**ANALYSIS REPORT**

# Water Quality Risk Evaluation for Proposed Benchmarks/Action Levels in the Industrial Stormwater General Permit

Prepared for

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# Introduction

The Washington State Department of Ecology (Ecology) is currently working with an external stakeholder workgroup to facilitate public participation during the reissuance of the Industrial Stormwater General Permit (ISWGP). In connection with this effort, Ecology and the workgroup are evaluating a broad range of related issues related to the ISWGP, including the adequacy of permit targets (i.e., benchmarks and action levels) for industrial stormwater effluent.

To support this evaluation, Ecology requested that Herrera Environmental Consultants (Herrera) perform analyses to determine the risk of exceeding acute water quality standards given the proposed benchmarks and action levels. Because this analysis must take into account the broad range of facility types and receiving waters that would be covered under the ISWGP, compliance with water quality standards cannot be evaluated based solely on site-specific information. Therefore, this analysis utilized simple dilution models to evaluate the potential for exceeding water quality standards given the following model inputs: representative receiving water data for western and eastern Washington, representative dilution factors, and the proposed permit targets.

To provide some basis for assessing uncertainty in these analyses, a Monte Carlo simulation was employed in running the dilution models to determine the probability of exceeding water quality standards based on the receiving water conditions having the highest potential for occurrence. This methodology was adapted from similar analyses that were performed by Herrera in association with the “6415 report” (EnviroVision and Herrera 2006) that examined an alternative suite of proposed benchmarks and action levels. The analyses presented herein focus solely on copper, lead, and zinc because these are the primary parameters of concern with regard to the ISWGP and there are relevant water quality criteria for each metal.

A detailed description of the methods used for these analyses is provided below, followed by the results of this assessment for western and eastern Wasington.

# Data Analysis Methods

This analysis utilized a simple spreadsheet dilution model with the following equation to evaluate the risk of exceeding acute water quality standards given the proposed benchmarks and action levels for copper, lead, and zinc, and different levels of dilution within the receiving water:

$$C_r = (1/F_d \times C_f) + ([1 - 1/F_d] \times C_b)$$

where:
$C_r$ = receiving water concentration at facility point of discharge
$F_d$ = dilution factor
$C_f$ = effluent concentration
$C_b$ = receiving water background concentration.

Separate analyses were performed using representative receiving water background concentrations ($C_b$) for western and eastern Washington and dilution factors ($F_d$) of 1, 5, and 10. The predicted receiving water concentration from the dilution model at the facility point of discharge ($C_r$) was subsequently compared to the applicable water quality standard to determine if the proposed benchmark or action level is protective of water quality at a given dilution factor.

Monte Carlo simulation was incorporated into the spreadsheet model in order to quantify uncertainty in the analyses that may arise from the following variables:

- Receiving water background concentrations
- Translator values for estimating dissolved metals concentrations from total metals concentrations
- Hardness dependent water quality standards for metals.

In order to perform the Monte Carlo simulation, the Crystal Ball® software package was used to generate theoretical probability distributions for these variables. These probability distributions were then used to derive input data for each variable during 5,000 iterations of the dilution model. The receiving water dilution factor ($F_d$) and effluent concentration ($C_f$) were each held as constants during these iterations. The risk of exceeding the state water quality standard for a given combination of dilution factors and effluent concentrations was subsequently determined based on the number (percentage) of these iterations where the predicted receiving water concentration at the facility point of discharge ($C_r$) exceeded the predicted hardness-dependent water quality standard. These model runs were performed across a range of potential effluent concentrations in order to generate “risk curves” that show the probability of exceeding water quality standards as a function of the effluent concentration. A separate series of curves were developed for dilution factors of 1, 5, and 10, respectively.

The following subsections describe in more detail the procedures that were used to generate theoretical probability distributions for the variables identified above.

## Receiving Water Background Concentrations

Theoretical probability distributions for background receiving water concentrations were derived based on data obtained from Ecology’s Environmental Information Management (EIM) database (Ecology 2008). Separate queries of the EIM database were performed to obtain data for dissolved copper, dissolved lead, and dissolved zinc from stream and river systems in eastern and western Washington. The specific search criteria that were used in connection with these queries are documented in Appendix A.

Because these data were meant to represent generalized water quality conditions in each of the two regions, data obtained from the initial query were screened to include only sample concentrations obtained from ambient monitoring programs and to exclude concentrations from focused studies of known water quality problems (e.g., mine remediations, Total Maximum Daily Loads, contaminated site investigations). Data were classified into one of these two categories based on an examination of descriptive information that is provided in the "Study_Name" and "Study_Type" fields within the EIM database. Where information obtained from these fields was too ambiguous to make a definitive classification either way, attempts were made to obtain more detailed information on specific studies through on-line searches. Appendix B documents the specific studies from the original EIM database query that were identified as ambient monitoring programs through this process. The data from these studies were subsequently utilized for analyses related to this effort.

Summary statistics derived from these data are provided in Table 1 for eastern and western Washington. Due to the relatively large number of non-detected values (i.e., censored values) in the datasets for each of the three target metals, these summary statistics were calculated using regression on order statistics (ROS) where applicable. ROS develops probability plotting positions for each data point (censored and uncensored) based on the ordering of the data (CALTRANS 2001; Helsel 1990; Shumway and Azari 2000). A least squares line is then fit by regressing the log transformed concentrations to the uncensored probability plotting positions. The censored data points are assigned concentrations for calculating summary statistics based on their probability plotting positions and the regression line equation. Summary statistics are then calculated based on the uncensored data points and the "filled-in" censored values.

The mean and standard deviation for dissolved copper, dissolved lead, and dissolved zinc in Table 1 were subsequently used as input for the Crystal Ball® software package to derive theoretical log-normal distributions for each metal. Graphical representations of these distributions are provided in Appendix C for each metal in eastern and western Washington. These distributions were then used to generate input data for receiving water background concentrations ($C_b$) in the dilution model described above, during the Monte Carlo simulations.

### Translator Values

Federal guidelines require benchmarks and action levels identified in the ISWGP for copper, lead, and zinc to be expressed as "total recoverable metals". However, state water quality standards are based on the dissolved fractions of these metals. Therefore, in order to facilitate comparisons to these standards, a "translator value" must be used to estimate the dissolve fraction that would be present in the receiving water for effluent concentrations ($C_f$) that are expressed as total recoverable metals.

In this analysis, these conversions were made using translator values that were derived from guidance presented by Pelletier (1996). Because these translator values vary depending on the total suspended solids concentration in the receiving water, the EIM database was again queried to obtain representative data for this parameter from stream and river systems in eastern and western Washington. The specific search criteria that were used in connection with these queries are documented in Appendix A. As described in the previous subsection, the data obtained from the initial query were screened to include only sample concentrations obtained from ambient

**Table 1. Summary statistics for data obtained from the Environmental Information Management database to characterize receiving water background concentrations of dissolved copper, dissolved lead, and dissolved zinc in eastern and western Washington.**

| | Dissolved Copper | | Dissolved Lead | | Dissolved Zinc | |
|---|---|---|---|---|---|---|
| | Western Washington | Eastern Washington | Western Washington | Eastern Washington | Western Washington | Eastern Washington |
| n | **833** | **353** | **681** | **346** | **828** | **353** |
| Percent detected | **71.7%** | **99.2%** | **36.6%** | **61.8%** | **62.2%** | **86.4%** |
| Mean (µg/L) | 1.01 | 0.94 | 0.06 | 0.19 | 3.36 | 13.9 |
| Standard Deviation (µg/L) | 1.43 | 5.27 | 0.18 | 0.88 | 6.70 | 25.4 |
| Coefficient of Variation | 1.42 | 5.59 | 2.72 | 4.58 | 2.00 | 1.83 |
| Lower 95% Confidence Limit about Mean (µg/L) | 0.91 | 0.39 | 0.05 | 0.10 | 2.90 | 11.25 |
| Upper 95% Confidence Limit about Mean (µg/L) | 1.10 | 1.49 | 0.08 | 0.29 | 3.81 | 16.55 |
| 25th percentile (µg/L) | 0.35 | 0.44 | 0.01 | 0.01 | 0.50 | 0.95 |
| Median (µg/L) | 0.65 | 0.65 | 0.02 | 0.03 | 1.28 | 3.02 |
| 75th percentile (µg/L) | 1.19 | 0.96 | 0.06 | 0.11 | 3.27 | 9.63 |
| Inter Quartile Range (µg/L) | 0.84 | 0.53 | 0.05 | 0.10 | 2.77 | 8.69 |
| Minimum Detected Value (µg/L) | **0.10** | **0.07** | **0.01** | **0.02** | **0.17** | **0.26** |
| Maximum Detected Value (µg/L) | **17.0** | **71.6** | **3.00** | **12.6** | **57.0** | **124** |
| Minimum Reporting Limit (µg/L) | **0.05** | **0.05** | **0.02** | **0.01** | **0.03** | **0.40** |
| Maximum Reporting Limit (µg/L) | **5.00** | **0.50** | **1.00** | **0.10** | **5.00** | **5.00** |

**Bold** values are exact calculations. Unbolded values are estimated using regression on ordered statistics (ROS).
ROS statistics calculated using the CALTRANS (2001) data analysis tool (DAT).
µg/L: micrograms per liter

monitoring programs. Appendix B documents the specific studies that were identified through this process. The data from these studies were subsequently utilized for analyses related to this effort. Summary statistics derived from these data are provided in Table 2 for eastern and western Washington.

**Table 2. Summary statistics for data obtained from the Environmental Information Management database to characterize receiving water total suspended solids concentrations in eastern and western Washington.**

| | Total Suspended Solids | |
|---|---|---|
| | **Western Washington** | **Eastern Washington** |
| n | 29,631 | 31,811 |
| Mean (mg/L) | 34.4 | 49.1 |
| Standard Deviation (mg/L) | 295.1 | 383.2 |
| Coefficient of Variation | 8.6 | 7.8 |
| Lower 95% Confidence Limit about Mean (mg/L) | 31.0 | 44.9 |
| Upper 95% Confidence Limit about Mean (mg/L) | 37.7 | 53.3 |
| 25th percentile (mg/L) | 2.0 | 3.0 |
| Median (mg/L) | 5.0 | 7.0 |
| 75th percentile (mg/L) | 13.0 | 21.0 |
| Inter Quartile Range (mg/l) | 11.0 | 18.0 |

mg/L: milligrams per liter

The Crystal Ball® software package was then used to fit theoretical probability distributions to these data. Results from these analyses indicated the total suspended solids data from both eastern and western Washington were fit best by a gamma distribution. Graphical representations of these distributions are provided in Appendix C for eastern and western Washington. These distributions were then used to generate input data for estimating the dissolved fraction that would be present in the receiving water during Monte Carlo simulations given effluent concentrations ($C_f$) that are expressed as total recoverable metals. Probability plots for the actual translator values that were used in the calculations are provided in Appendix D.

## Hardness Dependant Numeric Criteria for Metals

As described above, predicted receiving water concentrations at the facility point of discharge ($C_r$) were compared to applicable water quality standards to determine if a proposed benchmark or action level is protective. Because state water quality standards for zinc, copper, and lead vary with the hardness of the receiving water, the EIM database was again queried to obtain representative data for this parameter from rivers systems in eastern and western Washington. The specific search criteria that were used in connection with these queries are documented in Appendix A. As described in the previous two subsections, the data obtained from the initial query were screened to include only sample concentrations obtained from ambient monitoring programs. Appendix B documents the specific studies that were identified through this process. The data from these studies were subsequently extracted for analyses related to this effort. Summary statistics derived from these data are provided in Table 3 for eastern and western Washington.

**Table 3. Summary statistics for data obtained from the Environmental Information Management database to characterize receiving water hardness concentrations in eastern and western Washington.**

| | Hardness | |
|---|---|---|
| | **Western Washington** | **Eastern Washington** |
| n | 8,983 | 7,670 |
| Mean (mg/L) | 32.8 | 82.8 |
| Standard Deviation (mg/L) | 30.8 | 199.0 |
| Coefficient of Variation | 0.9 | 2.4 |
| Lower 95% Confidence Limit about Mean (mg/L) | 32.2 | 78.4 |
| Upper 95% Confidence Limit about Mean (mg/L) | 33.4 | 87.3 |
| 25th percentile (mg/L) | 18.0 | 35.0 |
| Median (mg/L) | 25.6 | 68.0 |
| 75th percentile (mg/L) | 38.0 | 100.0 |
| Inter Quartile Range (mg/l) | 20.0 | 65.0 |

mg/L: milligrams per liter

The Crystal Ball® software package was then used to fit theoretical probability distributions to these data. Results from these analyses indicated the hardness data from eastern Washington were fit best by a gamma distribution, whereas the data from western Washington were fit best by a log-normal distribution. Graphical representations of these distributions are provided in Appendix C for eastern and western Washington. These distributions were then used to estimate state water quality standards during Monte Carlo simulations for comparisons to predicted receiving water concentrations at the facility point of discharge ($C_r$).

## Analysis Results

Results from this analysis are summarized in Figures 1 through 3 for copper, Figures 4 through 6 for lead, and Figures 7 through 9 for zinc. Each figure presents the risk curves described previously that show the probability of exceeding water quality standards as a function of effluent concentration given one of three dilution factors (i.e., 1, 5, or 10). Separate curves are presented in each figure with the results for eastern and western Washington.

The actual risk level that is deemed acceptable for exceeding water quality standards is a policy issue that must be resolved by Ecology with input from other stakeholders associated with the ISWGP. In connection with ongoing discussions between Ecology and the external stakeholder workgroup, proposed benchmarks and action levels are being considered based on a dilution factor of 5, and a 10 percent risk threshold for exceeding the applicable water quality standard for each metal. The approximate effluent concentrations for each metal that meet these criteria are summarized in Table 4 for eastern and western Washington. For reference, the 10 percent risk threshold for exceedence of the applicable water quality standard is also shown in Figures 1 through 9.

**Table 4. Effluent concentrations for each metal corresponding to a 10 percent risk for exceeding the applicable water quality standard given a dilution factor of 5.**

| Parameter | Effluent Concentration (µg/L) | Probability of Exceeding Acute Water Quality Standard (%) | | |
|---|---|---|---|---|
| | | Dilution Factor = 1 | Dilution Factor = 5 | Dilution Factor = 10 |
| Copper, total | Western WA: 14 | 52.61 | 9.86 | 5.73 |
| | Eastern WA: 32 | 52.50 | 9.66 | 4.27 |
| Lead, total | Western WA: 310 | 90.07 | 10.22 | 0.80 |
| | Eastern WA: 640 | 74.27 | 10.38 | 2.49 |
| Zinc, total | Western WA: 200 | 85.68 | 9.77 | 2.67 |
| | Eastern WA: 255 | 55.56 | 10.17 | 5.36 |

µg/L: micrograms per liter

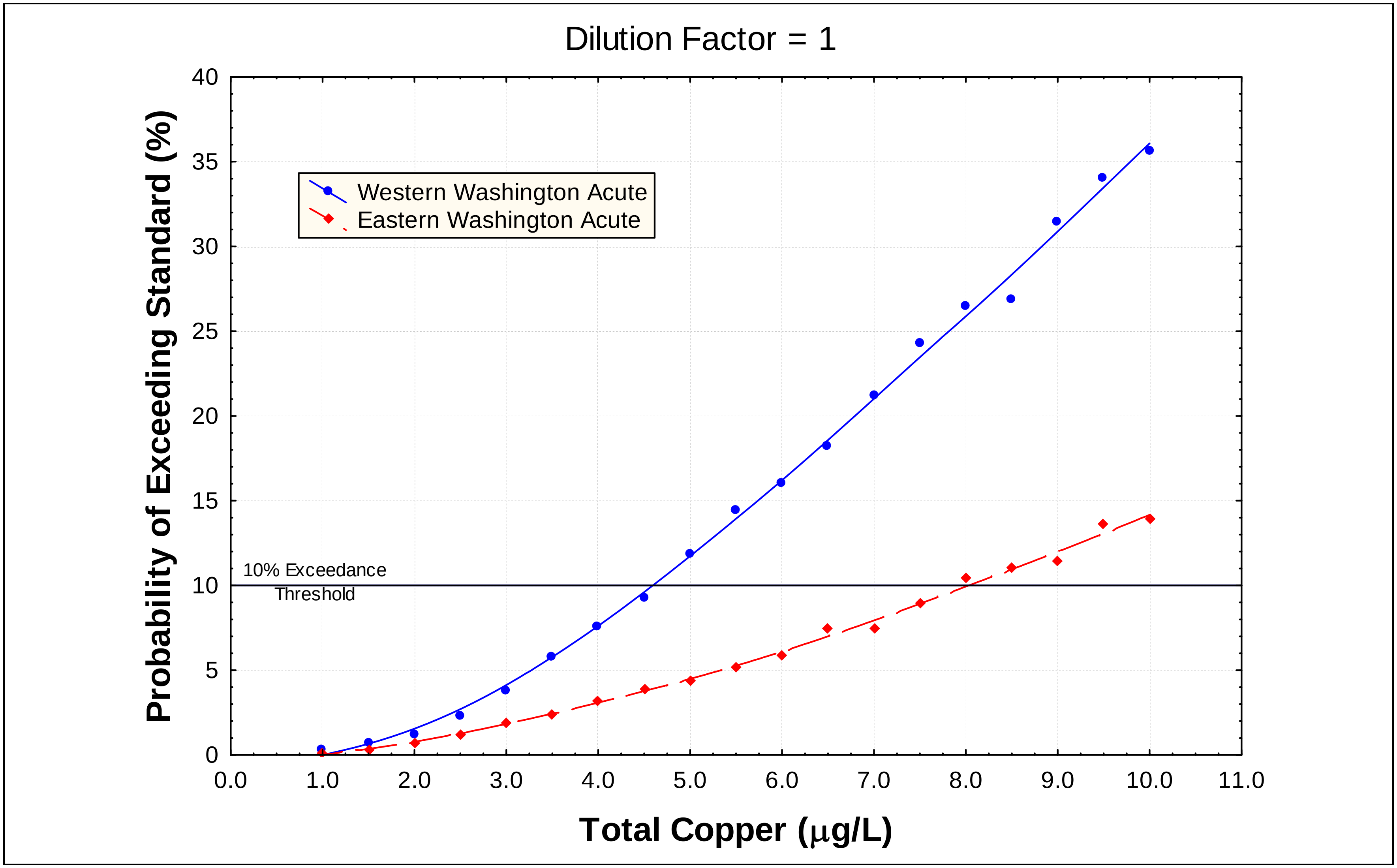


**Figure 1. Risk curve for copper showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 1.**

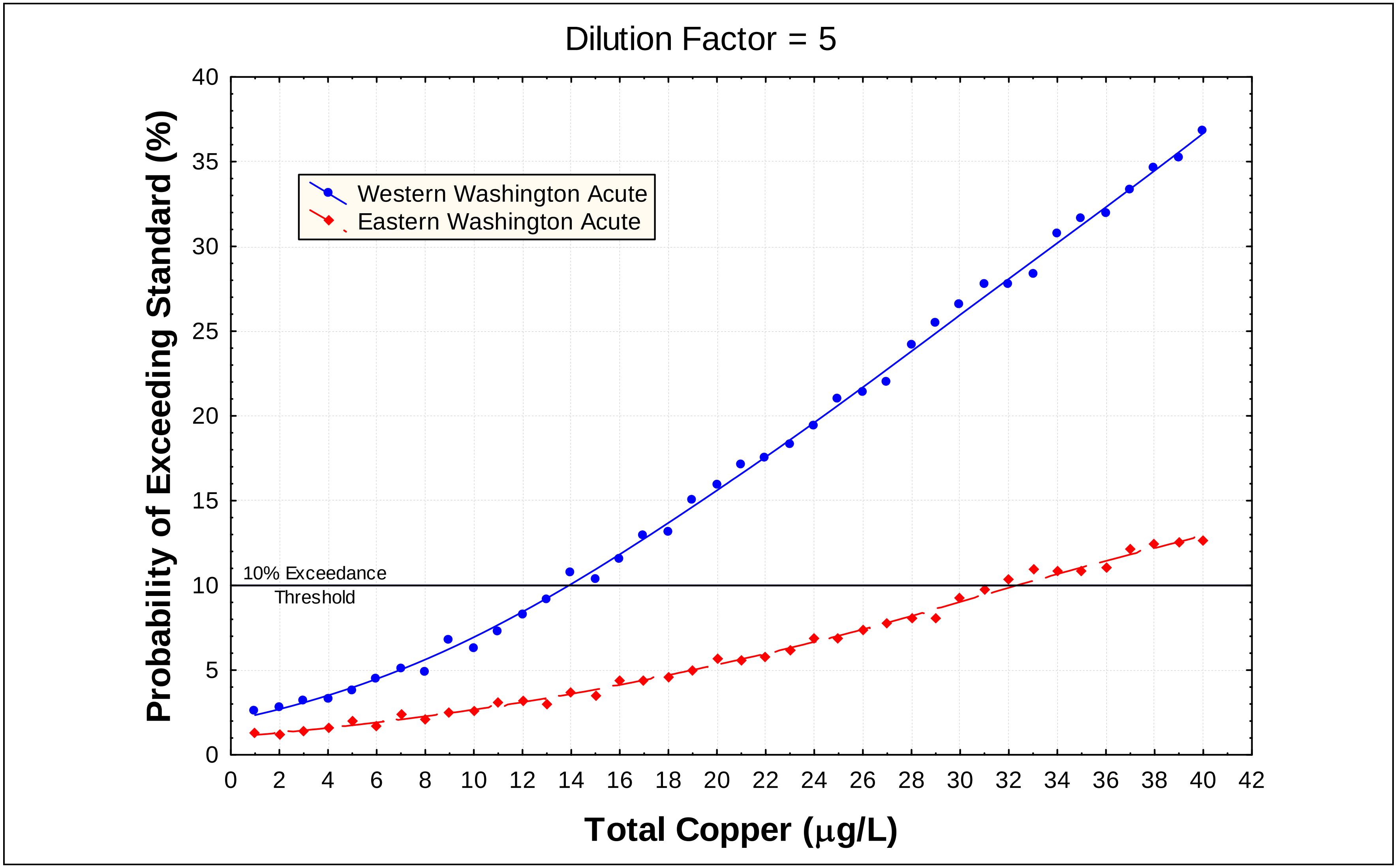


**Figure 2. Risk curve for copper showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 5.**

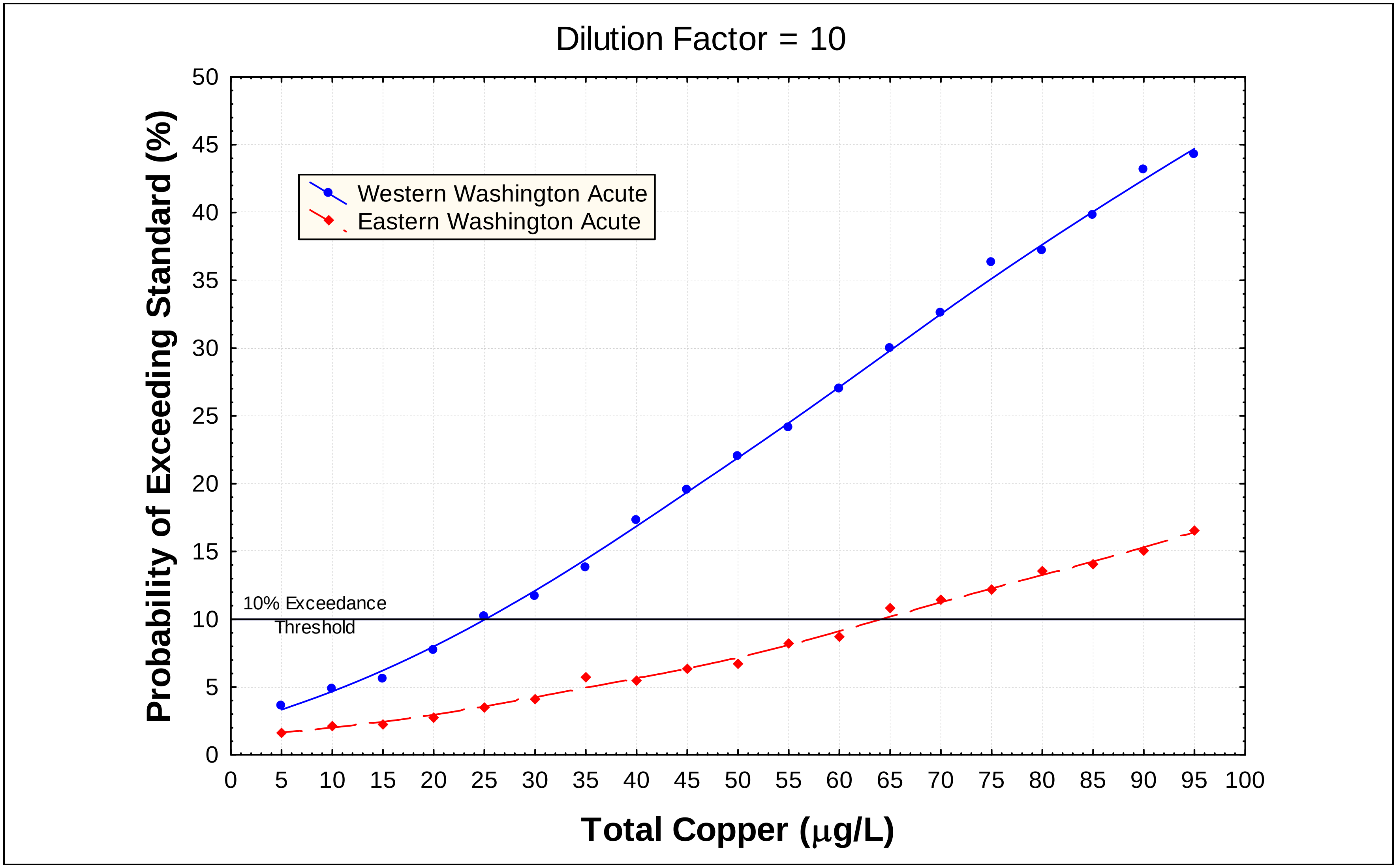


**Figure 3. Risk curve for copper showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 10.**

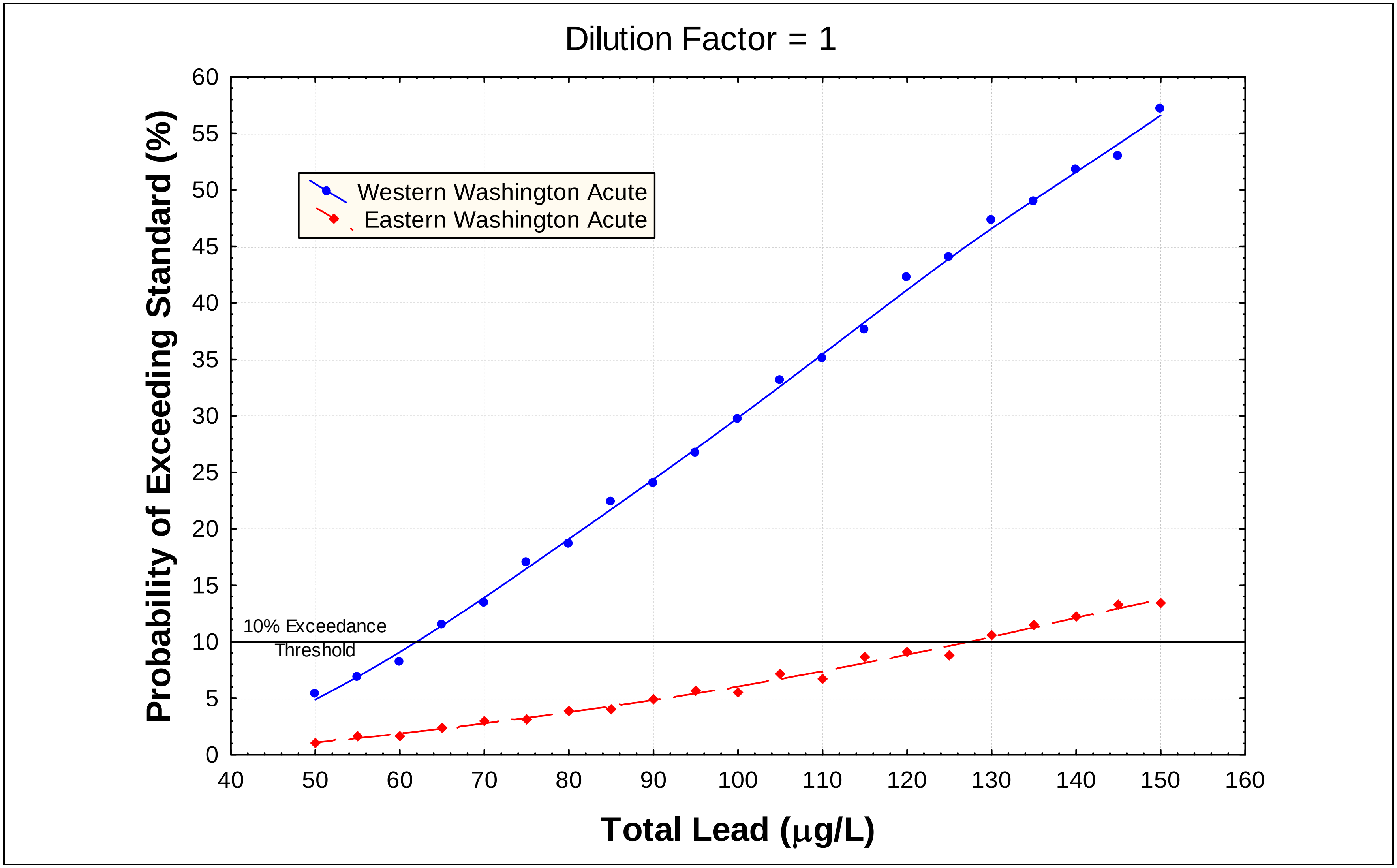


**Figure 4. Risk curve for lead showing the probability of exceeding the applicable water quality standard as a function of effluent `concentration given a dilution factor of 1.**

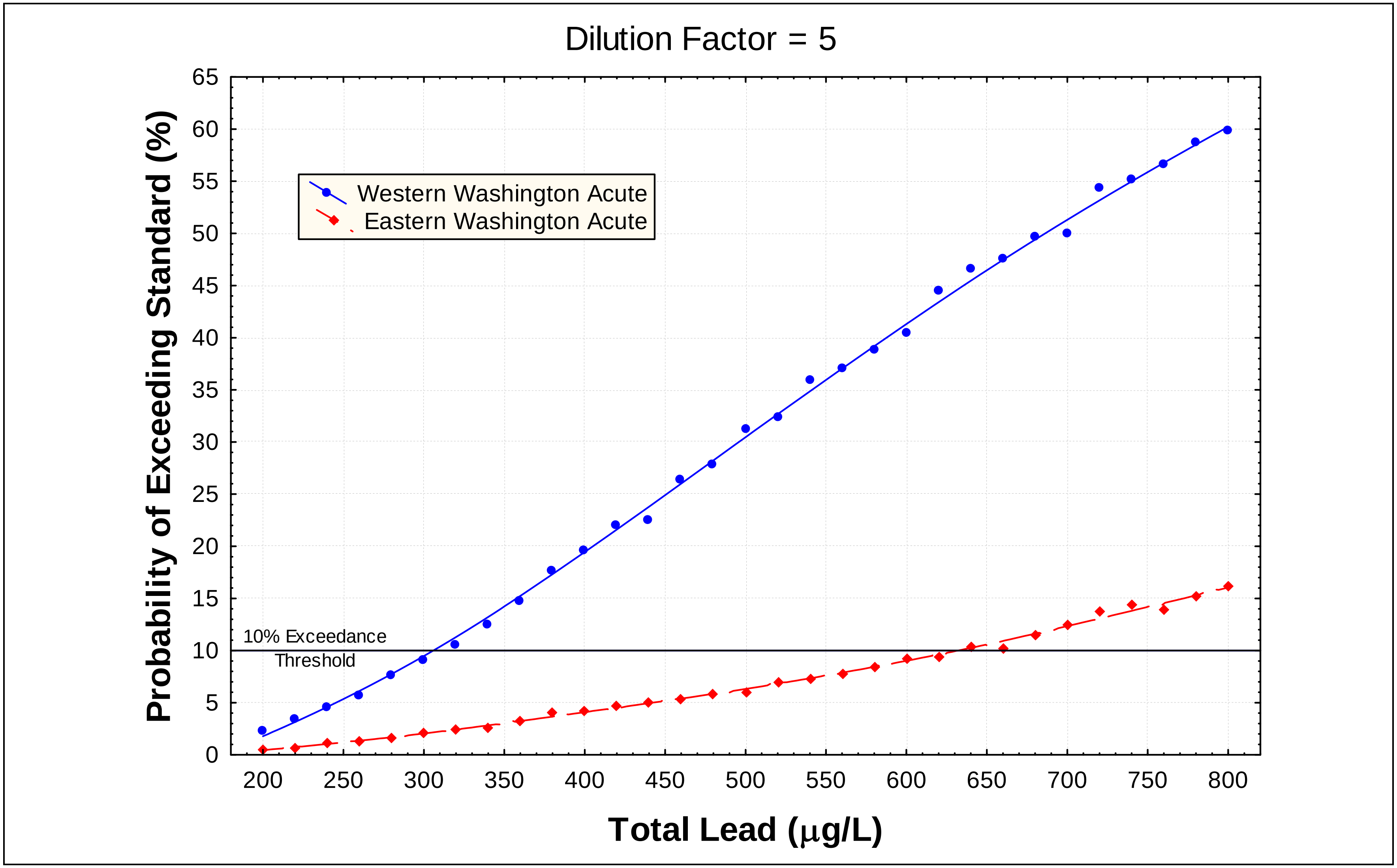


**Figure 5. Risk curve for lead showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 5.**

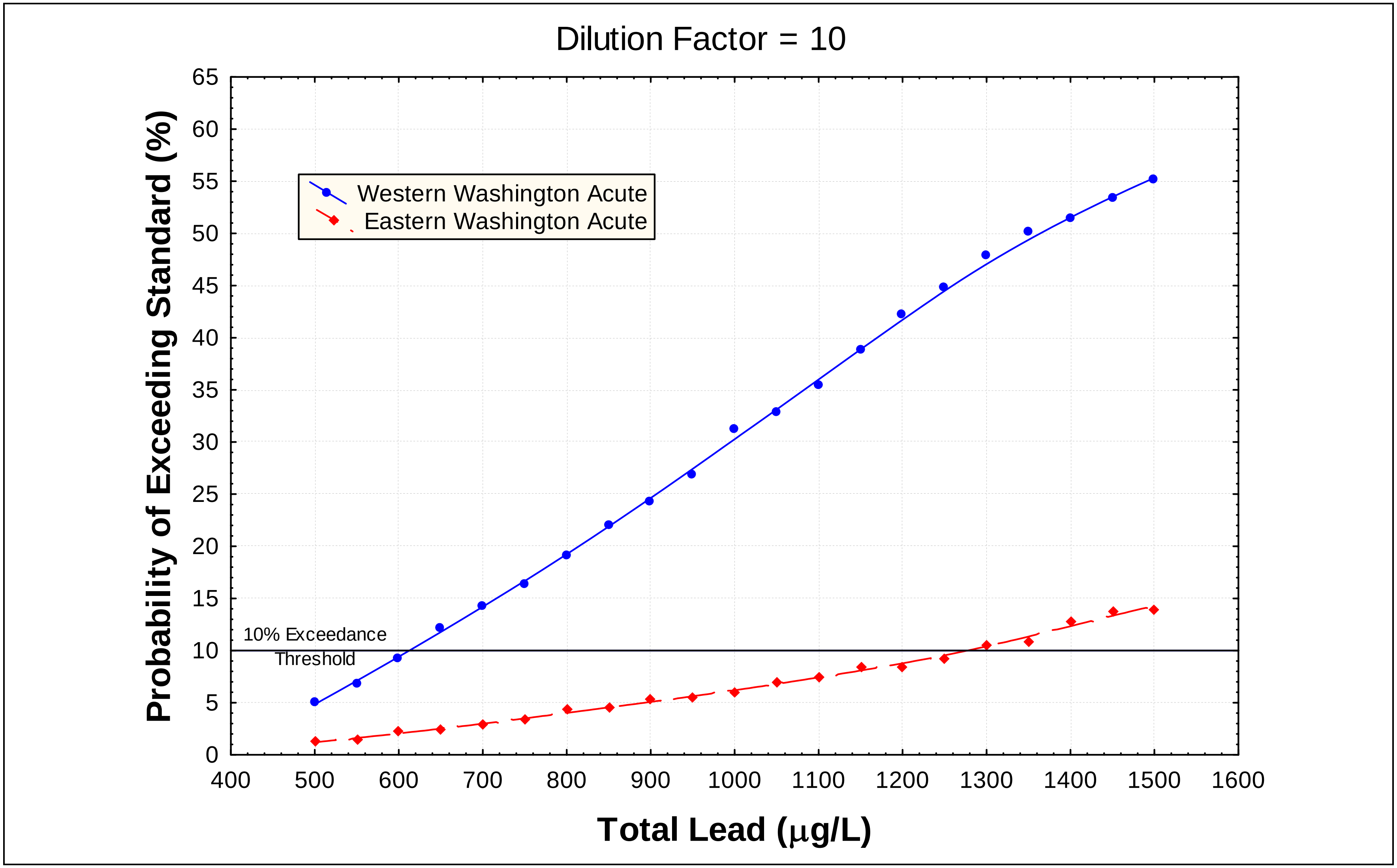


**Figure 6. Risk curve for lead showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 10.**

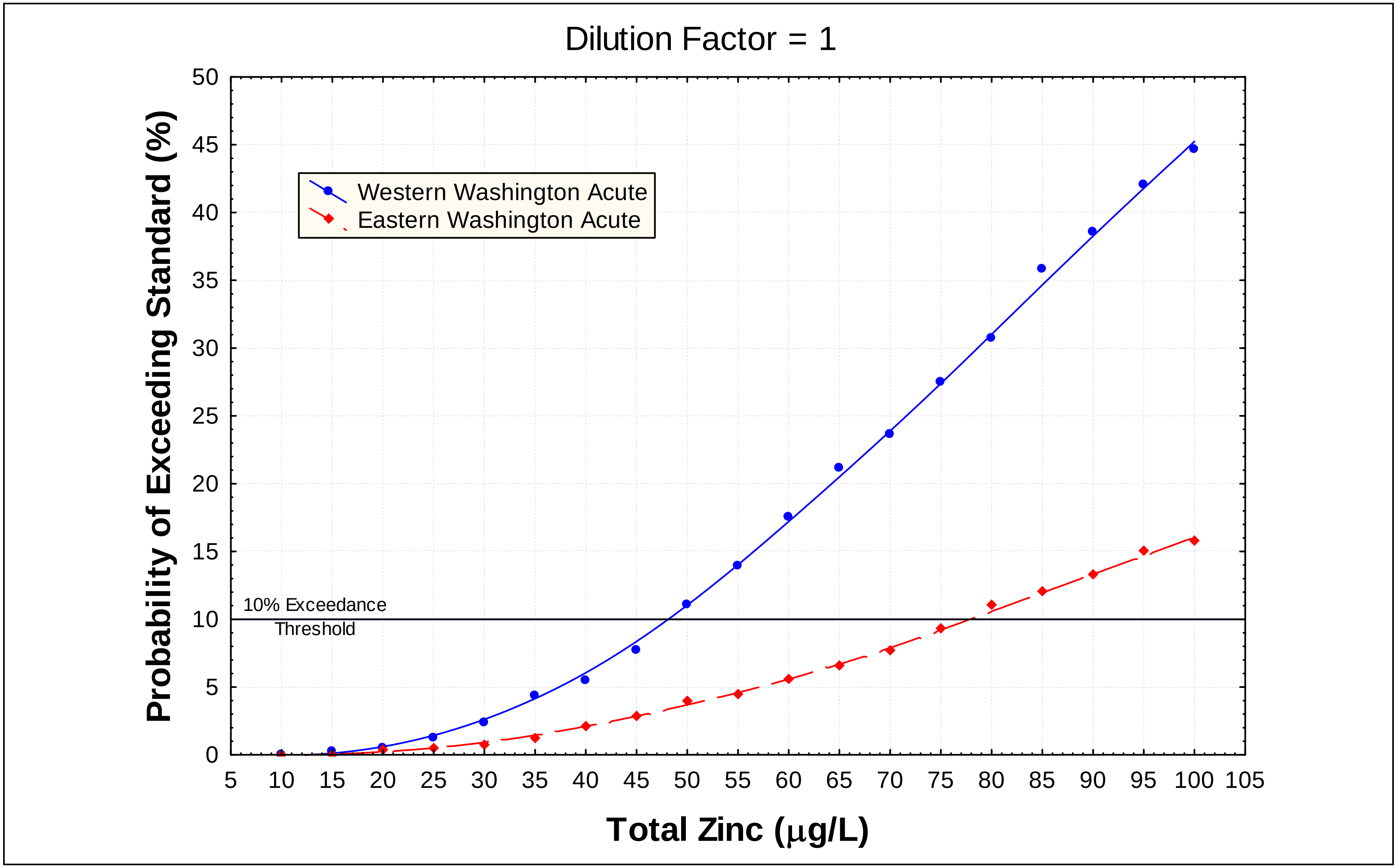


**Figure 7. Risk curve for zinc showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 1.**

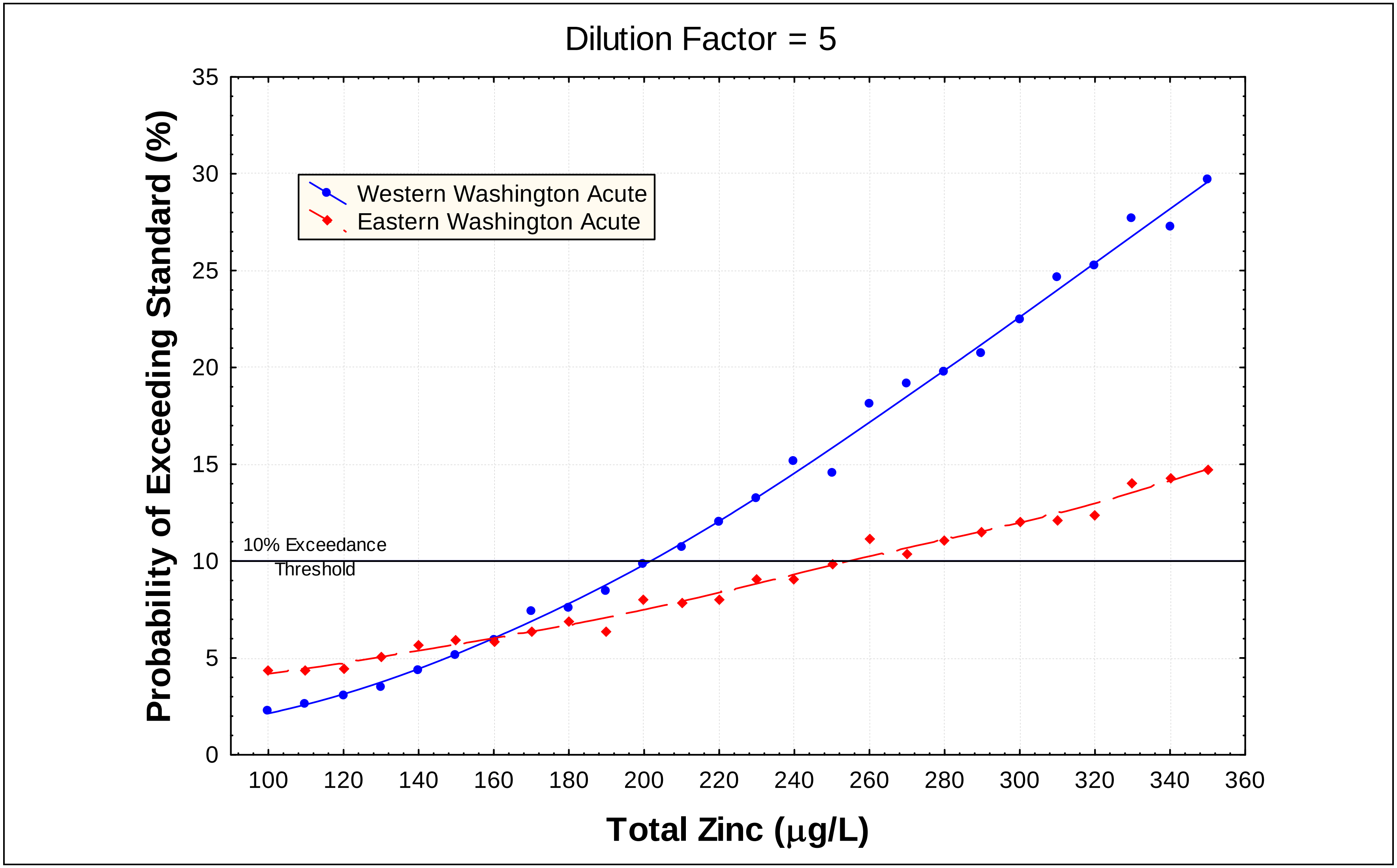


**Figure 8. Risk curve for zinc showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 5.**

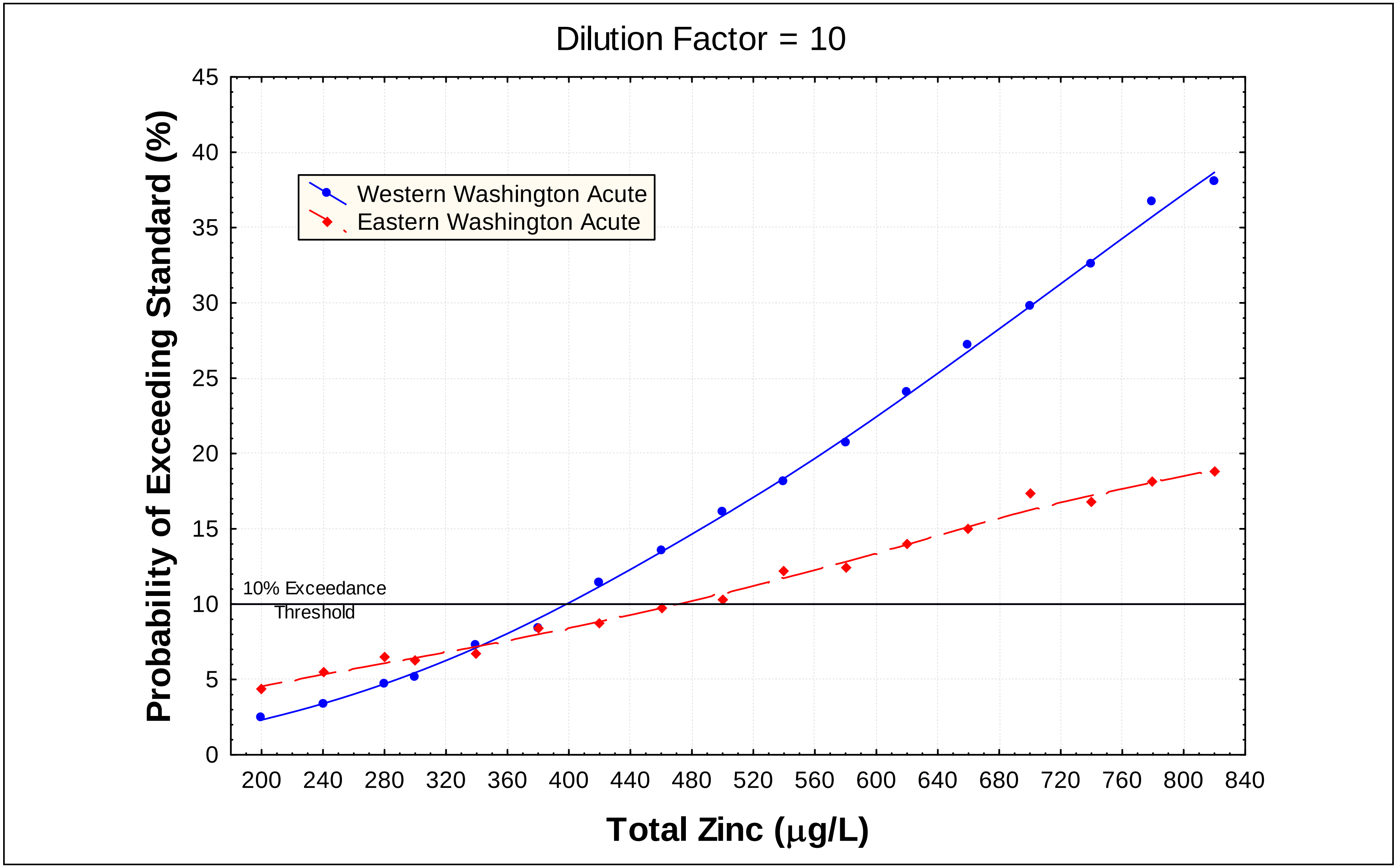


**Figure 9. Risk curve for zinc showing the probability of exceeding the applicable water quality standard as a function of effluent concentration given a dilution factor of 10.**

# References


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# APPENDIX A

# Search Criteria Used in Queries of the Environmental Information Management Database

# Search Criteria Used in Queries of the Environmental Information Management Database for Western Washington

## Result Parameter List

Copper
Hardness as CaCO3
Lead
Total Suspended Solids
Turbidity
Zinc

| | |
|---|---|
| **Sample Matrix** | Water |
| **Sample Source** | Fresh/Surface Water |
| **Location Type** | Stream/River |
| **WRIA Number** | ALL |

## County

Clallam
Clark
Cowlitz
Grays Harbor
Island
Jefferson
King
Kitsap
Lewis
Mason
Pacific
Pierce
San Juan
Skagit
Skamania
Snohomish
Thurston
Wahkiakum
Whatcom

# Search Criteria Used in Queries of the Environmental Information Management Database for Eastern Washington

## Result Parameter List

Copper
Hardness as CaCO3
Lead
Total Suspended Solids
Turbidity
Zinc

| | |
|---|---|
| **Sample Matrix** | Water |
| **Sample Source** | Fresh/Surface Water |
| **Location Type** | Stream/River |
| **WRIA Number** | ALL |

## County

Adams
Asotin
Benton
Chelan
Columbia
Douglas
Ferry
Franklin
Garfield
Grant
Kittitas
Klickitat
Lincoln
Okanogan
Pend Oreille
Spokane
Stevens
Walla Walla
Whitman
Yakima

**APPENDIX B**

# Sources of Ambient Receiving Water Background Concentrations from the Environmental Information Management Database

**Table B1. Sources of ambient dissolved copper data for rivers and streams in western Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| G0300038 | Camano Island Baseline Water Quality Monitoring Program |
| KCstrm-1 | King County Routine Ambient and Wet Weather Streams Monitoring |
| G0100027 | S.F. Nooksack River Water Quality Study |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| G0100202 | White River Water Quality Study |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B2. Sources of ambient dissolved copper data for rivers and streams in eastern Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
| --- | --- |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B3. Sources of ambient dissolved lead data for rivers and streams in western Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| G0300038 | Camano Island Baseline Water Quality Monitoring Program |
| KCstrm-1 | King County Routine Ambient and Wet Weather Streams Monitoring |
| G0100027 | S.F. Nooksack River Water Quality Study |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| G0100202 | White River Water Quality Study |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B4.** **Sources of ambient dissolved lead data for rivers and streams in eastern Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B5. Sources of ambient dissolved zinc data for rivers and streams in western Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
| --- | --- |
| G0300038 | Camano Island Baseline Water Quality Monitoring Program |
| KCstrm-1 | King County Routine Ambient and Wet Weather Streams Monitoring |
| G0100027 | S.F. Nooksack River Water Quality Study |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| G0100202 | White River Water Quality Study |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B6. Sources of ambient dissolved zinc data for rivers and streams in eastern Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B7. Sources of ambient total suspended solids data for rivers and streams in western Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| G0000106 | Baseline Assessment of Lower Hood Canal Streams |
| BBCWQ06 | Burnt Bridge Creek - 2006 Water Quality Monitoring |
| G0300038 | Camano Island Baseline Water Quality Monitoring Program |
| KCstrm-1 | King County Routine Ambient and Wet Weather Streams Monitoring |
| G9300265 | Mashel/Ohop Water Quality Investigations |
| TAX90187 | Nisqually River Basin Water Quality Monitoring |
| G0100027 | S.F. Nooksack River Water Quality Study |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| G0000258 | Samish Basin Watershed Water Quality Monitoring Project |
| G0400133 | Skagit County Monitoring Program |
| G9700218 | Snohomish Watershed Water Quality Monitoring Project |
| G0100205 | Stabler Water Quality/Quantity Study project |
| AJOH0029 | Statewide Arsenic Sampling in Selected Rivers |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001C | Statewide River and Stream Ambient Monitoring-1980 to 1988 |
| AMS001B | Statewide River and Stream Ambient Monitoring-Pre 1980 |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| TAX91050 | Upper Stillaguamish Monitoring/Database |
| SPMDTR07 | Washington State Toxics Monitoring Program (WSTMP), Semipermeable Membrane Device's (SPMDs) Trends Monitoring. |
| WSTMP02 | Washington State Toxics Monitoring Program: Exploratory Monitoring 2002 |
| G0300021 | Water Quality Monitoring Implementation |
| G9800201 | Whatcom Water Quality Improvement Project |
| G0100202 | White River Water Quality Study |

**Table B8. Sources of ambient total suspended solids data for rivers and streams in eastern Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| G9700156 | Chamokane Creek Watershed Planning Project |
| G0000116 | Cooperative Water Quality Monitoring Project |
| G9700063 | Crab Creek Water Quality Monitoring |
| G0200377 | Fecal Coliform Baseline Study |
| G9600127 | Hangman Creek Subwatershed Improvement |
| G0000026 | Irrigation Management Zone Demonstration Project |
| G9900069 | Jumpoff Joe Implementation Project |
| G9600152 | Jump-Off Joe Watershed Planning |
| G9900036 | Little Spokane Water Quality Assessment |
| G0300037 | Lower Palouse River Scoping Project |
| WKEN0001 | Methow River Water Quality Survey and Assessment |
| G0200314 | Mill Creek Watershed Implementation Plan |
| G9700221 | Mill Creek Watershed Planning Project |
| G0000225 | Okanogan Water Quality Monitoring Project |
| G9800072 | Onion Creek Integrated Planning Project |
| G0100141 | Pingston Creek Watershed Planning |
| GMER0001 | R-EMAP Bioassessment Study-Yakima Basin & Coast Range |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| G0000279 | Species Habitat Improvement Project |
| G9600119 | Spring Creek Watershed Project |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001C | Statewide River and Stream Ambient Monitoring-1980 to 1988 |
| AMS001B | Statewide River and Stream Ambient Monitoring-Pre 1980 |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| 99-40-IM | The Hangman Creek Water Quality Network |
| G0000233 | Upper Crab Creek Watershed, Phase II Project |
| G0200179 | Upper Pend oreille Sub-Watershed Ranking |
| G0600368 | Yakama Nation Surface Water Quality Investigation |
| G0300183 | Yakima Mainstem Monitoring and BMP Implementation Project |
| G0200276 | Yakima River Salmonid Habitat Improvement Project |
| G0000280 | Yakima River Water Quality Improvement Project |
| AJOH0007 | Zinc, Copper, Lead, and Cadmium in four WA rivers |

**Table B9. Sources of ambient hardness data for rivers and streams in western Washington from the Environmental Information Management database.**

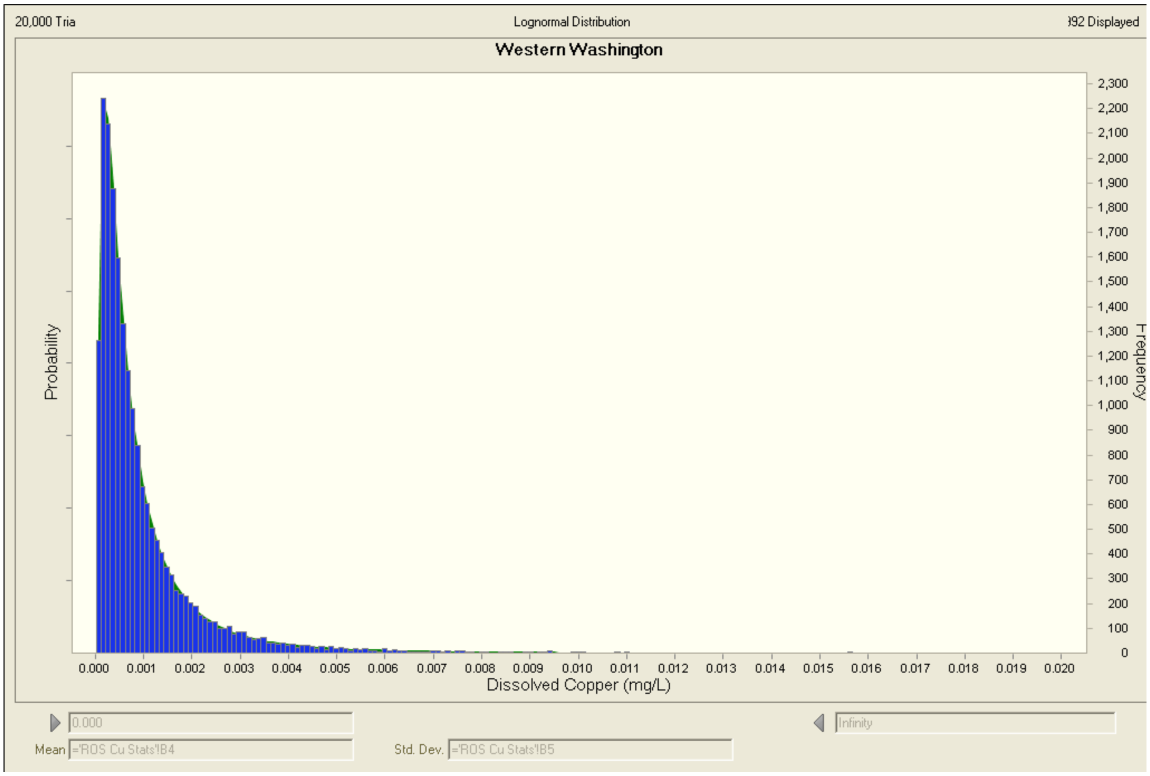
| User Study ID | Study Name |
|---|---|
| G0300038 | Camano Island Baseline Water Quality Monitoring Program |
| KCstrm-1 | King County Routine Ambient and Wet Weather Streams Monitoring |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| KCsamm | Sammamish River Water and Sediment Quality Assessment |
| AMS002 | Statewide Lake Monitoring |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001C | Statewide River and Stream Ambient Monitoring-1980 to 1988 |
| AMS001B | Statewide River and Stream Ambient Monitoring-Pre 1980 |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| G0100202 | White River Water Quality Study |

**Table B10. Sources of ambient hardness data for rivers and streams in eastern Washington from the Environmental Information Management database.**

| User Study ID | Study Name |
|---|---|
| G9700156 | Chamokane Creek Watershed Planning Project |
| G9600152 | Jump-Off Joe Watershed Planning |
| G0200314 | Mill Creek Watershed Implementation Plan |
| G9700221 | Mill Creek Watershed Planning Project |
| JHSVII01 | Salmon Recovery Index Watershed Program (SRIW) |
| AJOH0028 | Statewide Metals in Selected Rivers & Creeks |
| AMS001C | Statewide River and Stream Ambient Monitoring-1980 to 1988 |
| AMS001B | Statewide River and Stream Ambient Monitoring-Pre 1980 |
| AMS001D | Statewide River and Stream Ambient Monitoring-WY1989 through WY1999 |
| AMS001 | Statewide River and Stream Ambient Monitoring-WY2000 to present |
| MinesII | Water & Sediment Quality in Ten Metals Mining Districts II |

# APPENDIX C

# Graphical Representations of Theoretical Probability Distributions for Input Data Used in Monte Carlo Simulations



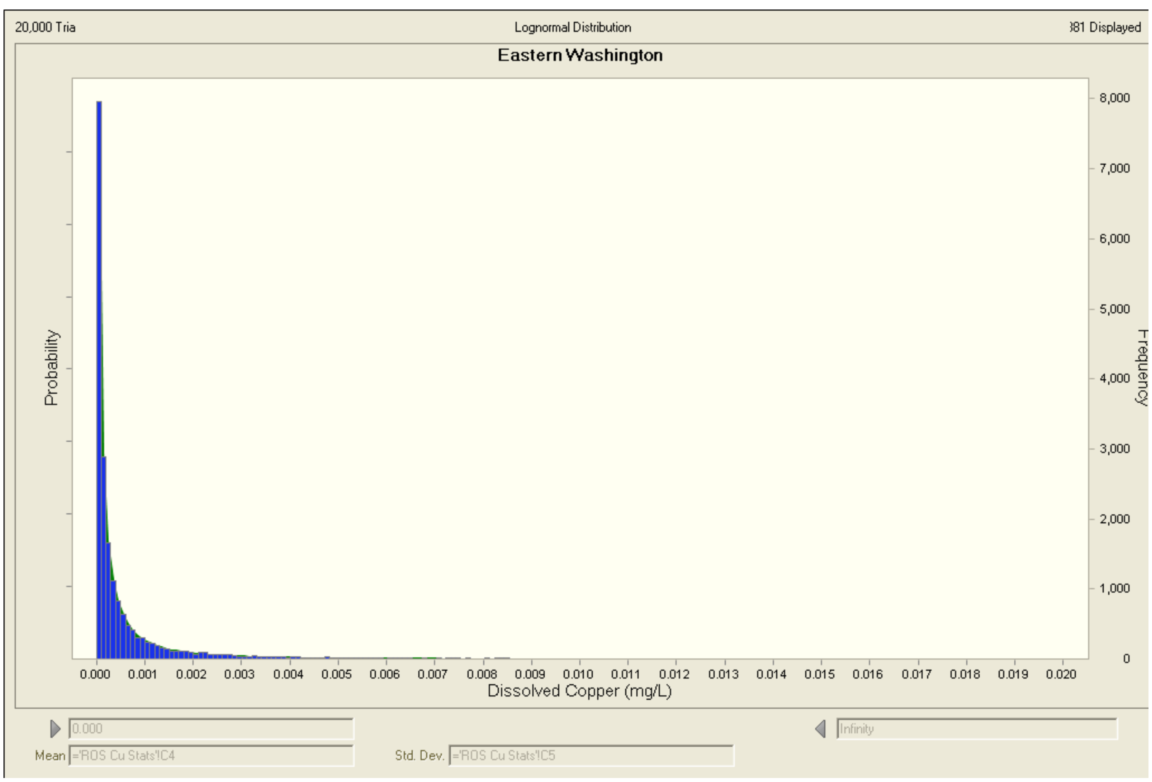
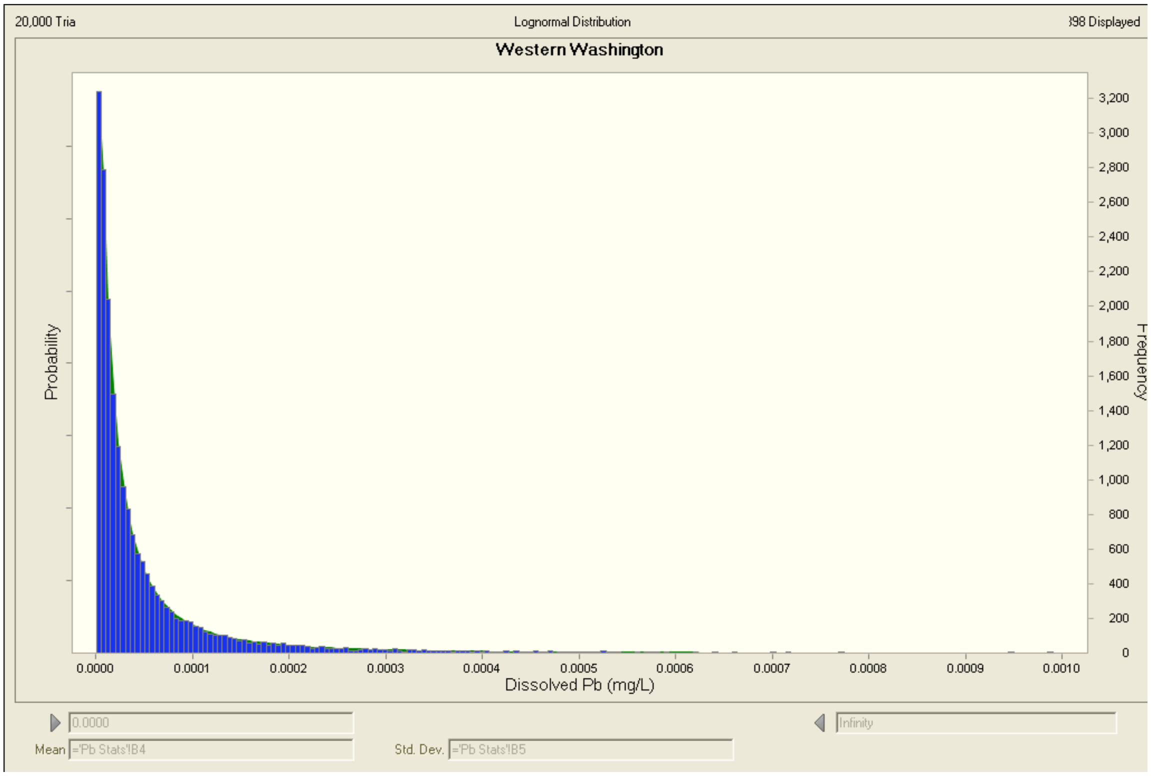




**Figure C1. Theoretical probability distributions for dissolved copper data used in Monte Carlo simulations.**



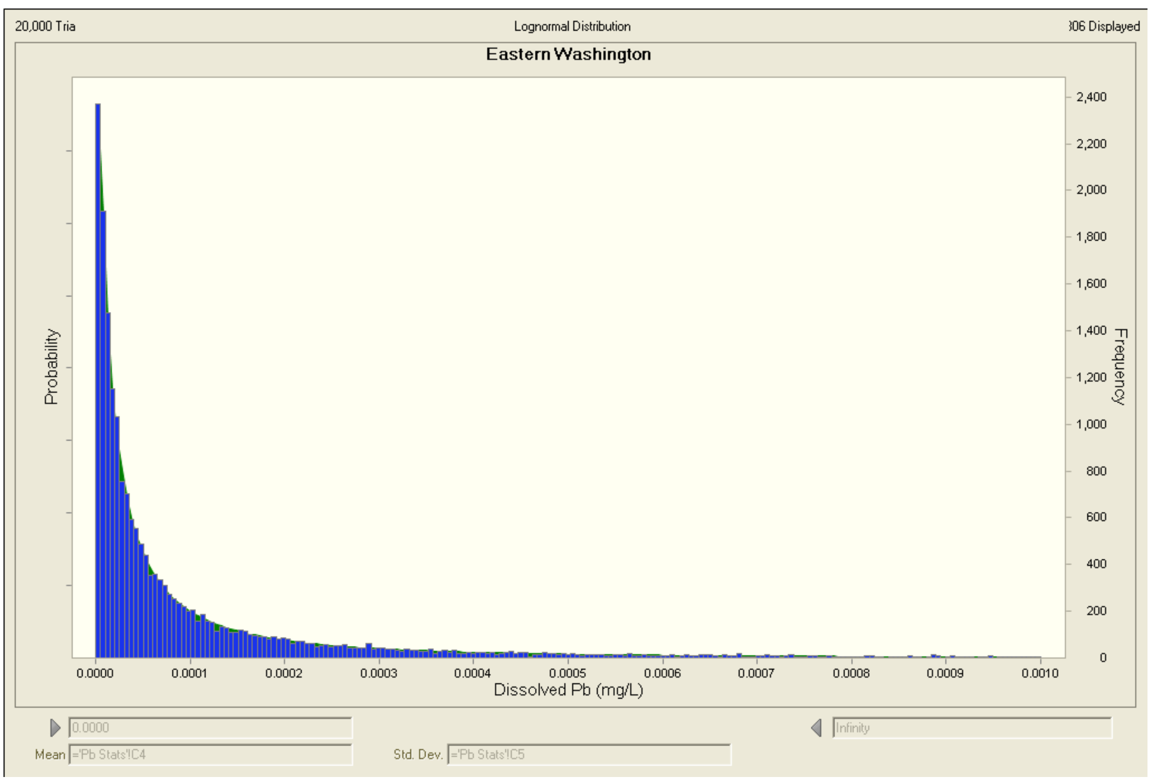
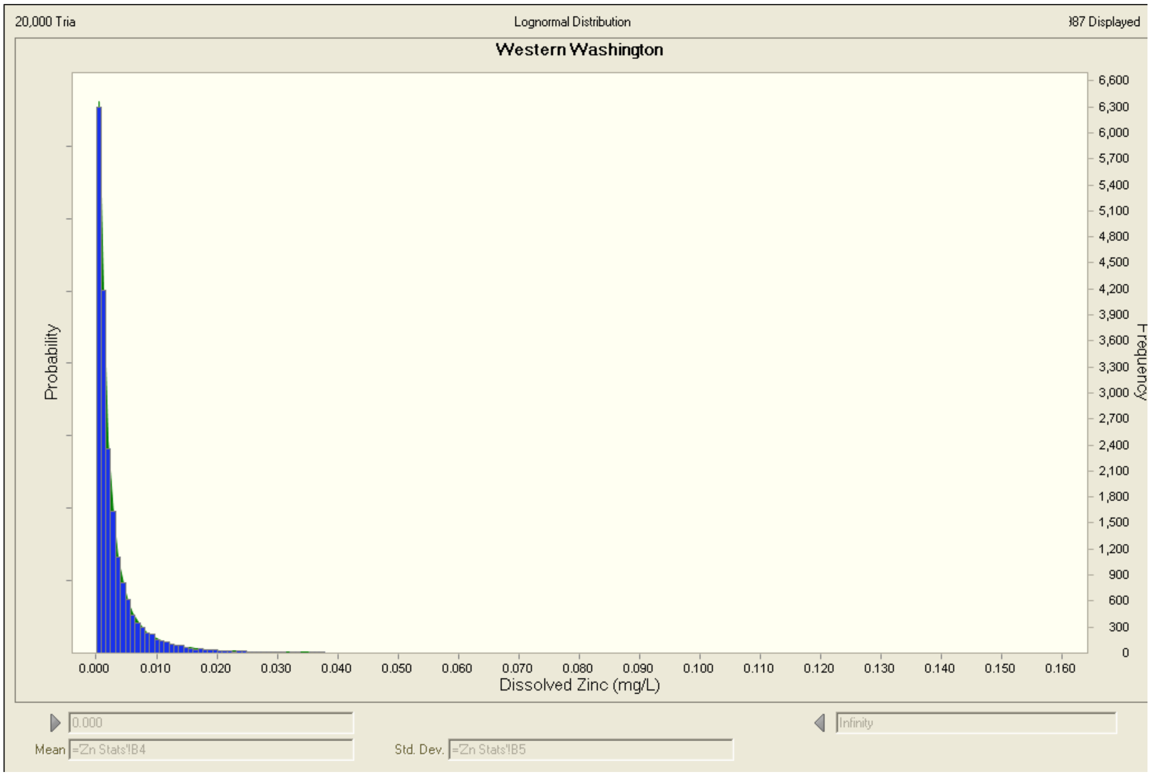




**Figure C2. Theoretical probability distribution for dissolved lead data used in Monte Carlo simulations.**



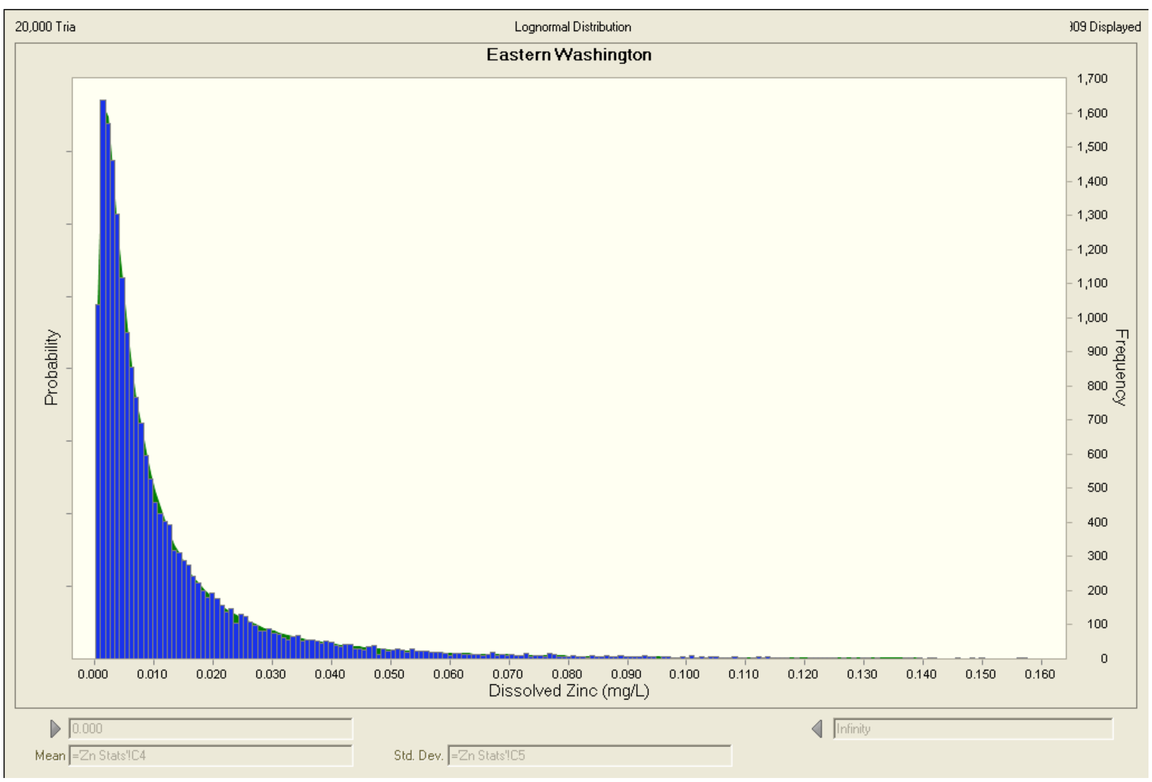
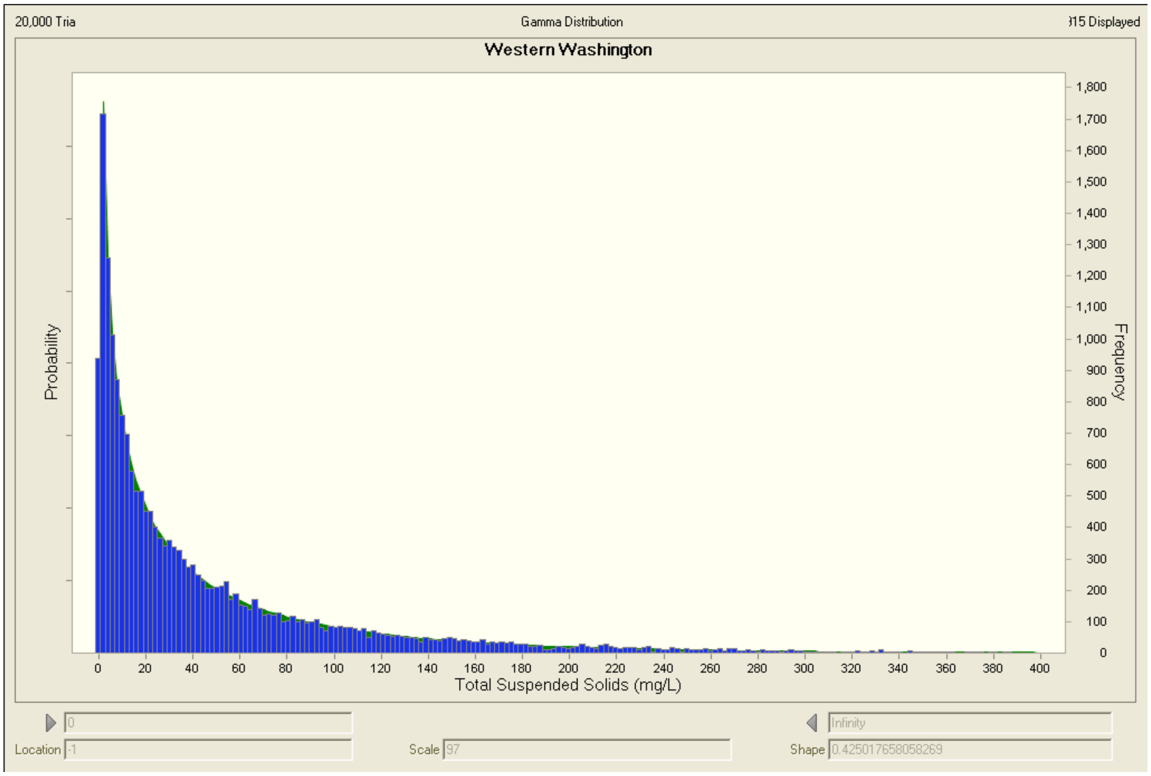




**Figure C3. The theoretical probability distribution for dissolved zinc data used in Monte Carlo simulations.**



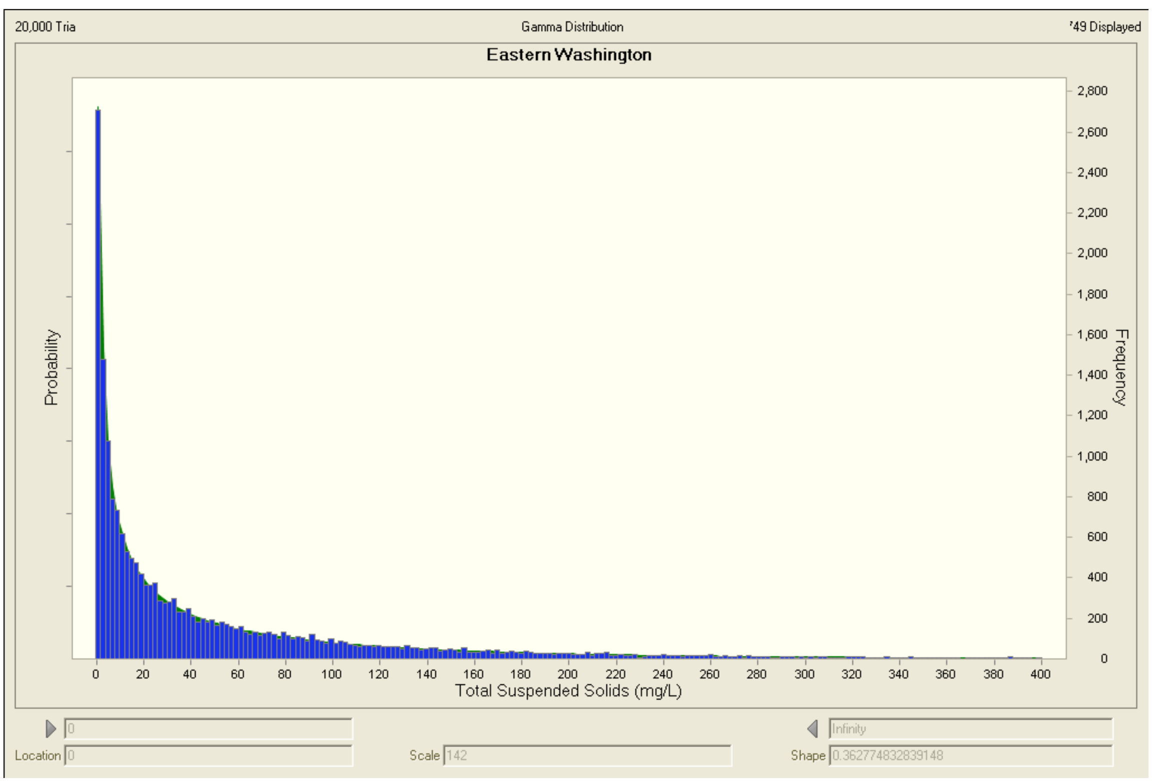




**Figure C4. Theoretical probability distribution for total suspended solids data used in Monte Carlo simulations.**

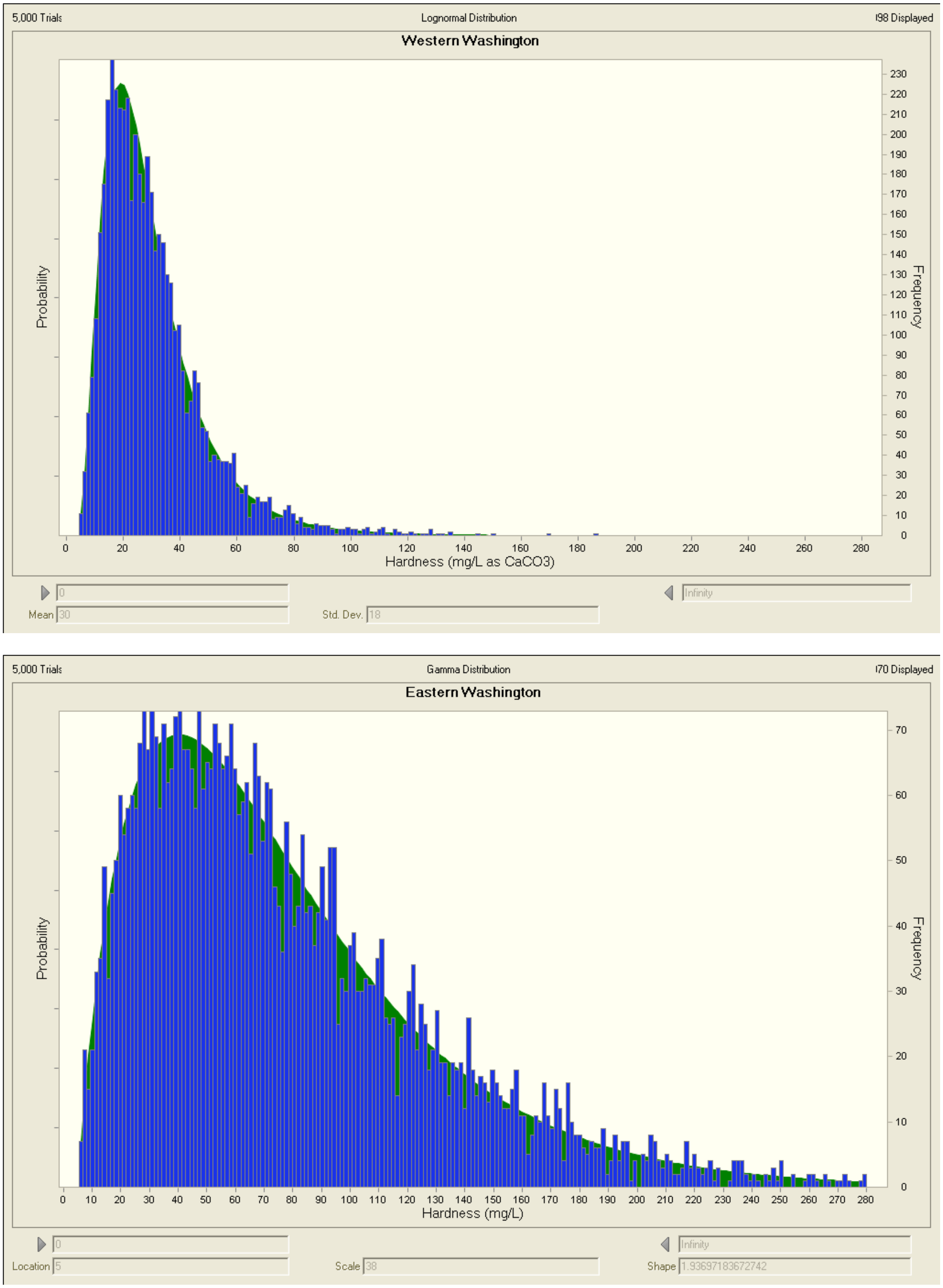
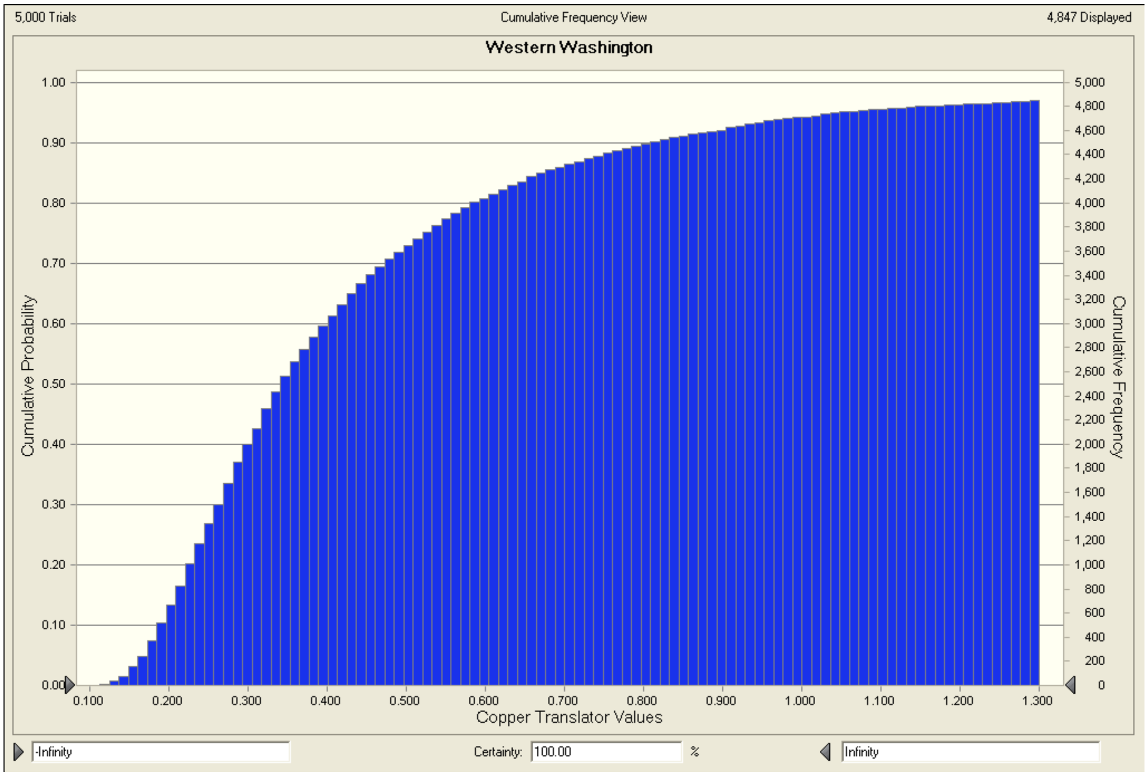



**Figure C5. Theoretical probability distribution for hardness data used in Monte Carlo simulations.**

# APPENDIX D

# Cumulative Probability Plots for Translator Values Used in Monte Carlo Simulations



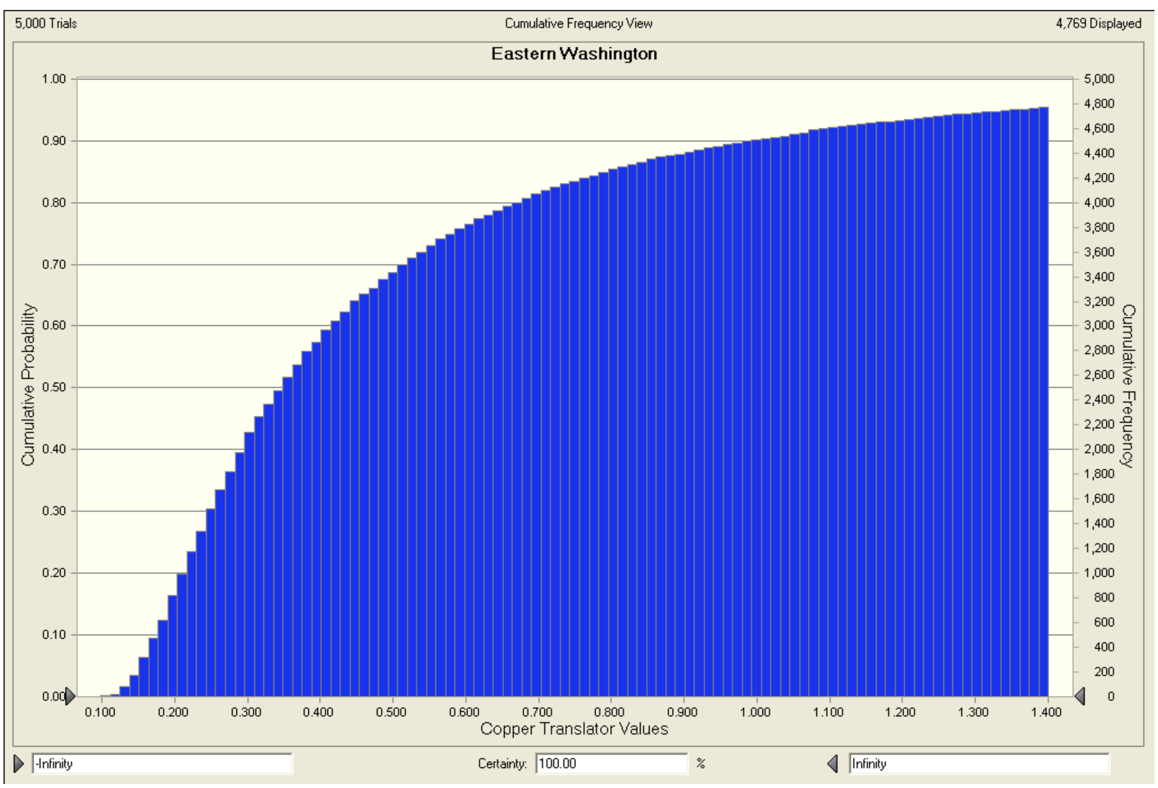
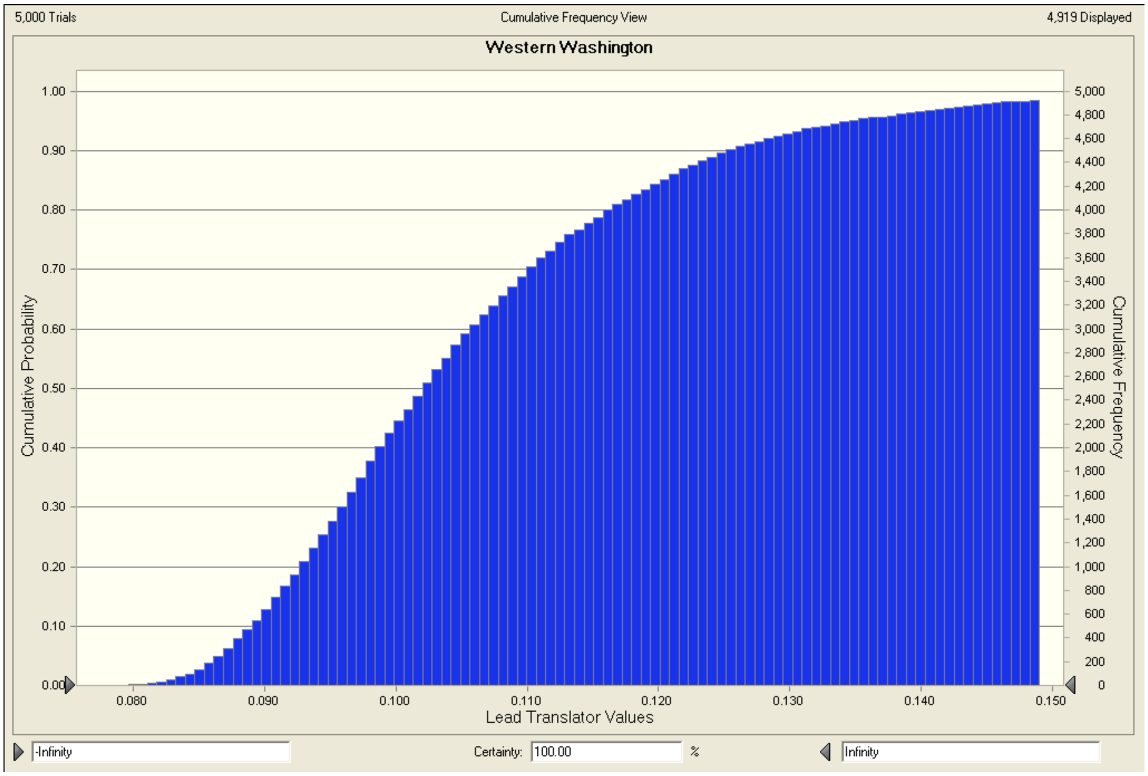




**Figure D1. Cumulative probability plot for copper translator values used in Monte Carlo simulations.**



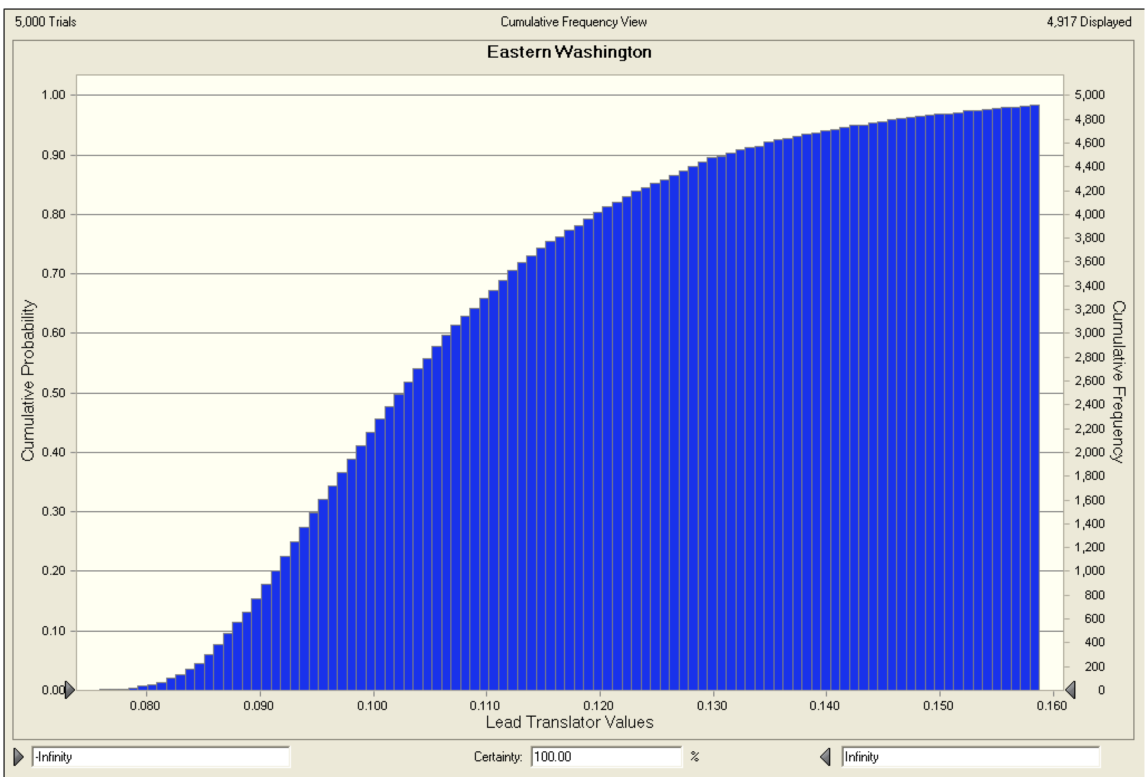




**Figure D2. Cumulative probability plot for lead translator values used in Monte Carlo simulations.**

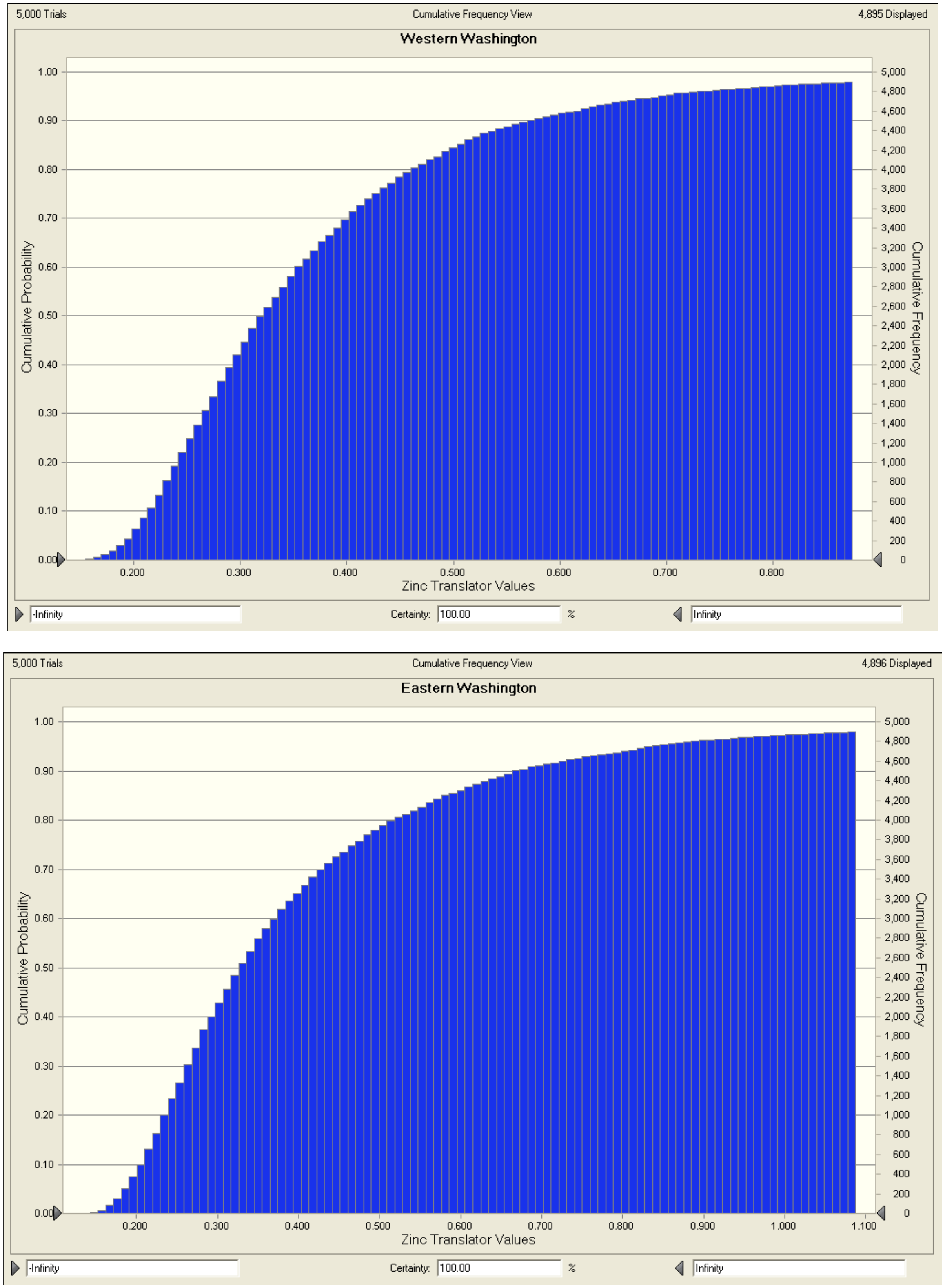



**Figure D3. Cumulative probability plot for zinc translator values used in Monte Carlo simulations.**