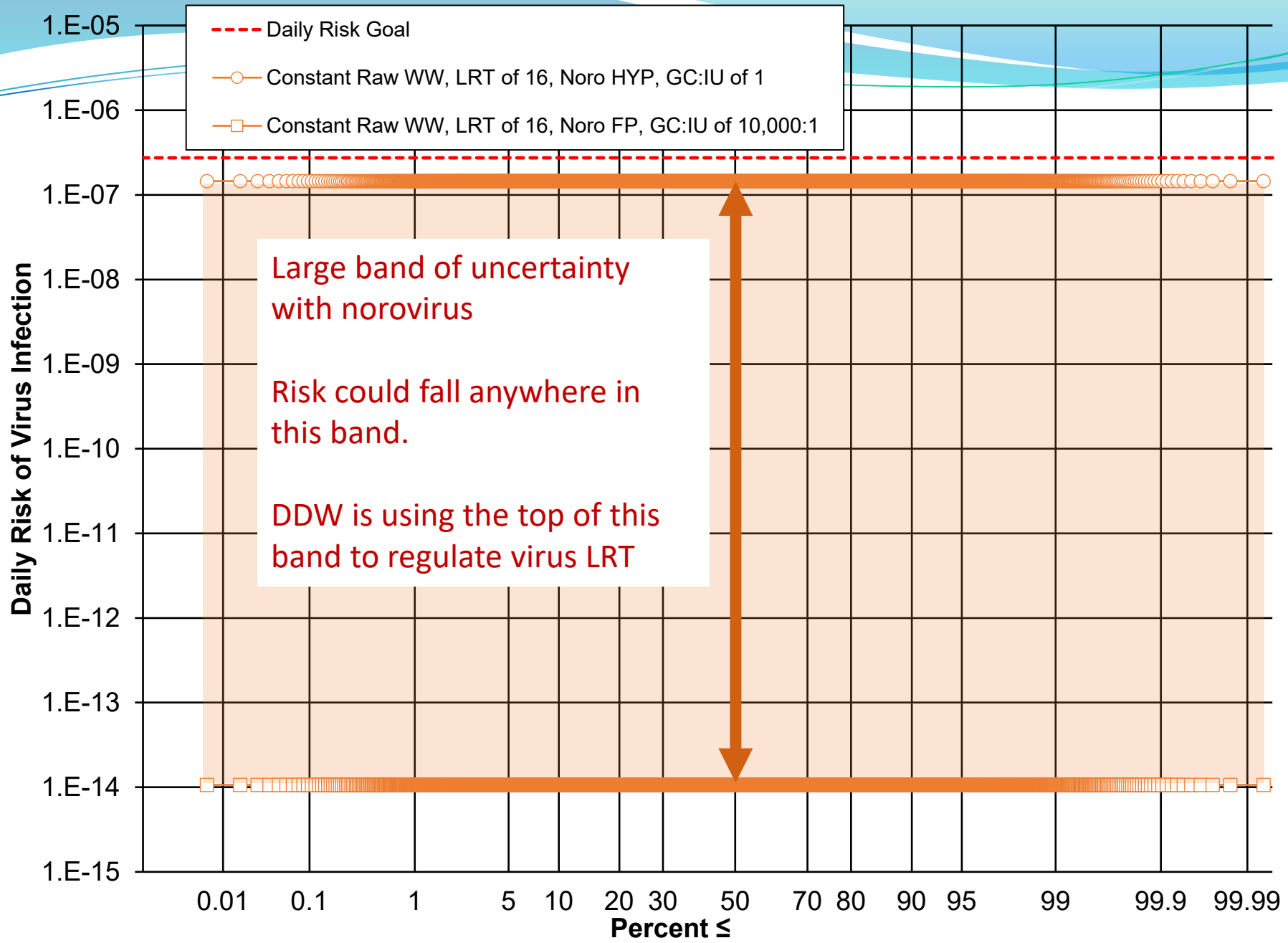


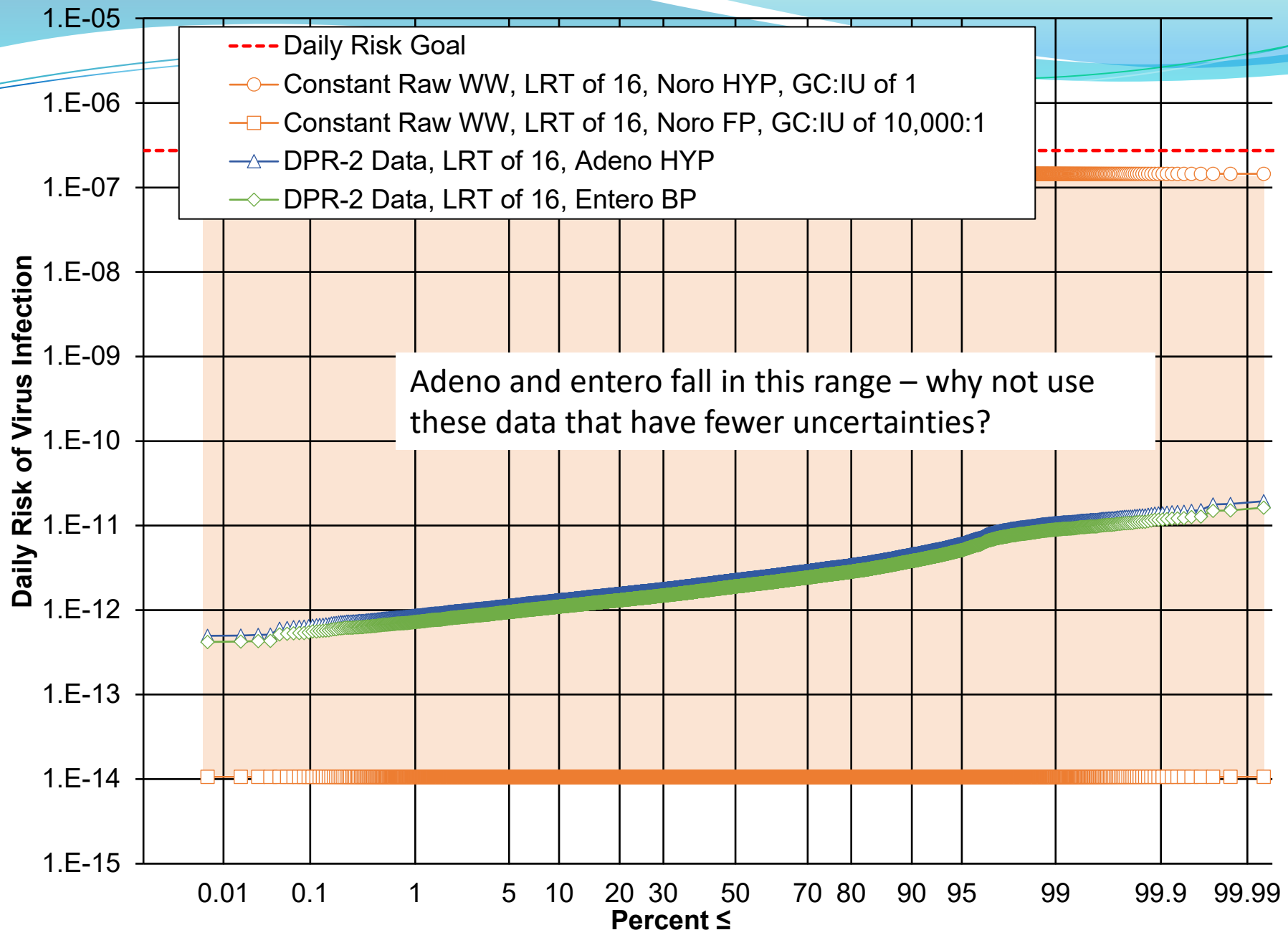
Point estimate
GC:IU = 1:1
HYP DR

Distribution
GC:IU = 1:1
HYP DR

Point estimate
GC:IU = 10,000:1
FP DR

Distribution
GC:IU = 10,000:1
FP DR

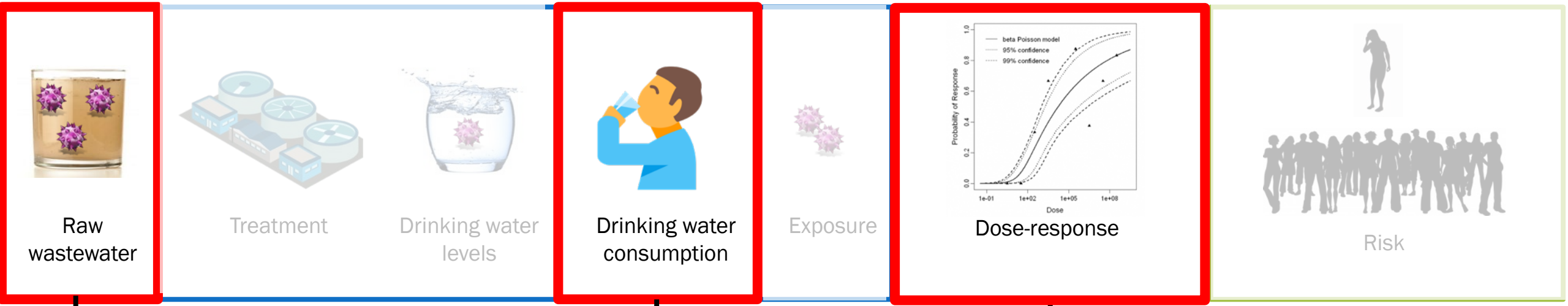

Daily Risk Goal
Constant Raw WW, LRT of 16, Noro HYP, GC:IU of 1
Constant Raw WW, LRT of 16, Noro FP, GC:IU of 10,000:1
Large band of uncertainty with norovirus
Risk could fall anywhere in this band.
DDW is using the top of this band to regulate virus LRT
Daily Risk of Virus Infection
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤


Daily Risk Goal
Constant Raw WW, LRT of 16, Noro HYP, GC:IU of 1
Constant Raw WW, LRT of 16, Noro FP, GC:IU of 10,000:1
DPR-2 Data, LRT of 16, Adeno HYP
DPR-2 Data, LRT of 16, Entero BP
Adeno and entero fall in this range – why not use these data that have fewer uncertainties?
Daily Risk of Virus Infection
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤

Calculating the Benchmark Treatment

1. Exposure Assessment

2. Dose-Response



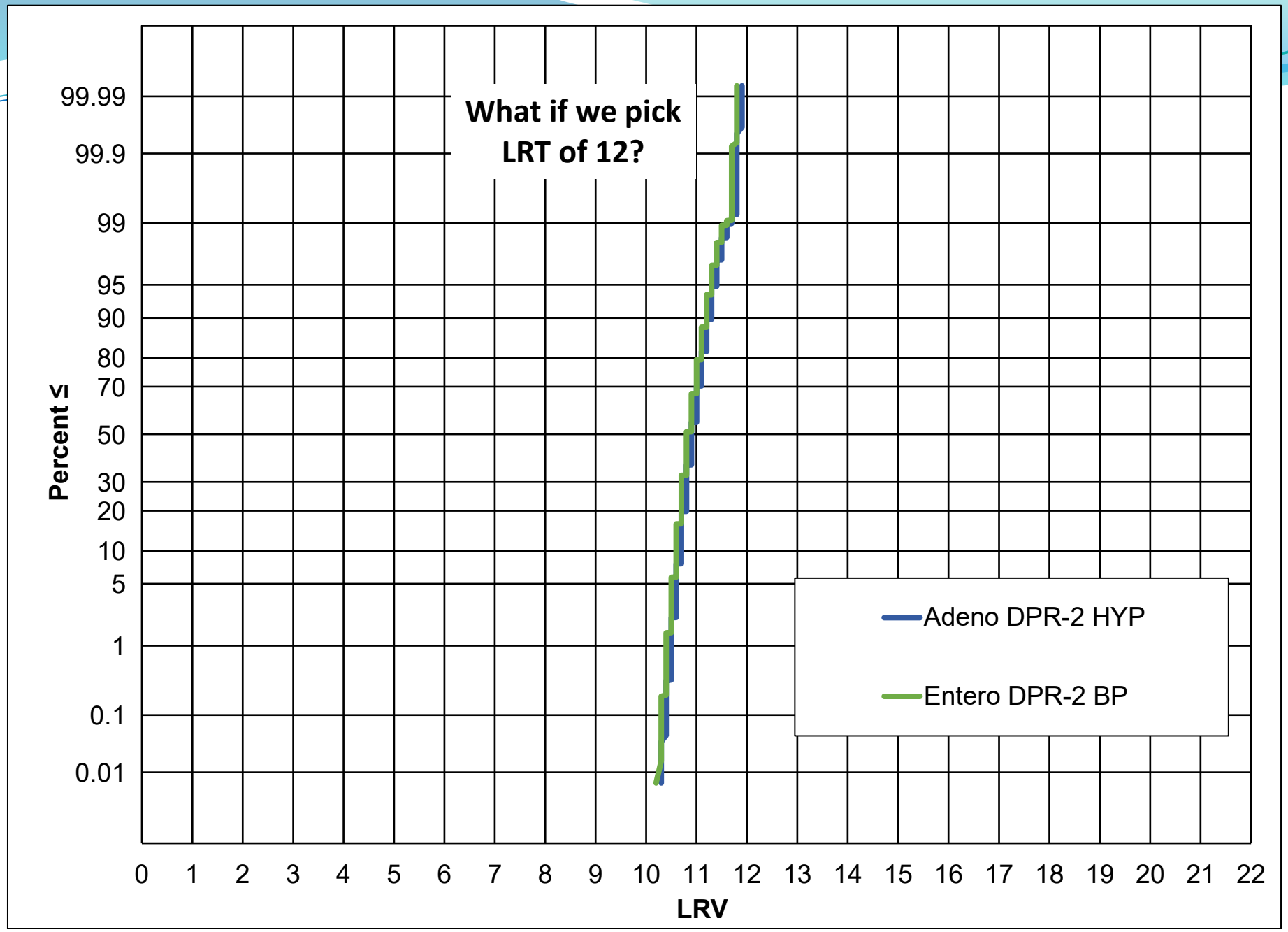
What if we use this same approach, but just use adenovirus and enterovirus instead?

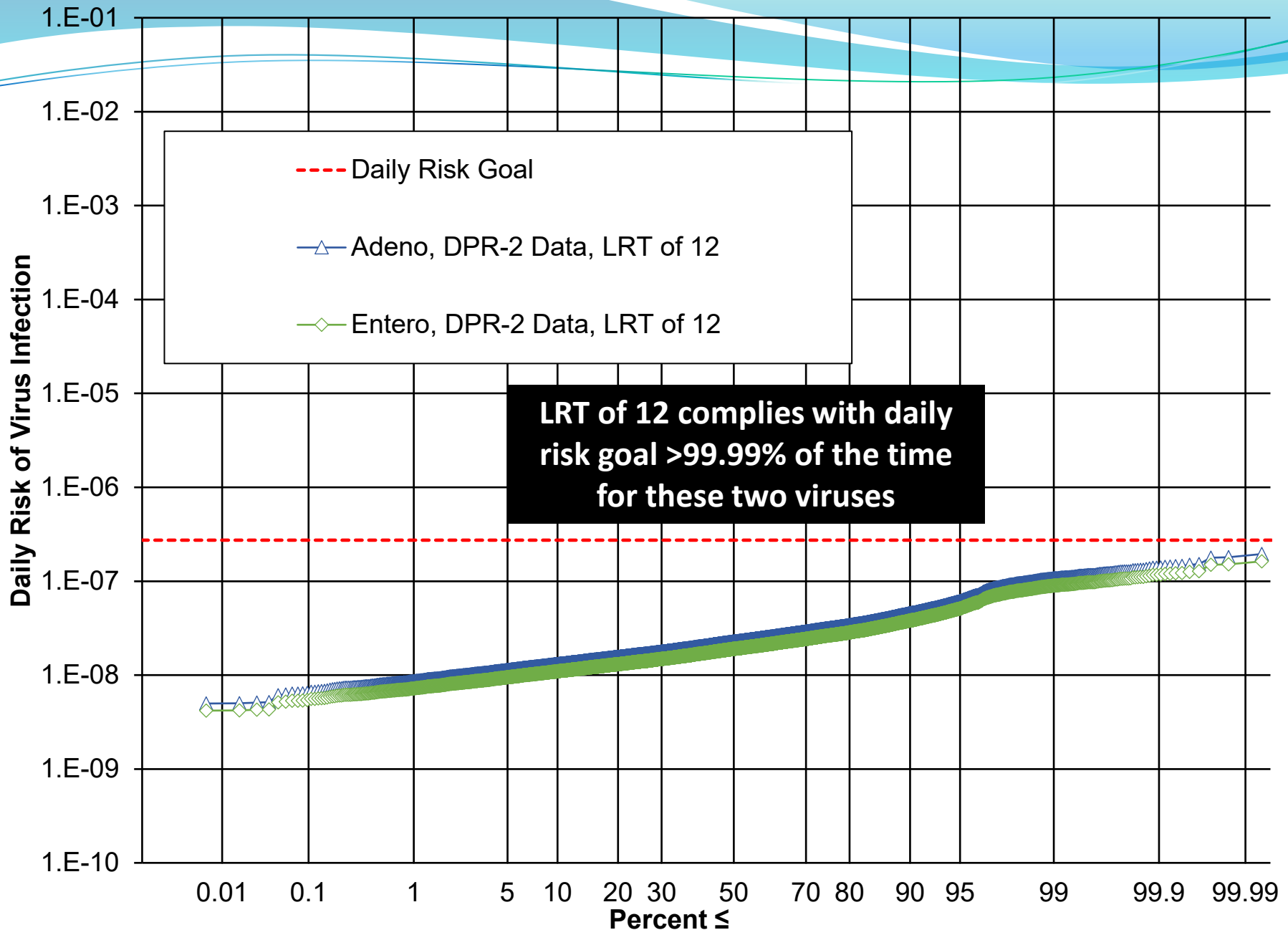
Use DPR-2 distributions from culture data

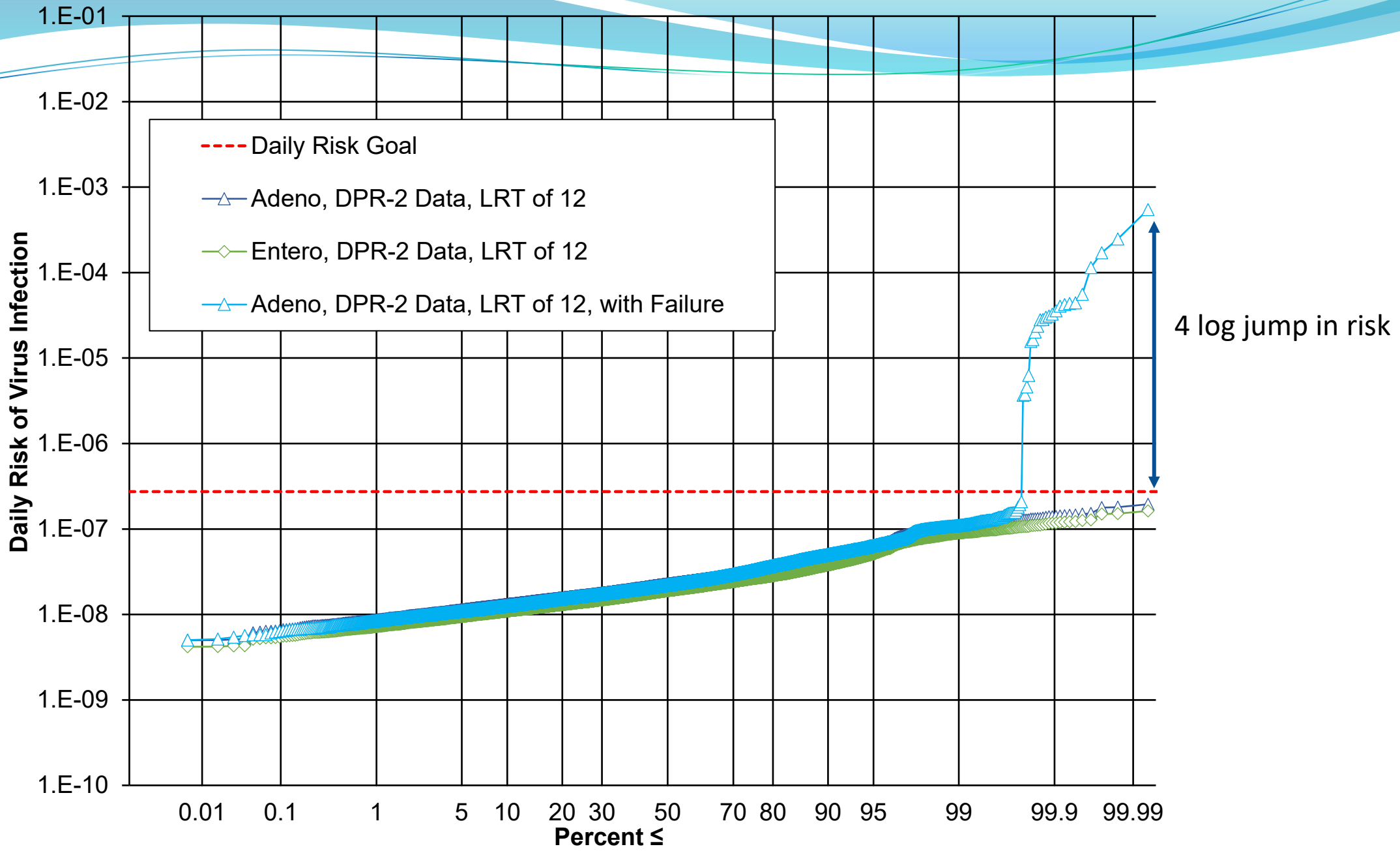
No assumptions about GC:IU

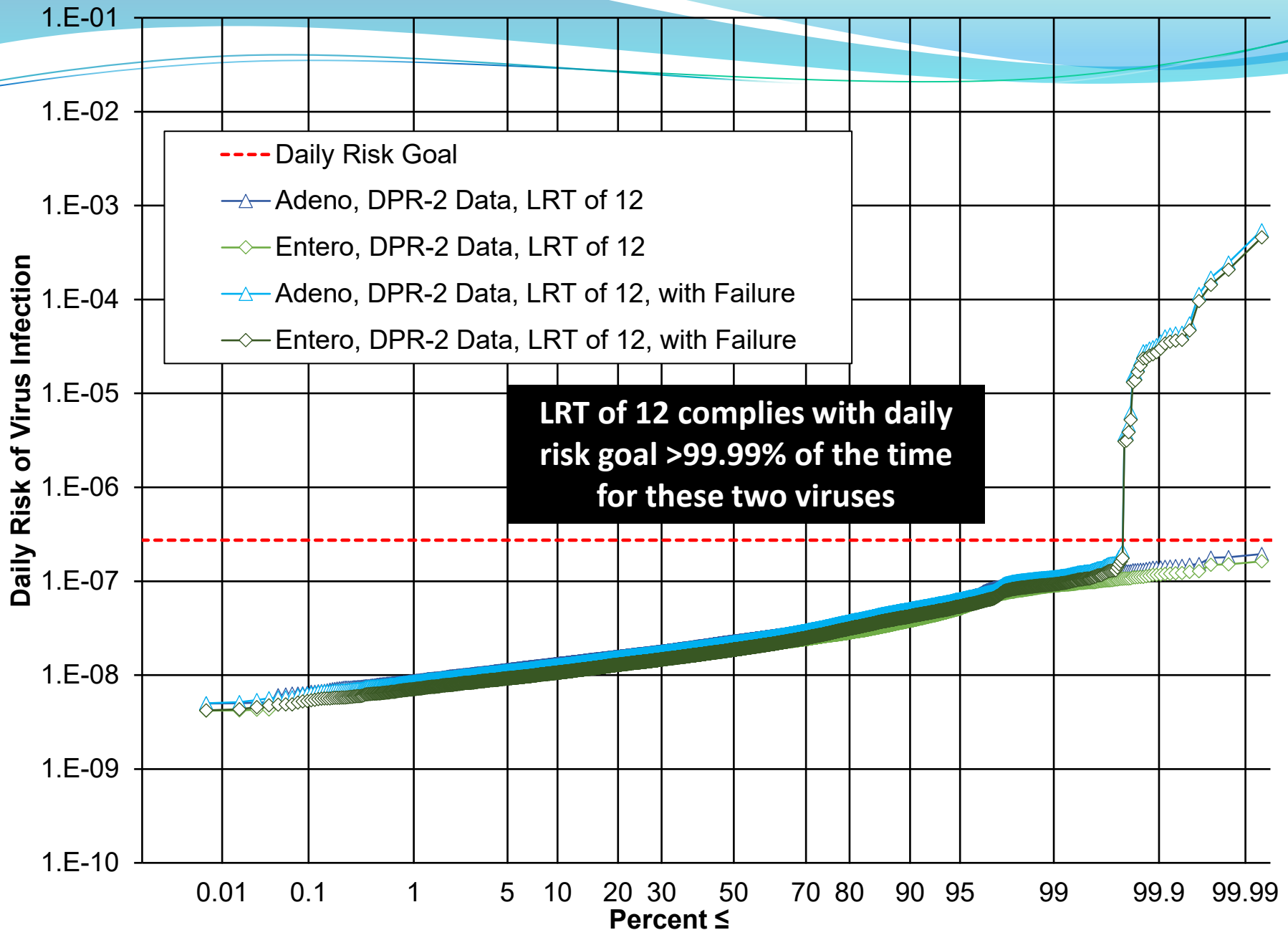
2L/day

Only one dose-response for adeno
Only one dose-response for enterovirus (rotavirus)


What if we pick LRT of 12?
Percent ≤
99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
0.1
0.01
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
LRV
Adeno DPR-2 HYP
Entero DPR-2 BP


1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
Daily Risk of Virus Infection
Daily Risk Goal
Adeno, DPR-2 Data, LRT of 12
Entero, DPR-2 Data, LRT of 12
LRT of 12 complies with daily risk goal >99.99% of the time for these two viruses
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤


1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
Daily Risk of Virus Infection
Daily Risk Goal
Adeno, DPR-2 Data, LRT of 12
Entero, DPR-2 Data, LRT of 12
Adeno, DPR-2 Data, LRT of 12, with Failure
4 log jump in risk
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤

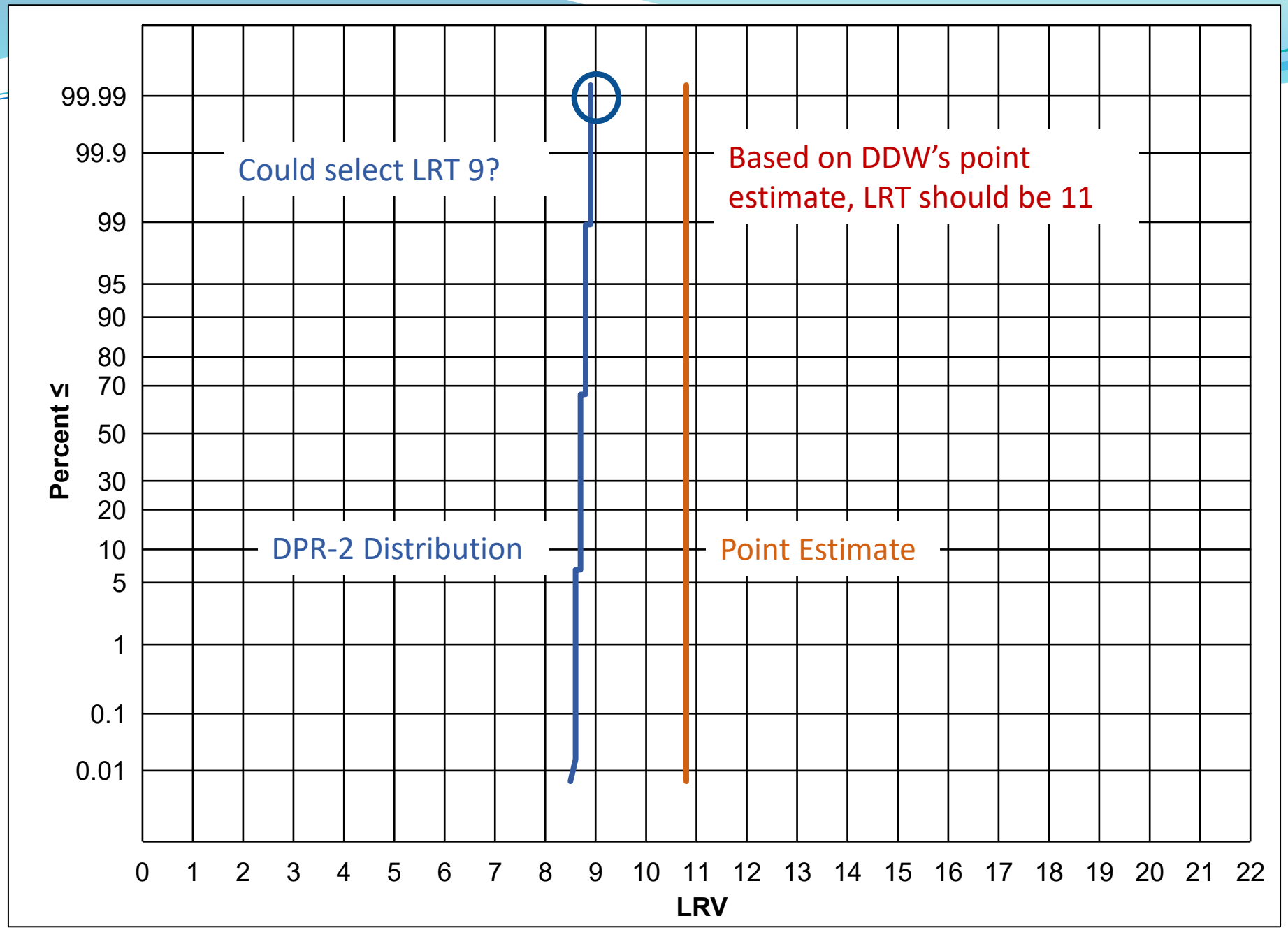

Daily Risk Goal
Adeno, DPR-2 Data, LRT of 12
Entero, DPR-2 Data, LRT of 12
Adeno, DPR-2 Data, LRT of 12, with Failure
Entero, DPR-2 Data, LRT of 12, with Failure
LRT of 12 complies with daily risk goal >99.99% of the time for these two viruses
Daily Risk of Virus Infection
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Percent ≤

Cryptosporidium

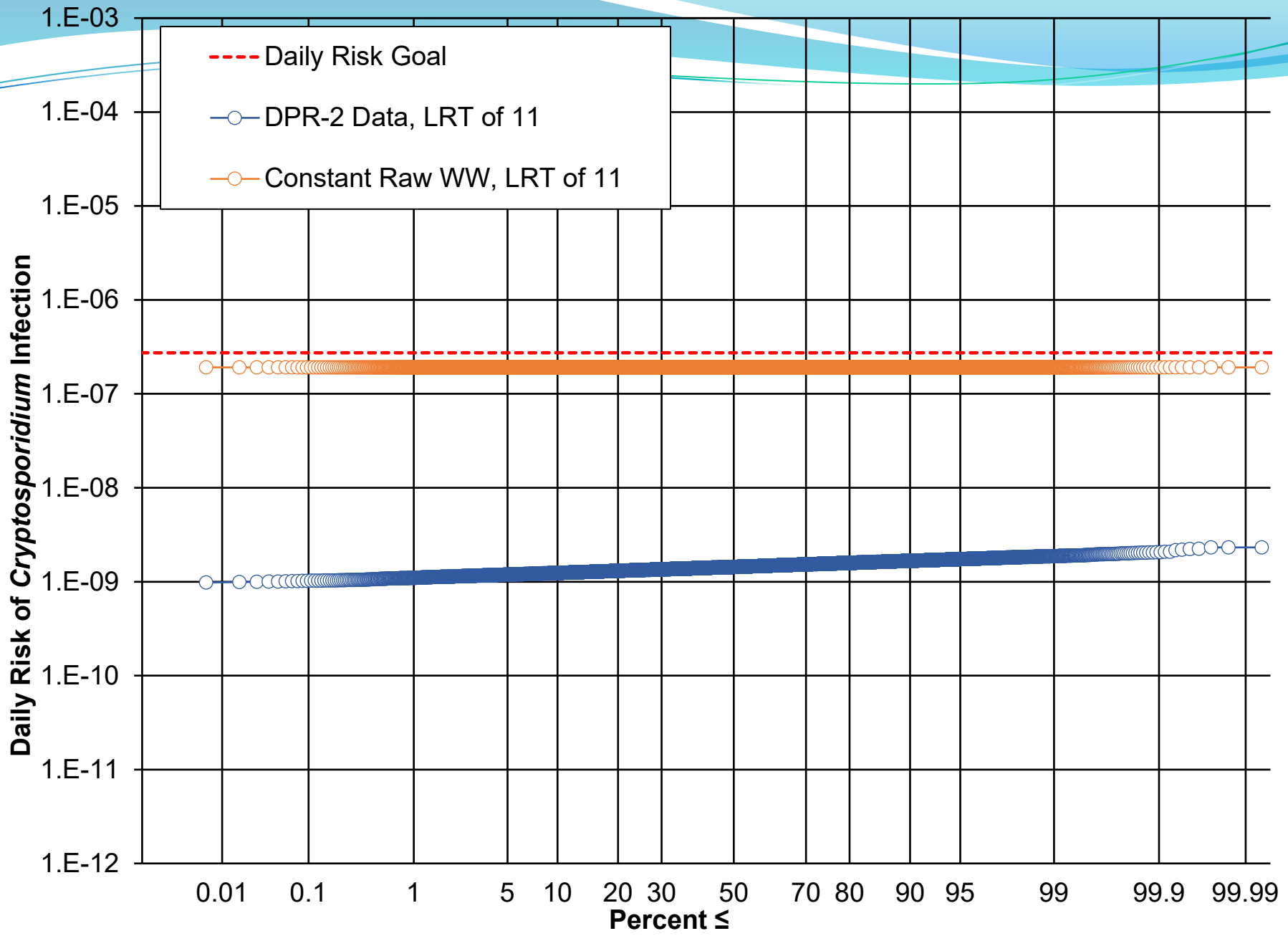
Raw Wastewater Pathogen Concentrations

- Point Estimate vs Distribution
  - DDW used point estimate of highest concentration recorded
    - 1E4 oocysts/L
  - DPR-2 data has been modeled as a lognormal distribution
    - 1.7 ± 0.4 log 10 oocysts/L
- How does this impact LRT required for compliance with daily risk?
- Let's look at the "benchmark" LRT curve and risk curves

Volume consumed = 2L/day; Dose response is fractional Poisson (unless otherwise noted)


99.99
99.9
99
95
90
80
70
50
30
20
10
5
1
0.1
0.01
Percent ≤
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
LRV
Could select LRT 9?
Based on DDW's point estimate, LRT should be 11
DPR-2 Distribution
Point Estimate

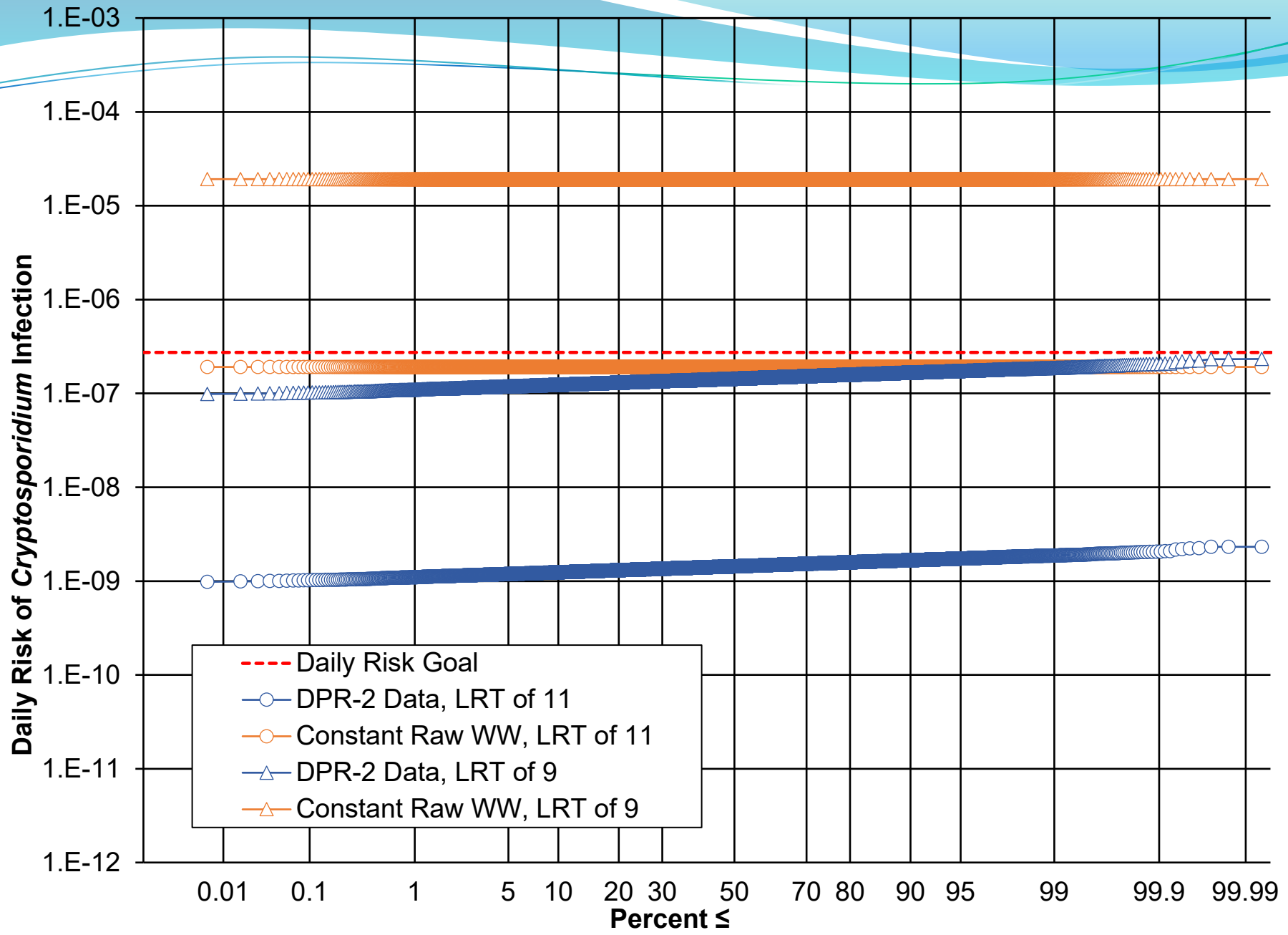
LRT 11



Point estimate
LRT 11

Distribution
LRT 11

LRT 11 vs LRT 9



Point estimate
LRT 9

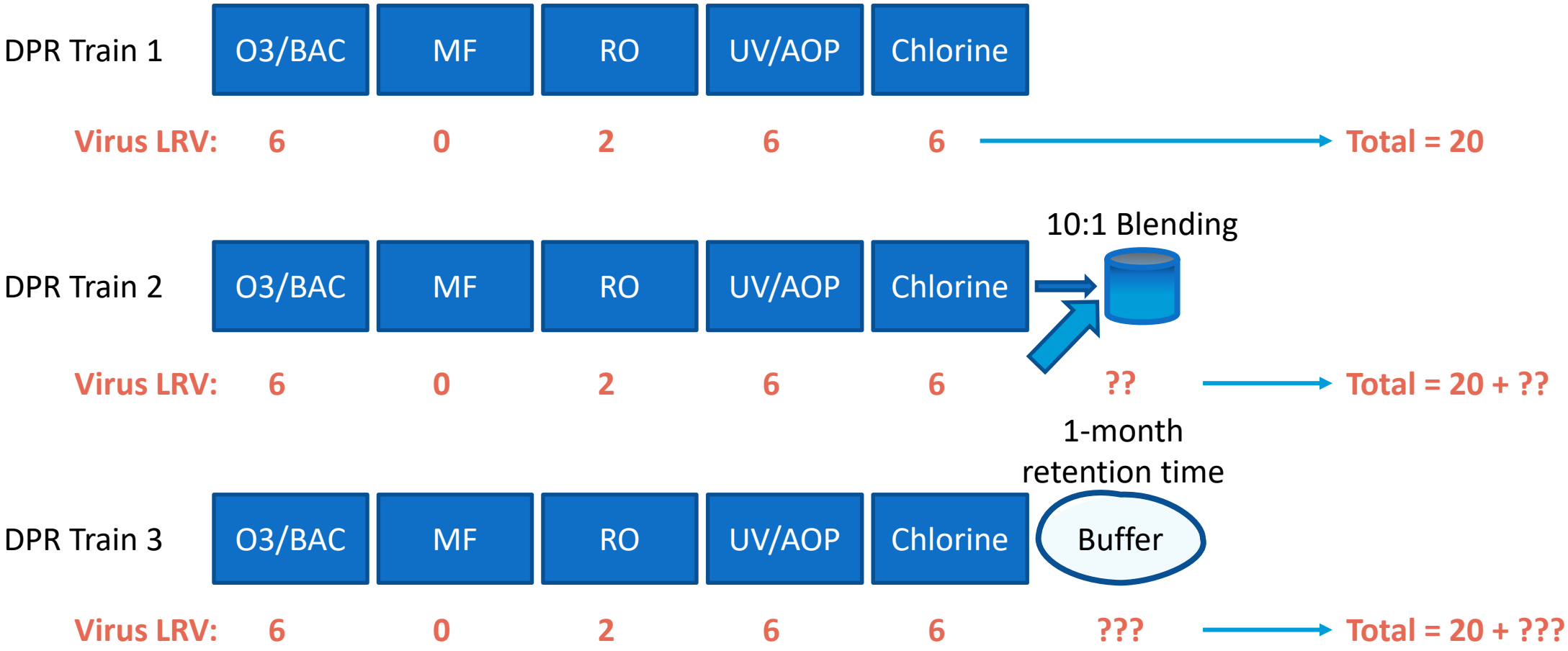
Distribution
LRT 9

Point estimate
LRT 11

Distribution
LRT 11

Management Barriers

DPRisk – Evaluate Inclusion of Different Elements



DPRisk – Evaluate Inclusion of Different Elements

DPR

DPR

DPR

Blending

Specify the log removal associated with blending. Please see Guidance Document on estimating log removals for blending.

Specify log removal for blending as:

Point estimate

Log Removal:

0

Dilution

Specify the log removal associated with dilution. Please see Guidance Document on estimating log removals for dilution.

Specify log removal for dilution as:

Point estimate

Log Removal:

0

Total = 20

10:1 Blending

??

1-month retention time

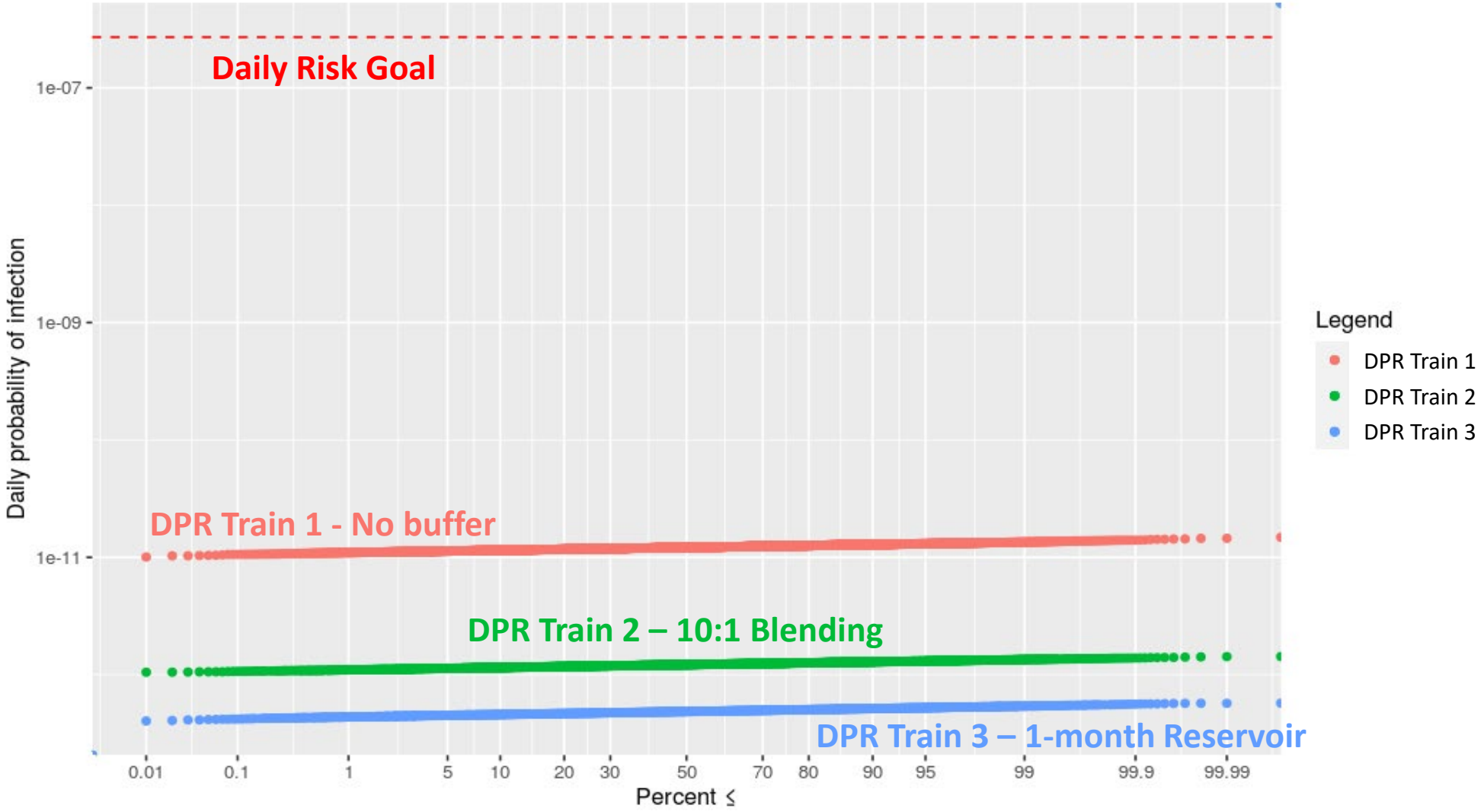
Buffer

???

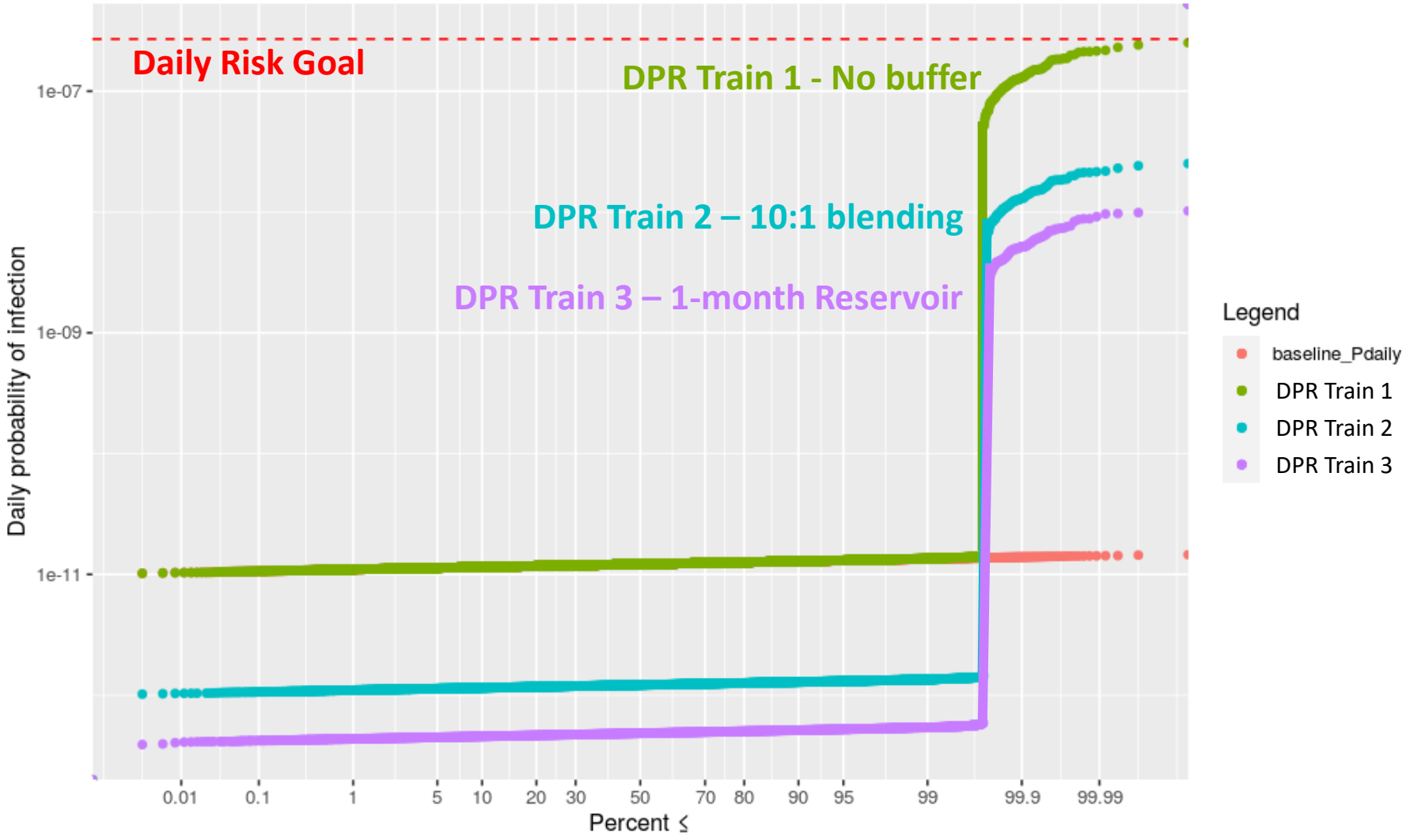
Total = 20 + ??

Total = 20 + ???

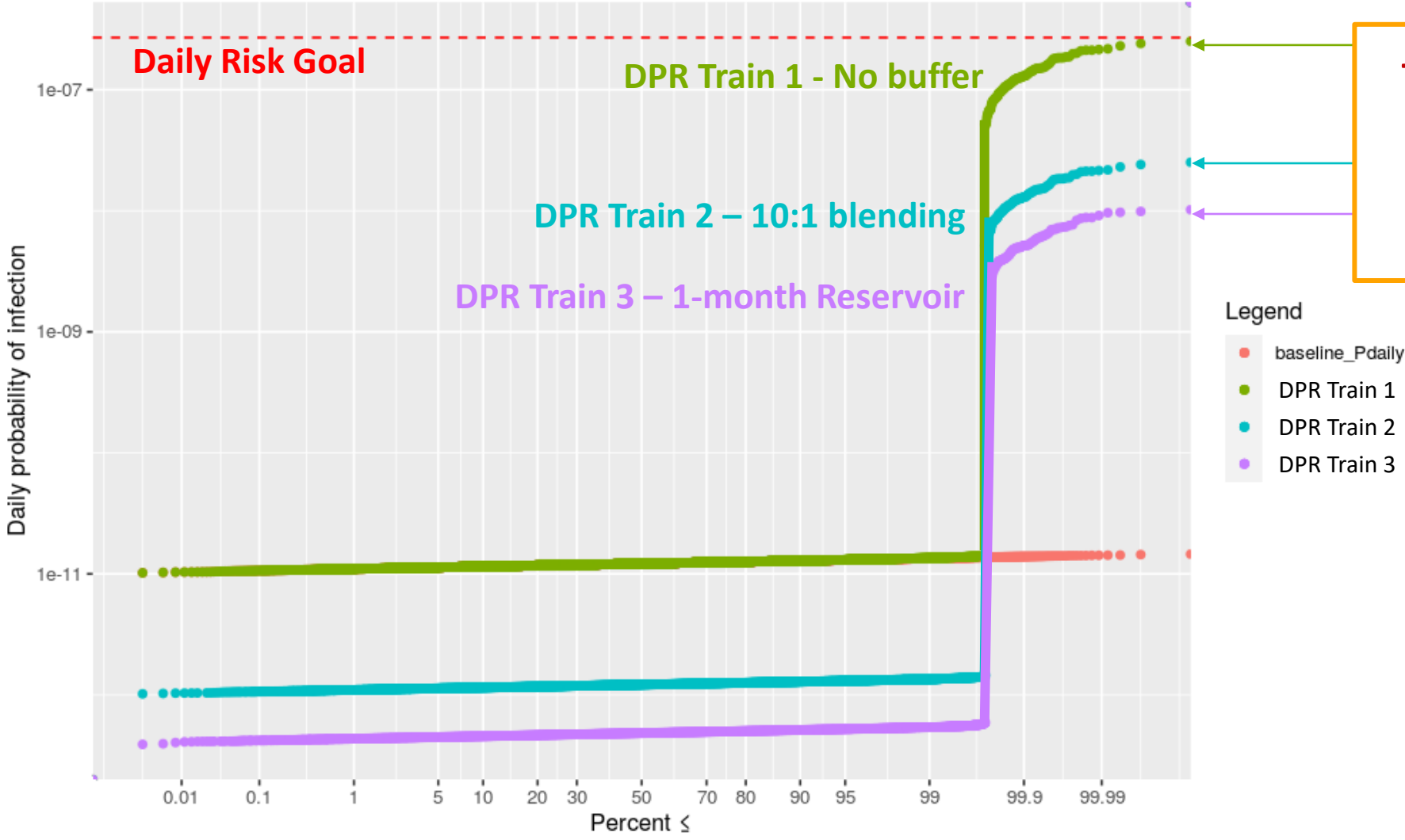
DPRisk – Risk Profiles of Projects with Different Elements



DPRisk – Risk Profiles of Projects with Failure Analysis



DPRisk – Risk Profiles of Projects with Failure Analysis



These projects have different risk profiles…

…should they have the same requirements?

Questions?