Development and Evaluation of Sediment and Pore-Water Toxicity Thresholds to Support Sediment Quality Assessments in the Tri-State Mining District (TSMD), Missouri, Oklahoma, and Kansas

Draft Final Technical Report
Volume I: Text

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List of Acronyms

Ag	silver
Al	aluminum
AoI	area of interest
As	arsenic
ASTM	American Society for Testing and Materials
AVS	acid volatile sulfide
BEC	blank equivalent concentration
BERA	baseline ecological risk assessment
BLM	biotic ligand model
CCC	criterion continuous concentration
Cd	cadmium
CERC	Columbia Environmental Research Center
COC	contaminant of concern
COPC	chemical of potential concern
Cr	chromium
CRM	concentration-response model
Cu	copper
-d	-day
DDT	dichlorodiphenyl-trichloroethane
DOC	dissolved organic carbon
DOI	Department of Interior
DQO	data quality objective
DW	dry weight
EDD	electronic data deliverable
$ESB\text{-}TU_{FCV}$	equilibrium partitioning-based sediment benchmarks toxic unit (final chronic value)
Fe	iron
f_{OC}	fraction total organic carbon
ICPAES	inductively-coupled plasma - atomic emission spectroscopy
ICPMS	inductively-coupled plasma - mass spectrometry
IOT	Incidence of toxicity
KS	Kansas
MDL	method detection limit
MESL	MacDonald Environmental Sciences Ltd.
MN	Minnesota
MO	Missouri
MOT	magnitude of toxicity
MQL	method quantitation limit
MSD	minimum significant difference
n	number of samples
NaCl	sodium chloride
NB	no benchmark
ND	not determined

Ni	nickel
NPL	National Priority List
NRDAR	natural resource damage assessment and restoration
NRT	Natural Resource Trustee
OC	organic carbon
OK	Oklahoma
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PCB	polychlorinated biphenyl
PEC	probable effect concentration
PEC-Q	probable effect concentration-quotient
PRGs	preliminary remediation goal
PW	pore water
PWTT	pore-water toxicity threshold
QAPP	quality assurance project plan
r^2	correlation coefficient
RAO	remedial action objective
RPD	relative percent difference
SD	standard deviation
Se	selenium
SEM	simultaneously extracted metal
SEM-AVS	simultaneously extracted metal minus acid volatile sulfide
SLERA	screening-level ecological risk assessment
SMDP	scientific management decision point
SOP	standard operating procedure
SQG	sediment quality guideline
STT	sediment toxicity threshold
STT-Q	sediment toxicity threshold-quotient
SVOC	semi-volatile organic compounds
TEC	threshold effect concentration
TCEQ	Texas Commission on Environmental Quality
TOC	total organic carbon
TSMD	Tri-State Mining District
TU	toxic unit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQC	water quality criteria
Zn	zinc

Glossary of Terms

a priori – Designated in advance.

Acute toxicity – The immediate or short-term response of an organism to exposure to a stressor (e.g., a chemical substance). Lethality is the response that is most commonly measured in acute toxicity tests.

Acute toxicity threshold – The concentration of a substance above which adverse effects on sediment-dwelling organisms are likely to occur in short-term toxicity tests

Adverse effects – Any injury (i.e., loss of chemical or physical quality or viability) to any ecological or ecosystem component, up to and including at the regional level, over both long and short terms.

Alevins – Newly hatched fish that still have the yolk sacs attached. This stage is prior to the fry stage of development.

Anthropogenic – Effects, processes, objects, or materials derived from human activities, as opposed to those occurring in natural environments without human influences.

Aquatic-dependent species – Species that are dependent on aquatic organisms and/or aquatic habitats for survival.

Aquatic-dependent wildlife – Wildlife species that are dependent on aquatic organisms and/or aquatic habitats for survival, including fish, amphibians, reptiles, birds, and mammals (e.g., egrets, herons, kingfishers, osprey, racoons, mink, otter).

Aquatic ecosystem – All the living and nonliving material interacting within an aquatic system (e.g., pond, lake, river, ocean).

Aquatic invertebrates – Animals without backbones that utilize habitats in freshwater, estuarine, or marine systems.

Aquatic organisms – The species that utilize habitats within aquatic ecosystems (e.g., microorganisms, aquatic plants, invertebrates, fish, amphibians, and reptiles).

Area of Interest – A portion of the study area that is targeted for investigation in a screening-level or baseline ecological risk assessment.

Autotrophic (self nourishing) – Organisms that are able to synthesize food from simple inorganic substances (e.g., carbon dioxide, nitrogen, and phosphorus) and the sun's energy. pond, lake, river, ocean).

Benthic – The lowest level of a body of water, such as an ocean or a lake inhabited by organisms that live in close relationship with (if not physically attached to) the ground, called benthos or benthic organisms.

Benthic invertebrate community – The assemblage of aquatic invertebrates that utilize the bottom substrate (e.g., sediment) within an aquatic ecosystem.

Bioaccumulation – The net accumulation of a substance by an organism as a result of uptake from all environmental sources.

Bioaccumulative substances – The chemicals that tend to accumulate in the tissues of aquatic or terrestrial organisms.

Biomass – The total mass of living biological material in a given area or of a biological community or group.

Calanoid (copepods) – Small crustaceans commonly found as part of the free-living zooplankton in freshwater lakes and ponds.

Chemicals of potential concern – The toxic or bioaccumulative substances that occur in environmental media at levels that could adversely affect ecological receptors.

Chronic toxicity – The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are typically measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.

Chronic toxicity threshold – The concentration of a substance above which adverse effects on sediment-dwelling organisms are likely to occur in longer-term toxicity tests.

Contaminants of concern – The toxic or bioaccumulative substances that occur at concentrations that are sufficient to cause or substantially contribute to adverse effects on sediment-dwelling organisms.

Contaminated sediment – Sediment that contains chemical substances at concentrations that could harm microbial, benthic invertebrate, plant, fish, avian or mammalian communities.

Detection limit – The lowest concentration of a substance that can be differentiated from zero with a 99% certainty.

Dissolved organic carbon – The organic matter in a solution that is able to pass through a filter (filters generally range in size between 0.7 and 0.22 μm).

Divalent metals – A metal whose atoms are each capable of chemically combining with two atoms of hydrogen (i.e., cadmium, copper, lead, nickel, zinc).

Ecosystem – All the living (e.g., plants, animals, and humans) and nonliving (rocks, sediments, soil, water, and air) material interacting within a specified location in time and space.

Endpoint – A measured response of a receptor to a stressor. An endpoint can be measured in a toxicity test or a field survey.

Epibenthic species – The species that live on the surface of bottom sediments.

Exposure – Co-occurrence of or contact between a stressor (e.g., chemical substance) and an ecological component a receptor (e.g., aquatic organism).

Final Chronic Value – An estimation of the concentration of the toxicant corresponding to geometric means of a No Observed Effects Concentration (NOEC) and the Lowest Observed Effects Concentration (LOEC).

Heterotrophic (other nourishing) – Organisms that utilize, transform, and decompose the materials that are synthesized by autotrophic organisms (i.e., by consuming or decomposing autotrophic and other heterotrophic organisms).

Heterotrophic organism – An organism that requires organic substrates to get its carbon for growth and development. A heterotroph is known as a consumer in the food chain.

Impaired benthic invertebrate community – An assemblage of benthic invertebrates that has characteristics (i.e., mIBI score, abundance of selected taxa, etc.) that are generally inconsistent with those that have been observed at uncontaminated reference sites.

Infaunal organisms – The organisms that live in bottom sediments.

Injury – A measurable adverse change, either long or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a discharge of oil or release of a hazardous substance, or exposure to a product of reactions resulting from the discharge to oil or release of a hazardous substance.

Inorganic compounds – Considered to be of mineral, not biological, origin.

Macrophyte – An individual alga large enough to be seen easily with the unaided eye.

Mean PEC-Q – Mean Probable Effects Concentration Quotient, which was calculated using the procedure that was established by USEPA (2000). Using this method, a PEC-Q was first determined for each metal for which a reliable PEC was available. Then, an average PEC-Q for metals was calculated by summing the PEC-Qs of each metal and dividing by the number of metals that were included in the calculation. PEC-Qs were also calculated for total PAHs and total PCBs. Finally, the mean of the average PEC-Q for metals, the PEC-Q for PAHs, and the PEC-Q for PCBs was determined for each sediment sample (termed the mean PEC-Q).

Method detection limit (MDL) – The concentration in a sample that can be differentiated from zero with 99% certainty for a specific method and sample type.

Metric – A variable that is measured to provide information on the status of an indicator of environmental quality conditions (e.g., the concentration of cadmium in sediment).

Organic matter – Matter which has come from a recently living organism; is capable of decay, or the product of decay; or is composed of organic compounds.

Periphyton – A complex matrix of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems.

Piscivorous – Primarily subsists on fish tissue.

Pore water – The water that occupies the spaces between sediment particles.

Predictive ability – A measure of the ability of a toxicity threshold to correctly classify a sediment sample as toxic or not toxic, based on data independent of those used to derive the toxicity threshold. High predictive ability occurs if the incidence of toxicity was $<$20% below the toxicity thresholds for all endpoints, if the incidence of toxicity was $>$50% above the toxicity threshold for the most sensitive endpoint, and the overall correct classification rate was $\geq$80 for the most sensitive endpoint.

Probable effect level – Concentration of a chemical in sediment above which adverse biological effects are likely to occur.

Protozoa – Single-celled eukaryotes (organisms whose cells have nuclei) that commonly show characteristics usually associated with animals, most notably mobility and heterotrophy.

Quality Assurance Project Plan – The document that outlines, defines and provides guidance for the operation of a laboratory. This document generally contains, but is not limited to, information pertaining to: laboratory personnel, sampling procedures and sample rejection criteria, sample handling and chain of custody routines, the equipment employed by the laboratory, analytical methods, data reduction, validation and reporting, calibration and quality control procedures, equipment maintenance, routine procedure for precision and accuracy, method validation, verification and corrective actions, health and safety policy and training.

Receptor – A plant or animal that may be exposed to a stressor.

Reference envelope - A statistical representation of data from reference locations that is used to evaluate data for test sites.

Reference sample – A comparatively uncontaminated sample used for comparison to samples from contaminated sites in environmental monitoring studies. It can be from the least impacted (or unimpacted) area of the site or from a nearby site that is ecologically similar, but not affected by the contaminants at the site under investigation (often incorrectly referred to as a control).

Reliability – A measure of accuracy of a toxicity threshold in terms of correctly classifying a sediment sample as toxic or not toxic, base on the data that were used to derive the toxicity threshold. A threshold was considered reliable if <20% incidence of toxicity was observed below the toxicity threshold, >50% incidence of toxicity was observed above the toxicity threshold, and the overall correct classification rate was ≥80%.

Remedial action objectives – Objectives intended to describe the narrative intent of any remedial actions that are undertaken to mitigate risks to the ecological receptors that are exposed to contaminants of concern.

Remediation goal – Concentration limits for chemical in environmental media that are anticipated to protect human health or the environment.

Riparian – Pertaining to the banks of a natural water course.

Risk – The probability or likelihood an adverse effect will occur.

Risk assessor – The person who analyzes information from a cleanup/Superfund site to determine if there is the possibility of harm to the local ecosystem.

Risk characterization – An element of conventional risk assessment procedure. A systematic, scientific assessment of potential adverse health effects resulting from exposure to hazardous agents or situations which uses information from the site characterization.

Risk management – Actions, including monitoring, designed to prevent or mitigate risks to human health or the environment caused by contamination at a site.

Sediment – Particulate material that usually lies below the ponds, lakes, stream, and rivers.

Sediment-associated contaminants – Contaminants that are present in sediments, including whole sediments or pore water.

Sediment chemistry data – Information on the concentrations of chemical substances in whole sediments or pore water.

Sediment-dwelling organisms – The organisms that live in, on, or near bottom sediments, including both epibenthic and infaunal species.

Sediment quality guidelines – Chemical benchmark that is intended to define the concentration of sediment-associated contaminants that is associated with a high or a low probability of observing harmful biological effects or unacceptable levels of bioaccumulation, depending on its purpose and narrative intent.

Simultaneously extracted metals – Divalent metals - commonly cadmium, copper, lead, mercury, nickel, and zinc - that form less soluble sulfides than does iron or manganese and are solubilized during the acidification step (0.5m HCl for 1 hour) used in the determination of acid volatile sulfides in sediments.

Threshold effect concentration – Concentration of a chemical in sediment below which adverse biological effects are unlikely to occur.

Threshold effect level – Concentration of a chemical in sediment below which adverse biological effects are unlikely to occur.

Toxic – Capable of causing injury or death. In this study, the toxicity of sediment samples was evaluated using a reference envelop approach.

Toxicity threshold – Chemical benchmark for water or sediment quality which define the concentration of chemicals of potential concern that are associated with high or low probabilities of observing harmful biological effects, depending on the narrative intent; or, a chemical benchmark that is intended to define the concentration of a substance in the tissues of fish or invertebrates that will protect wildlife against effects that are associated with dietary exposure to hazardous substances.

Trophic level – The position that an organism occupies in a food chain, food web, or food pyramid, as pertaining to nutrition.

Trustee – Any Federal natural resources management agency designated in the National Contingency Plan and any State agency designated by the Governor of each State, pursuant to Section 107(f)(2)(B) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), that may prosecute claims for damages under Section 107(f) or 111(b) of CERCLA; or an Indiana tribe, that may commence an action under Section 126(d) of CERCLA.

Type I Error – Incorrectly classifying a not toxic sample as toxic. Also referred to as a false positive.

Type II Error – Incorrectly classifying a toxic sample as not toxic. Also referred to as a false negative.

Whole sediment – Sediment and associated pore water.

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Executive Summary

This study was conducted to evaluate matching sediment chemistry and sediment toxicity data that have been collected by United States Environmental Protection Agency and its partners in the Tri-State Mining District (TSMD) in 2006 and 2007. This evaluation of sediment chemistry and sediment toxicity data consisted of several steps. First, the sediment chemistry, pore-water chemistry, sediment toxicity, and associated data for the TSMD generated during the 2006 and 2007 sampling programs were assembled and reviewed. The data that met the acceptance criteria were compiled in the project database (see Ingersoll *et al.* 2008 for more information on the performance criteria for measurement data). In total, the project database includes matching chemistry and toxicity data for 76 sediment samples collected within the TSMD. These data include information on the effects on three benthic invertebrate species associated with exposure to sediments from the study area, including the amphipod, *Hyalella azteca* (Endpoints: 28-d survival, 28-d length, 28-d weight, and 28-d biomass), the midge, *Chironomus dilutus* (Endpoints: 10-d survival, 10-d weight, and 10-d biomass), and the fat-mucket mussel, *Lampsilis siliquoidea* (Endpoints: 28-d survival, 28-d length, 28-d weight, and 28-d biomass). These studies also provided data on the concentrations of metals (total and simultaneously extracted metals in sediment and dissolved metals in pore water), acid volatile sulfides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and organochlorine pesticides in sediment and/or pore water. Sediment grain size and total organic carbon, as well as pore-water dissolved organic carbon, ammonia, and/or hydrogen sulfide levels, were also determined for these sediment samples.

The data compiled in the project database were used to develop preliminary concentration-response relationships for a variety of Chemicals of Potential Concern (COPCs) and COPC mixtures. More specifically, concentration-response relationships were developed for those COPCs and COPC mixtures that: 1) were detected in at least one sample; 2) occurred in one or more sediment samples at concentrations above conservative sediment quality guidelines or water quality criteria; and, 3) that were negatively correlated with one or more toxicity test endpoints (based on the results of Spearman-Rank Correlation analysis; $p < 0.005$). Using these criteria, preliminary concentration-response relationships were developed for 220 COPC/COPC mixture-toxicity test endpoint pairs. These concentration-response relationships were generally defined by fitting a three-parameter sigmoid model to the matching sediment chemistry and toxicity data.

A total of 13 COPCs and COPC mixtures were selected for deriving toxicity thresholds for sediment and/or pore water, including cadmium, copper, lead, nickel, zinc, SEM-AVS, mean

PEC-Q, mean PEC-Q_{METALS}, PEC-$Q_{METALS(1\%OC)}$, $\sum$PEC-$Q_{Cd,Pb,Zn}$, $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$, $\sum$PW-TU_{METALS} and $\sum$PW-$TU_{DIVALENT\ METALS}$. These COPCs and COPC mixtures were selected based on the coefficients of determination (i.e., $r^2 \geq 0.40$) and associated p-values (i.e., $p < 0.05$) for the regressions determined for the preliminary concentration-response plots (i.e., the preliminary plots that demonstrated the strongest correlations between chemistry and toxicity results were selected for toxicity threshold derivation). Two toxicity thresholds were derived for each COPC/COPC mixture-biological response pair, including a low risk threshold (T_{10} value, associated with a 10% reduction in survival or biomass) and a high risk threshold (T_{20} value, associated with a 20% reduction in survival or biomass). The concentration-response models were refined prior to toxicity threshold development to ensure that they were based on the models that best fit the underlying data (i.e., definitive plots). In most cases, four-parameter sigmoid models were used to define the refined concentration-response relationships.

All of the toxicity thresholds developed during this investigation were evaluated to assess their reliability [i.e., the ability of the sediment toxicity thresholds (STTs) or pore-water toxicity thresholds (PWTTs) to correctly classify sediment samples as toxic and not toxic considering only the data used to derive the toxicity threshold; e.g., amphipod survival data] and predictive ability (i.e., the ability the STTs or PWTTs to correctly classify sediment samples as toxic or not toxic considering all of the data available; i.e., toxicity data for six individual endpoints, overall toxicity considering four endpoints, or overall toxicity considering six endpoints). The results of the evaluation indicated that many of the sediment and pore-water toxicity thresholds developed would provide reliable and predictive bases for classifying sediment samples from the TSMD as toxic and not toxic. A total of 29 STTs and 27 PWTTs were considered to provide reliable bases for classifying sediment samples from the TSMD as toxic or not toxic (i.e., all three criteria were met; i.e., <20% incidence of toxicity below the toxicity threshold, >50% incidence of toxicity above the toxicity threshold, and >80% of the samples correctly classified as toxic and not toxic). While none of the STTs or PWTTs met all three criteria for predictive ability (considering overall toxicity for four endpoints), the probability of making Type I and Type II errors is expected to be less than 25% for nine of the STTs and two of the PWTTs.

The STTs and PWTTs were further evaluated to support recommendation of toxicity thresholds for use in the Advanced Screening Level Risk Assessment of the TSMD (scheduled for completion in mid-2009). This subsequent evaluation considered three important factors in the toxicity threshold selection process, including applicability for assessing sediments with complex mixtures of COPCs, broad applicability across multiple data sets, and level of protection afforded to the benthic community (i.e., assuming that the selected toxicity tests provided reasonable surrogates for the benthic invertebrates that utilize habitats in the TSMD). The results of this evaluation revealed that the STTs based on amphipod survival for cadmium lead, and zinc (when used together) and the STTs for selected COPC mixtures (e.g., $\sum$PEC-$Q_{Cd,Pb,Zn}$), would be the most useful to risk assessors and risk managers. That is, these toxicity thresholds would provide reliable bases for classifying sediment samples as toxic and not toxic, can be applied to sediment samples that contain complex mixtures of COPCs, can be broadly applied across multiple data sets, and are likely to provide an adequate level of protection for the benthic invertebrate community.

Among the STTs for individual COPCs, the T_{10} values for cadmium (11.1 mg/kg DW), lead (150 mg/kg DW) and zinc (2083 mg/kg DW) derived using the amphipod survival data were among the most reliable and/or predictive of sediment toxicity. While the T_{20} values for lead and zinc were also reliable, the T_{20} value for cadmium was considered to have lower reliability. When used together, the T_{10} values for amphipod survival provide an accurate basis for classifying sediment samples from the TSMD as toxic or not toxic (overall correct classification rate of 76%; i.e., 76% of the samples classified using these STTs were correctly identified as toxic or not toxic). In this application, sediment samples would be classified as low risk if the measured concentrations of cadmium, lead, <u>and</u> zinc were all below their respective T_{10} values (i.e., about 20% of sediment samples are expected to be toxic to benthic invertebrates under these conditions). Sediment samples with concentrations of one or more of these metals above their respective T_{10} values would be classified as posing high risk to the benthic invertebrate community (i.e., incidence of toxicity is expected to be at 71% under these conditions). The average control-adjusted survival of amphipods was 101% $\pm$ 5.42% in low-risk samples (n = 41 samples with concentrations of cadmium, lead, <u>and</u> zinc below the T_{10} values) and 63.1 $\pm$ 41.4% in high-risk samples (n = 35 samples with concentrations of cadmium, lead, <u>or</u> zinc above the T_{10} values).

Among the various chemical mixture models evaluated, the T_{10} values (derived using the 28-d amphipod survival endpoint) for mean PEC-Q (0.556), mean PEC-Q_{METALS} (1.11), $\sum$PEC-$Q_{Cd,Pb,Zn}$ (7.92) and $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$ (2.97), as well as the T_{20} value for $\sum$SEM-AVS (13.7 µmol/g DW), were considered to be the most reliable and predictive of sediment toxicity. The overall correct classification rates for these STTs ranged from 79 to 80% when amphipod survival or biomass and mussel survival or biomass were considered (i.e., overall toxicity to four endpoints; OT-Four Endpoints). Of these models, the $\sum$PEC-$Q_{Cd,Pb,Zn}$ (i.e., Dudding Model) is the easiest to use for making sediment management decisions because only the concentrations of cadmium, lead, and zinc need to be measured (potentially by x-ray fluorescence in the field when decisions need to be made on a timely basis). Using this model, sediment samples are considered to pose a low risk if:

$$\frac{[\ Cd\ ]}{4.98} + \frac{[\ Pb\ ]}{128} + \frac{[\ Zn\ ]}{459} < 7.92$$

High risk sediment samples are considered to include those with $\sum PEC\text{-}Q_{Cd,Pb,Zn}$ that equal or exceed 7.92. The average control-adjusted survival of amphipods was 100 $\pm$ 5.7% in low-risk samples (n = 48) and 55 $\pm$ 43% in high-risk samples (n = 28) classified using this STT.

Overall, the PWTTs provided the most reliable and predictive tools for classifying sediment samples from the TSMD as toxic or not toxic. However, limitations on the availability of pore-water chemistry data make these toxicity thresholds less useful for broad application in the Advanced Screening-Level Ecological Risk Assessment of the TSMD. Nevertheless, the PWTTs will be used to evaluate sediment quality conditions in the TSMD using multiple lines-of-evidence.

1.0 Introduction

The Tri-State Mining District (TSMD) is a historic lead and zinc mining area that includes portions of Kansas (KS), Missouri (MO), and Oklahoma (OK; Figure 1). The TSMD was one of the world's foremost lead and zinc mining areas, yielding about 460 million tons of crude ore between 1885 and 1970 (Black and Veatch Special Projects Corporation 2006). The lead and zinc deposits within the TSMD, an area of about 500 square miles, were associated with the geologic region known as the Ozark Plateau, which is characterized by the presence of Mississippian rocks. The ore deposits were accessed using underground mining methods, with recovered ore typically crushed on site and concentrated using gravity separation and/or flotation. These two ore-concentration processes resulted in the production of two types of solid waste, including chat (sand- and gravel-sized particles) and fine tailings (sand- and smaller-sized particles). Further smelting and refining of these ore concentrates was conducted at various locations within the study area or elsewhere.

Historic mining activities in the TSMD have resulted in contamination of surface water, groundwater, sediments, and/or flood plain soils in the Tar Creek, Neosho River, and Spring River basins by lead, zinc, and other heavy metals. The nature and extent of this contamination has resulted in the identification of four National Priority List (NPL) sites in the TSMD, including the Jasper County site, MO, the Newton County site, MO, the Cherokee County site, KS, and the Ottawa County site, OK. Although the TSMD consists of four NPL sites, there are a number of similarities among the sites. Importantly, historic land use activities were similar for the four sites, with mining and smelting activities occurring throughout the study area. There are also numerous similarities in terms of the physical, chemical, and biological characteristics of the areas. For this reason, United States Environmental Protection Agency (USEPA) and its partners have decided to adopt a watershed-based approach to the assessment and management of aquatic habitats within the TSMD.

1.1 Remedial Investigation and Feasability Study

In response to concerns regarding environmental contamination, USEPA will conduct an Advanced Screening-Level Ecological Risk Assessment (SLERA) of aquatic habitats in the TSMD during 2009. The Advanced SLERA will be conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (USEPA 1997; Figure 2). The USEPA guidance document describes an eight-step process for conducting an ERA (Figure 3), including:

Step 1: Screening-Level Preliminary Problem Formulation and Ecological Effects Evaluation;

Step 2: Screening-Level Preliminary Exposure Estimate and Risk Calculation. A Scientific Management Decision Point (SMDP) occurs at the end of this step to decide if a Baseline Ecological Risk Assessment (BERA) is necessary;

Step 3: BERA Problem Formulation. An SMDP occurs at the end of this step to achieve agreement on the conceptual site model;

Step 4: Study Design and Data Quality Objectives. An SMDP occurs at the end of this step to achieve agreement on the measurement endpoints, study design, and data analysis;

Step 5: Field Verification of Sampling Design. An SMDP occurs at the end of this step to facilitate approval of the work plan and the sampling and analysis plan for the BERA;

Step 6: Site Investigation and Analysis of Exposure and Effects. An SMDP occurs at the end of this step only if a change to the sampling and analysis plan is needed;

Step 7: Risk Characterization; and,

Step 8: Risk Management. An SMDP occurs at the end of this step to support signing of the Record of Decision.

In accordance with the USEPA guidance, the Advanced SLERA of the TSMD represents the first two steps of the ERA process. The objectives of the Advanced SLERA are to:

- Estimate the risks posed to ecological receptors by contamination of aquatic habitats in the four NPL sites that comprise the TSMD;
- Provide the information needed by risk managers to make decisions regarding the need for remedial actions, including source control measures; and,
- Establish preliminary remediation goals (PRGs) for the site.

An Advanced SLERA, rather than a conventional SLERA, will be conducted at these sites because the results of the sediment sampling conducted to date indicate that the concentrations of metals in sediments frequently exceed conservative toxicity thresholds (i.e., threshold effect concentrations; TECs; MacDonald *et al.* 2000) throughout much of the study area. As a result of the widespread sediment contamination, completion of a conventional SLERA is unlikely to provide a basis for prioritizing subsequent risk assessment and risk management activities in the Spring River Basin and the Neosho River Basin (i.e., the results of such an assessment would likely show that sediments throughout the study area pose potential risks to aquatic receptors). For this reason, the Advanced SLERA will be conducted using site-specific toxicity thresholds (i.e., as presented in this document) that will provide a more reliable basis for identifying sediment samples that pose low, intermediate, and/or high risks to sediment-dwelling organisms and/or other aquatic receptors. This site-specific calibration of the generic sediment quality guidelines is intended to help focus subsequent risk assessment and risk management activities on the areas that pose the highest risks to sediment-dwelling organisms and other aquatic receptors in the study area. In the future, additional ERA activities (e.g., BERAs) may be conducted to further identify conditions that would benefit from specific risk management initiatives.

1.2 Purpose of this Report

Over the past several years, USEPA and the Natural Resources Trustees (NRTs) have cooperated in the development and implementation of several investigations of sediment quality conditions in the TSMD. The results of two of these studies provide synoptically-collected sediment chemistry and sediment toxicity data specific to the Neosho River Basin and Spring River Basin (Ingersoll *et al.* 2008). More specifically, the matching sediment chemistry, sediment toxicity, and associated data collected during the 2007 sediment sampling program of the TSMD provide relevant information for assessing the effects on benthic invertebrates associated with exposure to metal-contaminated sediments from the study area (see MacDonald *et al.* 2007a; Pehrman *et al.* 2007 for more information on the design of this sampling program; all of the data collected in this study are presented in Ingersoll *et al.* 2008). In addition, the results of an earlier study, conducted by United States Geological Survey (USGS) in 2006, provide additional matching sediment chemistry and toxicity data from the study area. All of the data from the 2006 study are also presented in Ingersoll *et al.* (2008). Although bioaccumulation data were also collected as part of the 2007 study, this information was not evaluated in this report because the data were considered to be potentially biased due to the presence of sediment in the guts of oligochaetes after depuration (which complicates interpretation of these data; see Ingersoll *et al.* 2008 for a summary of the bioaccumulative data collected in this study).

The principal objective of this study is to recommend sediment and/or pore-water toxicity thresholds that can be used to assess risks to benthic invertebrates associated with exposure to contaminated sediments in the TSMD. To support this objective, the results of the two studies summarized in Ingersoll *et al.* (2008) were evaluated and compiled to support the derivation of site-specific concentration-response relationships for individual chemicals of potential concern (COPCs) and COPC mixtures (Appendix 1). Site-specific toxicity thresholds were then developed for the individual COPCs and various COPC mixtures in TSMD sediments and pore water that were well-correlated with the results of selected toxicity tests. These toxicity thresholds for sediment and pore water were then evaluated to determine which ones provided the most reliable basis for classifying sediment samples from the TSMD as toxic or not toxic to benthic invertebrates. The results of the reliability and predictive ability evaluations were then used to recommend a suite of toxicity thresholds that apply directly to the TSMD.

The toxicity thresholds derived in this investigation are intended to support a variety of risk assessment and risk management activities in the TSMD. More specifically, the toxicity thresholds for sediment and pore water will be used to identify conditions that pose acceptable risks to aquatic receptors in the TSMD (i.e., in the Advanced SLERA). In this context, the toxicity thresholds will also be used to identify the contaminants of concern (COCs) in sediment and pore water (i.e., risk drivers). The toxicity thresholds also provide the technical basis for establishing preliminary remediation goals for the COCs that are identified in the Advanced SLERA. It is anticipated that the selected toxicity thresholds will also be used to identify source materials that have been released into stream systems within the study area. Finally, these toxicity thresholds are also intended to support assessments of sediment injury that may be conducted by Department of Interior (DOI) and/or the other NRTs under the Natural Resource Damage Assessment and Restoration (NRDAR) Program.

2.0 Background

Information from numerous sources indicates that sediments within the Neosho and Spring river basins are contaminated by metals and/or other COPCs. Exposure to sediment-associated COPCs can pose potential risks to a variety of ecological receptors. This section provides background information on the role of sediments in aquatic ecosystems, the issues and concerns associated with releases of COPCs into the environment, and on the selection of metrics for assessing sediment quality conditions in the TSMD.

2.1 Role of Sediments in Freshwater Ecosystems

The particulate materials that lie below the water in ponds, lakes, streams, and rivers are called sediments (ASTM 2008). Sediments represent essential elements of aquatic ecosystems because they support both autotrophic and heterotrophic organisms. Autotrophic (which means self-nourishing) organisms are those that are able to synthesize food from simple inorganic substances (e.g., carbon dioxide, nitrogen, and phosphorus) and the sun's energy. Green plants, such as algae, bryophytes (e.g., mosses and liverworts), and aquatic macrophytes (e.g., sedges, reeds, and pond weed), are the main autotrophic organisms in freshwater ecosystems. In contrast, heterotrophic (which means other-nourishing) organisms utilize, transform, and decompose the materials that are synthesized by autotrophic organisms (i.e., by consuming or decomposing autotrophic and other heterotrophic organisms). Some of the important heterotrophic organisms that can be present in aquatic ecosystems include bacteria, epibenthic, and infaunal invertebrates, fish, amphibians, and reptiles. Birds and mammals can also represent important heterotrophic components of aquatic food webs (i.e., through the consumption of aquatic organisms).

2.1.1 Supporting Primary Productivity

Sediments support the production of food organisms in several ways. For example, hard-bottom sediments, which are characteristic of faster-flowing streams and are comprised largely of sands, gravels, cobbles, and boulders, provide stable substrates to which periphyton (i.e., the algae that grows on rocks) can attach and grow. Soft sediments, which are common in ponds, lakes, estuaries, and slower-flowing sections of rivers and streams, are comprised largely of sand, silt, and clay. Such sediments provide substrates in which aquatic macrophytes can root and grow. The nutrients that are present in such sediments can also nourish aquatic macrophytes. By providing habitats and nutrients for aquatic plants, sediments support autotrophic production (i.e., the production of green plants) in aquatic systems. Sediments can also support prolific bacterial and meiobenthic communities, the latter including protozoans, nematodes, rotifers, benthic cladocerans, copepods, and other organisms. Bacteria represent important elements of aquatic ecosystems because they decompose organic matter (e.g., the organisms that die and accumulate on the surface of the sediment, and anthropogenic organic chemicals) and, in so doing, release nutrients to the water column and increase bacterial biomass. Bacteria represent the primary heterotrophic producers in aquatic ecosystems, upon which many meiobenthic organisms depend. The role that sediments play in supporting primary productivity (both autotrophic and heterotrophic) is essential because green plants and bacteria represent the foundation of food webs upon which all other aquatic organisms depend (i.e., they are consumed by many other aquatic species).

2.1.2 Providing Essential Habitats

In addition to their role in supporting primary productivity, sediments also provide essential habitats for many sediment-dwelling invertebrates and benthic fish. Some of these invertebrate species live on the sediments (termed epibenthic species), while others live in the sediments (termed infaunal species). Both epibenthic and infaunal invertebrate species consume plants, bacteria, and other organisms that are associated with the sediments. Invertebrates represent important elements of aquatic ecosystems because they are consumed by a wide range of wildlife species, including fish, amphibians, reptiles, birds, and mammals. For example, virtually all fish species consume aquatic invertebrates during all or a portion of their life cycle. In addition, many birds (e.g., dippers, sand pipers, and swallows) consume aquatic invertebrates. Similarly, aquatic invertebrates represent important food sources for both amphibians (e.g., frogs and salamanders) and reptiles (e.g., turtles and snakes). Therefore, sediments are of critical importance to many wildlife species due to the role that they play in terms of the production of aquatic invertebrates.

Importantly, sediments can also provide habitats for many wildlife species during portions of their life cycle. For example, a variety of fish species utilize sediments for spawning and incubation of their eggs and alevins (e.g., trout, salmon, and whitefish). In addition, juvenile fish often find refuge from predators in sediments and/or in the aquatic vegetation that is supported by the sediments. Furthermore, many amphibian species burrow into the sediments in the fall and remain there throughout the winter months, such that sediments provide important overwintering habitats. Therefore, sediments play a variety of essential roles in terms of maintaining the structure (i.e., assemblage of organisms in the system) and function (i.e., the processes that occur in the system) of aquatic ecosystems.

2.2 Issues and Concerns Relative to Releases of Metals and Other Hazardous Substances into the Environment

Historic mining activities have resulted in substantial releases of metals into the environment within the TSMD. The metals that have been released to aquatic and riparian ecosystems represent a concern for aquatic, aquatic-dependent, and terrestrial organisms for several reasons. First, aquatic organisms can be exposed to water-borne metals, potentially causing direct toxicity to sensitive aquatic invertebrates and/or fish. In addition, water-borne metals can accumulate in the tissues of aquatic organisms and, subsequently, be transferred to higher trophic levels in the food web.

The metals that are released into surface waters can also become associated with bottom sediments and/or flood-plain soils, making them accessible over the long-term to a variety of aquatic and aquatic-dependent organisms. Sediment-associated metals can be toxic to benthic invertebrates and/or accumulate in aquatic food webs. Similarly, soil-associated metals can be directly toxic to terrestrial invertebrates and/or accumulate in terrestrial food webs.

Accumulation of metals (e.g., lead or mercury) in aquatic organisms represents a serious concern for many ecological receptors. Importantly, accumulation of certain metals to elevated concentrations in the tissues of aquatic organisms has been shown to adversely affect the survival, growth, and/or reproduction of fish and invertebrates. Such adverse effects can impact piscivorus wildlife by decreasing the availability of prey items upon which they depend to meet their energy and nutritional requirements. In addition, consumption of metal-contaminated food has been shown to adversely affect the survival, growth, and reproduction of aquatic-dependent avian and mammalian species. Therefore, accumulation of metals in fish and invertebrate tissues poses risks to aquatic-dependent wildlife that consume aquatic prey species.

Releases of other hazardous substances into the environment also have the potential to adversely affect aquatic organisms and aquatic-dependent wildlife. For example, water-borne polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, and polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs) have all been shown to be toxic to aquatic organisms. In addition, all of these substances have the potential to accumulate to elevated levels in sediments. Exposure to contaminated sediments has been shown to adversely affect the survival, growth, and/or reproduction of fish and invertebrate species. Furthermore, many of these other hazardous substances tend to bioaccumulate in the tissues of benthic invertebrates and fish, thereby posing a hazard to these aquatic organisms and to the wildlife species that consume them during foraging activities.

Cadmium, lead, and zinc have been identified as the primary COPCs in the TSMD. Due to concerns relative to the potential effects associated with exposure to these metals, USEPA will conduct an Advanced SLERA to evaluate risks to ecological receptors utilizing aquatic habitats within the study area. Such an assessment necessitates selection of a suite of indicators of environmental quality and a variety of metrics that can be used to evaluate conditions in the watershed. Sediment chemistry and pore-water chemistry represent two key indicators of sediment quality conditions in the TSMD. The following section of this document describes the metrics that were selected to evaluate sediment and pore-water chemistry.

2.3 Selection of Metrics for Evaluating Sediment Chemistry and Pore-Water Chemistry

Metrics are the variables that are measured to provide information on the status of each indicator of sediment quality conditions (for example the concentration of cadmium in sediments is a metric that provides information on sediment chemistry). In this study, sediment chemistry and pore-water chemistry were identified as key indicators of sediment quality conditions. Sediment chemistry represents one of the most important indicators because it provides a linkage between sources and releases of COPCs and their potential effects on sediment-dwelling organisms. While data on the concentrations of individual COPCs is useful in this respect, several chemical mixture models were also selected as metrics for sediment chemistry [such as mean probable effect concentration-quotients (PECs-Qs), sum equilibrium partitioning-based sediment benchmark-toxic units final chronic values ($\sum$ESB-TUs$_{FCV}$), and sum simultaneously extracted metal minus acid volatile sulfide ($\sum$SEM-AVS)]. The metrics for chemical mixtures that were selected for assessing sediment quality conditions in the TSMD are described in Section 3.3 and the procedures for calculating these metrics are illustrated in Appendix 2.

3.0 Methods

This investigation was conducted to develop and evaluate site-specific toxicity thresholds for metals and other COPCs in sediments and associated pore water from the TSMD. A step-wise process was used to evaluate and compile the matching chemistry and toxicity data obtained during the sediment sampling programs that have been conducted in the TSMD watershed, to derive site-specific toxicity thresholds, and to evaluate the reliability and predictive ability of the toxicity thresholds. This process consisted of eight main steps, including:

- Establish preliminary remedial action objectives (RAOs) for the TSMD;
- Compile and evaluate the sediment chemistry and sediment toxicity data;
- Calculate additional parameters that describe various mixtures of COPCs;
- Develop a reference envelope for each toxicity test endpoint to support designation of each sediment sample as toxic or not toxic;
- Develop concentration-response models for selected COPCs and COPC mixtures;
- Refine the concentration-response models and derive preliminary sediment toxicity thresholds (STTs) and pore-water toxicity thresholds (PWTTs) for each of the selected COPCs and COPC mixtures;
- Evaluate the reliability and predictive ability of the preliminary STTs/PWTTs; and,
- Recommend one or more site-specific STTs and/or PWTTs for use in the Advanced SLERA.

This approach is generally in accordance with the methods that were used to develop PRGs for the Calcasieu Estuary (MacDonald *et al.* 2003), the West Branch of the Grand Calumet River (MacDonald *et al.* 2005a), and the Indiana Harbor Area of Concern (MacDonald *et al.* 2005b). Each of these steps in the data analysis process is briefly described in the following sections of this document. It should be noted that this study did not include an evaluation of the spatial extent of risks to ecological receptors (i.e., application of the selected toxicity thresholds), as this will be completed in subsequent documentation (i.e., the Advanced SLERA). In addition, the sediment bioaccumulation data that were collected as part of the 2007 sampling program will be evaluated as part of the Advanced SLERA.

3.1 Establishment of Preliminary Remedial Action Objectives

The first step in the development of site-specific STTs and PWTTs involved the establishment of RAOs for the TSMD watershed that are relevant to aquatic organisms. The RAOs are intended to describe the narrative intent of any remedial actions that are undertaken to mitigate risks to the ecological receptors that are exposed to COCs. The COCs are the COPCs that are identified as risk drivers, based on the results of the evaluation of relationships between sediment chemistry and sediment toxicity, the Advanced SLERA, and/or the BERA. The RAOs for aquatic receptors were established using input solicited from the tribal, state, and federal NRTs and representatives of the USEPA at the Ecological Risk Assessment workshop held in Joplin, MO on January 18 and 19, 2007 (MESL and CH2M Hill 2007). At this workshop, participants were asked to establish long-term goals and objectives for the Neosho and Spring River watershed ecosystem to support the development of RAOs and restoration goals for the TSMD. These ecosystem goals and objectives were used directly to establish preliminary RAOs for aquatic habitats at the site.

3.2 Evaluation of Sediment Chemistry and Toxicity Data

As part of the 2007 sediment sampling program, a total of 70 sediment samples were collected from eight Areas of Interest (AoIs) within the TSMD watershed (Ingersoll *et al.* 2008). All of these samples were sieved to remove the coarse particles (i.e., >2 mm) and were then submitted to various analytical laboratories for determination of the concentrations of selected COPCs [USEPA Region VI laboratory for PAHs; Texas Commission on Environmental Quality (TCEQ) for total organic carbon (TOC) and grain size; USEPA Region VII CLP laboratories for metals, organochlorine pesticides, and PCBs; Columbia Environmental Research Center (CERC) for SEM-AVS]. The samples were sieved to obtain the <250 μm size fraction and analyzed for metals (USEPA Region VII CLP laboratory) and TOC (TCEQ). In addition, pore water was obtained from all of the sediment samples to determine the concentrations of dissolved metals in pore-water samples (CERC) obtained from peepers, and dissolved metals, cations, anions, and dissolved organic carbon (DOC) in pore-water samples obtained by centrifugation (CERC, ESS Laboratory, USGS-GD, LET laboratory). The toxicity of 70 sediment samples was evaluated by assessing the survival and growth of the amphipod, *Hyalella azteca*, in 28-d exposures and the survival and growth of the midge, *Chironomus dilutus*, in 10-d exposures. Forty-two of the 70 sediment samples were selected for toxicity testing with fat mucket (mussels), *Lampsilis siliquoidea*, in 28-d exposures. Twenty of the 70 sediment samples were selected for bioaccumulation testing with the oligochaete, *Lumbriculus variegatus*, in 28-d exposures (Ingersoll *et al.* 2008).

An additional six sediment samples were collected by CERC in 2006, which were not part of the USEPA-DOI 2007 sediment sampling program of the TSMD (although the approach to sample collection and evaluation was generally consistent with the 2007 sampling effort; Ingersoll *et al.* 2008). The six sediment samples were collected from three of the eight AoIs within the TSMD watershed. All of these samples were sieved to remove the large materials (i.e., to <2 mm for amphipod and midge testing and <250 μm for mussel testing) and were then submitted to the CERC analytical laboratory for determination of the concentrations of SEM-AVS, TOC and grain size. In addition, these six samples underwent toxicity testing by evaluating the survival and growth of amphipods (*Hyalella azteca*) in 28-d sediment exposures, the survival and growth of midge (*Chironomus dilutus*) in 10-d sediment exposures, and the survival and growth of fat mucket (*Lampsilis siliquoidea*) in 28-d sediment exposures.

The acceptability of the chemistry and toxicity data was evaluated to ensure that the data met the data quality objectives (DQOs) specified in the project quality assurance project plan (QAPP; Ingersoll 2007; Ingersoll *et al.* 2008; USEPA 2008a; 2008b). Acceptable data were compiled in the project database and, subsequently, a detailed database audit was performed to identify inconsistencies in the underlying data [as per MacDonald Environmental Sciences Ltd. (MESL) standard operating procedures (SOPs) for database-specific auditing]. Any data quality issues that arose during the audit were resolved by referring to the original laboratory electronic data deliverables (EDDs) and/or communicating with the lead project scientists for the laboratories. Finally, data decision criteria for the project (e.g., treatment of less than detection limit values) were established and applied (see Section 4.2 for more detail).

3.3 Calculation of Additional Parameters to Represent Chemical of Potential Concern Mixtures

Several chemical mixture models for sediment and pore-water samples were calculated using the data presented in Ingersoll *et al.* (2008). The potential effects of mixtures of sediment-associated contaminants were evaluated using toxic units (TUs) models for pore water and/or sediment that have been validated using data from other sites (MacDonald *et al.* 2000; USEPA 2000; 2003; 2005; Ingersoll *et al.* 2001). Application of these TU models was facilitated by calculating the following parameters for the sediment samples:

- Mean PEC-Qs (MacDonald *et al.* 2000; USEPA 2000; Ingersoll *et al.* 2001);
- Mean PEC-Q_{METALS} (MacDonald *et al.* 2000);
- Mean PEC-$Q_{METALS(1\%OC)}$ (MacDonald *et al.* 2007a);
- $\sum$PEC-$Q_{Cd,Pb,Zn}$ (i.e., Dudding Model);

- $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$ using the site-specific T_{10}- or T_{20}-values for these metals based on the survival of the amphipod, *Hyalella azteca*, in 28-d toxicity tests (the most reliable T value was selected for use in this model);
- The $\sum$SEM-AVS and ($\sum$SEM-AVS)/f_{OC} (USEPA 2005);
- Total PAHs (MacDonald *et al.* 2000; USEPA 2000; Ingersoll *et al*. 2001);
- $\sum$ESB-TU_{FCVs} (for PAHs; USEPA 2003); and,
- Total PCBs (MacDonald *et al.* 2000; USEPA 2000; Ingersoll *et al*. 2001).

The OC-normalized concentrations of certain non-polar organic substances (e.g., PAHs) were also calculated and incorporated into the database (to complement the dry-weight data). For pore-water samples, toxic units (PW-TUs) for metals were generally calculated using the methods described in USEPA (2005). In all cases, PW-TUs were determined by dividing the measured concentration of the metal in pore water from peeper samples by the criteria continuous concentration (CCC) provided by USEPA (2006) or by a functionally-equivalent value (i.e., water quality guidelines with similar narrative intent). Sum PW-TUs were calculated for divalent metals (USEPA 2005) and for all metals combined. When applicable, the CCCs were corrected for pore-water hardness. In addition, the concentrations of selected metals (i.e., lead and zinc) were normalized to pore-water DOC by dividing the calculated PW-TU for the metal by the measured concentration of DOC (in µg/L) in the pore-water sample (i.e., results for all samples were normalized to 1 µg/L of DOC). The selected chemical mixture model metrics for assessing sediment quality conditions in the TSMD are described below and more detailed procedures for calculating these mixture models are provided in Appendix 2.

3.3.1 Mean Probable Effect Concentration-Quotients and Mean Probable Effect Concentration-Quotients for Metals

Mean PEC-Qs provide a means of quantifying the chemical composition of sediments that contain mixtures of environmental contaminants and were calculated using the procedure reported in USEPA (2000). Using this method, a PEC-Q was first determined for each metal for which a reliable PEC was available. A PEC-Q is calculated by dividing the measured total concentration of a substance in a sediment sample by the corresponding PEC. For example, a PEC-Q of 2.0 for arsenic would be calculated for a sediment sample with a concentration of 66 mg/kg DW of arsenic and a PEC-Q of 33 mg/kg DW (i.e., 66 mg/kg DW ÷ 33 mg/kg DW = 2.0). Then, an average PEC-Q for metals (mean PEC-Q_{METALS}) was calculated by summing the PEC-Qs of each metal and dividing by the number of metals that were included in the calculation. PEC-Qs were also calculated for total PAHs and total PCBs. Finally, the mean of the average PEC-Q for metals, the PEC-Q for PAHs, and the PEC-Q for PCBs was determined for each sediment sample (termed the mean PEC-Q). An OC-normalized mean PEC-$Q_{METALS(1\%OC)}$ metric was also calculated for each sample. For the six sediment samples collected in 2006, mean PEC-Q_{METALS} and mean PEC-$Q_{METALS(1\%OC)}$ were calculated using SEM concentrations. See Appendix 2 for an example calculation for mean PEC-Q and mean PEC-Q_{METALS}.

3.3.2 Sum Equilibrium Partitioning-Based Sediment Benchmark-Toxic Units for Polycyclic Aromatic Hydrocarbons

The USEPA (2003) developed procedures for evaluating PAH-contaminated sediments using ESBs for 34 parent and alkylated PAHs. This approach was chosen by USEPA because it provides a basis for evaluating the potential toxicity of PAH-contaminated sediments that accounts for differences in the biological availability of these substances in various sediment types and considers the additive toxicity of PAHs (USEPA 2003). Application of this approach necessitates calculation of the OC-normalized concentration of each measured PAH (expressed on a $\mu g/g_{OC}$ basis). The OC-normalized concentration of each PAH is then divided by the corresponding concentration of concern for that substance [which is the concentration that would be predicted to be associated with a pore-water concentration equal to the final chronic value (FCV); i.e., based on equilibrium partitioning modeling]. The quotients that are calculated for each of the up to 34 measured parent and alkylated PAHs are then summed to estimate $\sum$ESB-TU_{FCV} for that sediment sample. Using this approach, sediment samples with $\sum$ESB-TU_{FCV} of <1.0 are predicted to be not toxic due to PAHs, while those with $\sum$ESB-TU_{FCV} >1.0 are predicted to be toxic to sediment-dwelling organisms.

3.3.3 Sum Simultaneously Extracted Metals Minus Acid Volatile Sulfides and Sum Simultaneously Extracted Metals Minus Acid Volatile Sulfides (Fraction Organic Carbon)

Recently, USEPA (2005) developed a model to evaluate the toxicity of divalent metals (i.e., cadmium, copper, lead, nickel, silver, zinc) to sediment-dwelling organisms. Application of this model is dependent on the collection of data on the molar concentrations of SEM and AVS in sediment samples. The model is based on the assumption that divalent metals can only cause or contribute to sediment toxicity when the sum of the molar concentrations of cadmium, copper, lead, nickel, silver, and/or zinc exceeds the molar concentration of AVS. Under such conditions, insufficient AVS is available to bind all of the divalent metals in the particulate matrix and, hence, metals can accumulate in pore water to levels that can adversely affect sediment-dwelling organisms. Because metals can also bind to organic carbon in the sediment, the reliability of the model has been improved by incorporating the fraction of TOC of the sediment (i.e., the f_{OC}) into the model [i.e., ($\sum$SEM-AVS)/f_{OC}].

3.3.4 Evaluation of Other Mixtures of Chemicals of Potential Concern in Sediments

Although sediments in the TSMD may be contaminated by a variety of COPCs, cadmium, lead, and zinc have been identified as the principal COPCs. For this reason, several other chemical mixture models were developed to support assessment of contaminated sediments in the study area. First, a $\sum$PEC-Q model was developed to address concerns relative to the effects of sediment-associated cadmium (Cd), lead (Pb), and zinc (Zn) on benthic invertebrates. Calculation of $\sum$PEC-$Q_{Cd,Pb,Zn}$ involves summing the PEC-Qs for these three metals (termed the "Dudding model" in this report). Second, a model was developed that utilizes the most reliable STTs that were developed for cadmium (11.1 mg/kg DW), copper (Cu; 27.1 mg/kg DW), lead (219 mg/kg DW) and zinc (2083 mg/kg DW) for the TSMD. Calculation of the $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$ involves dividing the measured concentration of each of the four metals by the corresponding STT. Then, the quotients for the four metals are summed.

3.3.5 Metrics for Pore-Water Chemistry

A variety of metrics were selected for evaluating pore-water chemistry in the TSMD. First, the concentrations (dissolved) of individual metals in pore water represents the primary metrics that were used to evaluate pore-water quality. These data were interpreted by calculating PW-TUs for each metal in each pore-water sample (e.g., PW-TU zinc). These parameters were calculated by dividing the measured concentrations of each metal in pore water (dissolved) by the corresponding criterion continuous concentrations (USEPA 2006; which were hardness corrected when appropriate). In addition, the potential for additive toxicity of multiple metals was evaluated by calculating the sum of PW-TUs for divalent metals ($\sum$PW-$TU_{DIVALENT\ METALS}$) and the sum of PW-TUs for all measured metals ($\sum$PW-TU_{METALS}).

3.4 Development of Reference Envelopes to Support Toxicity Designation

A reference envelope approach was used to designate which sediment samples from the TSMD were considered to be toxic or not toxic (Hunt *et al.* 1998). As a first step, sediment samples representative of reference conditions were identified (i.e., substantially free of metal contamination). Reference sediment samples were identified using the following criteria relative to sediment chemistry (USEPA 2005; MacDonald *et al.* 2007a):

- Mean PEC-$Q_{METALS(1\%OC)}$ <0.1; and,

- ($\sum$SEM-AVS)/f_{OC} <130 µmol/g.

Reference sediment samples that met these chemical criteria were further evaluated to confirm that they were not toxic to sediment-dwelling organisms. More specifically, the reference sediment samples that had survival of at least 75% that of controls were retained for use in the development of the reference envelope for each toxicity test (USEPA 2004). This biological criterion was applied to ensure that samples that were adversely affected due to the presence of non-metal or unmeasured COPCs were not used in the reference envelope calculation. This approach was recommended by the members of the Science Advisory Group on Sediment Quality Assessment. The reference samples that were selected using these criteria were considered to represent locations in the watershed that were least affected by point-source discharges of contaminants and other releases of COPCs. A total of eight samples were included in the reference envelope for the midge toxicity test. Ten samples met the chemical and biological criteria for the amphipod test, while five reference samples were used to establish reference conditions for the mussel toxicity test.

Once the reference samples had been identified, the range of the biological responses in these samples was determined for each toxicity test conducted and endpoint measured. In this study, the reference envelope was defined as the range of biological responses that encompassed 95% of the response data for the reference sediment samples. Accordingly, the lower limit of the reference envelope was calculated as the 5^{th} percentile of the control-adjusted response data for each toxicity test and endpoint, using the data for the reference sediment samples that were selected for each toxicity test (the underlying data were log transformed prior to calculating the 5^{th} percentile). The reference envelope, then, encompassed all of the control-adjusted response data between the 5^{th} percentile value and the maximum value for each endpoint. The reference envelope was considered to define the normal range of responses to exposure to relatively uncontaminated sediment samples. Sediment samples with effect values lower than the lower limit of the normal range of control-adjusted responses for the reference samples (i.e., lower than the 5^{th} percentile) were designated as toxic for the endpoint under consideration. See Appendix E2 of MacDonald *et al.* 2002 for a more detailed description of these procedures.

The sediment samples in the project database were also designated as toxic or not toxic based on the results of multiple toxicity test endpoints. First, a sediment sample was designated as toxic if it had been designated as toxic for any of the six toxicity test endpoints measured in this study (i.e., overall toxicity; OT-Six Endpoints). Examination of the underlying sediment chemistry and toxicity data revealed that neither midge survival nor midge biomass was significantly correlated (i.e., $r^2 \geq 0.4$; $p < 0.05$) to the concentrations of COPCs or COPC mixtures in pore water. For this reason, overall toxicity was also determined using the amphipod and mussel results only (survival and biomass). In this case, a sediment sample was designated as toxic if it had been designated as toxic for any one of the four endpoints (i.e., OT-Four Endpoints). These toxicity designations for individual endpoints and multiple endpoints were used in the evaluations of the reliability and predictive ability of the various sediment and pore-water toxicity thresholds.

3.5 Development of Preliminary Concentration-Response Models for Key Chemicals of Potential Concern

A step-wise approach was used to analyze the chemistry and toxicity data that were collected during the 2006 and 2007 studies in the TSMD. As a first step, key indicators of sediment chemistry were identified from the list of COPCs and COPC mixtures included in the problem formulation for the Advanced SLERA (MacDonald *et al.* 2007b). Next, the initial list of COPCs was refined by conducting the following preliminary analyses:

- Eliminating COPCs that were not measured in any sample at detectable concentrations;

- Eliminating the COPCs that were not measured in any sample at concentrations in excess of conservative benchmarks for evaluating sediment quality and water quality; and,
- Conducting Spearman Rank Correlation analyses using the matching chemistry (i.e., pore-water chemistry and sediment chemistry) and toxicity data to identify the physical or chemical characteristics of sediment or pore water (e.g., COPC, COPC mixtures, grain size, TOC, ammonia) that were significantly correlated with sediment toxicity ($p < 0.005$).

Several additional chemical mixture models were identified based on consultations with the NRTs and USEPA (i.e., $\sum PEC\text{-}Q_{Cd,Pb,Zn}$ and $\sum STT\text{-}Q_{Cd,Cu,Pb,Zn}$).

Preliminary concentration-response relationships were developed for each of the COPCs and COPC mixtures in sediment and pore water that were retained following these initial analyses (Appendix 1). More specifically, the site-specific chemistry and toxicity data for these COPCs and COPC mixtures were used to develop concentration-response relationships based on the magnitude of toxicity (i.e., control-adjusted survival and biomass) to the amphipod, *Hyalella azteca*, the midge, *Chironomus dilutus*, and the fat-mucket mussel, *Lampsilis siliquoidea*. Biomass of toxicity test organisms was calculated as the product of the survival and weight endpoints for amphipods and measured directly for midges and mussels. Development of the preliminary relationships involved plotting the concentration-response model and determining the correlation between the independent (concentration) and dependent (response) variables (as described MacDonald *et al.* 2002; 2003; 2005a; 2005b). Three-parameter sigmoid regression equations were generally used to describe these preliminary relationships; however, three-parameter logistic or linear equations were used when the three-parameter sigmoid equation could not generate a relationship. All of the relationships were defined using SigmaPlot™ software.

3.6 Development of Preliminary Toxicity Thresholds for Sediment and Pore Water

Preliminary STTs and PWTTs were established for selected COPCs/COPC mixtures and toxicity metrics, based on the preliminary site-specific concentration-response models derived from matching chemistry and toxicity data for amphipods, midges, and mussels. These COPCs and COPC mixtures were selected based on the coefficients of determination (r^2) and associated p-values that were calculated for the preliminary regression equations. Because the relationships between the concentrations of COPCs and the responses of benthic invertebrates tend to be variable (i.e., due to differences in the physical and chemical characteristics among the sediment samples collected), COPCs and COPC mixtures were selected for toxicity threshold derivation if $r^2 \geq 0.40$ and $p < 0.05$. Experience at other sites suggests that toxicity thresholds derived for COPCs or COPC mixtures that exhibited such correlations with survival or biomass of invertebrates tended to be the most reliable (i.e., most accurately predict toxicity based on chemical concentration). Following selection of the key COPCs and COPC mixtures, the preliminary concentration-response relationships were refined by fitting the data using a series of models and selecting the model that best described the toxicity and chemistry data (based on r^2 values; i.e., definitive plots).

A variety of approaches could be used to develop toxicity thresholds for sediment and pore water. Participants who attended the problem formulation workshop in April 2007 agreed that toxicity thresholds for assessing risks to aquatic receptors in the TSMD watershed should account for the baseline level of contamination that exists due to releases from the various point and non-point contaminant sources in the watershed (MESL *et al.* 2007). For this reason, the preliminary STTs and PWTTs for the TSMD were established by determining the chemical concentrations that corresponded to specific increases in the magnitude of toxicity relative to reference conditions in the watershed.

In this study, reference conditions were described by using the reference envelope approach (see Section 3.4 for additional information). More specifically, toxicity to amphipods, midges, and mussels under reference conditions was evaluated by calculating the mean control-adjusted response rate for each toxicity test endpoint. The preliminary STTs and PWTTs were identified by determining the chemical concentrations that corresponded to a 10% (i.e, T_{10} value) and a 20% (i.e., T_{20} value) reduction in the control-adjusted survival or biomass of amphipods, midges, or mussels compared to the average response rate for toxicity test organisms exposed to reference sediments (i.e., using the regression equations that were developed). The STTs for midges and amphipods were developed using the data for the <2 mm sediment size fraction, while the STTs for mussels were derived using the data for the <250 µm and/or <2 mm sediment size fractions.

As indicated above, low-risk toxicity thresholds were determined by calculating the concentration of each COPC or COPC mixture that corresponded to a 10% reduction in the average control-adjusted survival or biomass of toxicity test organisms exposed to reference sediment samples. This response rate was selected for deriving the low-risk STTs because it roughly corresponds to the maximum acceptable response rates of amphipods exposed to control materials (i.e., test acceptability criteria) and because such response rates (i.e., >90% control-adjusted survival or biomass) are consistent with those associated with exposure to reference sediments at other sites (Ingersoll *et al.* 2001; USEPA 2000). Therefore, control-adjusted survival or biomass of >90% is likely to be associated with conditions that would support healthy benthic invertebrate communities.

The high-risk STTs were derived by calculating the concentrations of COPCs or COPC mixtures that corresponded to a 20% increase in the magnitude of toxicity (i.e., control-adjusted survival or biomass of 80%). This response rate generally corresponds to the minimum significant difference (MSD) from control responses for certain toxicity tests, based on the results of power analyses (e.g., Thursby *et al.* 1997). In addition, MacDonald *et al.* (2004) reported that samples from Tampa Bay, Florida that exhibited approximately this response rate in amphipod toxicity tests also had impaired benthic invertebrate community structure, including reduced abundance and diversity of benthic invertebrates. Similar results have been reported elsewhere in the U.S. (e.g., Swartz *et al.* 1994; Long *et al.* 2002). Therefore, control-adjusted survival or biomass of <80% is likely to be associated with conditions that would impair benthic invertebrate communities.

3.7 Evaluation of the Preliminary Sediment and Pore-Water Toxicity Thresholds

The principal objective of this report is to establish toxicity thresholds that can be used in the Advanced SLERA to assess risks to aquatic receptors (i.e., benthic invertebrates) associated with exposure to contaminated sediments within the TSMD. As such, the preliminary STTs and PWTTs developed for each of the selected COPCs and COPC mixtures were evaluated to support selection of toxicity thresholds for assessing risks to benthic invertebrates and other aquatic receptors in the TSMD watershed.

The evaluation of the reliability (i.e., the ability of the STTs or PWTTs to correctly classify sediment samples as toxic or not toxic, using the same data that were applied to derive the toxicity threshold) and predictive ability (i.e., as evaluated using an independent data set) of preliminary STTs and PWTTs (i.e., T_{10} and T_{20} values) consisted of several steps. In the first step of the process, the preliminary STTs and PWTTs were used to classify sediment samples into two categories (i.e., toxic or not toxic to the test organisms) based on measures of sediment chemistry or pore-water chemistry. More specifically, samples with measured concentrations of the selected COPC or COPC mixture that exceeded the preliminary STT or PWTT were predicted to be toxic to the test organisms. The samples that had chemical concentrations less than the corresponding preliminary STT or PWTT were predicted to be not toxic to the test organisms (e.g., any sample with zinc concentrations less than the T_{10} of 2083 mg/kg DW in sediment was predicted to be not toxic). The accuracy of these predictions was then evaluated by determining the proportion of samples within each group of samples (i.e., predicted toxic and predicted not toxic) that were actually toxic to the test organisms, based on the results of the sediment toxicity tests. For the reliability calculation, the frequency of toxicity above and below the toxicity threshold was determined using data on the toxicity test endpoint and test organism used to derive the STT or PWTT. For the predictive ability evaluation, the frequency of toxicity above and below the toxicity thresholds was determined for all six of the toxicity test endpoints and for overall toxicity (based on four endpoints combined or six endpoints combined).

Criteria for evaluating the reliability of the preliminary STTs and PWTTs were established on an *a priori* basis, using the procedures that had been established previously for evaluating toxicity thresholds in the Calcasieu Estuary and Indiana Harbor (MacDonald *et al.* 2003; 2005a; 2005b). More specifically, a preliminary STT or PWTT was considered to be reliable if the incidence of toxicity (IOT) was <20% below the STT or PWTT, if the IOT was >50% above the STT or PWTT, and if the overall correct classification rate was ≥80% (MacDonald *et al.* 2002; 2003; 2005a; 2005b; 2008a). Preliminary STTs or PWTTs that met these criteria were considered to provide a reliable basis for classifying sediment samples as toxic or not toxic (i.e., the overall error rate would be no greater than 20%). Such toxicity thresholds also minimize the potential for false negative errors (i.e., Type II error rate would be less than 20%) and for identifying sediment samples that would be toxic, more likely than not (i.e., Type I error rate would be less than 50%). The same criteria were applied to evaluate predictive ability, except the performance of the toxicity thresholds was assessed using up to six toxicity endpoints, both singly and in combination.

3.8 Selection of Sediment and/or Pore-Water Toxicity Thresholds for Use in the Advanced Screening-Level Ecological Risk Assessment

The results of the reliability and predictive ability evaluation provide essential information for recommending toxicity threshold(s) for assessing risks to sediment-dwelling organisms associated with exposure to contaminated sediments in the TSMD watershed, based on the results of the laboratory toxicity tests. In this evaluation, the number of criteria that were met by the preliminary STTs/PWTTs were determined and compared. The preliminary STTs and PWTTs that most accurately predicted the presence and absence of toxicity for individual endpoints and overall toxicity (OT-Four Endpoints or OT-Six Endpoints). In this evaluation, the overall toxicity designation assigned based on the results for four endpoints (i.e., amphipod and survival and biomass and mussel survival and biomass) was relied on more heavily because the results of the 10-d toxicity tests with midges were generally poorly correlated with sediment and pore-water chemistry (i.e., factors other than exposure to the COPCs were influencing the results of these tests). Several other factors were also considered in the selection of toxicity thresholds for use in the Advanced SLERA, including applicability to sediments that contain complex mixtures of COPCs, broad applicability across multiple data sets, and level of protection afforded the benthic invertebrate community.

The biological responses of toxicity test organisms in sediment samples with concentrations above and below the recommended toxicity threshold(s) were also determined by calculating the average response rates above and below the toxicity threshold for each toxicity test endpoint. This analysis was intended to provide information on the magnitude of toxicity that was observed for sediment samples with COPC concentrations below the selected toxicity thresholds (i.e., low risk samples) and those with COPC concentrations above the selected toxicity thresholds (i.e., high risk samples). Average control-adjusted response rates for reference sediment samples were also calculated to provide a basis for comparison with those calculated for the low risk samples and the high risk samples. The underlying concentration-response relationships for the selected COPCs or COPC mixtures will be used in the Advanced SLERA to evaluate the magnitude of risk associated with exposure to sediment-associated contaminants in the watershed (i.e., low, moderate, or high risk).

4.0 Results and Discussion

This study was undertaken to support the development and evaluation of site-specific toxicity thresholds for use in the Advanced SLERA to evaluate risks associated with exposure to sediments and/or pore water in the TSMD. Preliminary site-specific toxicity thresholds were developed by evaluating and compiling the matching sediment chemistry and toxicity data that have been generated for the study area, developing and refining concentration-response models for selected COPCs and COPC mixtures in sediment and pore water, and determining the concentrations of COPCs and COPC mixtures that correspond to specific increases in response rates of toxicity test organisms relative to those that were observed for animals exposed to reference sediment samples. The preliminary site-specific toxicity thresholds were then evaluated to determine which of these toxicity thresholds would be the most useful for assessing risks to aquatic receptors in the TSMD. These results are presented and discussed in the following sections of this report.

4.1 Establishment of Preliminary Remedial Action Objectives

Participants at the Ecological Risk Assessment Workshop, convened in Joplin, MO on January 18 and 19, 2008, were asked to establish long-term ecosystem goals and objectives for the Neosho and Spring Rivers (MESL and CH2M Hill 2007). ***Ecosystem goals*** are broad narrative statements that define the management goals that have been established for a specific ecosystem. Definition of management goals for an aquatic ecosystem is a fundamental step towards the development of defensible management plans for the system. Definition of these ecosystem goals requires input from a number of sources to ensure that societal values are adequately represented.

Workshop participants indicated that protection of ecological receptors and restoration of natural resources are important long-term management goals in the Neosho and Spring River watersheds. Ecosystem goals, by themselves, are too general to support the development of meaningful planning, research, and management initiatives for the study area. To be useful, ecosystem goals must be further clarified and refined to establish ***ecosystem objectives*** that are more closely linked with ecosystem science (Harris *et al.* 1987). Establishment of such ecosystem objectives directly supports the development of RAOs and restoration objectives for the Neosho and Spring River watersheds. The following objectives for aquatic ecosystems in the study area were identified by workshop participants (MESL and CH2M Hill 2007):

- Achieve water quality standards in all of the receiving waters within the study area (or the best water quality that is possible to achieve);
- Ensure that benthic conditions are sufficient to support a healthy and diverse benthic community, including freshwater mussels;
- Restore freshwater mussel populations in the study area;
- Ensure that aquatic environmental conditions are sufficient to support a healthy and diverse fish community;
- Restore the quality and productivity of aquatic habitats such that they support healthy populations of aquatic organisms and aquatic-dependent wildlife (including migratory birds);
- Eliminate fish and shellfish consumption advisories within the study area; and,
- Restore aquatic habitats in the study area to a condition that facilitates the recovery of threatened or endangered species and supports their subsequent delisting.

The RAOs for aquatic receptors that were developed based on input provided by workshop participants are as follows:

- Exposure to sediment or associated pore water that is sufficiently contaminated to pose moderate risks to the microbial community, aquatic plant community, benthic invertebrate community, and/or benthic fish community should be minimized; and,

- Exposure to sediment or pore water that is sufficiently contaminated to pose high risks to the microbial community, aquatic plant community, benthic invertebrate community, and/or benthic fish community should be prevented.

In the context of this document, sediment samples were considered to pose a low risk to ecological receptors if the concentrations of COPCs are below those that are typically associated with a low probability of observing sediment toxicity (i.e., <20%). By comparison, high risk sediment samples are those that have COPC concentrations expected to be associated with a high probability of observing sediment toxicity (i.e., >50%). Moderate risk sediment samples are considered to be those with COPC concentrations that have an intermediate probability of observing sediment toxicity (i.e., 20-50%; see MacDonald *et al.* 2002 for more information).

In applying these RAOs, it was understood that site-specific data on the toxicity of contaminated sediments to microbes, aquatic plants, or fish would not be generated to support the Advanced SLERA. Rather, the results of evaluations of the toxicity of TSMD sediments to sediment-dwelling organisms would be used to develop site-specific toxicity thresholds for benthic invertebrates. Such toxicity thresholds would then be assumed to provide adequate levels of protection for other aquatic receptors utilizing benthic habitats in the study area. This assumption is supported by the results of intensive toxicological studies in the Calcasieu Estuary, which showed that the selected microbes (i.e., solid-phase Microtox test), aquatic plants (i.e., the alga, *Ulva fasciata*), and fish (i.e., red fish, *Sciaenops ocellatus*) tended to be less sensitive than benthic invertebrates when exposed to sediments contaminated by metals, PAHs, PCBs, and/or other COPCs (MacDonald *et al.* 2002). Other studies have also shown that fish tend to be less sensitive to sediment-associated COPCs than are benthic invertebrates (Dorkin 1994; Burton 1994). Accordingly, any remedial decisions that are made to minimize or eliminate exposure to sediments and/or pore water that pose moderate or high risks to benthic invertebrates would be considered to minimize or eliminate risks to other aquatic receptors, as well. RAOs for other ecological receptor groups (e.g., reptiles, aquatic-dependent birds and mammals) will be presented elsewhere.

4.2 Evaluation of Sediment Chemistry and Toxicity Data

The matching chemistry and sediment toxicity data for sediment and pore water summarized in Ingersoll *et al.* (2008) were evaluated to assess their applicability to the toxicity threshold-derivation process. The results of this evaluation indicated that data collected in 2006 and 2007 generally met the performance criteria for measurement data that were established for this project. Appendix 3 provides an overview of the results of the data quality evaluation that was conducted. The reader is directed to Ingersoll (2007) for detailed information on the project DQOs and associated performance criteria for measurement data. Ingersoll *et al.* (2008) provides a summary of the data that were collected during the 2006 and 2007 sampling efforts and the results of the data evaluation process (Appendix 3). Importantly, the results of these two studies were considered to be comparable because the methods that were used to generate the chemistry and toxicity data were generally consistent. Therefore, all the data collected in 2006 and 2007 were compiled in the project database that was used to generate toxicity thresholds for selected COPCs and COPCs mixtures in sediment or pore water. The data that did not meet the performance criteria for measurement data were flagged in the database and were not used in the toxicity threshold-derivation process (e.g., midge toxicity tests conducted in 2006 were excluded because of control results that did not meet test acceptability criteria; Ingersoll *et al.* 2008). When concentrations of COPCs less than detection limits were reported, a value of one-half detection limit was used in the various data analyses for the analyte except when the detection limit exceeded the screening-level toxicity thresholds (Table 1). In such cases, the data for that analyte for that sample were not used in the site-specific toxicity threshold derivation process.

4.3 Development of Reference Envelopes to Support Toxicity Designation

A reference-envelope approach was used to designate sediment samples from the TSMD as toxic or not toxic to test organisms. To develop the reference envelope for each toxicity test endpoint, all of the samples in the project database were evaluated against the criteria that were established for identifying reference conditions. A total of 10 sediment samples met the chemical criteria (i.e., mean PEC-$Q_{METALS(1\%OC)}$ <0.1 and ($\sum$SEM-AVS)/f_{OC} <130 µmoles/g) and were further considered for defining reference conditions in the TSMD (Table 2; Figure 4). None of the samples selected based on the chemical criteria were excluded based on the biological criterion that was established for this project (i.e., all of the reference sediment samples had control-adjusted survival greater than 75%). The reference envelopes for the various toxicity test endpoints were calculated using control-adjusted response rates because control responses were different among the three batches of results represented in the project database (Ingersoll *et al.* 2008; Table 3). Overall, a total of 10, eight, and five sediment samples were identified for developing the reference envelopes for amphipods, midges, and mussels, respectively (Table 3).

The normal range of responses of amphipods, midges, and mussels associated with exposure to reference sediments from the TSMD was defined as the 5th percentile to the maximum effect value for each endpoint. An effect value lower than the 5th percentile value was considered to fall outside the normal range of reference responses (i.e., the reference envelope; Table 3). Samples from the TSMD for which effect values were lower than the normal range of reference responses were designated as toxic for the toxicity test endpoint considered. For example, the normal range of control-adjusted survival of amphipods, *H. azteca*, exposed to reference sediments from the TSMD was 93.2 to 111% (Table 3). Therefore, sediment samples for which the survival of amphipods in 28-day exposures was less than 93.2% were considered to be toxic relative to amphipod survival. The reference envelopes for each of the toxicity test endpoints evaluated in these studies are presented in Table 3.

4.4 Development of Preliminary Concentration-Response Models for Key Chemicals of Potential Concern

A number of preliminary analyses were conducted to select the COPCs and COPC mixtures that would be included in the concentration-response model development process. First, the sediment and pore-water chemistry data were reviewed and COPCs that were not measured in any sample at detectable concentrations were eliminated from further consideration. Next, the sediment chemistry data were compared to conservative sediment quality guidelines (SQGs), while pore-water chemistry data were compared to conservative water quality criteria (WQC; see Table 1 for a summary of the SQGs and WQC used in this evaluation). COPCs and COPC mixtures that were not measured in any sample at concentrations above the SQGs or WQC were also eliminated from further consideration. Subsequently, the results of Spearman-Rank Correlation analyses conducted using the matching chemistry (i.e., pore-water chemistry and sediment chemistry) and toxicity data were evaluated to identify the substances that were correlated with sediment toxicity (i.e., $p < 0.005$). Preliminary concentration-response relationships were developed of all of the COPCs and COPC mixtures that were retained following these preliminary analyses. Several additional chemical mixture models were added based on consultation with NRTs and USEPA. The following sediment-associated COPCs and COPC mixtures were selected for developing preliminary relationships between sediment chemistry and sediment toxicity:

- Total Cadmium;
- Total Chromium;
- Total Copper;
- Total Lead;
- Total Nickel;
- Total Zinc;
- $\sum$PAHs (expressed on a dry-weight basis);

- $\sum$SEM-AVS;
- ($\sum$SEM-AVS)/f_{OC} ;
- $\sum$ESB-TU_{FCV}s (for PAHs);
- Mean PEC-Qs (expressed on a dry-weight basis);
- Mean PEC-Q_{METALS} (expressed on a dry-weight basis); and,
- Mean PEC-$Q_{METALS(1\%OC)}$;
- $\sum$PEC-$Q_{Cd,Pb,Zn}$; and,
- $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$.

In addition to the above sediment-associated COPCs and COPC mixtures, the relationships between pore-water chemistry and sediment toxicity were evaluated for the following COPCs and COPC mixtures:

- $\sum$PW-TU_{METALS} (all metals);
- $\sum$PW-$TU_{DIVALENT\ METALS}$ (divalent metals only);
- PW-$TU_{ALUMINUM}$;
- PW-$TU_{ARSENIC}$;
- PW-$TU_{CADMIUM}$;
- PW-$TU_{CHROMIUM}$;
- PW-TU_{COPPER};
- PW-TU_{IRON};
- PW-TU_{LEAD} and PW-$TU_{LEAD(DOC)}$;
- PW-TU_{NICKEL};
- PW-$TU_{SELENIUM}$;
- PW-TU_{SILVER}; and,
- PW-TU_{ZINC} and PW-$TU_{ZINC(DOC)}$.

In total, preliminary concentration-response relationships were developed for 220 combinations of COPCs/COPC mixtures and toxicity test endpoints (Appendix 1). Table 4 provides a summary of the preliminary concentration-response models presented in Appendix 1. Plots A1-1 to A1-30 present the relationships between amphipod survival or biomass and the concentrations of sediment-associated COPCs or COPC mixtures. The comparable plots for mussel survival or biomass are presented in Plots A1-31 to A1-60 and for midge survival or biomass are presented in Plots A1-61 to A1-90. Similarly, the relationships between amphipod survival and biomass (Plots A1-91 to A1-140), mussel survival and biomass (Plots A1-141 to A1-190), and midge survival and biomass (Plots A1-191 to A1-220) and the concentrations of selected COPCs and COPC mixtures in pore water are presented in Appendix 1.

Following development of the preliminary concentration-response relationships for sediment and pore water, the coefficient of determination and p-value for each regression were examined. The combinations of COPCs or COPC mixtures and toxicity test endpoints that had significant regressions ($p < 0.05$) with r^2-values ≥ 0.4 were retained for refinement of the concentration-response models and development of toxicity thresholds. The other COPCs or COPC mixture-toxicity test endpoint pairs were not further evaluated in the analysis.

4.4.1 Preliminary Concentration-Response Relationships for Sediment

Examination of the preliminary concentration-response relationships for sediment-associated COPCs and COPC mixtures indicated that midge survival or biomass was generally not well-correlated with sediment chemistry (Plots A1-61 to A1-90; Appendix 1). Coefficients of determination ranged from 0.001 for $\sum$ESB-TU$_{FCV}$ ($p = 0.8$; Plot A1-70) to 0.23 for $\sum$SEM-AVS ($p = 0.0001$; Plot A1-68) for the survival endpoint. These relationships did not improve when the survival and growth (i.e., weight) endpoints were integrated to estimate midge biomass. More specifically, coefficients of determination ranged from 0.03 for nickel ($p = 0.31$; Plot

A1-80) and chromium (p = 0.39; Plot A1-77) to 0.22 for ∑SEM-AVS (p = 0.0003; Plot A1-83) when the biomass endpoint was considered. Coefficients of determination were similar for mean PEC-Q ($r^2 = 0.14$; p = 0.007; Plot A1-86) and mean PEC-Q_{METALS} ($r^2 = 0.14$; p = 0.007; Plot A1-87) for the midge biomass endpoint. Organic-carbon normalization did not improve the observed relationships between concentration and midge biomass for either ∑SEM-AVS (Plot A1-84) or mean PEC-Q_{METALS} (Plot A1-88).

In general, the preliminary relationships between COPC concentrations and toxicity were stronger for amphipods (Plots A1-1 to A1-30) than they were for midges (Plot A1-61 to A1-90). For example, amphipod survival was well-correlated with the concentrations of cadmium ($r^2 = 0.46$; p <0.0001; Plot A1-1), lead ($r^2 = 0.48$; p <0.0001; Plot A1-4), and zinc ($r^2 = 0.51$; p <0.0001; Plot A1-6) in sediment. In addition, ∑SEM-AVS ($r^2 = 0.49$; p <0.0001; Plot A1-8), mean PEC-Qs ($r^2 = 0.51$; p <0.0001; Plot A1-11), mean PEC-Q_{METALS} ($r^2 = 0.53$; p <0.0001; Plot A1-12), ∑PEC-$Q_{Cd,Pb,Zn}$ ($r^2 = 0.52$; p <0.0001; Plot A1-14); and, ∑STT-$Q_{Cd,Cu,Pb,Zn}$ ($r^2 = 0.52$; p <0.0001; Plot A1-15) were all well-correlated with amphipod survival. Neither ∑PAHs nor ∑ESB-TU_{FCV} for PAHs were well correlated with amphipod survival.

In contrast to the results for amphipod survival, amphipod biomass was not well-correlated with sediment chemistry. Coefficients of determination for individual metals in sediment vs. amphipod biomass ranged from 0.003 for nickel (p = 0.88; Plot A1-20) to 0.33 for lead (p <0.0001; Plot A1-19). Among the various COPC mixture models examined, mean PEC-Qs ($r^2 = 0.34$; p <0.0001; Plot A1-26) and PEC-Q_{METALS} ($r^2 = 0.35$; p <0.0001; Plot A1-27) had the highest correlation against amphipod biomass. Organic-carbon normalization did not improve the relationships for amphipod survival or biomass [Plots A1-9 and A1-24 for (∑SEM-AVS)/f_{OC}, and Plot A1-13 and A1-28 for mean PEC-$Q_{METALS(1\%OC)}$].

For mussels, significant relationships between sediment chemistry and sediment toxicity were observed for both survival and biomass (Plots A1-31 to A1-60). For mussel survival, the coefficients of determination for individual metals ranged from

0.08 for nickel (p = 0.145; Plot A1-35) to 0.66 for copper (p <0.0001; Plot A1-33). ∑SEM-AVS (r^2 = 0.68; p <0.0001; Plot A1-38), mean PEC-Q_{METALS} (r^2 = 0.53; p <0.0001; Plot A1-41), and ∑STT-$Q_{Cd,Cu,Pb,Zn}$ (r^2 = 0.67; p <0.0001; Plot A1-45) explained a substantial amount of the variability in the data on the survival of mussels exposed to TSMD sediments. In contrast, the concentrations of cadmium, chromium, lead, nickel, PAHs, and mean PEC-Qs were not well correlated with mussel survival (Plots A1-31; A1-32; A1-34; A1-35; A1-37; A1-41). Organic carbon-normalization of the mean PEC-Q_{METALS} data further improved the relationship between metal concentrations (i.e., mean PEC-Q $_{METALS(1\%OC)}$) and toxicity to mussels (r^2 = 0.92; p <0.0001; Plot A1-43), but not for (∑SEM-AVS)/f_{OC} (r^2 = 0.19; p = 0.009; Plot A1-39).

In general, mussel biomass (Plots A1-46 to A1-60) was somewhat less correlated with sediment chemistry than was mussel survival (Plots A1-31 to A1-45). For example, coefficients of determination for individual metals ranged from 0.21 for nickel (p <0.0001; Plot A1-50) to 0.49 for copper (p <0.0001; Plot A1-48). For the various COPC mixture models, the best correlations with mussel biomass were observed for ∑SEM-AVS (r^2 = 0.50; p <0.0001; Plot A1-53), mean PEC-Q_{METALS} (r^2 = 0.45; p <0.0001; Plot A1-57), and ∑STT-$Q_{Cd,Cu,Pb,Zn}$ (r^2 = 0.43; p <0.0001; Plot A1-60). Organic-carbon normalization improved this relationship for mean PEC-$Q_{METALS(1\%OC)}$ (r^2 = 0.63; p <0.0001; Plot A1-58), but not for (∑SEM-AVS)/f_{OC} (r^2 = 0.19; p = 0.008; Plot A1-54). The biomass of mussels was not well correlated with the concentrations of PAHs in sediments, as indicated by the relationships for ∑PAHs (Plot A1-52) and ∑ESB-TU_{FCV} (Plot A1-55).

The goodness of fit of the regressions for concentrations of COPCs and responses of benthic invertebrates are important for identifying the COPC/COPC mixtures that are likely contributing to sediment toxicity. However, the correlation coefficients should not be used as an indicator of sensitivity of the toxicity test organisms used in this study. Rather, the toxicity thresholds that are derived from the concentration-response models (CRMs) provide tools that can be used to more reliably evaluate relative sensitivity to COPCs.

4.4.2 Preliminary Concentration-Response Relationships for Pore Water

In addition to the concentration-response relationships for sediment, preliminary relationships between the dissolved concentrations of selected COPCs and/or COPC mixtures in pore water and toxicity to the test organisms were also developed. Preliminary concentration-response models were developed for a total of 130 COPC/COPC mixtures and toxicity test endpoint pairs (Table 4; Appendix 1). Pore-water chemistry was measured on day 7 and day 28 of the toxicity tests for selected metals. The concentrations of COPCs and COPC mixtures measured in pore water on day 7 were used to develop the preliminary CRMs for midges (i.e., because the toxicity tests were 10-d in duration). Preliminary concentration-response relationships for amphipods and mussels were developed using the 7-d, 28-d, and mean results (i.e., because the toxicity tests were 28-d in duration). However, if both the 7-d and 28-d mean results had significant regressions (i.e., $r^2 \geq 0.4$; $p < 0.05$) only the CRM for the mean results were considered in further analysis.

Examination of the preliminary plots revealed that neither survival nor biomass of midge, *C. dilutus*, was well correlated with the concentrations of individual metals or mixtures of metals in pore water (Plots A1-191 to A1-220). Coefficients of determination ranged from 0.01 for $PW\text{-}TU_{SELENIUM}$ ($p = 0.63$; Plot A1-201) to 0.28 for $PW\text{-}TU_{ZINC}$ ($p < 0.0001$; Plot A1-203) for the survival endpoint. Normalization of $PW\text{-}TU_{ZINC}$ to the concentration of DOC in the pore water $PW\text{-}TU_{ZINC(DOC)}$ improved this relationship somewhat ($r^2 = 0.37$; $p < 0.0001$; Plot A1-205).

The preliminary relationships between pore-water COPC concentrations and sediment toxicity were somewhat stronger when the midge biomass endpoint was considered. More specifically, r^2 ranged from <0.0002 for $PW\text{-}TU_{CHROMIUM}$ ($p = 0.99$; Plot A1-211) to 0.30 for $\sum PW\text{-}TU_{DIVALENT\ METALS}$ ($p < 0.0001$; Plot A1-207) for the midge biomass endpoint. Overall, none of the preliminary relationships developed with the midge toxicity test data met the criteria for developing pore-water toxicity thresholds (i.e., $p < 0.05$; $r^2 \geq 0.4$) and, therefore, were not retained for refinement of the concentration-response models.

The results of regression analysis showed that the survival of amphipods, *H. azteca*, was well correlated with several indicators of pore-water chemistry (Plots A1-91 to A1-115). While the concentrations of $\sum$PW-TU_{METALS}, PW-$TU_{ALUMINUM}$, PW-$TU_{ARSENIC}$, PW-$TU_{CHROMIUM}$, PW-TU_{COPPER}, PW-TU_{IRON}, PW-TU_{NICKEL}, PW-$TU_{SELENIUM}$, and PW-TU_{SILVER} were not well correlated with amphipod survival, strong ($r^2 \geq 0.4$) and significant ($p < 0.05$) relationships were observed for PW-$TU_{CADMIUM}$ ($r^2 = 0.40$; $p < 0.0001$; Plot A1-97), PW-TU_{LEAD} ($r^2 = 0.59$; $p < 0.0001$; Plot A1-105), and PW-TU_{ZINC} ($r^2 = 0.83$; $p < 0.0001$; Plot A1-113). Normalization of lead or zinc pore-water TUs to the concentration of DOC in the pore water did not substantially improve these relationships [$r^2 = 0.59$; $p < 0.0001$; Plot A1-114 for PW-$TU_{LEAD(DOC)}$; $r^2 = 0.72$; $p < 0.0001$; Plot A1-115 for PW-$TU_{ZINC(DOC)}$]. The relationship between amphipod survival and $\sum$PW-$TU_{DIVALENT METALS}$ (i.e., Cd, Cu, Pb, Ni, and Zn; $r^2 = 0.84$; $p < 0.0001$; Plot A1-92) was similar to that for PW-TU_{ZINC} (Plot A1-113), suggesting that pore-water zinc concentrations may be explaining most of the toxicity to amphipods for the survival endpoint.

In general, the concentration-response relationships for amphipod biomass were not as strong as the relationships for amphipod survival (Plots A1-116 to A1-140). The individual metals that were well correlated with amphipod biomass included PW-TU_{LEAD} ($r^2 = 0.45$; $p < 0.0001$; Plot A1-130), PW-$TU_{LEAD(DOC)}$ ($r^2 = 0.45$; $p < 0.0001$; Plot A1-139), PW-TU_{ZINC} ($r^2 = 0.50$; $p < 0.0001$; Plot A1-138), and PW-$TU_{ZINC(DOC)}$ ($r^2 = 0.44$; $p < 0.0001$; Plot A1-140). These results showed that DOC-normalization did not improve the relationships between pore-water metal concentrations and amphipod biomass. The relationship between amphipod biomass and $\sum$PW-$TU_{DIVALENT METALS}$ (i.e., Cd, Cu, Pb, Ni, and Zn; $r^2 = 0.52$; $p < 0.0001$; Plot A1-117) was similar to that for PW-TU_{ZINC} (Plot A1-138), suggesting that pore-water zinc concentrations may be explaining much of the toxicity to amphipods for the biomass endpoint. Adding additional metals to the $\sum$PW-TUs calculation did not improve the concentration-response relationship (Plot A1-116), again suggesting that aluminum, arsenic, chromium, iron, selenium, and silver are not substantially contributing to sediment toxicity at this site.

The best relationships between pore-water chemistry and sediment toxicity were observed for mussel survival and biomass (Plots A1-141 to A1-190). For mussel survival, strong ($r^2 \geq 0.40$) and significant ($p < 0.05$) relationships were observed for PW-TU$_{CADMIUM}$ ($r^2 = 0.79$; $p < 0.0001$; Plot A1-145), PW-TU$_{COPPER}$ ($r^2 = 0.84$; $p < 0.0001$; Plot A1-149), PW-TU$_{LEAD}$ ($r^2 = 0.51$; $p < 0.0001$; Plot A1-155), PW-TU$_{NICKEL}$ ($r^2 = 0.79$; $p < 0.0001$; Plot A1-158), and PW-TU$_{ZINC}$ ($r^2 = 0.93$; $p < 0.0001$; Plot A1-163). Normalization of pore-water lead or zinc concentrations to DOC levels did not improve these relationships [$r^2 = 0.38$; $p < 0.0001$; Plot A164 for PW-TU$_{LEAD(DOC)}$; $r^2 = 0.91$; $p < 0.0001$; Plot A1-165 for PW-TU$_{ZINC(DOC)}$]. The relationship between mussel biomass and ∑PW-TU$_{DIVALENT\ METALS}$ (i.e., Cd, Cu, Pb, Ni, and Zn; $r^2 = 0.82$; $p < 0.0001$; Plot A1-142) was similar to that for several individual metals, suggesting that several of these metals (i.e., Cd, Cu, Ni, Zn) are co-occurring in pore water and are likely contributing to toxicity. Such co-occurrence makes it challenging to identify the divalent metal or metals that are driving the toxicity to mussels. Adding additional metals to the ∑PW-TUs calculation did not improve the concentration-response relationship (i.e., ∑PW-TU$_{METALS}$; Plot A1-141), suggesting that aluminum, arsenic, chromium, iron, selenium, and silver are not substantially contributing to sediment toxicity at this site.

In general, mussel biomass was somewhat less correlated with pore-water chemistry than was mussel survival (Plots A1-166 to A1-190). For example, coefficients of determination for the concentration-response relationships for individual metals ranged from <0.001 for PW-TU$_{SELENIUM}$ ($p = 0.99$; Plot A1-184) to 0.61 for PW-TU$_{ZINC}$ ($p < 0.0001$; Plot A1-186). Significant, negative relationships between the concentrations of individual metals in pore water and mussel biomass were also observed for PW-TU$_{CADMIUM}$ ($r^2 = 0.46$; $p < 0.0001$; Plot A1-172), PW-TU$_{COPPER}$ ($r^2 = 0.47$; $p < 0.0001$; Plot A1-174), PW-TU$_{LEAD}$ ($r^2 = 0.41$; $p < 0.0001$; Plot A1-180), and PW-TU$_{NICKEL}$ ($r^2 = 0.47$; $p < 0.0001$; Plot A1-183). These relationships did not improve substantially when the concentrations of lead or zinc in pore water were normalized to DOC levels [$r^2 = 0.42$; $p < 0.0001$; Plot A1-189 for PW-TU$_{LEAD(DOC)}$; $r^2 = 0.61$; $p < 0.0001$; Plot A1-190 for PW-TU$_{ZINC(DOC)}$]. In addition, consideration of the additive effects of multiple divalent metals (i.e., Cd, Cu, Pb, Ni, and Zn, expressed as $\sum$PW-TU$_{\text{DIVALENT METALS}}$) on mussel biomass ($r^2 = 0.60$; $p < 0.0001$; Plot A1-167) did not improve upon the concentration-response relationship that was observed for zinc, suggesting that zinc may be an important driver of toxicity for this endpoint. Adding additional metals to the $\sum$PW-TUs calculation did not improve the concentration-response relationship ($\sum$PW-TU$_{\text{METALS}}$; Plot A1-166), again suggesting that aluminum, arsenic, chromium, iron, selenium, and silver are not substantially contributing to sediment toxicity at this site.

4.5 Development of Preliminary Toxicity Thresholds for Sediment and Pore Water

The preliminary concentration-response relationships for 49 of the 220 COPC/COPC mixture - toxicity test endpoint pairs met the criteria for developing site-specific toxicity thresholds for sediment and/or pore water (i.e., $r^2 \geq 0.40$, $p < 0.05$). Each of these relationships was further examined to determine if the variability in the data could be better explained using a refined model (i.e., rather than the default three-parameter sigmoid models that were generally used to develop the preliminary concentration-response relationships). This step in the process involved sequentially fitting the data with four-parameter sigmoid, three-parameter logistic, and four-parameter logistic models, and subsequently comparing the results with those obtained for the original models. The model that provided the best fit (i.e., highest r^2 value) of the underlying data was selected for each of the COPC/COPC mixture - toxicity test endpoint pairs. The refined concentration-response relationships for sediment-associated COPCs are presented in Figures 5 to 32, while the refined concentration-response relationships for pore-water COPCs and COPC mixtures are presented in Figures 33 to 60.

The optimized concentration-response model was used to develop two site-specific toxicity thresholds for each COPC/COPC mixture - toxicity test endpoint pair (i.e., a T_{10} value and a T_{20} value). More specifically, the concentrations of COPCs or

COPC mixtures that corresponded to a 10% or 20% reduction in the control-adjusted survival or biomass of the toxicity test organism (relative to the average response rate observed for the selected reference samples; see Table 3) was determined using the refined regression equation for each COPC/COPC mixture - toxicity test endpoint pair. STTs were developed for each of the following COPCs and COPC mixtures (Table 5):

- Cadmium;
- Copper;
- Lead;
- Zinc;
- ∑SEM-AVS;
- Mean PEC-Q;
- Mean PEC-Q_{METALS};
- Mean PEC-$Q_{METALS(1\%OC)}$;
- ∑PEC-$Q_{Cd,Pb,Zn}$; and,
- ∑STT-$Q_{Cd,Cu,Pb,Zn}$.

In addition to the toxicity thresholds for sediments, toxicity thresholds were also developed for pore water. More specifically, PWTTs were developed for the following COPCs and COPC mixtures (Table 6):

- PW-$TU_{CADMIUM}$;
- PW-TU_{COPPER};
- PW-TU_{LEAD};
- PW-$TU_{LEAD(DOC)}$;
- PW-TU_{NICKEL};

- $PW\text{-}TU_{ZINC}$;
- $PW\text{-}TU_{ZINC(DOC)}$;
- $\sum PW\text{-}TU_{DIVALENT\ METALS}$; and,
- $\sum PW\text{-}TU_{METALS}$.

The toxicity thresholds for sediment and pore water were developed using a three-step process. In the first step, the mean control-adjusted response rate for the selected reference samples was determined for each toxicity test endpoint (Table 7). Then, the response rate that represented a 10% and a 20% reduction in the survival or biomass of the toxicity test organism was calculated (Table 7). Finally, these response rates were substituted into the corresponding regression equations to calculate the preliminary toxicity thresholds for sediment and pore water. The T_{10} and T_{20} values that were derived for sediment are presented in Table 5, while Table 6 presents the T_{10} and T_{20} values derived for pore water. The STTs based on amphipod survival apply explicitly to the <2 mm size fraction, while the SSTs based on mussel survival or biomass apply to <250 µm or <2 mm size fractions. The STTs for mussels based on the sediment chemistry data for the <2 mm size fraction were developed for the substances that met the selection criteria based on the results for the <250 µm six fraction. These additional STTs were derived to provide an additional basis for comparison to the STTs for amphipods.

Overall, a total of 56 STTs and 52 PWTTs were derived using the refined concentration-response models for the TSMD. In general, the STTs developed using the results of 28-d toxicity tests with the amphipod, *H. azteca* (endpoint: survival) were lower than the STTs that were based on either the mussel survival or biomass results. Similarly, the PWTTs derived using the amphipod toxicity data (survival or biomass) were generally lower than the PWTTs developed from the results of 28-d toxicity tests with fat mucket (survival or biomass). For both species, application of the biomass data resulted in lower PWTTs than was the case when the survival data were employed. These results suggest that amphipods tended to be more sensitive to sediment- or pore-water-associated COPCs than were mussels. These results also suggest that biomass tends to be a more sensitive endpoint than survival alone.

4.6 Evaluation of the Preliminary Sediment and Pore-Water Toxicity Thresholds

The results of regression analysis of the matching sediment chemistry and toxicity data suggest that the selected COPCs or COPC mixtures explain between 40 and 79% of the variability in the response data, depending on the substance and endpoint considered (Table 5). For pore water, the concentrations of the selected COPCs/COPC mixtures explained 40 to 94% of the response data (Table 6). These results are generally consistent with those that have been observed at other sites in the United States (e.g., MacDonald *et al.* 2002). Nevertheless, further analyses were conducted to provide decision-makers with additional information for applying the STTs and PWTTs within the TSMD.

All of the preliminary toxicity thresholds for sediment and pore water were evaluated to determine their reliability and predictive ability. The reliability evaluation consisted of classifying each sediment sample in the project database into one of two categories, based on the measured concentration of the COPC or the COPC mixture under consideration. Sediment samples with concentrations of COPCs or COPC mixtures less than the corresponding toxicity threshold (e.g., T_{10} value for cadmium of 11.1 mg/kg DW) were predicted to be not toxic, while those with concentrations equal to or greater than the corresponding toxicity threshold were predicted to be toxic. The accuracy of these predictions was then evaluated by calculating the incidence of toxicity for both groups of sediment samples (i.e., the samples predicted to be toxic and the samples predicted to be not toxic). The reliability of each toxicity threshold was evaluated using the toxicity data that were used to develop the T_{10} and T_{20} values [e.g., the reliability of the T_{10} value for cadmium based on amphipod survival (11.1 mg/kg DW) was evaluated using the data on the survival of amphipods exposed to TSMD sediments for 28 days]. The predictive ability of each toxicity threshold was evaluated using the other toxicity test data (e.g., the predictive ability of the T_{10} value for amphipod survival was evaluated using the data on amphipod biomass, on mussel survival and biomass, and on midge survival and biomass). Predictive ability was also evaluated based on the overall toxicity of each sediment sample, as designated using data on all six endpoints (OT-Six Endpoints) or using data on the four endpoints that were most correlated with measures of sediment and pore-water chemistry (i.e., OT-Four Endpoints; based on amphipod survival or growth and mussel survival or growth).

4.6.1 Reliability of the Sediment and Pore-Water Toxicity Thresholds

4.6.1.1 Reliability of the Sediment Toxicity Thresholds

The results of the reliability evaluation for the STTs based on amphipod survival, mussel survival, and mussel biomass are presented in Table 8. This table presents the T_{10} value and T_{20} value that were developed for each COPC/COPC mixture - toxicity test endpoint pair (e.g., cadmium and 28-d amphipod survival). In addition, the number of sediment samples used in the reliability analysis (n) is identified for each COPC/COPC mixture-toxicity test endpoint pair. Furthermore, the incidence of toxicity below the T value and the incidence of toxicity at COPC/COPC mixture concentrations above the T value are presented. For example, the incidence of toxicity is 11% (5 of 45 samples were toxic to amphipods, considering the results for the survival endpoint) at concentrations of cadmium below the T_{10} of 11.1 mg/kg DW (derived using the amphipod survival endpoint). At or above this concentration, 61% (19 of 31) of the sediment samples were observed to be toxic to amphipods, resulting in an overall correct classification rate of 78% for the T_{10} value (i.e., 40 of 45 samples were correctly classified as not toxic and 19 of 31 samples were correctly classified as toxic; overall, 59 of 76, or 78% of the samples were correctly classified using the T_{10} value for cadmium). The incidence of toxicity that was observed when cadmium concentrations were between the T_{10} and T_{20} values is also presented in Table 8. In this evaluation, STTs were considered to be reliable if the incidence of toxicity below the T value was <20%, the incidence of toxicity above the T value was >50%, and the overall correct classification rate for the T value was $\geq$80%.

The results of this evaluation indicated that many of the site-specific sediment toxicity thresholds provide reliable bases for estimating toxicity to the test organisms associated with exposure to metal-contaminated sediments from the TSMD. Among the toxicity thresholds that were developed based on amphipod survival, the following met all three criteria for reliability:

- T_{10} value for lead (150 mg/kg DW);
- T_{20} value for lead (219 mg/kg DW);
- T_{10} value for zinc (2083 mg/kg DW);
- T_{20} value for zinc (2949 mg/kg DW);
- T_{20} value for ∑SEM-AVS (13.7 µmol/g DW);
- T_{10} value for mean PEC-Q (0.556);
- T_{10} value for mean PEC-Q_{METALS} (1.11);
- T_{10} value for ∑PEC-$Q_{Cd,Pb,Zn}$ (7.92); and,
- T_{10} value for ∑STT-$Q_{Cd,Cu,Pb,Zn}$ (2.97).

The T_{10} value for cadmium had a slightly lower overall correct classification rate than was targeted by the reliability criteria (i.e., 78% vs. $\geq$80%), but is still considered to be reasonably reliable (see Table 8).

None of the STTs developed using the results of 28-d toxicity tests with mussels for the survival endpoint met all three criteria for assessing reliability. For all of the T_{10} and T_{20} values calculated using the mussel survival data, the incidence of toxicity observed at COPC/COPC mixture concentrations below the STTs exceeded 20%

(ranging from 28 to 38%). These results suggest that the T_{10} and T_{20} values would not provide a high level of protection for mussels utilizing habitats within the TSMD. As these STTs are generally substantially higher than the T_{10}/T_{20} values based on amphipod survival, the STTs based on mussel survival would not provide a high level of protection for other benthic invertebrates either.

In general, the STTs that were developed based on the results of 28-d toxicity tests with mussel biomass had higher reliability than the STTs for amphipod survival (Table 8). All of the T_{10} and T_{20} values that were derived met all three criteria for reliability. Overall correct classification rates ranged from 88% for the T_{20} value for copper and the T_{10} value for lead to 94% for the T_{20} value for ∑SEM-AVS and the T_{10} and T_{20} values for mean PEC-$Q_{METALS(1\%OC)}$. While the T values derived using the mussel biomass data were more reliable than those derived using the amphipod survival data, it is likely that they would not provide the most useful tools for assessing sediment quality conditions in the TSMD. The amphipod-based STTs will be more useful because they include T values for all three of the primary COPCs in the study area (Cd, Pb, and Zn) and are lower than the mussel STTs (i.e., the amphipod STTs would be protective of benthic invertebrates with sensitivities similar to that of amphipods).

4.6.1.2 Reliability of the Pore-Water Toxicity Thresholds

The results of this evaluation indicated that many of the site-specific toxicity thresholds for pore water would provide reliable bases for estimating toxicity to test organisms associated with exposure to sediments from the TSMD. Of the toxicity thresholds that were developed based on amphipod survival, the T_{10} value (1.03 TUs) and T_{20} value (1.41 TUs) for ∑PW-$TU_{DIVALENT\ METALS}$, and the T_{10} value (0.581 TUs) and T_{20} value (0.867 TUs) for PW-TU_{ZINC} were the most reliable (Table 9). For the T_{20} value for ∑PW-$TU_{DIVALENT\ METALS}$, the incidence of toxicity was 18% (i.e., 10 of 55 samples were toxic) below 1.41 TUs and 93% (14 of 15 samples were toxic) above 1.41 TUs, resulting in an overall correct classification rate of 84% (Table 9). The DOC-normalized T_{10} and T_{20} values for zinc, based on amphipod survival, were also found to be reliable (Table 9). The T_{20} values for $PW\text{-}TU_{ZINC}$, $PW\text{-}TU_{ZINC(DOC)}$, and $PW\text{-}TU_{DIVALENTMETAL}$, based on amphipod biomass were also found to be reliable, with overall correct classification rates ranging from 81 to 86%. Overall, nine of the 18 PWTTs developed for amphipod survival or biomass met all three criteria that were established for evaluating reliability (i.e., <20% incidence of toxicity below the PWTT, >50% incidence of toxicity above the PWTT, and overall correct classification rate $\geq$80%; Table 9). Therefore, any of those nine PWTTs could be used to correctly classify sediment samples from the TSMD as toxic or not toxic to amphipods.

The reliability of the PWTTs derived using data on the survival of mussels was lower than that for the PWTTs developed using the amphipod toxicity data. None of the PWTTs based on mussel survival met all three of the evaluation criteria for reliability (Table 9). However, all of the 18 PWTTs derived using data on mussel biomass were found to be reliable (Table 9; i.e., all three reliability criteria were met). Overall, the correct classification rates observed for the PWTTs based on mussel biomass ranged from 86 to 93%. While these T_{10} and T_{20} provide a reliable basis for classifying sediment samples as toxic or not toxic relative to mussel biomass, they tended to be substantially higher than the PWTTs derived based on amphipod survival or biomass.

4.6.2 Predictive Ability of the Sediment and Pore-Water Toxicity Thresholds

In the predictive ability evaluation, the incidence of toxicity above and below the toxicity threshold was determined for all six of the toxicity test endpoints (See Table 5 for the STTs and Table 6 for the PWTTs considered in this evaluation). Toxicity thresholds were considered to have high predictive ability if the incidence of toxicity was <20% below the T_{10} or T_{20} value, if the incidence of toxicity was >50% above the T_{10} or T_{20} value, and the overall correct classification rate was $\geq$80. These criteria were applied across all six toxicity test endpoints to support comparison of the relative predictive ability of the toxicity thresholds. In addition, each sediment sample was given an overall toxicity designation based on the results observed for all six toxicity test endpoints (i.e., amphipod survival, amphipod biomass, mussel survival, mussel biomass, midge survival and midge biomass). That is, the sample was designated as toxic if toxicity was observed for any one of the six endpoints measured for the sample (OT-Six Endpoints). Examination of the results presented in Tables 10 and 11 indicated that toxicity to midges frequently caused the incidence of toxicity to be elevated (i.e., >50%) at COPC/COPC mixture concentrations below the T_{10} or T_{20} values. In addition, the results of previous analyses showed that the responses of midges in 10-d toxicity tests were not well correlated with either sediment or pore-water chemistry. As midge appear to be responding to factors other than the principal COPCs in the TSMD, a second overall toxicity designation was established to exclude the midge results. The second overall toxicity designation considered only the results of the amphipod and mussel toxicity tests (OT-Four Endpoints). This latter overall toxicity designation provides an important tool for evaluating the predictive ability of the STTs and PWTTs.

4.6.2.1 Predictive Ability of the Sediment Toxicity Thresholds

The results of the predictive ability evaluation for the sediment toxicity thresholds are presented in Table 10. These results show that several of the STTs evaluated met all three criteria for predictive ability for one or more endpoints. However, none of the T_{10} or T_{20} values met all three criteria when overall toxicity, considering six endpoints (i.e., OT-Six Endpoints) or four endpoints (i.e., OT-Four Endpoints), was considered. Therefore, none of the STTs provide infallible tools for classifying sediment samples from the TSMD as toxic or not toxic. Nevertheless, many of the STTs provide useful tools for accurately classifying sediment samples as toxic or not toxic for multiple species and toxicity test endpoints. For example, the incidence of toxicity below the STT is $\leq$25%, the incidence of toxicity above the STT is $\geq$75%, and the overall correct classification rate is $\geq$75% for all of the following STTs derived based on amphipod toxicity:

- T_{10} value for lead (150 mg/kg DW);

- T_{10} value for zinc (2083 mg/kg DW);
- T_{20} value for zinc (2949 mg/kg DW);
- T_{10} value for mean PEC-Q (0.556);
- T_{20} value for ∑SEM-AVS (13.7 µmol/g DW);
- T_{10} value for mean PEC-Q_{METALS} (1.11);
- T_{10} value for ∑PEC-$Q_{Cd,Pb,Zn}$ (7.92); and,
- T_{10} value for ∑STT-$Q_{Cd,Cu,Pb,Zn}$ (2.97).

For all of the STTs identified above, the incidence of toxicity below the T value was ≤25%, the incidence of toxicity above the T value was ≥75%, and the overall correct classification rate was ≥75%, based on overall toxicity for four endpoints (OT-Four Endpoints). Therefore, the probability of making Type I errors (incorrectly classifying a not toxic sample as toxic; i.e., false positive) and Type II errors (incorrectly classifying a toxic sample as not toxic; i.e., false negative) is expected to be ≤25% using any of these STTs. Considering the differences in the sensitivities of the various species tested and endpoints measured to contaminant challenges, the importance of having STTs that can predict overall toxicity with this high level of accuracy is difficult to over-emphasize. For the T_{10} value for cadmium, the incidence of toxicity above and below 11.1 mg/kg DW was 22% and 74%, respectively, for an overall correct classification rate of 76%. These results for predictive ability indicate that the T_{10} value for cadmium would also provide a useful tool for assessing sediment quality conditions in the TSMD.

An evaluation was also conducted to determine the predictive ability of STTs for cadmium, lead, and zinc when they are used together to assess sediment quality conditions (Table 12). The results of this evaluation showed that the incidence of toxicity to amphipods or mussels, considering survival or biomass (i.e., OT-Four Endpoints), was low (20%; 8 of 41 samples were toxic) when the T_{10} values for cadmium (11.1 mg/kg DW), lead (150 mg/kg DW), and zinc (2083 mg/kg DW) were not exceeded in TSMD sediment samples. The incidence of toxicity was 71% (i.e., 25 of 35 samples were toxic) when one or more of these T_{10} values were exceeded in TSMD sediment samples. Therefore, the correct classification rate was 76% when the T_{10} values for cadmium, lead, and zinc were applied in this manner. Predictive ability improved somewhat when the T_{20} values for these metals were used together to identify sediment samples that were expected to be toxic (one or more T_{20} values exceeded) or not toxic (no T_{20} values exceeded; Table 12).

To provide a basis for comparison, the predictive ability of the generic SQGs that were used to conduct preliminary assessments of sediment quality conditions in the TSMD (e.g., identify reference conditions) were also evaluated [i.e., mean PEC-$Q_{METALS(1\%OC)}$ and ($\sum$SEM-AVS)/f_{OC})]. The results of this evaluation showed that overall toxicity (OT-Four Endpoints) was somewhat elevated (i.e., 30%; 3 of 10 samples were toxic) at mean PEC-$Q_{METALS(1\%OC)}$ of less than 0.1 (Table 13). A similar incidence of toxicity was observed (28%; 7 of 25 samples were toxic) when ($\sum$SEM-AVS)/f_{OC} was less than 130 µmol/g. A higher incidence of toxicity was observed when mean PEC-$Q_{METALS(1\%OC)}$ exceeded 5.0 (i.e., 92%; 12 of 13 samples were toxic) or ($\sum$SEM-AVS)/f_{OC} exceeded 3000 µmol/g (i.e., 88%; 15 of 17 samples were toxic; Table 13). Overall, these results show that the generic SQGs can also provide useful tools for identifying sediment samples that are likely to be toxic or not toxic. However, the site-specific STTs provide a more accurate basis for classifying sediment samples from the TSMD relative to their potential toxicity to benthic invertebrates. Importantly, the site-specific STTs also facilitate accurate classification of sediment samples into two categories, including likely not toxic (low risk to benthic invertebrates) and likely toxic (high risk to benthic invertebrates). Therefore, all sediment samples can be classified relative to the risks that they pose to benthic invertebrates. In contrast, the generic SQGs can be used to classify sediment samples into three categories based on the risks that they pose to benthic invertebrates (i.e., low, moderate, and high risks). As such, the site-specific toxicity thresholds will provide more useful tools for making risk management decisions in the TSMD.

4.6.2.2 Predictive Ability of the Pore-Water Toxicity Thresholds

In general, the predictive ability of the PWTTs was similar to or lower than that of the STTs. Among the PWTTs that were evaluated, none met all three criteria for predictability when overall toxicity was considered (OT-Six Endpoints or OT-Four Endpoints). However, the incidence of toxicity was $\leq$25% below the PWTT and >75% above the PWTT for the following (Table 11):

- T_{10} value for zinc, based on amphipod survival (0.581 TUs); and,
- T_{20} values for zinc, based on amphipod biomass (0.638 and 0.867 TUs);

Therefore, the probability of making Type I (false positive) and Type II (false negative), errors is expected to be $\leq$25% using either of these two PWTTs for zinc. While the PWTTs are likely to work as well as the STTs in terms of correctly classifying sediment samples as toxic or not toxic, they were not recommended as primary tools for assessing risks to benthic invertebrates in the TSMD (i.e., for use in the Advanced SLERA) because few data are available on pore-water chemistry within the study area (i.e., such PWTTs would not support an evaluation of the spatial extent of risks to benthic invertebrates) and collection of the additional data needed to provide comprehensive spatial coverage of the study area would be difficult and expensive to accomplish. Nevertheless, these PWTTs will provide a useful line-of-evidence for assessing risks to the benthic invertebrate community in the TSMD.

4.7 Selection of Sediment and/or Pore-Water Toxicity Thresholds for Use in the Advanced Screening-Level Ecological Risk Assessment

A substantial number of sediment and pore-water toxicity thresholds were derived using the matching chemistry and toxicity data for amphipods and mussels exposed to sediments collected from the TSMD. All of these toxicity thresholds were evaluated to determine their reliability and predictive ability in terms of correctly classifying sediment samples from the study area as toxic or not toxic. The results of this evaluation showed that many of the toxicity thresholds for sediment and pore water could be used, either alone or in conjunction with other toxicity thresholds, to reliably evaluate sediment quality conditions in the TSMD (See Section 4.5 and 4.6 for more information). The availability of several reliable and predictive toxicity thresholds is important because it means that factors beyond reliability and predictive ability can also be considered in the selection of toxicity thresholds for assessing risks to benthic invertebrates in the study area.

In this study, several factors were considered in the selection of toxicity thresholds to support the SLERA, including applicability to sediments that contain complex mixtures of COPCs, broad applicability across multiple data sets, and level of protection provided to the benthic community. Importantly, the results of this study suggest that there are multiple risk drivers in the watershed, potentially including cadmium, copper, lead, and zinc. As such, toxicity thresholds that can be used to evaluate the effects of mixtures of COPCs are likely to be more useful than toxicity thresholds that apply to individual COPCs. The mean PEC-Q, mean PEC-Q_{METALS}, mean PEC-$Q_{METALS(1\%OC)}$, $\sum$SEM-AVS, ($\sum$SEM-AVS)/f_{OC}, $\sum$PEC-$Q_{Cd,Pb,Zn}$, $\sum STT_{Cd,Cu,Pb,Zn}$, $\sum$PW-$TU_{DIVALENTMETALS}$, and $\sum$PW-TU_{METALS} were the principal COPC mixture models considered in this study. Therefore, the toxicity thresholds developed for these COPC-mixture models are likely to provide the most effective tools for assessing risks to benthic invertebrates associated with exposure to contaminated sediments in the TSMD. However, the toxicity thresholds for individual COPCs could also be used together to identify conditions that pose incremental risks to benthic invertebrates.

Broad applicability across the multiple data sets represents another important criterion for evaluating candidate toxicity thresholds for the TSMD. Over the past year, CH2M Hill and MESL have compiled sediment quality data from a number of studies conducted in the watershed to support the Advanced SLERA. While these data sets provide some information on surface-water chemistry, pore-water chemistry, invertebrate-tissue chemistry, fish-tissue chemistry, and/or sediment toxicity, most of the compiled data provide information on the chemical composition of TSMD sediments. Therefore, toxicity thresholds for sediment chemistry are likely to be the most useful for assessing risks to sediment-dwelling organisms. That is, such toxicity thresholds can be applied to the most robust data set for the study area (i.e., sediment chemistry), thereby providing broad spatial coverage for assessing risks to the benthic invertebrate community in the study area. The other data can then be used to provide additional lines-of-evidence for evaluating risks to benthic invertebrates, when such data are available.

Finally, level of protection afforded to benthic invertebrates represents a critical factor that needs to be considered in the selection of toxicity thresholds. The relative sensitivity of the six toxicity test endpoints was evaluated in three ways. First, the toxicity thresholds developed for various COPCs and COPC mixtures were compared across toxicity test endpoints. This comparison showed that the toxicity thresholds for amphipod survival tended to be the lowest. In addition, the incidence of toxicity above the various toxicity thresholds was compared for the six toxicity test endpoints (i.e., the predictive ability evaluation). The results of this evaluation showed that the highest incidence of toxicity was typically observed above the STTs and the PWTTs for amphipod survival, mussel survival, and midge biomass (Tables 10 and 11). Next, the relationship between amphipod survival and the other five endpoints was examined in scatter plots (Figures 61 to 65). In general, these results showed that more samples were designated as toxic using the amphipod survival endpoint than was the case for the other endpoints considered. Overall, the results of the three evaluations show that amphipod survival was generally the most sensitive endpoint examined in this study. Accordingly, the STT based on amphipod survival are likely to provide the most useful tools for assessing risks to benthic invertebrates in the TSMD.

Among the various toxicity thresholds that were developed using data on the survival of amphipods exposed to TSMD sediment and associated pore water, several were found to provide reliable and predictive tools for classifying sediment samples from the study area as toxic and not toxic, including:

Sediment Toxicity Thresholds

- T_{10} value for lead (150 mg/kg DW);
- T_{10} value for zinc (2083 mg/kg DW);
- T_{20} value for zinc (2949 mg/kg DW);
- T_{10} value for mean PEC-Q (0.556);
- T_{20} value for ∑SEM-AVS (13.7 µmol/g DW);
- T_{10} value for mean PEC-Q_{METALS} (1.11);
- T_{10} value for ∑PEC-$Q_{Cd,Pb,Zn}$ (7.92); and,
- T_{10} value for ∑STT-$Q_{Cd,Cu,Pb,Zn}$ (2.97).

Pore-Water Toxicity Thresholds

- T_{10} value for zinc, based on amphipod survival (0.581 TUs); and,
- T_{20} values for zinc, based on amphipod biomass (0.638 and 0.867 TUs).

Any of these STTs and PWTTs could be used to identify sediment samples that pose low risk, (i.e., samples with COPC/COPC mixture concentrations that are less than the selected T value) and high risk (i.e., samples with COPC/COPC mixture concentrations exceed the selected T value) to the benthic invertebrate community. To provide additional information on the utility of these tools for assessing sediment quality conditions in the TSMD, selected STTs and PWTTs were used to classify the sediment samples from the TSMD into two categories, low-risk samples and high-risk samples. Subsequently, the average control-adjusted response rates were determined for each category of samples, on an endpoint-by-endpoint basis. The biological response rates above and below the selected STTs are presented in Table 14, while those observed above and below the selected PWTTs are shown in Table 15. In both tables, the average response rates observed for the reference sediment samples are shown for comparison.

Based on the results presented in Table 14, all of the selected STTs could be used to accurately identify low-risk and high-risk sediment samples in the TSMD. For all of the selected STTs, the average control-adjusted response rates were substantially higher (i.e., survival or biomass was at least 10% lower) in the high-risk samples than the response rates that were observed for the low-risk samples for at least five of the six endpoints. Less separation between the low-risk and high-risk samples were observed for midge survival, which ranged from 7 to 11% lower for the high-risk group. Similar results were observed for the PWTTs, except that average response rates for the high-risk samples tended to be higher than was the case for the STTs (i.e., survival and biomass tended to be lower in the high risks samples; Table 15). In most cases, the average control-adjusted response rates for the low-risk samples were similar to those observed for the reference samples, indicating that benthic communities would likely be adequately protected if the selected STTs or PWTTs were used to support sediment management decisions in the TSMD.

Overall, the results of the various evaluations of the STTs and PWTTs demonstrated that a number of toxicity thresholds could be used to reliably classify sediment samples from the TSMD as toxic and not toxic to benthic invertebrates. Participants at a workshop that was conducted on toxicity thresholds for the TSMD expressed a preference for STTs for individual chemicals such as cadmium, lead, and zinc (i.e., because such STTs would be easy to use in sediment assessment and management initiatives). The results of this study show that the T_{10} values for cadmium (11.1 mg/kg DW), lead (150 mg/kg DW) and zinc (2083 mg/kg DW), based on amphipod survival can be used together to accurately classify sediment samples as toxic and not toxic. Among the chemical mixture models, the T_{10} values for mean PEC-Q (0.556), mean PEC-Q_{METALS} (1.11), $\sum$PEC-$Q_{Cd,Pb,Zn}$ (7.92); and,$\sum$STT-$Q_{Cd,Cu,Pb,Zn}$ (2.97), and the T_{20} for $\sum$SEM-AVS (13.7 µmol/g DW) were the most reliable and predictive tools for assessing risks to benthic invertebrates.

None of the STTs or PWTTs derived in this investigation provide infallible tools for classifying sediment samples from the TSMD relative to the risks that they pose to benthic invertebrates. In some cases, sediment samples with COPC/COPC mixture concentrations below the selected STTs or PWTTs were found to be toxic to one or more of the toxicity test endpoints (Tables 10, 11, 14, and 15). In other cases, sediment samples with COPC/COPC mixture concentrations above the selected STTs or PWTTs were found to be not toxic to one or more toxicity test endpoints (Tables 10, 11, 14, and 15). While false positive (Type I error) and false negative (Type II error) rates are both expected to be less than 25% using the recommended STTs, it is possible that lower error rates could be realized if a better understanding of the factors that are influencing toxicity could be identified in each sample. To that end, a series of scatter plots were prepared to illustrate relationships between selected sediment and/or pore-water chemistry metrics (Appendix 4). In each of these plots, the toxicity of each sample to amphipods, mussels, or midges, is shown. Overall, these scatter plots indicate that the relationships between the various chemistry metrics are not consistent throughout the study area. These results suggest that location-specific differences in conditions could be influencing the bioavailability of metals. Therefore, it is recommended that additional tools, such as the biotic ligand model (BLM; DiToro *et al.* 2001), be explored to determine if site-specific factors influencing metal bioavailability can be further described.

5.0 Summary and Conclusions

This study was conducted to evaluate matching sediment chemistry and sediment toxicity data that have been collected by USEPA and its partners in the TSMD in 2006 and 2007. This evaluation of sediment chemistry and sediment toxicity data consisted of several steps. First, the sediment chemistry, pore-water chemistry, sediment toxicity, and associated data for the TSMD generated during the 2006 and 2007 sampling programs were assembled and reviewed. The data that met the acceptance criteria were compiled in the project database (see Ingersoll *et al.* 2008 for more information on the performance criteria for measurement data). In total, the project database includes matching chemistry and toxicity data for 76 sediment samples collected within the TSMD. These data include information on the effects on three benthic invertebrate species associated with exposure to sediments from the study area, including the amphipod, *H. azteca* (Endpoints: 28-d survival, 28-d length, 28-d weight, and 28-d biomass), the midge, *C. dilutus* (Endpoints: 10-d survival, 10-d weight, and 10-d biomass), and the fat-mucket mussel, *L. siliquoidea* (Endpoints: 28-d survival, 28-d length, 28-d weight, and 28-d biomass). These studies also provided data on the concentrations of metals (total and simultaneously extracted metals in sediment and dissolved metals in pore water), acid volatile sulfides, PAHs, PCBs, and organochlorine pesticides in sediment and/or pore water. Sediment grain size and TOC, as well as pore-water dissolved organic carbon, ammonia, and/or hydrogen sulfide levels, were also determined for these sediment samples.

The data compiled in the project database were used to develop preliminary concentration-response relationships for a variety of COPCs and COPC mixtures. More specifically, concentration-response relationships were developed for those COPCs and COPC mixtures that: 1) were detected in at least one sample; 2) occurred in one or more sediment samples at concentrations above conservative SQGs or WQC; and, 3) that were negatively correlated with one or more toxicity test endpoints (based on the results of Spearman-Rank Correlation analysis; $p < 0.005$). Using these criteria, preliminary concentration-response relationships were developed for 220 COPC/COPC mixture-toxicity test endpoint pairs. These concentration-response relationships were generally defined by fitting a three-parameter sigmoid model to the matching sediment chemistry and toxicity data.

A total of 13 COPCs and COPC mixtures were selected for deriving toxicity thresholds for sediment and/or pore water, including cadmium, copper, lead, nickel, zinc, SEM-AVS, mean PEC-Q, mean PEC-Q_{METALS}, PEC-$Q_{METALS(1\%OC)}$, $\sum$PEC-$Q_{Cd,Pb,Zn}$, $\sum$STT-$Q_{Cd,Cu,Pb,Zn}$, $\sum$PW-TU_{METALS} and $\sum$PW-$TU_{DIVALENT METALS}$. These COPCs and COPC mixtures were selected based on the coefficients of determination (i.e., $r^2 \geq 0.40$) and associated p-values (i.e., $p < 0.05$) for the regressions determined for the preliminary concentration-response plots (i.e., the preliminary plots that demonstrated the strongest correlations between chemistry and toxicity results were selected for toxicity threshold derivation). Two toxicity thresholds were derived for each COPC/COPC mixture-biological response pair, including a low risk threshold (T_{10} value, associated with a 10% reduction in survival or biomass) and a high risk threshold (T_{20} value, associated with a 20% reduction in survival or biomass). The concentration-response models were refined prior to toxicity threshold development to ensure that they were based on the models that best fit the underlying data (i.e., definitive plots). In most cases, four-parameter sigmoid models were used to define the refined concentration-response relationships.

All of the toxicity thresholds developed during this investigation were evaluated to assess their reliability (i.e., the ability of the STTs or PWTTs to correctly classify sediment samples as toxic and not toxic considering only the data used to derive the toxicity threshold; e.g., amphipod survival data) and predictive ability (i.e., the ability the STTs or PWTTs to correctly classify sediment samples as toxic or not toxic considering all of the data available; i.e., toxicity data for six individual endpoints, overall toxicity considering four endpoints, or overall toxicity considering six endpoints). The results of the evaluation indicated that many of the sediment and pore-water toxicity thresholds developed would provide reliable and predictive bases for classifying sediment samples from the TSMD as toxic and not toxic. A total of 29 STTs and 27 PWTTs were considered to provide reliable bases for classifying sediment samples from the TSMD as toxic or not toxic (i.e., all three criteria were met; i.e., <20% incidence of toxicity below the toxicity threshold, >50% incidence of toxicity above the toxicity threshold, and >80% of the samples correctly classified as toxic and not toxic). While none of the STTs or PWTTs met all three criteria for predictive ability (considering overall toxicity for four endpoints), the probability of making Type I and Type II errors is expected to be less than 25% for nine of the STTs and two of the PWTTs.

The STTs and PWTTs were further evaluated to support recommendation of toxicity thresholds for use in the Advanced SLERA of the TSMD (scheduled for completion in mid-2009). This subsequent evaluation considered three important factors in the toxicity threshold selection process, including applicability for assessing sediments with complex mixtures of COPCs, broad applicability across multiple data sets, and level of protection afforded to the benthic community (i.e., assuming that the selected toxicity tests provided reasonable surrogates for the benthic invertebrates that utilize habitats in the TSMD). The results of this evaluation revealed that the STTs based on amphipod survival for cadmium lead, and zinc (when used together) and the STTs for selected COPC mixtures (e.g., $\sum PEC\text{-}Q_{Cd,Pb,Zn}$), would be the most useful to risk assessors and risk managers. That is, these toxicity thresholds would provide reliable bases for classifying sediment samples as toxic and not toxic, can be applied to sediment samples that contain complex mixtures of COPCs, can be broadly applied across multiple data sets, and are likely to provide an adequate level of protection for the benthic invertebrate community.

Among the STTs for individual COPCs, the T_{10} values for cadmium (11.1 mg/kg DW), lead (150 mg/kg DW) and zinc (2083 mg/kg DW) derived using the amphipod survival data were among the most reliable and/or predictive of sediment toxicity. While the T_{20} values for lead and zinc were also reliable, the T_{20} value for cadmium was considered to have lower reliability. When used together, the T_{10} values for amphipod survival provide an accurate basis for classifying sediment samples from the TSMD as toxic or not toxic (overall correct classification rate of 76%; i.e., 76% of the samples classified using these STTs were correctly identified as toxic or not toxic). In this application, sediment samples would be classified as low risk if the measured concentrations of cadmium, lead, and zinc were all below their respective T_{10} values (i.e., about 20% of sediment samples are expected to be toxic to benthic invertebrates under these conditions). Sediment samples with concentrations of one or more of these metals above their respective T_{10} values would be classified as posing high risk to the benthic invertebrate community (i.e., incidence of toxicity is expected to be at 71% under these conditions). The average control-adjusted survival of amphipods was 101% $\pm$ 5.42% in low-risk samples (n = 41 samples with concentrations of cadmium, lead, and zinc below the T_{10} values) and 63.1 $\pm$ 41.4% in high-risk samples (n = 35 samples with concentrations of cadmium, lead, or zinc above the T_{10} values).

Among the various chemical mixture models evaluated, the T_{10} values (derived using the 28-d amphipod survival endpoint) for mean PEC-Q (0.556), mean $\text{PEC-Q}_{\text{METALS}}$ (1.11), $\sum\text{PEC-Q}_{\text{Cd,Pb,Zn}}$ (7.92) and $\sum\text{STT-Q}_{\text{Cd,Cu,Pb,Zn}}$ (2.97), as well as the T_{20} value for $\sum$SEM-AVS (13.7 µmol/g DW), were considered to be the most reliable and predictive of sediment toxicity. The overall correct classification rates for these STTs ranged from 79 to 80% when amphipod survival or biomass and mussel survival or biomass were considered (i.e., overall toxicity to four endpoints; OT-Four Endpoints). Of these models, the $\sum\text{PEC-Q}_{\text{Cd,Pb,Zn}}$ (i.e., Dudding Model) is the easiest to use for making sediment management decisions because only the concentrations of cadmium, lead, and zinc need to be measured (potentially by x-ray fluorescence in the field when decisions need to be made on a timely basis). Using this model, sediment samples are considered to pose a low risk if:

$$\frac{[\text{ Cd }]}{4.98} + \frac{[\text{ Pb }]}{128} + \frac{[\text{ Zn }]}{459} < 7.92$$

High risk sediment samples are considered to include those with $\sum\text{PEC-Q}_{\text{Cd,Pb,Zn}}$ that equal or exceed 7.92. The average control-adjusted survival of amphipods was 100 $\pm$ 5.7% in low-risk samples (n = 48) and 55 $\pm$ 43% in high-risk samples (n = 28) classified using this STT.

Overall, the PWTTs provided the most reliable and predictive tools for classifying sediment samples from the TSMD as toxic or not toxic. However, limitations on the availability of pore-water chemistry data make these toxicity thresholds less useful for broad application in the Advanced SLERA of the TSMD. Nevertheless, the PWTTs will be used to evaluate sediment quality conditions in the TSMD using multiple lines-of-evidence.

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Tables

Table 1. Summary of sediment quality guidelines and water quality criteria used to evaluate sediment chemistry and pore-water chemistry data from the Tri-State Mining District.

COPC/COPC Mixture	Sediment Chemistry		Pore-Water Chemistry	
	SQG[1]	Units	WQC[2]	Units
Metals				
Aluminum	NB		87	µg/L
Antimony	NB		ND	
Arsenic	33	mg/kg	150	µg/L
Barium	NB		ND	
Beryllium	NB		ND	
Cadmium	4.98	mg/kg	0.25	µg/L
Calcium	NB		ND	
Chromium, total	111	mg/kg	74	µg/L
Cobalt	NB		ND	
Copper	149	mg/kg	9	µg/L
Iron	NB		1000	µg/L
Lead	128	mg/kg	2.5	µg/L
Magnesium	NB		ND	
Manganese	NB		ND	
Mercury	NB		ND	
Molybdenum[3]	ND		395	µg/L
Nickel	48.6	mg/kg	52	µg/L
Potassium	NB		ND	
Selenium	NB		5.0	µg/L
Silver[4]	NB		0.32	µg/L
Sodium	NB		ND	
Thallium[3]	NB		9.85	µg/L
Tin[3]	ND		84.8	µg/L
Uranium[3]	ND		2.6	µg/L
Vanadium[3]	NB		17.7	µg/L
Zinc	459	mg/kg	120	µg/L
Simultaneously Extracted Metals (SEM) and Acid Volatile Sulfides (AVS)				
AVS	NB		ND	
Simultaneously extracted cadmium	4.98	mg/kg	ND	
Simultaneously extracted copper	149	mg/kg	ND	
Simultaneously extracted lead	128	mg/kg	ND	
Simultaneously extracted nickel	48.6	mg/kg	ND	
Simultaneously extracted silver	NB		ND	
Simultaneously extracted zinc	459	mg/kg	ND	
ΣSEM-AVS	NB		ND	
(ΣSEM-AVS)/f_{OC}	NB		ND	
Polycyclic Aromatic Hydrocarbons (PAHs)				
2-Methylnaphthalene	NB		ND	
2-Nitroaniline	NB		ND	

Table 1. Summary of sediment quality guidelines and water quality criteria used to evaluate sediment chemistry and pore-water chemistry data from the Tri-State Mining District.

COPC/COPC Mixture	Sediment Chemistry		Pore-Water Chemistry	
	SQG[1]	Units	WQC[2]	Units
PAHs (cont.)				
3,3'-Dichlorobenzidine	NB		ND	
3-Nitroaniline	NB		ND	
4-Nitroaniline	NB		ND	
Acenaphthene	NB		ND	
Acenaphthylene	NB		ND	
Anthracene	845	µg/kg	ND	
Benzo(a)anthracene	1050	µg/kg	ND	
Benzo(a)pyrene	1450	µg/kg	ND	
Benzo(b)fluoranthene	NB		ND	
Benzo(g,h,i)perylene	NB		ND	
Benzo(k)fluoranthene	NB		ND	
Biphenyl	NB		ND	
Carbazole	NB		ND	
Chrysene	1290	µg/kg	ND	
Dibenzo(a,h)anthracene	NB		ND	
Dibenzofuran	NB		ND	
Fluoranthene	2230	µg/kg	ND	
Fluorene	536	µg/kg	ND	
Indeno(1,2,3-c,d)pyrene	NB		ND	
Naphthalene	561	µg/kg	ND	
Nitrobenzene	NB		ND	
Phenanthrene	1170	µg/kg	ND	
Pyrene	1520	µg/kg	ND	
Total PAHs	22800	µg/kg	ND	
ΣESB-TU_{FCV}	NB		ND	
Polychlorinated Biphenyls (PCBs)				
Aroclor 1016	676	µg/kg	ND	
Aroclor 1221	676	µg/kg	ND	
Aroclor 1232	676	µg/kg	ND	
Aroclor 1242	676	µg/kg	ND	
Aroclor 1248	676	µg/kg	ND	
Aroclor 1254	676	µg/kg	ND	
Aroclor 1260	676	µg/kg	ND	
Aroclor 1262	676	µg/kg	ND	
Aroclor 1268	676	µg/kg	ND	
Total PCBs	676	µg/kg	ND	
Organochlorine Pesticides				
Aldrin	NB		ND	
Atrazine	NB		ND	
Chlordane, cis-	17.6	µg/kg	ND	

Table 1. Summary of sediment quality guidelines and water quality criteria used to evaluate sediment chemistry and pore-water chemistry data from the Tri-State Mining District.

COPC/COPC Mixture	Sediment Chemistry		Pore-Water Chemistry	
	SQG[1]	Units	WQC[2]	Units
Organochlorine Pesticides (cont.)				
Chlordane, trans-	NB		ND	
Dieldrin	61.8	µg/kg	ND	
Endosulfan sulfate	NB		ND	
Endosulfan-alpha	NB		ND	
Endosulfan-beta	NB		ND	
Endrin	207	µg/kg	ND	
Endrin aldehyde	207	µg/kg	ND	
Endrin ketone	207	µg/kg	ND	
Heptachlor	NB		ND	
Heptachlor epoxide	16	µg/kg	ND	
Hexachlorobenzene	NB		ND	
Hexachlorocyclohexane-alpha	NB		ND	
Hexachlorocyclohexane-beta	NB		ND	
Hexachlorocyclohexane-delta	NB		ND	
Hexachlorocyclohexane-gamma	4.99	µg/kg	ND	
Hexachlorocyclopentadiene	NB		ND	
Isophorone	NB		ND	
Methoxychlor	NB		ND	
p,p'-DDD	28	µg/kg	ND	
p,p'-DDE	31.3	µg/kg	ND	
p,p'-DDT	62.9	µg/kg	ND	
Toxaphene	NB		ND	
Semi-Volatile Compounds				
1,2,4-Trichlorobenzene	NB		ND	
1,2-Dichlorobenzene	NB		ND	
1,3-Dichlorobenzene	NB		ND	
1,4-Dichlorobenzene	NB		ND	
2,4,5-Trichlorophenol	NB		ND	
2,4,6-Trichlorophenol	NB		ND	
2,4-Dichlorophenol	NB		ND	
2,4-Dimethylphenol	NB		ND	
2,4-Dinitrophenol	NB		ND	
2,4-Dinitrotoluene	NB		ND	
2,6-Dinitrotoluene	NB		ND	
2-Chloronaphthalene	NB		ND	
2-Chlorophenol	NB		ND	
2-Methylphenol	NB		ND	
2-Nitrophenol	NB		ND	
3&4 Methylphenol: Revised code.	NB		ND	
4-Bromophenyl phenyl ether	NB		ND	
4-Chloro-3-methylphenol	NB		ND	

Table 1. Summary of sediment quality guidelines and water quality criteria used to evaluate sediment chemistry and pore-water chemistry data from the Tri-State Mining District.

COPC/COPC Mixture	Sediment Chemistry		Pore-Water Chemistry	
	SQG[1]	Units	WQC[2]	Units
Semi-Volatile Compounds (cont.)				
4-Chloroaniline	NB		ND	
4-Chlorophenyl phenyl ether	NB		ND	
4-Nitrophenol	NB		ND	
Acetophenone	NB		ND	
Benzaldehyde	NB		ND	
Benzoic acid	NB		ND	
Benzyl alcohol	NB		ND	
Bis(2-chloroethoxy)methane	NB		ND	
Bis(2-chloroethyl)ether	NB		ND	
Bis(2-chloroisopropyl) ether	NB		ND	
Bis(2-ethylhexyl) phthalate	NB		ND	
Butylbenzyl phthalate	NB		ND	
Caprolactam	NB		ND	
Diethyl phthalate	NB		ND	
Dimethyl phthalate	NB		ND	
Di-n-butyl phthalate	NB		ND	
Dinitro-o-cresol	NB		ND	
Di-n-octyl phthalate	NB		ND	
Hexachlorobutadiene	NB		ND	
Hexachloroethane	NB		ND	
N-nitrosodi-N-propylamine	NB		ND	
N-nitrosodiphenylamine	NB		ND	
Pentachlorophenol	NB		ND	
Phenol	NB		ND	
Mean Quotients (no units)				
Mean PEC-Q	NB		ND	
Mean PEC-Q_{METAL}	NB		ND	
Mean PEC-$Q_{METAL(1\%OC)}$	NB		ND	

NB = no benchmark; ND = not determined; SQG = sediment quality guideline; WQC = water quality criterion; COPC = chemical of potential concern; PEC-Q = probable effect concentration-quotients; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; f_{OC} = fraction organic carbon; ESB-TU = equilibrium-based sediment benchmark-toxic units; FCV = final chronic value; OC = organic carbon.

[1]Probable effect concentrations (MacDonald *et al.* 2000) were used to evaluate sediment chemistry data.

[2]The current national WQC (USEPA 2006) for metals were used to evaluate pore-water chemistry data. The Criterion Continuous Concentrations were used, assuming water hardness of 100 mg/L, except for molybdenum, silver, thallium, tin, uranium, and vanadium.

[3]Toxicity screening values (TSVs; MacDonald *et al.* 2008b) were used to evaluate pore-water chemistry data for molybdenum, thallium, tin, uranium, and vanadium.

[4]The Criterion Maximum Concentration (USEPA 2006) divided by 10 was used to estimate a TRV for assessing the pore-water chemistry data for silver.

Table 2. Summary of physical and chemical conditions for the reference samples that were selected in the Tri-State Mining District.

Station Identification Number	TOC (%)	% Fines (silt & clay)	% Sand	% Gravel	Mean PEC-Q_{METALS}	Mean PEC-$Q_{METALS(1\%OC)}$	ΣSEM-AVS	$(\Sigma SEM\text{-}AVS)/f_{OC}$
CERC-01	1.92	16.70	82.81	0.49	0.163	0.0851	0.05	2
CERC-06	2.57	62.05	37.95	0	0.233	0.0905	0.34	13
CERC-07	2.55	55.38	44.62	0	0.132	0.0516	-2.06	-81
CERC-11	0.822	45.14	54.86	0	0.0783	0.0953	0.36	44
CERC-15	2.59	65.93	34.07	0	0.228	0.0881	1.64	63
CERC-26	2.74	78.28	21.72	0	0.139	0.0507	0.83	30
CERC-47	2.92	71.17	28.84	0	0.171	0.0585	1.38	47
CERC-48	2.38	82.4	17.60	0	0.226	0.0951	1.43	60
CERC-S1	3.20	No Data	No Data	No Data	0.198	0.0619	-1	-31
CERC-S4	0.80	57.62	42.38	0	0.019	0.0237	0.14	18
Minimum	0.80	16.70	17.60	0	0.0190	0.0237	-2.06	-81
Maximum	3.20	82.40	82.81	0.49	0.233	0.0953	1.64	63
Mean	2.25	59.41	40.54	0.05	0.159	0.0701	0.31	17

TOC = total organic carbon; PEC-Q = probable effect concentration-quotients; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; f_{OC} = fraction organic carbon.

Table 3. Summary of the results of sediment toxicity tests conducted on the reference samples that were selected in the Tri-State Mining District (all of the results shown are control adjusted).

Station Identification Number	Midge			Amphipod				Mussel			
	Survival (%)	Weight (%)	Biomass (%)	Survival (%)	Length (%)	Weight (%)	Biomass (%)	Survival (%)	Length (%)	Weight (%)	Biomass (%)
CERC-01	114	76	89.4	94.9	94.1	83	79				
CERC-06	94.7	78.4	73.8	94.4	91.7	75.6	72.6				
CERC-07	111	116.6	136.2	94.9	109.7	133.4	126.6				
CERC-11	96	103.9	99.3	92.3	87.1	65.1	60				
CERC-15	108	80.6	90.5	97.4	89.1	70	68.1	95	89.9	76.9	73.4
CERC-26	111	115.7	132.6	102.6	114.7	152.2	155.9				
CERC-47	102.6	113.2	115.9	111.1	108.5	136.8	154.2	100	99.7	101.6	101.1
CERC-48	100	111.7	108.1	102.8	124.8	204.1	210.4	102.6	90.5	61.2	62.7
CERC-S1				97.5	107.1	124.1	120.6	105.7	95.2	102.4	109.4
CERC-S4				97.5	93.6	83.3	81.4	100	86.2	70.7	70.5
Mean of Reference Samples	104.7	99.5	105.7	98.5	102.0	112.8	112.9	100.7	92.3	82.6	83.4
5th Percentile[1]	95.2	76.8	78.9	93.2	88.0	67.3	63.5	96.0	86.9	63.0	64.2
Minimum of Reference Samples	94.7	76.0	73.8	92.3	87.1	65.1	60.0	95.0	86.2	61.2	62.7
Maximum of Reference Samples	114.0	116.6	136.2	111.1	124.8	204.1	210.4	105.7	99.7	102.4	109.4
Threshold for Toxicity Designation	<95.2	<76.8	<78.9	<93.2	<88	<67.3	<63.5	<96	<86.9	<63	<64.2

[1]Note: All data were log transformed prior to calculating the 5th percentile of the distribution.

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Sediment						
Amphipod 28-d Survival	< 2 mm	***Cadmium***	***1***	***Sig3***	***0.46***	***<0.0001***
		Chromium	2	Sig3	0.03	0.4059
		Copper	3	Sig3	0.27	<0.0001
		Lead	***4***	***Sig3***	***0.48***	***<0.0001***
		Nickel	5	Sig3	0.002	0.9276
		Zinc	***6***	***Sig3***	***0.51***	***<0.0001***
		Total PAH	7	Sig3	0.16	0.0033
		ΣSEM-AVS[1]	***8***	***Sig3***	***0.49***	***<0.0001***
		(ΣSEM-AVS)/f_{OC}[1]	9	Sig3	0.28	<0.0001
		$\Sigma ESB\text{-}TU_{FCV}$	10	Sig3	0.07	0.0888
		Mean PEC-Q	***11***	***Sig3***	***0.51***	***<0.0001***
		Mean PEC-Q $_{METAL}$	***12***	***Sig3***	***0.53***	***<0.0001***
		Mean PEC-$Q_{METAL(1\%OC)}$	13	Log3	0.34	<0.0001
		ΣPEC-Q $_{Cd,Pb,Zn}$	***14***	***Sig3***	***0.52***	***<0.0001***
		ΣSTT-Q $_{Cd,Cu,Pb,Zn}$	***15***	***Sig3***	***0.52***	***<0.0001***
Sediment						
Amphipod 28-d Biomass	< 2 mm	Cadmium	16	Sig3	0.27	<0.0001
		Chromium	17	Sig3	0.007	0.7832
		Copper	18	Sig3	0.20	0.0003
		Lead	19	Sig3	0.33	<0.0001
		Nickel	20	Sig3	0.003	0.8825
		Zinc	21	Sig3	0.28	<0.0001
		Total PAH	22	Sig3	0.09	0.0415
		ΣSEM-AVS[1]	23	Sig3	0.24	<0.0001
		(ΣSEM-AVS)/f_{OC}[1]	24	Sig3	0.13	0.0074
		$\Sigma ESB\text{-}TU_{FCV}$	25	Sig3	0.05	0.1545
		Mean PEC-Q	26	Sig3	0.34	<0.0001
		Mean PEC-Q_{METAL}	27	Sig3	0.35	<0.0001
		Mean PEC-$Q_{METAL(1\%OC)}$	28	Sig3	0.15	0.0046
		ΣPEC-$Q_{Cd,Pb,Zn}$	29	Sig3	0.31	<0.0001
		ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	30	Sig3	0.32	<0.0001
Sediment						
Mussel 28-d Survival	<250 µm *(unless otherwise noted)*	Cadmium	31	Sig3	0.28	0.0005
		Chromium	32	Sig3	0.28	0.0016
		Copper	***33***	***Sig3***	***0.66***	***<0.0001***
		Lead	34	Sig3	0.32	0.0002
		Nickel	35	Log3	0.08	0.1453
		Zinc	***36***	***Sig3***	***0.54***	***<0.0001***

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Sediment		Total PAH[2]	37	Sig3	0.003	0.9457
Mussel		***ΣSEM-AVS*** [1,3]	***38***	***Sig3***	***0.68***	***<0.0001***
28-d Survival		(ΣSEM-AVS)/f_{OC}[1,3]	39	Sig3	0.19	0.0089
(cont.)		ΣESB-TU_{FCV}[2]	40	Sig3	0.02	0.7361
		Mean PEC-Q[2]	41	Sig3	0.09	0.1646
		Mean PEC-Q $_{METAL}$	***42***	***Sig3***	***0.53***	***<0.0001***
		Mean PEC-Q $_{METAL(1\%OC)}$	***43***	***Sig3***	***0.92***	***<0.0001***
		ΣPEC-Q $_{Cd,Pb,Zn}$	***44***	***Log3***	***0.47***	***<0.0001***
		ΣSTT-Q $_{Cd,Cu,Pb,Zn}$	***45***	***Sig3***	***0.67***	***<0.0001***
Sediment						
Mussel	<250 µm	Cadmium	46	Sig3	0.30	0.0003
28-d Biomass	*(unless*	Chromium	47	Sig3	0.25	0.0035
	otherwise	***Copper***	***48***	***Sig3***	***0.49***	***<0.0001***
	noted)	***Lead***	***49***	***Sig3***	***0.48***	***<0.0001***
		Nickel	50	Sig3	0.21	0.0051
		Zinc	51	Sig3	0.37	<0.0001
		Total PAH[2]	52	Sig3	0.003	0.9494
		ΣSEM-AVS [1,3]	***53***	***Sig3***	***0.50***	***<0.0001***
		(ΣSEM-AVS)/f_{OC}[1,3]	54	Sig3	0.19	0.0083
		ΣESB-TU_{FCV}[2]	55	Log3	0.05	0.3380
		Mean PEC-Q[2]	56	Sig3	0.30	0.0009
		Mean PEC-Q $_{METAL}$	***57***	***Sig3***	***0.45***	***<0.0001***
		Mean PEC-Q $_{METAL(1\%OC)}$	***58***	***Sig3***	***0.63***	***<0.0001***
		ΣPEC-$Q_{Cd,Pb,Zn}$	59	Sig3	0.39	<0.0001
		ΣSTT-Q $_{Cd,Cu,Pb,Zn}$	***60***	***Sig3***	***0.43***	***<0.0001***
Sediment						
Midge	< 2 mm	Cadmium	61	Sig3	0.10	0.0312
10-d Survival		Chromium	62	Sig3	0.08	0.0564
		Copper	63	Sig3	0.05	0.1889
		Lead	64	Sig3	0.09	0.0383
		Nickel	65	Sig3	0.009	0.7361
		Zinc	66	Sig3	0.14	0.0056
		Total PAH	67	Sig3	0.02	0.5541
		ΣSEM-AVS[4]	68	Log3	0.23	0.0001
		(ΣSEM-AVS)/f_{OC}[4]	69	Sig4	0.22	0.0007
		ΣESB-TU_{FCV}	70	Linear	0.001	0.7961
		Mean PEC-Q	71	Sig3	0.13	0.0079

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Sediment		Mean PEC-Q_{METAL}	72	Sig3	0.14	0.0070
Midge		Mean PEC-$Q_{METAL(1\%OC)}$	73	Sig3	0.03	0.3504
10-d Survival		ΣPEC-$Q_{Cd,Pb,Zn}$	74	Log3	0.16	0.0035
(cont.)		ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	75	Sig3	0.14	0.0066
Sediment						
Midge	< 2 mm	Cadmium	76	Sig3	0.08	0.0513
10-d Biomass		Chromium	77	Sig3	0.03	0.3903
		Copper	78	Sig3	0.15	0.0050
		Lead	79	Sig3	0.19	0.0010
		Nickel	80	Sig3	0.03	0.3074
		Zinc	81	Sig3	0.11	0.0229
		Total PAH	82	Sig3	0.06	0.1227
		ΣSEM-AVS[4]	83	Log3	0.22	0.0003
		(ΣSEM-AVS)/f_{OC}[4]	84	Log3	0.16	0.0028
		ΣESB-TU_{FCV}	85	Sig3	0.04	0.2164
		Mean PEC-Q	86	Sig3	0.14	0.0068
		Mean PEC-Q_{METAL}	87	Sig3	0.14	0.0066
		Mean PEC-$Q_{METAL(1\%OC)}$	88	Sig3	0.04	0.2789
		ΣPEC-$Q_{Cd,Pb,Zn}$	89	Log3	0.16	0.0030
		ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	90	Sig3	0.16	0.0031
Pore Water[5]						
Amphipod	NA	ΣPW-TU_{METALS}	91	Sig3	0.082	0.0565
28-d Survival		***ΣPW-$TU_{DIVALENT\ METALS}$***	***92***	***Sig3***	***0.84***	***<0.0001***
		PW-$TU_{ALUMINUM}$	93	Sig3	0.003	0.9162
		PW-$TU_{ARSENIC}$	94	Sig3	0.10	0.0279
		PW-$TU_{CADMIUM}$ (7 Day)	95	Sig3	0.40	<0.0001
		PW-$TU_{CADMIUM}$ (28 Day)	96	Sig3	0.39	<0.0001
		PW-$TU_{CADMIUM}$ (Mean)	***97***	***Sig3***	***0.40***	***<0.0001***
		PW-$TU_{CHROMIUM}$	98	Sig3	0.04	0.2481
		PW-TU_{COPPER} (7 Day)	99	Sig3	0.001	0.9606
		PW-TU_{COPPER} (28 Day)	100	Linear	0.0006	0.8391
		PW-TU_{COPPER} (Mean)	101	Linear	0.0	0.9636
		PW-TU_{IRON}	102	Sig3	0.11	0.0186
		PW-TU_{LEAD} (7 Day)	103	Sig3	0.56	<0.0001
		PW-TU_{LEAD} (28 Day)	104	Sig3	0.52	<0.0001
		PW-TU_{LEAD} (Mean)	***105***	***Sig3***	***0.59***	***<0.0001***
		PW-TU_{NICKEL} (7 Day)	106	Sig3	0.14	0.0076
		PW-TU_{NICKEL} (28 Day)	107	Sig3	0.003	0.9171

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Pore Water[5]		$PW\text{-}TU_{NICKEL}$ (Mean)	108	Sig3	0.05	0.1594
Amphipod		$PW\text{-}TU_{SELENIUM}$	109	Sig3	0.01	0.6168
28-d Survival		$PW\text{-}TU_{SILVER}$	110	Sig3	0.04	0.2383
(cont.)		$PW\text{-}TU_{ZINC}$ (7 Day)	111	Sig3	0.81	<0.0001
		$PW\text{-}TU_{ZINC}$ (28 Day)	112	Sig3	0.82	<0.0001
		PW-TU $_{ZINC}$ ***(Mean)***	***113***	***Sig3***	***0.83***	***<0.0001***
		PW-TU $_{LEAD(DOC)}$	***114***	***Sig3***	***0.59***	***<0.0001***
		PW-TU $_{ZINC(DOC)}$	***115***	***Sig3***	***0.72***	***<0.0001***
Pore Water[5]						
Amphipod	NA	$\Sigma PW\text{-}TU_{METALS}$	116	Sig3	0.05	0.1781
28-d Biomass		***ΣPW-TU*** $_{DIVALENT\ METALS}$	***117***	***Sig3***	***0.52***	***<0.0001***
		$PW\text{-}TU_{ALUMINUM}$	118	Sig3	0.004	0.8775
		$PW\text{-}TU_{ARSENIC}$	119	Sig3	0.03	0.4094
		$PW\text{-}TU_{CADMIUM}$ (7 Day)	120	Sig3	0.24	0.0001
		$PW\text{-}TU_{CADMIUM}$ (28 Day)	121	Sig3	0.23	0.0002
		$PW\text{-}TU_{CADMIUM}$ (Mean)	122	Sig3	0.24	0.0001
		$PW\text{-}TU_{CHROMIUM}$	123	Linear	0.0002	0.9112
		$PW\text{-}TU_{COPPER}$ (7 Day)	124	Linear	0.004	0.6228
		$PW\text{-}TU_{COPPER}$ (28 Day)	125	Sig3	0.06	0.1494
		$PW\text{-}TU_{COPPER}$ (Mean)	126	Sig3	0.04	0.2517
		$PW\text{-}TU_{IRON}$	127	Sig3	0.14	0.0054
		$PW\text{-}TU_{LEAD}$ (7 Day)	128	Sig3	0.42	<0.0001
		$PW\text{-}TU_{LEAD}$ (28 Day)	129	Sig3	0.41	<0.0001
		PW-TU $_{LEAD}$ ***(Mean)***	***130***	***Sig3***	***0.45***	***<0.0001***
		$PW\text{-}TU_{NICKEL}$ (7 Day)	131	Sig3	0.14	0.0059
		$PW\text{-}TU_{NICKEL}$ (28 Day)	132	Linear	0.005	0.5709
		$PW\text{-}TU_{NICKEL}$ (Mean)	133	Sig3	0.07	0.0988
		$PW\text{-}TU_{SELENIUM}$	134	Linear	0.0	0.9605
		$PW\text{-}TU_{SILVER}$	135	Linear	0.003	0.6534
		$PW\text{-}TU_{ZINC}$ (7 Day)	136	Sig3	0.50	<0.0001
		$PW\text{-}TU_{ZINC}$ (28 Day)	137	Sig3	0.49	<0.0001
		PW-TU $_{ZINC}$ ***(Mean)***	***138***	***Sig3***	***0.50***	***<0.0001***
		PW-TU $_{LEAD(DOC)}$	***139***	***Sig3***	***0.45***	***<0.0001***
		PW-TU $_{ZINC(DOC)}$	***140***	***Sig3***	***0.44***	***<0.0001***

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Pore Water[5]						
Mussel	NA	***ΣPW-TU $_{METALS}$***	***141***	***Sig3***	***0.77***	***<0.0001***
28-d Survival		***ΣPW-TU $_{DIVALENT\ METALS}$***	***142***	***Sig3***	***0.82***	***<0.0001***
		$PW\text{-}TU_{ALUMINUM}$	143	Sig3	0.02	0.659
		$PW\text{-}TU_{ARSENIC}$	144	Sig3	0.04	0.4673
		PW-TU $_{CADMIUM}$ (7 Day)	***145***	***Sig3***	***0.79***	***<0.0001***
		$PW\text{-}TU_{CADMIUM}$ (28 Day)	146	Sig3	0.31	0.0007
		$PW\text{-}TU_{CADMIUM}$ (Mean)	147	Linear	0.35	<0.0001
		$PW\text{-}TU_{CHROMIUM}$	148	Sig3	0.009	0.8415
		PW-TU $_{COPPER}$ (7 Day)	***149***	***Sig3***	***0.84***	***<0.0001***
		$PW\text{-}TU_{COPPER}$ (28 Day)	150	Linear	0.008	0.5626
		$PW\text{-}TU_{COPPER}$ (Mean)	151	Linear	0.12	0.0255
		$PW\text{-}TU_{IRON}$	152	Sig3	0.05	0.3376
		$PW\text{-}TU_{LEAD}$ (7 Day)	153	Sig3	0.47	<0.0001
		$PW\text{-}TU_{LEAD}$ (28 Day)	154	Sig3	0.78	<0.0001
		PW-TU $_{LEAD}$ (Mean)	***155***	***Sig3***	***0.51***	***<0.0001***
		$PW\text{-}TU_{NICKEL}$ (7 Day)	156	Sig3	0.79	<0.0001
		$PW\text{-}TU_{NICKEL}$ (28 Day)	157	Sig3	0.68	<0.0001
		PW-TU $_{NICKEL}$ (Mean)	***158***	***Sig3***	***0.79***	***<0.0001***
		$PW\text{-}TU_{SELENIUM}$	159	Sig3	0.02	0.664
		$PW\text{-}TU_{SILVER}$	160	Sig3	0.02	0.7356
		$PW\text{-}TU_{ZINC}$ (7 Day)	161	Sig3	0.93	<0.0001
		$PW\text{-}TU_{ZINC}$ (28 Day)	162	Sig3	0.93	<0.0001
		PW-TU $_{ZINC}$ (Mean)	***163***	***Sig3***	***0.93***	***<0.0001***
		$PW\text{-}TU_{LEAD(DOC)}$	164	Sig3	0.38	<0.0001
		PW-TU $_{ZINC(DOC)}$	***165***	***Sig3***	***0.91***	***<0.0001***
Pore Water[5]						
Mussel	NA	***ΣPW-TU $_{METALS}$***	***166***	***Sig3***	***0.47***	***<0.0001***
28-d Biomass		***ΣPW-TU $_{DIVALENT\ METALS}$***	***167***	***Sig3***	***0.60***	***<0.0001***
		$PW\text{-}TU_{ALUMINUM}$	168	Sig3	0.01	0.7857
		$PW\text{-}TU_{ARSENIC}$	169	Sig3	0.007	0.8775
		$PW\text{-}TU_{CADMIUM}$ (7 Day)	170	Sig3	0.52	<0.0001
		$PW\text{-}TU_{CADMIUM}$ (28 Day)	171	Sig3	0.38	<0.0001
		PW-TU $_{CADMIUM}$ (Mean)	***172***	***Sig3***	***0.46***	***<0.0001***
		$PW\text{-}TU_{CHROMIUM}$	173	Sig3	0.08	0.1939
		PW-TU $_{COPPER}$ (7 Day)	***174***	***Sig3***	***0.47***	***<0.0001***
		$PW\text{-}TU_{COPPER}$ (28 Day)	175	Sig3	0.01	0.7857
		$PW\text{-}TU_{COPPER}$ (Mean)	176	Sig3	0.07	0.2353

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Pore Water[5]		$PW\text{-}TU_{IRON}$	177	Sig3	0.004	0.9303
Mussel		$PW\text{-}TU_{LEAD}$ (7 Day)	178	Sig3	0.31	0.0008
28-d Biomass		$PW\text{-}TU_{LEAD}$ (28 Day)	179	Sig3	0.48	<0.0001
(cont.)		***$PW\text{-}TU_{LEAD}$ (Mean)***	***180***	***Sig3***	***0.41***	***<0.0001***
		$PW\text{-}TU_{NICKEL}$ (7 Day)	181	Sig3	0.47	<0.0001
		$PW\text{-}TU_{NICKEL}$ (28 Day)	182	Sig3	0.32	0.0005
		$PW\text{-}TU_{NICKEL}$ (Mean)	***183***	***Sig3***	***0.47***	***<0.0001***
		$PW\text{-}TU_{SELENIUM}$	184	Sig3	0.0006	0.9893
		$PW\text{-}TU_{SILVER}$	185	Linear	0.09	0.0488
		$PW\text{-}TU_{ZINC}$ (7 Day)	186	Sig3	0.61	<0.0001
		$PW\text{-}TU_{ZINC}$ (28 Day)	187	Sig3	0.59	<0.0001
		$PW\text{-}TU_{ZINC}$ (Mean)	***188***	***Sig3***	***0.60***	***<0.0001***
		$PW\text{-}TU_{LEAD(DOC)}$	***189***	***Sig3***	***0.42***	***<0.0001***
		$PW\text{-}TU_{ZINC(DOC)}$	***190***	***Sig3***	***0.61***	***<0.0001***
Pore Water[5]						
Midge	NA	$\Sigma PW\text{-}TU_{METALS}$ (7 Day)	191	Sig3	0.01	0.6967
10-d Survival		$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$ (7 Day)	192	Log3	0.33	<0.0001
		$PW\text{-}TU_{ALUMINUM}$	193	Sig3	0.08	0.0591
		$PW\text{-}TU_{ARSENIC}$	194	Sig3	0.17	0.002
		$PW\text{-}TU_{CADMIUM}$ (7 Day)	195	Linear	0.03	0.132
		$PW\text{-}TU_{CHROMIUM}$	196	Sig3	0.08	0.0608
		$PW\text{-}TU_{COPPER}$ (7 Day)	197	Sig3	0.06	0.1086
		$PW\text{-}TU_{IRON}$	198	Sig3	0.19	0.0009
		$PW\text{-}TU_{LEAD}$ (7 Day)	199	Sig3	0.02	0.5069
		$PW\text{-}TU_{NICKEL}$ (7 Day)	200	Sig3	0.02	0.5735
		$PW\text{-}TU_{SELENIUM}$	201	Sig3	0.01	0.6267
		$PW\text{-}TU_{SILVER}$	202	Sig3	0.07	0.0812
		$PW\text{-}TU_{ZINC}$ (7 Day)	203	Sig3	0.28	<0.0001
		$PW\text{-}TU_{LEAD\ (DOC)}$ - 7 Day	204	Log3	0.05	0.1524
		$PW\text{-}TU_{ZINC\ (DOC)}$ - 7 Day	205	Log3	0.37	<0.0001
Pore Water[5]						
Midge	NA	$\Sigma PW\text{-}TU_{METALS}$ (7 Day)	206	Sig3	0.07	0.0962
10-d Biomass		$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$ (7 Day)	207	Log3	0.30	<0.0001
		$PW\text{-}TU_{ALUMINUM}$	208	Sig3	0.004	0.887
		$PW\text{-}TU_{ARSENIC}$	209	Sig3	0.08	0.0575
		$PW\text{-}TU_{CADMIUM}$ (7 Day)	210	Sig3	0.21	0.0003

Table 4. Summary of the preliminary concentration-response relationships (Appendix 1). Bold, italicized font indicate preliminary plots that were selected for further analysis.

Media Type / Toxicity Test Endpoint	Sediment Sample Size Fraction	COPC/COPC Mixture	Appendix 1 Plot Number	Regression Equation Type	r^2	p
Pore Water[5]		$PW\text{-}TU_{CHROMIUM}$	211	Log3	0.0002	0.9935
Midge		$PW\text{-}TU_{COPPER}$ (7 Day)	212	Sig3	0.03	0.3345
10-d Biomass		$PW\text{-}TU_{IRON}$	213	Sig3	0.15	0.0052
(cont.)		$PW\text{-}TU_{LEAD}$ (7 Day)	214	Sig3	0.14	0.0056
		$PW\text{-}TU_{NICKEL}$ (7 Day)	215	Sig3	0.13	0.01
		$PW\text{-}TU_{SELENIUM}$	216	Sig3	0.006	0.8243
		$PW\text{-}TU_{SILVER}$	217	Sig3	0.004	0.8616
		$PW\text{-}TU_{ZINC}$ (7 Day)	218	Sig3	0.26	<0.0001
		$PW\text{-}TU_{LEAD(DOC)}$ - 7 Day	219	Log3	0.18	0.0011
		$PW\text{-}TU_{ZINC(DOC)}$ - 7 Day	220	Log3	0.25	<0.0001

d = day; COPC = chemical of potential concern; PAHs = polycyclic aromatic hydrocarbons; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; f_{OC} = fraction organic carbon; OC = organic carbon; ESB-TU = equilibrium partitioning sediment benchmark toxic units; FCV = final chronic value; PEC-Q = probable effect concentration-quotient; STT-Q = sediment toxicity threshold-quotient; PW-TU = pore-water toxic units; DOC = dissolved organic carbon.

[1]Sediment samples were collected for SEM and AVS measurement on Day 7 and on Day 28 of the sediment toxicity tests with amphipods. Preliminary concentration-response relationships for amphipods and mussels were developed using the mean of th 7-day and 28-day results.

[2]Concentration-response relationships for total PAHs, $\Sigma ESB\text{-}TU_{FCV}$, and mean PEC-Q and the mussel toxicity test endpoints were developed with concentration measurement data from the <2 mm size fraction.

[3]Concentration-response relationships for ΣSEM-AVS and the mussel toxicity test endpoints were developed with concentratio measurement data from the <2 mm size fraction for the Set 1 and 2 samples (n=42) and the <250 µm size fraction for the Set 3 samples (n = 6).

[4]Sediment samples were collected for SEM and AVS measurement on Day 7 and on Day 28 of the sediment toxicity tests with amphipods. Preliminary concentration-response relationships for midges were developed using the 7-day results.

[5]Pore-water peeper samples were collected on Day 7 and on Day 28 of the sediment toxicity tests. The mean of the pore-water chemistry results for the Day 7 and Day 28 samples was calculated for cadmium, copper, lead, nickel, and zinc. For these COPCs, the preliminary concentration-response relationships were developed using the 7-d, 28-d, and mean results. For the remaining COPCs (i.e., aluminum, arsenic, chromium, iron, selenium, and silver), pore-water chemistry from centrifuged samples was only measured on Day 7 of the toxicity tests,so the preliminary concentration-response relationships were developed using the 7-d results. For the pore-water mixture models (i.e., $\Sigma PW\text{-}TU_{METALS}$ and $\Sigma PW\text{-}TU_{DIVALENT\ METALS}$) and $PW\text{-}TU_{LEAD(DOC)}$ and $PW\text{-}TU_{ZINC(DOC)}$, the concentration-response models were developed using the mean of the 7-d and 28-d results (except for the models developed for the midge endpoints, where the 7-d results were used).

Table 5. Summary of the concentration-response relationships derived for sediment based on magnitude of toxicity to the freshwater amphipod, *Hyalella azteca* , and fat mucket, *Lampsilis siliquoidea* in 28-day sediment toxicity tests. The toxicity thresholds derived using these regression equations are also presented.

Toxicity Test Endpoint Used to Develop the Relationship	COPC/COPC Mixture	Regression Equation Type	Regression Equation	r^2	p	Preliminary Toxicity Threshold	
						T_{10}	T_{20}
Amphipod 28-d Survival	Cadmium (mg/kg DW)	Sig4	$y=28.2135+88.4446/\{1+e^{-[(x-21.0632)/-12.9236]}\}$	0.47	<0.0001	11.1	17.3
	Lead (mg/kg DW)	Sig4	$y=29.2988+82.9014/\{1+e^{-[(x-269.1421)/-128.2169]}\}$	0.49	<0.0001	150	219
	Zinc (mg/kg DW)	Sig4	$y=29.6916+77.835/\{1+e^{-[(x-3715.6059)/-1428.6852]}\}$	0.54	<0.0001	2083	2949
	ΣSEM-AVS[1] (µmol/g DW)	Sig3	$y=442.6747/\{1+e^{-[(x-47.9743)/-40.314]}\}$	0.49	<0.0001	7.82	13.7
	Mean PEC-Q	Sig4	$y=41.7638+65.3563/\{1+e^{-[(x-0.8031)/-0.2637]}\}$	0.43	<0.0001	0.556	0.732
	Mean PEC-Q_{METAL}	Sig4	$y=6.625+193.7111/\{1+e^{-[(x-0.138)/-3.1485]}\}$	0.50	<0.0001	1.11	1.78
	ΣPEC-$Q_{Cd,Pb,Zn}$	Log4	$y=6.4381+95.4215/[1+(x/21.9965)^{1.7944}]$	0.53	<0.0001	7.92	11.6
	ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	Log4	$y=-7.8905+111.166/[1+(x/10.5242)^{1.4929}]$	0.52	<0.0001	2.97	4.51
Mussel 28-d Survival <2 mm fraction	Lead (mg/kg DW)	Sig4	$y=23.0357+72.8675/\{1+e^{-[(x-1387.4222)/-10.8603]}\}$	0.74	<0.0001	1360	1373
	Copper (mg/kg DW)	Sig4	$y=23.6883+73.3791/\{1+e^{-[(x-56.8773)/-8.4574]}\}$	0.75	<0.0001	37.1	46.4
	ΣSEM-AVS[1,2] (µmol/g DW)	Sig4	$y=-360.5551+467.1141/\{1+e^{-[(x-206.2787)/-50.3828]}\}$	0.7	<0.0001	37.9	63.5
Mussel 28-d Survival <250 µm fraction	Copper (mg/kg DW)	Sig3	$y=98.4115/\{1+e^{-[(x-189.9154)/-45.1048}]\}$	0.66	<0.0001	79.4	122
	Zinc (mg/kg DW)	Sig4	$y=-5454.6084+5550.7656/\{1+e^{-[(x-41465.8412)/-3020.0447]}\}$	0.57	<0.0001	20600	23700
	ΣSEM-AVS[1,2] (µmol/g DW)	Sig4	$y=-347.5648+453.6174/\{1+e^{-[(x-203.0035)/-49.1899]}\}$	0.69	<0.0001	38.5	64.1
	Mean PEC-Q_{METAL}	Sig4	$y=36.3973+68.3504/\{1+e^{-[(x-14.6021)/-6.3781]}\}$	0.48	<0.0001	6.03	10.7
	Mean PEC-$Q_{METAL(1\%OC)}$	Sig4	$y=9.8642+87.9476/\{1+e^{-[(x-8.1606)/-1.3818]}\}$	0.79	<0.0001	4.82	6.21
	ΣPEC-$Q_{Cd,Pb,Zn}$	Sig4	$y=36.7532+68.6537/\{1+e^{-[(x-98.4491)/-45.4636]}\}$	0.48	<0.0001	39.7	72.6
	ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	Log4	$y=23.75+72.7211/[1+(x/51.0254)^{369.1295}]$	0.75	<0.0001	50.7	50.8

Table 5. Summary of the concentration-response relationships derived for sediment based on magnitude of toxicity to the freshwater amphipod, *Hyalella azteca*, and fat mucket, *Lampsilis siliquoidea* in 28-day sediment toxicity tests. The toxicity thresholds derived using these regression equations are also presented.

Toxicity Test Endpoint Used to Develop the Relationship	COPC/COPC Mixture	Regression Equation Type	Regression Equation	r^2	p	Preliminary Toxicity Threshold	
						T_{10}	T_{20}
Mussel 28-d Biomass <2 mm fraction	Copper (mg/kg DW)	Sig4	$y=5.2117+145.8217/\{1+e^{-[(x-23.2333)/-46.9459]}\}$	0.47	<0.0001	27.1	38.1
	Lead (mg/kg DW)	Sig4	$y=6.6433+92.7796/\{1+e^{-[(x-1108.7792)/-469.7834]}\}$	0.44	<0.0001	623	823
	ΣSEM-AVS[1,2] (µmol/g DW)	Sig4	$y=-2.2589+99.3592/\{1+e^{-[(x-71.821)/-24.9857]}\}$	0.51	<0.0001	40.4	51.4
	$\Sigma STT\text{-}Q_{Cd,Cu,Pb,Zn}$	Log4	$y=20.4158+67.2429/\{1+e^{-[(x-20.86)/-0.2244]}\}$	0.44	<0.0001	20.5	20.7
Mussel 28-d Biomass <250 µm fraction	Copper (mg/kg DW)	Sig4	$y=9.1638+366.3476/\{1+e^{-[(x+100.6502)/-88.6904]}\}$	0.49	<0.0001	33.9	48.4
	Lead (mg/kg DW)	Sig4	$y=6.5496+86.6815/\{1+e^{-[(x-1781.385)/-515.3694]}\}$	0.48	<0.0001	1096	1359
	ΣSEM-AVS[1,2] (µmol/g DW)	Sig4	$y=-3.7333+100.2413/\{1+e^{-[(x-74.4199)/-25.126]}\}$	0.50	<0.0001	41.7	52.8
	Mean $PEC\text{-}Q_{METAL}$	Sig4	$y=11.3889+89.0922/\{1+e^{-[(x-13.404)/-6.3403]}\}$	0.40	<0.0001	7.57	10.3
	Mean $PEC\text{-}Q_{METAL(1\%OC)}$	Log4	$y=7.8604+82.2723/[1+(x/5.6235)^{6.6235}]$	0.56	<0.0001	4.49	4.90
	$\Sigma STT\text{-}Q_{Cd,Cu,Pb,Zn}$	Log4	$y=7.9746+87.8048/\{1+e^{-[(x-40.1032)/-14.9012]}\}$	0.43	<0.0001	22.6	29.6

r^2 = correlation coefficient; p = p value for the F statistic (ANOVA); TOC = total organic carbon; COPC = chemical of potential concern; PEC-Q = probable effect concentration-quotients; OC = organic carbon; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; STT-Q = sediment toxicity threshold-quotient; Log3 = 3 parameter logistic model; Log4 = 4 parameter logistic model; Sig3 = 3 parameter sigmoidal model; Sig4 = 4 parameter sigmoidal model.

[1]Sediment samples were collected for SEM and AVS measurement on Day 7 and on Day 28 of the sediment toxicity tests with amphipods. The mean results were selected for development of sediment toxicity thresholds (STTs; i.e., presented in this table).

[2]Concentration-response relationships for ΣSEM-AVS and the mussel toxicity test endpoints were developed with concentration measurement data from the <2 mm size fraction for the Set 1 and 2 samples (n=42) and the <250 µm size fraction for the Set 3 samples (n = 6).

Table 6. Summary of the concentration-response relationships derived for pore water based on magnitude of toxicity to the freshwater amphipod, *Hyalella azteca*, and fat mucket, *Lampsilis siliquoidea* in 28-day sediment toxicity tests. The toxicity thresholds derived using these regression equations are also presented.

Toxicity Test Endpoint Used to Develop the Relationship	COPC/COPC Mixture[1]	Regression Equation Type	Regression Equation	r^2	p	Preliminary Toxicity Threshold	
						T_{10}	T_{20}
Amphipod 28-d Survival	$PW\text{-}TU_{CADMIUM}$	Sig4	$y=-2.5614+218.1334/\{1+e^{-[(x+0.3276)/-1.4796]}\}$	0.40	<0.0001	0.160	0.441
	$PW\text{-}TU_{LEAD}$	Sig4	$y=4.6589+99.3025/\{1+e^{-[(x-0.2572)/-0.0945]}\}$	0.59	<0.0001	0.0960	0.155
	$PW\text{-}TU_{LEAD(DOC)}$	Sig4	$y=-0.6186+128.6546/\{1+e^{-[(x-0.00005396)/-0.000044944]}\}$	0.59	<0.0001	0.0000171	0.0000325
	$PW\text{-}TU_{ZINC}$	Sig4	$y=1.0437+105.2856/\{1+e^{-[(x-1.3915)/-0.5054]}\}$	0.83	<0.0001	0.581	0.867
	$PW\text{-}TU_{ZINC(DOC)}$	Log4	$y=-25.4046+125.5712/[1+(x/0.0006)^{1.1283}]$	0.72	<0.0001	0.0000783	0.000147
	$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$	Sig4	$y=4.0503+101.35/\{1+e^{-[(x-2.0644)/-0.6358]}\}$	0.84	<0.0001	1.03	1.41
Amphipod 28-d Biomass	$PW\text{-}TU_{LEAD}$	Sig4	$y=3.0977+171.2738/\{1+e^{-[(x-0.0493)/-0.173]}\}$	0.45	<0.0001	ND	0.0430
	$PW\text{-}TU_{LEAD(DOC)}$	Log4	$y=-15.075+117.030/[1+(x/0.00006317)^{1.022}]$	0.45	<0.0001	0.000000218	0.00000733
	$PW\text{-}TU_{ZINC}$	Sig4	$y=3.2181+92.1601/\{1+e^{-[(x-1.5077)/-0.306]}\}$	0.50	<0.0001	ND	0.638
	$PW\text{-}TU_{ZINC(DOC)}$	Sig4	$y=-0.9768+146.3428/\{1+e^{-[(x-0.0002297)/-0.0003520]}\}$	0.44	<0.0001	ND	0.0000518
	$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$	Sig3	$y=96.3868/\{1+e^{-[(x-2.1872)/-0.4447]}\}$	0.52	<0.0001	ND	0.988
Mussel 28-d Survival	$PW\text{-}TU_{CADMIUM}$	Sig3	$y=97.0848/\{1+e^{-[(x-6.7046)/-0.2104]}\}$	0.79	<0.0001	6.15	6.37
	$PW\text{-}TU_{COPPER}$	Log3	$y=97.0281/[1+(x/0.0849)^{3.4167}]$	0.85	<0.0001	0.0391	0.0533
	$PW\text{-}TU_{LEAD}$	Sig3	$y=339.2255/\{1+e^{-[(x+1.6539)/-1.8835]}\}$	0.51	<0.0001	0.248	0.542
	$PW\text{-}TU_{NICKEL}$	Log3	$y=97.085/[1+(x/0.0917)^{51.2156}]$	0.79	<0.0001	0.0871	0.0889
	$PW\text{-}TU_{ZINC}$	Sig4	$y=8.0671+120.4503/\{1+e^{-[(x-5.3193)/-4.7522]}\}$	0.94	<0.0001	1.62	3.35
	$PW\text{-}TU_{ZINC(DOC)}$	Sig3	$y=100.4647/\{1+e^{-[(x-0.0019766)/-0.0005486]}\}$	0.91	<0.0001	0.000760	0.00121
	$\Sigma PW\text{-}TU_{METALS}$	Sig3	$y=96.72/\{1+e^{-[(x-31.6344)/-0.5391]}\}$	0.77	<0.0001	30.2	30.8
	$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$	Sig4	$y=23.7119+81.6885/\{1+e^{-[(x-10.9407)/-4.6008]}\}$	0.90	<0.0001	4.00	7.12

Table 6. Summary of the concentration-response relationships derived for pore water based on magnitude of toxicity to the freshwater amphipod, *Hyalella azteca*, and fat mucket, *Lampsilis siliquoidea* in 28-day sediment toxicity tests. The toxicity thresholds derived using these regression equations are also presented.

Toxicity Test Endpoint Used to Develop the Relationship	COPC/COPC Mixture[1]	Regression Equation Type	Regression Equation	r^2	p	Preliminary Toxicity Threshold	
						T_{10}	T_{20}
Mussel 28-d Biomass	$PW\text{-}TU_{CADMIUM}$	Sig3	$y=269.1994/\{1+e^{-[(x+2.3843)/-3.2717]}\}$	0.46	<0.0001	0.723	1.25
	$PW\text{-}TU_{COPPER}$	Log3	$y=84.287/[1+(x/0.0743)^{4.8124}]$	0.48	<0.0001	0.0480	0.0563
	$PW\text{-}TU_{LEAD}$	Sig4	$y=16.3357+156.3486/\{1+e^{-[(x+0.1385)/-0.8269]}\}$	0.42	0.0001	0.281	0.477
	$PW\text{-}TU_{LEAD(DOC)}$	Sig4	$y=35.2314+52.0597/\{1+e^{-[(x-0.00009396)/-0.00001724]}\}$	0.44	<0.0001	0.0000735	0.0000866
	$PW\text{-}TU_{NICKEL}$	Sig3	$y=83.6/\{1+e^{-[(x-0.0928)/-0.0004]}\}$	0.47	<0.0001	0.0919	0.0923
	$PW\text{-}TU_{ZINC}$	Sig4	$y=5.9566+127.9876/\{1+e^{-[(x-1.6747)/-2.7277]}\}$	0.61	<0.0001	1.23	1.95
	$PW\text{-}TU_{ZINC(DOC)}$	Log4	$y=-64.6695+152.5752/[1+(x/0.0025)^{1.2862}]$	0.61	<0.0001	0.000390	0.000606
	$\Sigma PW\text{-}TU_{METALS}$	Log3	$y=84.4182/[1+(x/29.1916)^{25.7327}]$	0.47	<0.0001	26.9	27.7
	$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$	Sig4	$y=8.6921+146.757/\{1+e^{-[(x-1.238)/-5.9948]}\}$	0.60	<0.0001	2.38	3.79

r^2 = correlation coefficient; p = p value for the F statistic (ANOVA); COPC = chemical of potential concern; PW-TU = pore-water toxic units; DOC = dissolved organic carbon; d = day; Log3 = 3 parameter logistic model; Log4 = 4 parameter logistic model; Sig3 = 3 parameter sigmoidal model; Sig4 = 4 parameter sigmoidal model.

[1]Pore-water peeper samples were collected on Day 7 and on Day 28 of the sediment toxicity tests. The mean of the pore-water chemistry results for the Day 7 and Day 28 samples was calculated for cadmium, copper, lead, nickel, and zinc. For these COPCs,the preliminary concentration-response relationships were developed using the 7-d, 28-d, and mean results. For the remaining COPCs (i.e., aluminum, arsenic, chromium, iron, selenium, and silver), pore-water chemistry from centrifuged samples was only measured on Day 7 of the toxicity tests, so the preliminary concentration-response relationships were developed using the 7-d results. For the pore-water mixture models (i.e., $\Sigma PW\text{-}TU_{METALS}$ and $\Sigma PW\text{-}TU_{DIVALENT\ METALS}$) and $PW\text{-}TU_{LEAD(DOC)}$ and $PW\text{-}TU_{ZINC(DOC)}$, the concentration-response models were developed using the mean of the 7-d and 28-d results (except for the models developed for the midge endpoints, where the 7-d results were used). The COPCs and COPC mixutures that were selected for development of pore-water toxicity thresholds (PWTTs; i.e., presented in this table) are all based on the mean results, with the exception of $PW\text{-}TU_{CADMIUM}$ and $PW\text{-}TU_{COPPER}$.

Table 7. Summary of control-adjusted response rates used to derive the toxicity thresholds for the Tri-State Mining District.

Endpoint	Mean for Reference Samples[1]	Response Rate Corresponding To: 10% Reduction Relative to Reference Conditions[2]	Response Rate Corresponding To: 20% Reduction Relative to Reference Conditions[3]
Amphipod 28-d Survival	98.5	88.7	78.8
Amphipod 28-d Length	102	91.8	81.6
Amphipod 28-d Weight	112.8	101.5	90.2
Amphipod 28-d Biomass	112.9	101.6	90.3
Mussel 28-d Survival	100.7	90.6	80.6
Mussel 28-d Length	92.3	83.1	73.8
Mussel 28-d Weight	82.6	74.3	66.1
Mussel 28-d Biomass	83.4	75.1	66.7
Midge 10-d Survival	104.7	94.2	83.8
Midge 10-d Weight	99.5	89.6	79.6
Midge 10-d Biomass	105.7	95.1	84.6

d = day

[1]See Table 2 for more information on the reference envelope calculations.
[2]Represents a 10% increase in the magnitude of toxicity relative to the mean for reference samples. These response rates were used to develop the T_{10} STTs and PWTTs.
[3]Represents a 20% increase in the magnitude of toxicity relative to the mean for reference samples. These response rates were used to develop the T_{20} STTs and PWTTs.

Table 8. Reliability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Survival										
Cadmium (mg/kg DW)	76	11.1	17.3	**11% (5 of 45)**	**61% (19 of 31)**	78%	60% (6 of 10)	20% (11 of 55)	**62% (13 of 21)**	75%
Lead (mg/kg DW)	76	150	219	**9% (4 of 45)**	**65% (20 of 31)**	**80%**	33% (3 of 9)	**13% (7 of 54)**	**77% (17 of 22)**	**84%**
Zinc (mg/kg DW)	76	2083	2949	**13% (7 of 53)**	**74% (17 of 23)**	**83%**	No Data	**13% (7 of 53)**	**74% (17 of 23)**	**83%**
ΣSEM-AVS (μmol/g DW)	76	7.82	13.7	**11% (5 of 44)**	**59% (19 of 32)**	76%	29% (2 of 7)	**14% (7 of 51)**	**68% (17 of 25)**	**80%**
Mean PEC-Q	76	0.556	0.732	**11% (5 of 47)**	**66% (19 of 29)**	**80%**	83% (5 of 6)	**19% (10 of 53)**	**61% (14 of 23)**	75%
Mean PEC-Q_{METALS}	76	1.11	1.78	**9% (4 of 45)**	**65% (20 of 31)**	**80%**	67% (6 of 9)	**19% (10 of 54)**	**64% (14 of 22)**	76%
ΣPEC-$Q_{Cd,Pb,Zn}$	76	7.92	11.6	**10% (5 of 48)**	**68% (19 of 28)**	**82%**	67% (4 of 6)	**17% (9 of 54)**	**68% (15 of 22)**	79%
ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	76	2.97	4.51	**11% (5 of 47)**	**66% (19 of 29)**	**80%**	57% (4 of 7)	**17% (9 of 54)**	**68% (15 of 22)**	79%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival (<2 mm size fraction)										
Copper (mg/kg DW)	48	37.1	46.4	34% (15 of 44)	**100% (4 of 4)**	69%	100% (2 of 2)	37% (17 of 46)	**100% (2 of 2)**	65%
Lead (mg/kg DW)	48	1360	1373	37% (17 of 46)	**100% (2 of 2)**	65%	No Data	37% (17 of 46)	**100% (2 of 2)**	65%
ΣSEM-AVS	48	37.9	63.5	28% (11 of 40)	**100% (8 of 8)**	77%	100% (5 of 5)	36% (16 of 45)	**100% (3 of 3)**	67%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival (<250 μm size fraction)										
Copper (mg/kg DW)	48	79.4	122	37% (17 of 46)	**100% (2 of 2)**	65%	No Data	37% (17 of 46)	**100% (2 of 2)**	65%
Zinc (mg/kg DW)	48	20600	23700	38% (17 of 45)	**67% (2 of 3)**	63%	No Data	38% (17 of 45)	**67% (2 of 3)**	63%
ΣSEM-AVS (μmol/g DW)[2]	48	38.5	64.1	28% (11 of 40)	**100% (8 of 8)**	77%	100% (5 of 5)	36% (16 of 45)	**100% (3 of 3)**	67%
Mean PEC-Q_{METALS}	48	6.03	10.7	33% (14 of 42)	**83% (5 of 6)**	69%	100% (2 of 2)	36% (16 of 44)	**75% (3 of 4)**	65%
Mean PEC-$Q_{METALS(1\%OC)}$	48	4.82	6.21	33% (14 of 43)	**100% (5 of 5)**	71%	100% (3 of 3)	37% (17 of 46)	**100% (2 of 2)**	65%
ΣPEC-$Q_{Cd,Pb,Zn}$	48	39.7	72.6	33% (14 of 42)	**83% (5 of 6)**	69%	100% (2 of 2)	36% (16 of 44)	**75% (3 of 4)**	65%
ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	48	50.7	50.8	36% (16 of 45)	**100% (3 of 3)**	67%	100% (1 of 1)	37% (17 of 46)	**100% (2 of 2)**	65%

Table 8. Reliability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	>T_{20} Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass (<2 mm size fraction)										
Copper (mg/kg DW)	48	27.1	38.1	**7% (3 of 43)**	**80% (4 of 5)**	**92%**	100% (2 of 2)	**11% (5 of 45)**	**67% (2 of 3)**	**88%**
Lead (mg/kg DW)	48	623	823	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
ΣSEM-AVS (µmol/g DW)	48	40.4	51.4	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	0% (0 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	48	20.5	20.7	**9% (4 of 45)**	**100% (3 of 3)**	**92%**	No Data	**9% (4 of 45)**	**100% (3 of 3)**	**92%**
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass (<250 µm size fraction)										
Copper (mg/kg DW)	48	33.9	48.4	**5% (2 of 41)**	**71% (5 of 7)**	**92%**	75% (3 of 4)	**11% (5 of 45)**	**67% (2 of 3)**	**88%**
Lead (mg/kg DW)	48	1096	1359	**7% (3 of 41)**	**57% (4 of 7)**	**88%**	33% (1 of 3)	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
ΣSEM-AVS (µmol/g DW)[2]	48	41.7	52.8	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	0% (0 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
Mean PEC-Q_{METALS}	48	7.57	10.3	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Mean PEC-$Q_{METALS(1\%OC)}$	48	4.49	4.90	**5% (2 of 42)**	**83% (5 of 6)**	**94%**	50% (1 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
ΣSTT-$Q_{Cd,Cu,Pb,Zn}$	48	22.6	29.6	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**

d = day; S = survival; B = biomass; n = number of samples; COPC = chemical of potential concern; Class. = classification; PEC-Q = probable effect concentration-qotients; STT-Q = sediment toxicity threshold-quotient; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; OC = organic carbon.

[1]Bolded results indicate that the toxicity threshold met the individual evaluation criteria for the T_{10} value, T_{20} value, or correct classification rate.

[2]Concentration-response relationships for ΣSEM-AVS and the mussel toxicity test endpoints were developed with concentration measurement data from the <2 mm size fraction for the Set 1 and 2 samples (n=42) and the <250 µm size fraction for the Set 3 samples (n = 6).

Table 9. Reliability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Survival										
$\text{PW-TU}_{\text{CADMIUM}}$	70	0.16	0.441	31% (13 of 42)	39% (11 of 28)	57%	24% (4 of 17)	29% (17 of 59)	**64% (7 of 11)**	70%
$\text{PW-TU}_{\text{LEAD}}$	70	0.096	0.155	20% (10 of 51)	**74% (14 of 19)**	79%	33% (1 of 3)	20% (11 of 54)	**81% (13 of 16)**	**80%**
$\text{PW-TU}_{\text{LEAD(DOC)}}$	70	0.0000171	0.0000325	**19% (9 of 48)**	**68% (15 of 22)**	77%	33% (2 of 6)	20% (11 of 54)	**81% (13 of 16)**	**80%**
$\text{PW-TU}_{\text{ZINC}}$	70	0.581	0.867	**15% (8 of 52)**	**89% (16 of 18)**	**86%**	100% (2 of 2)	**19% (10 of 54)**	**88% (14 of 16)**	**83%**
$\text{PW-TU}_{\text{ZINC(DOC)}}$	70	0.0000783	0.000147	**17% (8 of 48)**	**73% (16 of 22)**	**80%**	25% (1 of 4)	**17% (9 of 52)**	**83% (15 of 18)**	**83%**
$\Sigma\text{PW-TU}_{\text{DIVALENT METALS}}$	70	1.03	1.41	**16% (8 of 49)**	**76% (16 of 21)**	**81%**	33% (2 of 6)	**18% (10 of 55)**	**93% (14 of 15)**	**84%**
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Biomass										
$\text{PW-TU}_{\text{LEAD}}$	70	NB	0.043	NB	NB	NB	7% (3 of 45)	**7% (3 of 45)**	**52% (13 of 25)**	79%
$\text{PW-TU}_{\text{LEAD(DOC)}}$	70	0.000000218	0.00000733	**0% (0 of 4)**	24% (16 of 66)	29%	5% (2 of 38)	**5% (2 of 42)**	50% (14 of 28)	77%
$\text{PW-TU}_{\text{ZINC}}$	70	NB	0.638	NB	NB	NB	8% (4 of 52)	**8% (4 of 52)**	**67% (12 of 18)**	**86%**
$\text{PW-TU}_{\text{ZINC(DOC)}}$	70	NB	0.0000518	NB	NB	NB	7% (3 of 46)	**7% (3 of 46)**	**54% (13 of 24)**	**80%**
$\Sigma\text{PW-TU}_{\text{DIVALENT METALS}}$	70	NB	0.988	NB	NB	NB	8% (4 of 49)	**8% (4 of 49)**	**57% (12 of 21)**	**81%**
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival										
$\text{PW-TU}_{\text{CADMIUM}}$	42	6.15	6.37	33% (13 of 39)	**100% (3 of 3)**	69%	100% (1 of 1)	35% (14 of 40)	**100% (2 of 2)**	67%
$\text{PW-TU}_{\text{COPPER}}$	42	0.0391	0.0533	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
$\text{PW-TU}_{\text{LEAD}}$	42	0.248	0.542	29% (10 of 34)	**75% (6 of 8)**	71%	60% (3 of 5)	33% (13 of 39)	**100% (3 of 3)**	69%
$\text{PW-TU}_{\text{NICKEL}}$	42	0.0871	0.0889	33% (13 of 39)	**100% (3 of 3)**	69%	100% (1 of 1)	35% (14 of 40)	**100% (2 of 2)**	67%
$\text{PW-TU}_{\text{ZINC}}$	42	1.62	3.35	31% (11 of 36)	**83% (5 of 6)**	71%	67% (2 of 3)	33% (13 of 39)	**100% (3 of 3)**	69%
$\text{PW-TU}_{\text{ZINC(DOC)}}$	42	0.00076	0.00121	32% (12 of 38)	**100% (4 of 4)**	71%	100% (2 of 2)	35% (14 of 40)	**100% (2 of 2)**	67%
$\Sigma\text{PW-TU}_{\text{METALS}}$	42	30.2	30.8	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
$\Sigma\text{PW-TU}_{\text{DIVALENT METALS}}$	42	4	7.12	32% (12 of 38)	**100% (4 of 4)**	71%	100% (1 of 1)	33% (13 of 39)	**100% (3 of 3)**	69%

Table 9. Reliability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass										
$PW\text{-}TU_{CADMIUM}$	42	0.723	1.25	**11% (4 of 38)**	**75% (3 of 4)**	**88%**	0% (0 of 1)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
$PW\text{-}TU_{COPPER}$	42	0.048	0.0563	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
$PW\text{-}TU_{LEAD}$	42	0.281	0.477	**8% (3 of 36)**	**67% (4 of 6)**	**88%**	67% (2 of 3)	**13% (5 of 39)**	**67% (2 of 3)**	**86%**
$PW\text{-}TU_{LEAD(DOC)}$	42	0.0000735	0.0000866	**8% (3 of 36)**	**67% (4 of 6)**	**88%**	0% (0 of 1)	**8% (3 of 37)**	**80% (4 of 5)**	**90%**
$PW\text{-}TU_{NICKEL}$	42	0.0919	0.0923	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
$PW\text{-}TU_{ZINC}$	42	1.23	1.95	**6% (2 of 35)**	**71% (5 of 7)**	**90%**	50% (2 of 4)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
$PW\text{-}TU_{ZINC(DOC)}$	42	0.00039	0.000606	**6% (2 of 36)**	**83% (5 of 6)**	**93%**	50% (1 of 2)	**8% (3 of 38)**	**100% (4 of 4)**	**93%**
$\Sigma PW\text{-}TU_{METALS}$	42	26.9	27.7	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
$\Sigma PW\text{-}TU_{DIVALENT\ METALS}$	42	2.38	3.79	**6% (2 of 36)**	**83% (5 of 6)**	**93%**	50% (1 of 2)	**8% (3 of 38)**	**100% (4 of 4)**	**93%**

d = day; S = survival; B = biomass; n = number of samples; COPC = chemical of potential concern; Class. = classification; PW-TU = pore-water toxic units; NB = No Benchmark; DOC = dissolved organic carbon.

[1]Bolded results indicate that the toxicity threshold met the individual evaluation criteria for the T_{10} value, T_{20} value, or correct classification rate.

[2]Based on the results of all three toxicity tests (six endpoints).

[3]Based on the results of the amphipod and mussel toxicity tests (four endpoints).

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Survival										
Cadmium (mg/kg DW)										
Amphipod 28-d S	76	11.1	17.3	**11% (5 of 45)**	**61% (19 of 31)**	78%	60% (6 of 10)	20% (11 of 55)	**62% (13 of 21)**	75%
Amphipod 28-d B	76	11.1	17.3	**7% (3 of 45)**	42% (13 of 31)	72%	20% (2 of 10)	**9% (5 of 55)**	**52% (11 of 21)**	**80%**
Mussel 28-d S	48	11.1	17.3	**18% (5 of 28)**	**70% (14 of 20)**	77%	75% (3 of 4)	25% (8 of 32)	**69% (11 of 16)**	73%
Mussel 28-d B	48	11.1	17.3	**4% (1 of 28)**	30% (6 of 20)	69%	25% (1 of 4)	**6% (2 of 32)**	31% (5 of 16)	73%
Midge 10-d S	70	11.1	17.3	24% (10 of 41)	48% (14 of 29)	64%	44% (4 of 9)	28% (14 of 50)	50% (10 of 20)	66%
Midge 10-d B	70	11.1	17.3	39% (16 of 41)	**69% (20 of 29)**	64%	56% (5 of 9)	42% (21 of 50)	**75% (15 of 20)**	63%
OT-Six Endpoints[2]	76	11.1	17.3	58% (26 of 45)	**87% (27 of 31)**	61%	90% (9 of 10)	64% (35 of 55)	**86% (18 of 21)**	50%
OT-Four Endpoints[3]	76	11.1	17.3	22% (10 of 45)	**74% (23 of 31)**	76%	70% (7 of 10)	31% (17 of 55)	**76% (16 of 21)**	71%
Lead (mg/kg DW)										
Amphipod 28-d S	76	150	219	**9% (4 of 45)**	**65% (20 of 31)**	**80%**	33% (3 of 9)	**13% (7 of 54)**	**77% (17 of 22)**	**84%**
Amphipod 28-d B	76	150	219	**2% (1 of 45)**	48% (15 of 31)	78%	33% (3 of 9)	**7% (4 of 54)**	**55% (12 of 22)**	**82%**
Mussel 28-d S	48	150	219	22% (6 of 27)	**62% (13 of 21)**	71%	40% (2 of 5)	25% (8 of 32)	**69% (11 of 16)**	73%
Mussel 28-d B	48	150	219	**4% (1 of 27)**	29% (6 of 21)	67%	0% (0 of 5)	**3% (1 of 32)**	38% (6 of 16)	77%
Midge 10-d S	70	150	219	22% (9 of 41)	**52% (15 of 29)**	67%	38% (3 of 8)	24% (12 of 49)	**57% (12 of 21)**	70%
Midge 10-d B	70	150	219	37% (15 of 41)	**72% (21 of 29)**	67%	75% (6 of 8)	43% (21 of 49)	**71% (15 of 21)**	61%
OT-Six Endpoints[2]	76	150	219	56% (25 of 45)	**90% (28 of 31)**	63%	89% (8 of 9)	61% (33 of 54)	**91% (20 of 22)**	54%
OT-Four Endpoints[3]	76	150	219	20% (9 of 45)	**77% (24 of 31)**	79%	56% (5 of 9)	26% (14 of 54)	**86% (19 of 22)**	78%
Zinc (mg/kg DW)										
Amphipod 28-d S	76	2083	2949	**13% (7 of 53)**	**74% (17 of 23)**	**83%**	No Data	**13% (7 of 53)**	**74% (17 of 23)**	**83%**
Amphipod 28-d B	76	2083	2949	**6% (3 of 53)**	**57% (13 of 23)**	**83%**	No Data	**6% (3 of 53)**	**57% (13 of 23)**	**83%**
Mussel 28-d S	48	2083	2949	22% (7 of 32)	**75% (12 of 16)**	77%	No Data	22% (7 of 32)	**75% (12 of 16)**	77%
Mussel 28-d B	48	2083	2949	**3% (1 of 32)**	38% (6 of 16)	77%	No Data	**3% (1 of 32)**	38% (6 of 16)	77%
Midge 10-d S	70	2083	2949	23% (11 of 48)	**59% (13 of 22)**	71%	No Data	23% (11 of 48)	**59% (13 of 22)**	71%
Midge 10-d B	70	2083	2949	42% (20 of 48)	**73% (16 of 22)**	63%	No Data	42% (20 of 48)	**73% (16 of 22)**	63%
OT-Six Endpoints[2]	76	2083	2949	60% (32 of 53)	**91% (21 of 23)**	55%	No Data	60% (32 of 53)	**91% (21 of 23)**	55%
OT-Four Endpoints[3]	76	2083	2949	25% (13 of 53)	**87% (20 of 23)**	79%	No Data	25% (13 of 53)	**87% (20 of 23)**	79%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
ΣSEM-AVS (µmol/g DW)										
Amphipod 28-d S	76	7.82	13.7	**11% (5 of 44)**	**59% (19 of 32)**	76%	29% (2 of 7)	**14% (7 of 51)**	**68% (17 of 25)**	**80%**
Amphipod 28-d B	76	7.82	13.7	**7% (3 of 44)**	41% (13 of 32)	71%	14% (1 of 7)	**8% (4 of 51)**	48% (12 of 25)	78%
Mussel 28-d S	48	7.82	13.7	**17% (5 of 29)**	**74% (14 of 19)**	79%	0% (0 of 2)	**16% (5 of 31)**	**82% (14 of 17)**	**83%**
Mussel 28-d B	48	7.82	13.7	**3% (1 of 29)**	32% (6 of 19)	71%	0% (0 of 2)	**3% (1 of 31)**	35% (6 of 17)	75%
Midge 10-d S	70	7.82	13.7	23% (9 of 40)	50% (15 of 30)	66%	14% (1 of 7)	21% (10 of 47)	**61% (14 of 23)**	73%
Midge 10-d B	70	7.82	13.7	35% (14 of 40)	**73% (22 of 30)**	69%	86% (6 of 7)	43% (20 of 47)	**70% (16 of 23)**	61%
OT-Six Endpoints[2]	76	7.82	13.7	55% (24 of 44)	**91% (29 of 32)**	64%	86% (6 of 7)	59% (30 of 51)	**92% (23 of 25)**	58%
OT-Four Endpoints[3]	76	7.82	13.7	23% (10 of 44)	**72% (23 of 32)**	75%	29% (2 of 7)	24% (12 of 51)	**84% (21 of 25)**	79%
Mean PEC-Q										
Amphipod 28-d S	76	0.556	0.732	**11% (5 of 47)**	**66% (19 of 29)**	**80%**	83% (5 of 6)	**19% (10 of 53)**	**61% (14 of 23)**	75%
Amphipod 28-d B	76	0.556	0.732	**4% (2 of 47)**	48% (14 of 29)	78%	50% (3 of 6)	**9% (5 of 53)**	48% (11 of 23)	78%
Mussel 28-d S	48	0.556	0.732	21% (6 of 28)	**65% (13 of 20)**	73%	0% (0 of 2)	20% (6 of 30)	**72% (13 of 18)**	77%
Mussel 28-d B	48	0.556	0.732	**4% (1 of 28)**	30% (6 of 20)	69%	0% (0 of 2)	**3% (1 of 30)**	33% (6 of 18)	73%
Midge 10-d S	70	0.556	0.732	25% (11 of 44)	50% (13 of 26)	66%	50% (3 of 6)	28% (14 of 50)	50% (10 of 20)	66%
Midge 10-d B	70	0.556	0.732	39% (17 of 44)	**73% (19 of 26)**	66%	67% (4 of 6)	42% (21 of 50)	**75% (15 of 20)**	63%
OT-Six Endpoints[2]	76	0.556	0.732	60% (28 of 47)	**86% (25 of 29)**	58%	100% (6 of 6)	64% (34 of 53)	**83% (19 of 23)**	50%
OT-Four Endpoints[3]	76	0.556	0.732	21% (10 of 47)	**79% (23 of 29)**	79%	83% (5 of 6)	28% (15 of 53)	**78% (18 of 23)**	74%
Mean PEC-Q $_{METALS}$										
Amphipod 28-d S	76	1.11	1.78	**9% (4 of 45)**	**65% (20 of 31)**	**80%**	67% (6 of 9)	**19% (10 of 54)**	**64% (14 of 22)**	76%
Amphipod 28-d B	76	1.11	1.78	**4% (2 of 45)**	45% (14 of 31)	75%	33% (3 of 9)	**9% (5 of 54)**	50% (11 of 22)	79%
Mussel 28-d S	48	1.11	1.78	**19% (5 of 27)**	**67% (14 of 21)**	75%	25% (1 of 4)	**19% (6 of 31)**	**76% (13 of 17)**	79%
Mussel 28-d B	48	1.11	1.78	**4% (1 of 27)**	29% (6 of 21)	67%	0% (0 of 4)	**3% (1 of 31)**	35% (6 of 17)	75%
Midge 10-d S	70	1.11	1.78	24% (10 of 41)	48% (14 of 29)	64%	44% (4 of 9)	28% (14 of 50)	50% (10 of 20)	66%
Midge 10-d B	70	1.11	1.78	37% (15 of 41)	**72% (21 of 29)**	67%	67% (6 of 9)	42% (21 of 50)	**75% (15 of 20)**	63%
OT-Six Endpoints[2]	76	1.11	1.78	56% (25 of 45)	**90% (28 of 31)**	63%	100% (9 of 9)	63% (34 of 54)	**86% (19 of 22)**	51%
OT-Four Endpoints[3]	76	1.11	1.78	20% (9 of 45)	**77% (24 of 31)**	79%	67% (6 of 9)	28% (15 of 54)	**82% (18 of 22)**	75%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
***ΣPEC-Q** $_{Cd,Pb,Zn}$*										
Amphipod 28-d S	76	7.92	11.6	**10% (5 of 48)**	**68% (19 of 28)**	**82%**	67% (4 of 6)	**17% (9 of 54)**	**68% (15 of 22)**	79%
Amphipod 28-d B	76	7.92	11.6	**6% (3 of 48)**	46% (13 of 28)	76%	17% (1 of 6)	**7% (4 of 54)**	**55% (12 of 22)**	**82%**
Mussel 28-d S	48	7.92	11.6	**17% (5 of 29)**	**74% (14 of 19)**	79%	67% (2 of 3)	22% (7 of 32)	**75% (12 of 16)**	77%
Mussel 28-d B	48	7.92	11.6	**3% (1 of 29)**	32% (6 of 19)	71%	0% (0 of 3)	**3% (1 of 32)**	38% (6 of 16)	77%
Midge 10-d S	70	7.92	11.6	23% (10 of 44)	**54% (14 of 26)**	69%	60% (3 of 5)	27% (13 of 49)	**52% (11 of 21)**	67%
Midge 10-d B	70	7.92	11.6	41% (18 of 44)	**69% (18 of 26)**	63%	60% (3 of 5)	43% (21 of 49)	**71% (15 of 21)**	61%
OT-Six Endpoints[2]	76	7.92	11.6	58% (28 of 48)	**89% (25 of 28)**	59%	100% (6 of 6)	63% (34 of 54)	**86% (19 of 22)**	51%
OT-Four Endpoints[3]	76	7.92	11.6	21% (10 of 48)	**82% (23 of 28)**	**80%**	83% (5 of 6)	28% (15 of 54)	**82% (18 of 22)**	75%
***ΣSTT-Q** $_{Cd,Cu,Pb,Zn}$*										
Amphipod 28-d S	76	2.97	4.51	**11% (5 of 47)**	**66% (19 of 29)**	**80%**	57% (4 of 7)	**17% (9 of 54)**	**68% (15 of 22)**	79%
Amphipod 28-d B	76	2.97	4.51	**4% (2 of 47)**	48% (14 of 29)	78%	43% (3 of 7)	**9% (5 of 54)**	50% (11 of 22)	79%
Mussel 28-d S	48	2.97	4.51	21% (6 of 29)	**68% (13 of 19)**	75%	33% (1 of 3)	22% (7 of 32)	**75% (12 of 16)**	77%
Mussel 28-d B	48	2.97	4.51	**3% (1 of 29)**	32% (6 of 19)	71%	0% (0 of 3)	**3% (1 of 32)**	38% (6 of 16)	77%
Midge 10-d S	70	2.97	4.51	26% (11 of 43)	48% (13 of 27)	64%	50% (3 of 6)	29% (14 of 49)	48% (10 of 21)	64%
Midge 10-d B	70	2.97	4.51	37% (16 of 43)	**74% (20 of 27)**	67%	67% (4 of 6)	41% (20 of 49)	**76% (16 of 21)**	64%
OT-Six Endpoints[2]	76	2.97	4.51	57% (27 of 47)	**90% (26 of 29)**	61%	100% (7 of 7)	63% (34 of 54)	**86% (19 of 22)**	51%
OT-Four Endpoints[3]	76	2.97	4.51	21% (10 of 47)	**79% (23 of 29)**	79%	71% (5 of 7)	28% (15 of 54)	**82% (18 of 22)**	75%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival (<2 mm size fraction)										
Copper (mg/kg DW)										
Amphipod 28-d S	76	37.1	46.4	27% (19 of 71)	**100% (5 of 5)**	75%	100% (2 of 2)	29% (21 of 73)	**100% (3 of 3)**	72%
Amphipod 28-d B	76	37.1	46.4	**17% (12 of 71)**	**80% (4 of 5)**	**83%**	100% (2 of 2)	**19% (14 of 73)**	**67% (2 of 3)**	**80%**
Mussel 28-d S	48	37.1	46.4	34% (15 of 44)	**100% (4 of 4)**	69%	100% (2 of 2)	37% (17 of 46)	**100% (2 of 2)**	65%
Mussel 28-d B	48	37.1	46.4	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	50% (1 of 2)	**11% (5 of 46)**	**100% (2 of 2)**	**90%**
Midge 10-d S	70	37.1	46.4	31% (20 of 65)	**80% (4 of 5)**	70%	100% (2 of 2)	33% (22 of 67)	**67% (2 of 3)**	67%
Midge 10-d B	70	37.1	46.4	49% (32 of 65)	**80% (4 of 5)**	53%	50% (1 of 2)	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	76	37.1	46.4	68% (48 of 71)	**100% (5 of 5)**	37%	100% (2 of 2)	68% (50 of 73)	**100% (3 of 3)**	34%
OT-Four Endpoints[3]	76	37.1	46.4	39% (28 of 71)	**100% (5 of 5)**	63%	100% (2 of 2)	41% (30 of 73)	**100% (3 of 3)**	61%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Lead (mg/kg DW)										
Amphipod 28-d S	76	1360	1373	30% (22 of 74)	**100% (2 of 2)**	71%	No Data	30% (22 of 74)	**100% (2 of 2)**	71%
Amphipod 28-d B	76	1360	1373	**19% (14 of 74)**	**100% (2 of 2)**	**82%**	No Data	**19% (14 of 74)**	**100% (2 of 2)**	**82%**
Mussel 28-d S	48	1360	1373	37% (17 of 46)	**100% (2 of 2)**	65%	No Data	37% (17 of 46)	**100% (2 of 2)**	65%
Mussel 28-d B	48	1360	1373	**11% (5 of 46)**	**100% (2 of 2)**	**90%**	No Data	**11% (5 of 46)**	**100% (2 of 2)**	**90%**
Midge 10-d S	70	1360	1373	32% (22 of 68)	**100% (2 of 2)**	69%	No Data	32% (22 of 68)	**100% (2 of 2)**	69%
Midge 10-d B	70	1360	1373	50% (34 of 68)	**100% (2 of 2)**	51%	No Data	50% (34 of 68)	**100% (2 of 2)**	51%
OT-Six Endpoints[2]	76	1360	1373	69% (51 of 74)	**100% (2 of 2)**	33%	No Data	69% (51 of 74)	**100% (2 of 2)**	33%
OT-Four Endpoints[3]	76	1360	1373	42% (31 of 74)	**100% (2 of 2)**	59%	No Data	42% (31 of 74)	**100% (2 of 2)**	59%
ΣSEM-AVS (µmol/g DW)										
Amphipod 28-d S	76	37.9	63.5	26% (18 of 68)	**75% (6 of 8)**	74%	60% (3 of 5)	29% (21 of 73)	**100% (3 of 3)**	72%
Amphipod 28-d B	76	37.9	63.5	**16% (11 of 68)**	**63% (5 of 8)**	**82%**	40% (2 of 5)	**18% (13 of 73)**	**100% (3 of 3)**	**83%**
Mussel 28-d S	48	37.9	63.5	28% (11 of 40)	**100% (8 of 8)**	77%	100% (5 of 5)	36% (16 of 45)	**100% (3 of 3)**	67%
Mussel 28-d B	48	37.9	63.5	**5% (2 of 40)**	**63% (5 of 8)**	**90%**	40% (2 of 5)	**9% (4 of 45)**	**100% (3 of 3)**	**92%**
Midge 10-d S	70	37.9	63.5	32% (20 of 63)	**57% (4 of 7)**	67%	25% (1 of 4)	31% (21 of 67)	**100% (3 of 3)**	70%
Midge 10-d B	70	37.9	63.5	46% (29 of 63)	**100% (7 of 7)**	59%	100% (4 of 4)	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	76	37.9	63.5	66% (45 of 68)	**100% (8 of 8)**	41%	100% (5 of 5)	68% (50 of 73)	**100% (3 of 3)**	34%
OT-Four Endpoints[3]	76	37.9	63.5	37% (25 of 68)	**100% (8 of 8)**	67%	100% (5 of 5)	41% (30 of 73)	**100% (3 of 3)**	61%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival (<250 µm size fraction)										
Copper (mg/kg DW)										
Amphipod 28-d S	75	79.4	122	27% (19 of 71)	**100% (4 of 4)**	75%	100% (2 of 2)	29% (21 of 73)	**100% (2 of 2)**	72%
Amphipod 28-d B	75	79.4	122	**17% (12 of 71)**	**75% (3 of 4)**	**83%**	50% (1 of 2)	**18% (13 of 73)**	**100% (2 of 2)**	**83%**
Mussel 28-d S	48	79.4	122	37% (17 of 46)	**100% (2 of 2)**	65%	No Data	37% (17 of 46)	**100% (2 of 2)**	65%
Mussel 28-d B	48	79.4	122	**11% (5 of 46)**	**100% (2 of 2)**	**90%**	No Data	**11% (5 of 46)**	**100% (2 of 2)**	**90%**
Midge 10-d S	69	79.4	122	31% (20 of 65)	**75% (3 of 4)**	70%	50% (1 of 2)	31% (21 of 67)	**100% (2 of 2)**	70%
Midge 10-d B	69	79.4	122	49% (32 of 65)	**100% (4 of 4)**	54%	100% (2 of 2)	51% (34 of 67)	**100% (2 of 2)**	51%
OT-Six Endpoints[2]	75	79.4	122	68% (48 of 71)	**100% (4 of 4)**	36%	100% (2 of 2)	68% (50 of 73)	**100% (2 of 2)**	33%
OT-Four Endpoints[3]	75	79.4	122	39% (28 of 71)	**100% (4 of 4)**	63%	100% (2 of 2)	41% (30 of 73)	**100% (2 of 2)**	60%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Zinc (mg/kg DW)										
Amphipod 28-d S	75	20600	23700	28% (20 of 71)	**75% (3 of 4)**	72%	100% (1 of 1)	29% (21 of 72)	**67% (2 of 3)**	71%
Amphipod 28-d B	75	20600	23700	**17% (12 of 71)**	**75% (3 of 4)**	**83%**	100% (1 of 1)	**18% (13 of 72)**	**67% (2 of 3)**	**81%**
Mussel 28-d S	48	20600	23700	38% (17 of 45)	**67% (2 of 3)**	63%	No Data	38% (17 of 45)	**67% (2 of 3)**	63%
Mussel 28-d B	48	20600	23700	**11% (5 of 45)**	**67% (2 of 3)**	**88%**	No Data	**11% (5 of 45)**	**67% (2 of 3)**	**88%**
Midge 10-d S	69	20600	23700	31% (20 of 65)	**75% (3 of 4)**	70%	100% (1 of 1)	32% (21 of 66)	**67% (2 of 3)**	68%
Midge 10-d B	69	20600	23700	51% (33 of 65)	**75% (3 of 4)**	51%	100% (1 of 1)	52% (34 of 66)	**67% (2 of 3)**	49%
OT-Six Endpoints[2]	75	20600	23700	69% (49 of 71)	**75% (3 of 4)**	33%	100% (1 of 1)	69% (50 of 72)	**67% (2 of 3)**	32%
OT-Four Endpoints[3]	75	20600	23700	41% (29 of 71)	**75% (3 of 4)**	60%	100% (1 of 1)	42% (30 of 72)	**67% (2 of 3)**	59%
ΣSEM-AVS (μmol/g DW)[2]										
Amphipod 28-d S	76	38.5	64.1	26% (18 of 68)	**75% (6 of 8)**	74%	60% (3 of 5)	29% (21 of 73)	**100% (3 of 3)**	72%
Amphipod 28-d B	76	38.5	64.1	**16% (11 of 68)**	**63% (5 of 8)**	**82%**	40% (2 of 5)	**18% (13 of 73)**	**100% (3 of 3)**	**83%**
Mussel 28-d S	48	38.5	64.1	28% (11 of 40)	**100% (8 of 8)**	77%	100% (5 of 5)	36% (16 of 45)	**100% (3 of 3)**	67%
Mussel 28-d B	48	38.5	64.1	**5% (2 of 40)**	**63% (5 of 8)**	**90%**	40% (2 of 5)	**9% (4 of 45)**	**100% (3 of 3)**	**92%**
Midge 10-d S	70	38.5	64.1	32% (20 of 63)	**57% (4 of 7)**	67%	25% (1 of 4)	31% (21 of 67)	**100% (3 of 3)**	70%
Midge 10-d B	70	38.5	64.1	46% (29 of 63)	**100% (7 of 7)**	59%	100% (4 of 4)	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	76	38.5	64.1	66% (45 of 68)	**100% (8 of 8)**	41%	100% (5 of 5)	68% (50 of 73)	**100% (3 of 3)**	34%
OT-Four Endpoints[3]	76	38.5	64.1	37% (25 of 68)	**100% (8 of 8)**	67%	100% (5 of 5)	41% (30 of 73)	**100% (3 of 3)**	61%
Mean PEC-Q $_{METALS}$										
Amphipod 28-d S	75	6.03	10.7	23% (15 of 66)	**89% (8 of 9)**	79%	100% (4 of 4)	27% (19 of 70)	**80% (4 of 5)**	73%
Amphipod 28-d B	75	6.03	10.7	**11% (7 of 66)**	**89% (8 of 9)**	**89%**	100% (4 of 4)	**16% (11 of 70)**	**80% (4 of 5)**	**84%**
Mussel 28-d S	48	6.03	10.7	33% (14 of 42)	**83% (5 of 6)**	69%	100% (2 of 2)	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	6.03	10.7	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	50% (1 of 2)	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	69	6.03	10.7	28% (17 of 60)	**67% (6 of 9)**	71%	50% (2 of 4)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	6.03	10.7	47% (28 of 60)	**89% (8 of 9)**	58%	100% (4 of 4)	50% (32 of 64)	**80% (4 of 5)**	52%
OT-Six Endpoints[2]	75	6.03	10.7	67% (44 of 66)	**89% (8 of 9)**	40%	100% (4 of 4)	69% (48 of 70)	**80% (4 of 5)**	35%
OT-Four Endpoints[3]	75	6.03	10.7	36% (24 of 66)	**89% (8 of 9)**	67%	100% (4 of 4)	40% (28 of 70)	**80% (4 of 5)**	61%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Mean PEC-Q $_{METALS(1\%OC)}$										
Amphipod 28-d S	75	4.82	6.21	21% (14 of 66)	**100% (9 of 9)**	**81%**	100% (4 of 4)	26% (18 of 70)	**100% (5 of 5)**	76%
Amphipod 28-d B	75	4.82	6.21	**9% (6 of 66)**	**100% (9 of 9)**	**92%**	100% (4 of 4)	**14% (10 of 70)**	**100% (5 of 5)**	**87%**
Mussel 28-d S	48	4.82	6.21	33% (14 of 43)	**100% (5 of 5)**	71%	100% (3 of 3)	37% (17 of 46)	**100% (2 of 2)**	65%
Mussel 28-d B	48	4.82	6.21	**5% (2 of 43)**	**100% (5 of 5)**	**96%**	100% (3 of 3)	**11% (5 of 46)**	**100% (2 of 2)**	**90%**
Midge 10-d S	69	4.82	6.21	25% (15 of 60)	**89% (8 of 9)**	77%	100% (4 of 4)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	4.82	6.21	45% (27 of 60)	**100% (9 of 9)**	61%	100% (4 of 4)	48% (31 of 64)	**100% (5 of 5)**	55%
OT-Six Endpoints[2]	75	4.82	6.21	65% (43 of 66)	**100% (9 of 9)**	43%	100% (4 of 4)	67% (47 of 70)	**100% (5 of 5)**	37%
OT-Four Endpoints[3]	75	4.82	6.21	35% (23 of 66)	**100% (9 of 9)**	69%	100% (4 of 4)	39% (27 of 70)	**100% (5 of 5)**	64%
ΣPEC-Q $_{Cd,Pb,Zn}$										
Amphipod 28-d S	75	39.7	72.6	23% (15 of 66)	**89% (8 of 9)**	79%	100% (4 of 4)	27% (19 of 70)	**80% (4 of 5)**	73%
Amphipod 28-d B	75	39.7	72.6	**11% (7 of 66)**	**89% (8 of 9)**	**89%**	100% (4 of 4)	**16% (11 of 70)**	**80% (4 of 5)**	**84%**
Mussel 28-d S	48	39.7	72.6	33% (14 of 42)	**83% (5 of 6)**	69%	100% (2 of 2)	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	39.7	72.6	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	50% (1 of 2)	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	69	39.7	72.6	28% (17 of 60)	**67% (6 of 9)**	71%	50% (2 of 4)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	39.7	72.6	47% (28 of 60)	**89% (8 of 9)**	58%	100% (4 of 4)	50% (32 of 64)	**80% (4 of 5)**	52%
OT-Six Endpoints[2]	75	39.7	72.6	67% (44 of 66)	**89% (8 of 9)**	40%	100% (4 of 4)	69% (48 of 70)	**80% (4 of 5)**	35%
OT-Four Endpoints[3]	75	39.7	72.6	36% (24 of 66)	**89% (8 of 9)**	67%	100% (4 of 4)	40% (28 of 70)	**80% (4 of 5)**	61%
ΣSTT-Q $_{Cd,Cu,Pb,Zn}$										
Amphipod 28-d S	75	50.7	50.8	28% (20 of 72)	**100% (3 of 3)**	73%	100% (1 of 1)	29% (21 of 73)	**100% (2 of 2)**	72%
Amphipod 28-d B	75	50.7	50.8	**17% (12 of 72)**	**100% (3 of 3)**	**84%**	100% (1 of 1)	**18% (13 of 73)**	**100% (2 of 2)**	**83%**
Mussel 28-d S	48	50.7	50.8	36% (16 of 45)	**100% (3 of 3)**	67%	100% (1 of 1)	37% (17 of 46)	**100% (2 of 2)**	65%
Mussel 28-d B	48	50.7	50.8	**9% (4 of 45)**	**100% (3 of 3)**	**92%**	100% (1 of 1)	**11% (5 of 46)**	**100% (2 of 2)**	**90%**
Midge 10-d S	69	50.7	50.8	30% (20 of 66)	**100% (3 of 3)**	71%	100% (1 of 1)	31% (21 of 67)	**100% (2 of 2)**	70%
Midge 10-d B	69	50.7	50.8	50% (33 of 66)	**100% (3 of 3)**	52%	100% (1 of 1)	51% (34 of 67)	**100% (2 of 2)**	51%
OT-Six Endpoints[2]	75	50.7	50.8	68% (49 of 72)	**100% (3 of 3)**	35%	100% (1 of 1)	68% (50 of 73)	**100% (2 of 2)**	33%
OT-Four Endpoints[3]	75	50.7	50.8	40% (29 of 72)	**100% (3 of 3)**	61%	100% (1 of 1)	41% (30 of 73)	**100% (2 of 2)**	60%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass (<2 mm size fraction)										
Copper (mg/kg DW)										
Amphipod 28-d S	76	27.1	38.1	25% (17 of 69)	**100% (7 of 7)**	78%	100% (3 of 3)	28% (20 of 72)	**100% (4 of 4)**	74%
Amphipod 28-d B	76	27.1	38.1	**16% (11 of 69)**	**71% (5 of 7)**	**83%**	67% (2 of 3)	**18% (13 of 72)**	**75% (3 of 4)**	**82%**
Mussel 28-d S	48	27.1	38.1	33% (14 of 43)	**100% (5 of 5)**	71%	100% (2 of 2)	36% (16 of 45)	**100% (3 of 3)**	67%
Mussel 28-d B	48	27.1	38.1	**7% (3 of 43)**	**80% (4 of 5)**	**92%**	100% (2 of 2)	**11% (5 of 45)**	**67% (2 of 3)**	**88%**
Midge 10-d S	70	27.1	38.1	30% (19 of 63)	**71% (5 of 7)**	70%	67% (2 of 3)	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	27.1	38.1	48% (30 of 63)	**86% (6 of 7)**	56%	100% (3 of 3)	50% (33 of 66)	**75% (3 of 4)**	51%
OT-Six Endpoints[2]	76	27.1	38.1	67% (46 of 69)	**100% (7 of 7)**	39%	100% (3 of 3)	68% (49 of 72)	**100% (4 of 4)**	36%
OT-Four Endpoints[3]	76	27.1	38.1	38% (26 of 69)	**100% (7 of 7)**	66%	100% (3 of 3)	40% (29 of 72)	**100% (4 of 4)**	62%
Lead (mg/kg DW)										
Amphipod 28-d S	76	623	823	29% (21 of 72)	**75% (3 of 4)**	71%	No Data	29% (21 of 72)	**75% (3 of 4)**	71%
Amphipod 28-d B	76	623	823	**18% (13 of 72)**	**75% (3 of 4)**	**82%**	No Data	**18% (13 of 72)**	**75% (3 of 4)**	**82%**
Mussel 28-d S	48	623	823	36% (16 of 44)	**75% (3 of 4)**	65%	No Data	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	623	823	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	70	623	823	32% (21 of 66)	**75% (3 of 4)**	69%	No Data	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	623	823	50% (33 of 66)	**75% (3 of 4)**	51%	No Data	50% (33 of 66)	**75% (3 of 4)**	51%
OT-Six Endpoints[2]	76	623	823	69% (50 of 72)	**75% (3 of 4)**	33%	No Data	69% (50 of 72)	**75% (3 of 4)**	33%
OT-Four Endpoints[3]	76	623	823	42% (30 of 72)	**75% (3 of 4)**	59%	No Data	42% (30 of 72)	**75% (3 of 4)**	59%
ΣSEM-AVS (µmol/g DW)										
Amphipod 28-d S	76	40.4	51.4	29% (20 of 70)	**67% (4 of 6)**	71%	0% (0 of 2)	28% (20 of 72)	**100% (4 of 4)**	74%
Amphipod 28-d B	76	40.4	51.4	**19% (13 of 70)**	50% (3 of 6)	79%	0% (0 of 2)	**18% (13 of 72)**	**75% (3 of 4)**	**82%**
Mussel 28-d S	48	40.4	51.4	31% (13 of 42)	**100% (6 of 6)**	73%	100% (2 of 2)	34% (15 of 44)	**100% (4 of 4)**	69%
Mussel 28-d B	48	40.4	51.4	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	0% (0 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
Midge 10-d S	70	40.4	51.4	32% (21 of 65)	**60% (3 of 5)**	67%	0% (0 of 1)	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	40.4	51.4	48% (31 of 65)	**100% (5 of 5)**	56%	100% (1 of 1)	48% (32 of 66)	**100% (4 of 4)**	54%
OT-Six Endpoints[2]	76	40.4	51.4	67% (47 of 70)	**100% (6 of 6)**	38%	100% (2 of 2)	68% (49 of 72)	**100% (4 of 4)**	36%
OT-Four Endpoints[3]	76	40.4	51.4	39% (27 of 70)	**100% (6 of 6)**	64%	100% (2 of 2)	40% (29 of 72)	**100% (4 of 4)**	62%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
ΣSTT-Q $_{Cd,Cu,Pb,Zn}$										
Amphipod 28-d S	76	20.5	20.7	29% (21 of 73)	**100% (3 of 3)**	72%	No Data	29% (21 of 73)	**100% (3 of 3)**	72%
Amphipod 28-d B	76	20.5	20.7	**18% (13 of 73)**	**100% (3 of 3)**	**83%**	No Data	**18% (13 of 73)**	**100% (3 of 3)**	**83%**
Mussel 28-d S	48	20.5	20.7	36% (16 of 45)	**100% (3 of 3)**	67%	No Data	36% (16 of 45)	**100% (3 of 3)**	67%
Mussel 28-d B	48	20.5	20.7	**9% (4 of 45)**	**100% (3 of 3)**	**92%**	No Data	**9% (4 of 45)**	**100% (3 of 3)**	**92%**
Midge 10-d S	70	20.5	20.7	31% (21 of 67)	**100% (3 of 3)**	70%	No Data	31% (21 of 67)	**100% (3 of 3)**	70%
Midge 10-d B	70	20.5	20.7	49% (33 of 67)	**100% (3 of 3)**	53%	No Data	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	76	20.5	20.7	68% (50 of 73)	**100% (3 of 3)**	34%	No Data	68% (50 of 73)	**100% (3 of 3)**	34%
OT-Four Endpoints[3]	76	20.5	20.7	41% (30 of 73)	**100% (3 of 3)**	61%	No Data	41% (30 of 73)	**100% (3 of 3)**	61%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass (<250 µm size fraction)										
Copper (mg/kg DW)										
Amphipod 28-d S	75	33.9	48.4	**19% (12 of 63)**	**92% (11 of 12)**	**83%**	100% (5 of 5)	25% (17 of 68)	**86% (6 of 7)**	76%
Amphipod 28-d B	75	33.9	48.4	**10% (6 of 63)**	**75% (9 of 12)**	**88%**	80% (4 of 5)	**15% (10 of 68)**	**71% (5 of 7)**	**84%**
Mussel 28-d S	48	33.9	48.4	32% (13 of 41)	**86% (6 of 7)**	71%	100% (4 of 4)	38% (17 of 45)	**67% (2 of 3)**	63%
Mussel 28-d B	48	33.9	48.4	**5% (2 of 41)**	**71% (5 of 7)**	**92%**	75% (3 of 4)	**11% (5 of 45)**	**67% (2 of 3)**	**88%**
Midge 10-d S	69	33.9	48.4	28% (16 of 57)	**58% (7 of 12)**	70%	60% (3 of 5)	31% (19 of 62)	**57% (4 of 7)**	68%
Midge 10-d B	69	33.9	48.4	44% (25 of 57)	**92% (11 of 12)**	62%	100% (5 of 5)	48% (30 of 62)	**86% (6 of 7)**	55%
OT-Six Endpoints[2]	75	33.9	48.4	65% (41 of 63)	**92% (11 of 12)**	44%	100% (5 of 5)	68% (46 of 68)	**86% (6 of 7)**	37%
OT-Four Endpoints[3]	75	33.9	48.4	33% (21 of 63)	**92% (11 of 12)**	71%	100% (5 of 5)	38% (26 of 68)	**86% (6 of 7)**	64%
Lead (mg/kg DW)										
Amphipod 28-d S	75	1096	1359	24% (16 of 66)	**78% (7 of 9)**	76%	75% (3 of 4)	27% (19 of 70)	**80% (4 of 5)**	73%
Amphipod 28-d B	75	1096	1359	**12% (8 of 66)**	**78% (7 of 9)**	**87%**	75% (3 of 4)	**16% (11 of 70)**	**80% (4 of 5)**	**84%**
Mussel 28-d S	48	1096	1359	34% (14 of 41)	**71% (5 of 7)**	67%	67% (2 of 3)	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	1096	1359	**7% (3 of 41)**	**57% (4 of 7)**	**88%**	33% (1 of 3)	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	69	1096	1359	28% (17 of 60)	**67% (6 of 9)**	71%	50% (2 of 4)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	1096	1359	47% (28 of 60)	**89% (8 of 9)**	58%	100% (4 of 4)	50% (32 of 64)	**80% (4 of 5)**	52%
OT-Six Endpoints[2]	75	1096	1359	67% (44 of 66)	**89% (8 of 9)**	40%	100% (4 of 4)	69% (48 of 70)	**80% (4 of 5)**	35%
OT-Four Endpoints[3]	75	1096	1359	38% (25 of 66)	**78% (7 of 9)**	64%	75% (3 of 4)	40% (28 of 70)	**80% (4 of 5)**	61%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
ΣSEM-AVS (µmol/g DW) [2]										
Amphipod 28-d S	76	41.7	52.8	29% (20 of 70)	**67% (4 of 6)**	71%	0% (0 of 2)	28% (20 of 72)	**100% (4 of 4)**	74%
Amphipod 28-d B	76	41.7	52.8	**19% (13 of 70)**	50% (3 of 6)	79%	0% (0 of 2)	**18% (13 of 72)**	**75% (3 of 4)**	**82%**
Mussel 28-d S	48	41.7	52.8	31% (13 of 42)	**100% (6 of 6)**	73%	100% (2 of 2)	34% (15 of 44)	**100% (4 of 4)**	69%
Mussel 28-d B	48	41.7	52.8	**7% (3 of 42)**	**67% (4 of 6)**	**90%**	0% (0 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
Midge 10-d S	70	41.7	52.8	32% (21 of 65)	**60% (3 of 5)**	67%	0% (0 of 1)	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	41.7	52.8	48% (31 of 65)	**100% (5 of 5)**	56%	100% (1 of 1)	48% (32 of 66)	**100% (4 of 4)**	54%
OT-Six Endpoints[2]	76	41.7	52.8	67% (47 of 70)	**100% (6 of 6)**	38%	100% (2 of 2)	68% (49 of 72)	**100% (4 of 4)**	36%
OT-Four Endpoints[3]	76	41.7	52.8	39% (27 of 70)	**100% (6 of 6)**	64%	100% (2 of 2)	40% (29 of 72)	**100% (4 of 4)**	62%
Mean PEC-Q $_{METALS}$										
Amphipod 28-d S	75	7.57	10.3	25% (17 of 68)	**86% (6 of 7)**	76%	100% (2 of 2)	27% (19 of 70)	**80% (4 of 5)**	73%
Amphipod 28-d B	75	7.57	10.3	**13% (9 of 68)**	**86% (6 of 7)**	**87%**	100% (2 of 2)	**16% (11 of 70)**	**80% (4 of 5)**	**84%**
Mussel 28-d S	48	7.57	10.3	36% (16 of 44)	**75% (3 of 4)**	65%	No Data	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	7.57	10.3	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	69	7.57	10.3	29% (18 of 62)	**71% (5 of 7)**	71%	50% (1 of 2)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	7.57	10.3	48% (30 of 62)	**86% (6 of 7)**	55%	100% (2 of 2)	50% (32 of 64)	**80% (4 of 5)**	52%
OT-Six Endpoints[2]	75	7.57	10.3	68% (46 of 68)	**86% (6 of 7)**	37%	100% (2 of 2)	69% (48 of 70)	**80% (4 of 5)**	35%
OT-Four Endpoints[3]	75	7.57	10.3	38% (26 of 68)	**86% (6 of 7)**	64%	100% (2 of 2)	40% (28 of 70)	**80% (4 of 5)**	61%
Mean PEC-Q $_{METALS(1\%OC)}$										
Amphipod 28-d S	75	4.49	4.90	20% (13 of 65)	**100% (10 of 10)**	**83%**	100% (2 of 2)	22% (15 of 67)	**100% (8 of 8)**	**80%**
Amphipod 28-d B	75	4.49	4.90	**8% (5 of 65)**	**100% (10 of 10)**	**93%**	100% (2 of 2)	**10% (7 of 67)**	**100% (8 of 8)**	**91%**
Mussel 28-d S	48	4.49	4.90	31% (13 of 42)	**100% (6 of 6)**	73%	100% (2 of 2)	34% (15 of 44)	**100% (4 of 4)**	69%
Mussel 28-d B	48	4.49	4.90	**5% (2 of 42)**	**83% (5 of 6)**	**94%**	50% (1 of 2)	**7% (3 of 44)**	**100% (4 of 4)**	**94%**
Midge 10-d S	69	4.49	4.90	25% (15 of 59)	**80% (8 of 10)**	75%	50% (1 of 2)	26% (16 of 61)	**88% (7 of 8)**	75%
Midge 10-d B	69	4.49	4.90	44% (26 of 59)	**100% (10 of 10)**	62%	100% (2 of 2)	46% (28 of 61)	**100% (8 of 8)**	59%
OT-Six Endpoints[2]	75	4.49	4.90	65% (42 of 65)	**100% (10 of 10)**	44%	100% (2 of 2)	66% (44 of 67)	**100% (8 of 8)**	41%
OT-Four Endpoints[3]	75	4.49	4.90	34% (22 of 65)	**100% (10 of 10)**	71%	100% (2 of 2)	36% (24 of 67)	**100% (8 of 8)**	68%

Table 10. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
ΣSTT-Q $_{Cd,Cu,Pb,Zn}$										
Amphipod 28-d S	75	22.6	29.6	26% (18 of 69)	**83% (5 of 6)**	75%	100% (1 of 1)	27% (19 of 70)	**80% (4 of 5)**	73%
Amphipod 28-d B	75	22.6	29.6	**14% (10 of 69)**	**83% (5 of 6)**	**85%**	100% (1 of 1)	**16% (11 of 70)**	**80% (4 of 5)**	**84%**
Mussel 28-d S	48	22.6	29.6	36% (16 of 44)	**75% (3 of 4)**	65%	No Data	36% (16 of 44)	**75% (3 of 4)**	65%
Mussel 28-d B	48	22.6	29.6	**9% (4 of 44)**	**75% (3 of 4)**	**90%**	No Data	**9% (4 of 44)**	**75% (3 of 4)**	**90%**
Midge 10-d S	69	22.6	29.6	29% (18 of 63)	**83% (5 of 6)**	72%	100% (1 of 1)	30% (19 of 64)	**80% (4 of 5)**	71%
Midge 10-d B	69	22.6	29.6	49% (31 of 63)	**83% (5 of 6)**	54%	100% (1 of 1)	50% (32 of 64)	**80% (4 of 5)**	52%
OT-Six Endpoints[2]	75	22.6	29.6	68% (47 of 69)	**83% (5 of 6)**	36%	100% (1 of 1)	69% (48 of 70)	**80% (4 of 5)**	35%
OT-Four Endpoints[3]	75	22.6	29.6	39% (27 of 69)	**83% (5 of 6)**	63%	100% (1 of 1)	40% (28 of 70)	**80% (4 of 5)**	61%

d = day; S = survival; B = biomass; n = number of samples; COPC = chemical of potential concern; Class. = classification; PEC-Q = probable effect concentration-qotients; STT-Q = sediment toxicity threshold-quotient; SEM-AVS = simultaneously extracted metals minus acid volatile sulfides; OC = organic carbon; OT = overall toxicity.

[1]Bolded results indicate that the toxicity threshold met the individual evaluation criteria for the T_{10} value, T_{20} value, or correct classification rate.

[2]Based on the results of all three toxicity tests (six endpoints).

[3]Based on the results of the amphipod and mussel toxicity tests (four endpoints).

[4]Concentration-response relationships for ΣSEM-AVS and the mussel toxicity test endpoints were developed with concentration measurement data from the <2 mm size fraction for the Set 1 and 2 samples (n=42) and the <250 µm size fraction for the Set 3 samples (n = 6).

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Survival										
PW-TU $_{CADMIUM}$										
Amphipod 28-d S	70	0.16	0.441	31% (13 of 42)	39% (11 of 28)	57%	24% (4 of 17)	29% (17 of 59)	**64% (7 of 11)**	70%
Amphipod 28-d B	70	0.16	0.441	**17% (7 of 42)**	32% (9 of 28)	63%	18% (3 of 17)	**17% (10 of 59)**	**55% (6 of 11)**	79%
Mussel 28-d S	42	0.16	0.441	38% (9 of 24)	39% (7 of 18)	52%	25% (3 of 12)	33% (12 of 36)	**67% (4 of 6)**	67%
Mussel 28-d B	42	0.16	0.441	**4% (1 of 24)**	33% (6 of 18)	69%	25% (3 of 12)	**11% (4 of 36)**	50% (3 of 6)	**83%**
Midge 10-d S	70	0.16	0.441	26% (11 of 42)	46% (13 of 28)	63%	35% (6 of 17)	29% (17 of 59)	**64% (7 of 11)**	70%
Midge 10-d B	70	0.16	0.441	45% (19 of 42)	**61% (17 of 28)**	57%	53% (9 of 17)	47% (28 of 59)	**73% (8 of 11)**	56%
OT-Six Endpoints[2]	70	0.16	0.441	69% (29 of 42)	**75% (21 of 28)**	49%	71% (12 of 17)	69% (41 of 59)	**82% (9 of 11)**	39%
OT-Four Endpoints[3]	70	0.16	0.441	40% (17 of 42)	46% (13 of 28)	54%	35% (6 of 17)	39% (23 of 59)	**64% (7 of 11)**	61%
PW-TU $_{LEAD}$										
Amphipod 28-d S	70	0.096	0.155	20% (10 of 51)	**74% (14 of 19)**	79%	33% (1 of 3)	20% (11 of 54)	**81% (13 of 16)**	**80%**
Amphipod 28-d B	70	0.096	0.155	**8% (4 of 51)**	**63% (12 of 19)**	**84%**	0% (0 of 3)	**7% (4 of 54)**	**75% (12 of 16)**	**89%**
Mussel 28-d S	42	0.096	0.155	27% (8 of 30)	**67% (8 of 12)**	71%	0% (0 of 1)	26% (8 of 31)	**73% (8 of 11)**	74%
Mussel 28-d B	42	0.096	0.155	**7% (2 of 30)**	42% (5 of 12)	79%	0% (0 of 1)	**6% (2 of 31)**	45% (5 of 11)	**81%**
Midge 10-d S	70	0.096	0.155	25% (13 of 51)	**58% (11 of 19)**	70%	33% (1 of 3)	26% (14 of 54)	**63% (10 of 16)**	71%
Midge 10-d B	70	0.096	0.155	45% (23 of 51)	**68% (13 of 19)**	59%	67% (2 of 3)	46% (25 of 54)	**69% (11 of 16)**	57%
OT-Six Endpoints[2]	70	0.096	0.155	65% (33 of 51)	**89% (17 of 19)**	50%	67% (2 of 3)	65% (35 of 54)	**94% (15 of 16)**	49%
OT-Four Endpoints[3]	70	0.096	0.155	31% (16 of 51)	**74% (14 of 19)**	70%	33% (1 of 3)	31% (17 of 54)	**81% (13 of 16)**	71%
PW-TU $_{LEAD(DOC)}$										
Amphipod 28-d S	70	0.0000171	0.0000325	**19% (9 of 48)**	**68% (15 of 22)**	77%	33% (2 of 6)	20% (11 of 54)	**81% (13 of 16)**	**80%**
Amphipod 28-d B	70	0.0000171	0.0000325	**6% (3 of 48)**	**59% (13 of 22)**	**83%**	17% (1 of 6)	**7% (4 of 54)**	**75% (12 of 16)**	**89%**
Mussel 28-d S	42	0.0000171	0.0000325	23% (6 of 26)	**63% (10 of 16)**	71%	60% (3 of 5)	29% (9 of 31)	**64% (7 of 11)**	69%
Mussel 28-d B	42	0.0000171	0.0000325	**8% (2 of 26)**	31% (5 of 16)	69%	0% (0 of 5)	**6% (2 of 31)**	45% (5 of 11)	**81%**
Midge 10-d S	70	0.0000171	0.0000325	27% (13 of 48)	50% (11 of 22)	66%	0% (0 of 6)	24% (13 of 54)	**69% (11 of 16)**	74%
Midge 10-d B	70	0.0000171	0.0000325	44% (21 of 48)	**68% (15 of 22)**	60%	50% (3 of 6)	44% (24 of 54)	**75% (12 of 16)**	60%
OT-Six Endpoints[2]	70	0.0000171	0.0000325	63% (30 of 48)	**91% (20 of 22)**	54%	83% (5 of 6)	65% (35 of 54)	**94% (15 of 16)**	49%
OT-Four Endpoints[3]	70	0.0000171	0.0000325	27% (13 of 48)	**77% (17 of 22)**	74%	67% (4 of 6)	31% (17 of 54)	**81% (13 of 16)**	71%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
PW-TU $_{ZINC}$										
Amphipod 28-d S	70	0.581	0.867	**15% (8 of 52)**	**89% (16 of 18)**	**86%**	100% (2 of 2)	**19% (10 of 54)**	**88% (14 of 16)**	**83%**
Amphipod 28-d B	70	0.581	0.867	**8% (4 of 52)**	**67% (12 of 18)**	**86%**	0% (0 of 2)	**7% (4 of 54)**	**75% (12 of 16)**	**89%**
Mussel 28-d S	42	0.581	0.867	**19% (6 of 31)**	**91% (10 of 11)**	**83%**	100% (1 of 1)	22% (7 of 32)	**90% (9 of 10)**	**81%**
Mussel 28-d B	42	0.581	0.867	**6% (2 of 31)**	45% (5 of 11)	**81%**	0% (0 of 1)	**6% (2 of 32)**	50% (5 of 10)	**83%**
Midge 10-d S	70	0.581	0.867	**19% (10 of 52)**	**78% (14 of 18)**	**80%**	50% (1 of 2)	20% (11 of 54)	**81% (13 of 16)**	**80%**
Midge 10-d B	70	0.581	0.867	44% (23 of 52)	**72% (13 of 18)**	60%	0% (0 of 2)	43% (23 of 54)	**81% (13 of 16)**	63%
OT-Six Endpoints[2]	70	0.581	0.867	62% (32 of 52)	**100% (18 of 18)**	54%	100% (2 of 2)	63% (34 of 54)	**100% (16 of 16)**	51%
OT-Four Endpoints[3]	70	0.581	0.867	25% (13 of 52)	**94% (17 of 18)**	**80%**	100% (2 of 2)	28% (15 of 54)	**94% (15 of 16)**	77%
PW-TU $_{ZINC(DOC)}$										
Amphipod 28-d S	70	0.0000783	0.000147	**17% (8 of 48)**	**73% (16 of 22)**	**80%**	25% (1 of 4)	**17% (9 of 52)**	**83% (15 of 18)**	**83%**
Amphipod 28-d B	70	0.0000783	0.000147	**8% (4 of 48)**	**55% (12 of 22)**	**80%**	0% (0 of 4)	**8% (4 of 52)**	**67% (12 of 18)**	**86%**
Mussel 28-d S	42	0.0000783	0.000147	21% (6 of 29)	**77% (10 of 13)**	79%	50% (1 of 2)	23% (7 of 31)	**82% (9 of 11)**	79%
Mussel 28-d B	42	0.0000783	0.000147	**7% (2 of 29)**	38% (5 of 13)	76%	0% (0 of 2)	**6% (2 of 31)**	45% (5 of 11)	**81%**
Midge 10-d S	70	0.0000783	0.000147	**19% (9 of 48)**	**68% (15 of 22)**	77%	25% (1 of 4)	**19% (10 of 52)**	**78% (14 of 18)**	**80%**
Midge 10-d B	70	0.0000783	0.000147	42% (20 of 48)	**73% (16 of 22)**	63%	50% (2 of 4)	42% (22 of 52)	**78% (14 of 18)**	63%
OT-Six Endpoints[2]	70	0.0000783	0.000147	60% (29 of 48)	**95% (21 of 22)**	57%	75% (3 of 4)	62% (32 of 52)	**100% (18 of 18)**	54%
OT-Four Endpoints[3]	70	0.0000783	0.000147	27% (13 of 48)	**77% (17 of 22)**	74%	25% (1 of 4)	27% (14 of 52)	**89% (16 of 18)**	77%
ΣPW-TU $_{DIVALENT\ METALS}$										
Amphipod 28-d S	70	1.03	1.41	**16% (8 of 49)**	**76% (16 of 21)**	**81%**	33% (2 of 6)	**18% (10 of 55)**	**93% (14 of 15)**	**84%**
Amphipod 28-d B	70	1.03	1.41	**8% (4 of 49)**	**57% (12 of 21)**	**81%**	0% (0 of 6)	**7% (4 of 55)**	**80% (12 of 15)**	**90%**
Mussel 28-d S	42	1.03	1.41	20% (6 of 30)	**83% (10 of 12)**	**81%**	75% (3 of 4)	26% (9 of 34)	**88% (7 of 8)**	76%
Mussel 28-d B	42	1.03	1.41	**7% (2 of 30)**	42% (5 of 12)	79%	0% (0 of 4)	**6% (2 of 34)**	**63% (5 of 8)**	**88%**
Midge 10-d S	70	1.03	1.41	**18% (9 of 49)**	**71% (15 of 21)**	79%	33% (2 of 6)	20% (11 of 55)	**87% (13 of 15)**	**81%**
Midge 10-d B	70	1.03	1.41	43% (21 of 49)	**71% (15 of 21)**	61%	50% (3 of 6)	44% (24 of 55)	**80% (12 of 15)**	61%
OT-Six Endpoints[2]	70	1.03	1.41	61% (30 of 49)	**95% (20 of 21)**	56%	83% (5 of 6)	64% (35 of 55)	**100% (15 of 15)**	50%
OT-Four Endpoints[3]	70	1.03	1.41	27% (13 of 49)	**81% (17 of 21)**	76%	50% (3 of 6)	29% (16 of 55)	**93% (14 of 15)**	76%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
Basis for T_{10}/T_{20} Values: 28-d *H. azteca* Biomass										
***PW-TU** $_{LEAD}$*										
Amphipod 28-d S	70	NB	0.043	NB	NB	NB	NB	**18% (8 of 45)**	**64% (16 of 25)**	76%
Amphipod 28-d B	70	NB	0.043	NB	NB	NB	NB	**7% (3 of 45)**	**52% (13 of 25)**	79%
Mussel 28-d S	42	NB	0.043	NB	NB	NB	NB	23% (6 of 26)	**63% (10 of 16)**	71%
Mussel 28-d B	42	NB	0.043	NB	NB	NB	NB	**8% (2 of 26)**	31% (5 of 16)	69%
Midge 10-d S	70	NB	0.043	NB	NB	NB	NB	27% (12 of 45)	48% (12 of 25)	64%
Midge 10-d B	70	NB	0.043	NB	NB	NB	NB	42% (19 of 45)	**68% (17 of 25)**	61%
OT-Six Endpoints[2]	70	NB	0.043	NB	NB	NB	NB	62% (28 of 45)	**88% (22 of 25)**	56%
OT-Four Endpoints[3]	70	NB	0.043	NB	NB	NB	NB	27% (12 of 45)	**72% (18 of 25)**	73%
***PW-TU** $_{LEAD(DOC)}$*										
Amphipod 28-d S	70	0.000000218	0.00000733	**0% (0 of 4)**	36% (24 of 66)	40%	21% (8 of 38)	**19% (8 of 42)**	**57% (16 of 28)**	71%
Amphipod 28-d B	70	0.000000218	0.00000733	**0% (0 of 4)**	24% (16 of 66)	29%	5% (2 of 38)	**5% (2 of 42)**	50% (14 of 28)	77%
Mussel 28-d S	42	0.000000218	0.00000733	50% (1 of 2)	38% (15 of 40)	38%	22% (5 of 23)	24% (6 of 25)	**59% (10 of 17)**	69%
Mussel 28-d B	42	0.000000218	0.00000733	**0% (0 of 2)**	18% (7 of 40)	21%	9% (2 of 23)	**8% (2 of 25)**	29% (5 of 17)	67%
Midge 10-d S	70	0.000000218	0.00000733	**0% (0 of 4)**	36% (24 of 66)	40%	26% (10 of 38)	24% (10 of 42)	50% (14 of 28)	66%
Midge 10-d B	70	0.000000218	0.00000733	25% (1 of 4)	**53% (35 of 66)**	54%	42% (16 of 38)	40% (17 of 42)	**68% (19 of 28)**	63%
OT-Six Endpoints[2]	70	0.000000218	0.00000733	25% (1 of 4)	**74% (49 of 66)**	74%	66% (25 of 38)	62% (26 of 42)	**86% (24 of 28)**	57%
OT-Four Endpoints[3]	70	0.000000218	0.00000733	25% (1 of 4)	44% (29 of 66)	46%	29% (11 of 38)	29% (12 of 42)	**64% (18 of 28)**	69%
***PW-TU** $_{ZINC}$*										
Amphipod 28-d S	70	NB	0.638	NB	NB	NB	NB	**15% (8 of 52)**	**89% (16 of 18)**	**86%**
Amphipod 28-d B	70	NB	0.638	NB	NB	NB	NB	**8% (4 of 52)**	**67% (12 of 18)**	**86%**
Mussel 28-d S	42	NB	0.638	NB	NB	NB	NB	**19% (6 of 31)**	**91% (10 of 11)**	**83%**
Mussel 28-d B	42	NB	0.638	NB	NB	NB	NB	**6% (2 of 31)**	45% (5 of 11)	**81%**
Midge 10-d S	70	NB	0.638	NB	NB	NB	NB	**19% (10 of 52)**	**78% (14 of 18)**	**80%**
Midge 10-d B	70	NB	0.638	NB	NB	NB	NB	44% (23 of 52)	**72% (13 of 18)**	60%
OT-Six Endpoints[2]	70	NB	0.638	NB	NB	NB	NB	62% (32 of 52)	**100% (18 of 18)**	54%
OT-Four Endpoints[3]	70	NB	0.638	NB	NB	NB	NB	25% (13 of 52)	**94% (17 of 18)**	**80%**

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
***PW-TU** $_{ZINC(DOC)}$*										
Amphipod 28-d S	70	NB	0.0000518	NB	NB	NB	NB	**15% (7 of 46)**	**71% (17 of 24)**	**80%**
Amphipod 28-d B	70	NB	0.0000518	NB	NB	NB	NB	**7% (3 of 46)**	**54% (13 of 24)**	**80%**
Mussel 28-d S	42	NB	0.0000518	NB	NB	NB	NB	22% (6 of 27)	**67% (10 of 15)**	74%
Mussel 28-d B	42	NB	0.0000518	NB	NB	NB	NB	**7% (2 of 27)**	33% (5 of 15)	71%
Midge 10-d S	70	NB	0.0000518	NB	NB	NB	NB	**17% (8 of 46)**	**67% (16 of 24)**	77%
Midge 10-d B	70	NB	0.0000518	NB	NB	NB	NB	43% (20 of 46)	**67% (16 of 24)**	60%
OT-Six Endpoints[2]	70	NB	0.0000518	NB	NB	NB	NB	61% (28 of 46)	**92% (22 of 24)**	57%
OT-Four Endpoints[3]	70	NB	0.0000518	NB	NB	NB	NB	26% (12 of 46)	**75% (18 of 24)**	74%
***ΣPW-TU** $_{DIVALENT\ METALS}$*										
Amphipod 28-d S	70	NB	0.988	NB	NB	NB	NB	**16% (8 of 49)**	**76% (16 of 21)**	**81%**
Amphipod 28-d B	70	NB	0.988	NB	NB	NB	NB	**8% (4 of 49)**	**57% (12 of 21)**	**81%**
Mussel 28-d S	42	NB	0.988	NB	NB	NB	NB	20% (6 of 30)	**83% (10 of 12)**	**81%**
Mussel 28-d B	42	NB	0.988	NB	NB	NB	NB	**7% (2 of 30)**	42% (5 of 12)	79%
Midge 10-d S	70	NB	0.988	NB	NB	NB	NB	**18% (9 of 49)**	**71% (15 of 21)**	79%
Midge 10-d B	70	NB	0.988	NB	NB	NB	NB	43% (21 of 49)	**71% (15 of 21)**	61%
OT-Six Endpoints[2]	70	NB	0.988	NB	NB	NB	NB	61% (30 of 49)	**95% (20 of 21)**	56%
OT-Four Endpoints[3]	70	NB	0.988	NB	NB	NB	NB	27% (13 of 49)	**81% (17 of 21)**	76%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Survival										
***PW-TU** $_{CADMIUM}$*										
Amphipod 28-d S	70	6.15	6.37	30% (20 of 66)	**100% (4 of 4)**	71%	100% (1 of 1)	31% (21 of 67)	**100% (3 of 3)**	70%
Amphipod 28-d B	70	6.15	6.37	**18% (12 of 66)**	**100% (4 of 4)**	**83%**	100% (1 of 1)	**19% (13 of 67)**	**100% (3 of 3)**	**81%**
Mussel 28-d S	42	6.15	6.37	33% (13 of 39)	**100% (3 of 3)**	69%	100% (1 of 1)	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	6.15	6.37	**10% (4 of 39)**	**100% (3 of 3)**	**90%**	100% (1 of 1)	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	6.15	6.37	30% (20 of 66)	**100% (4 of 4)**	71%	100% (1 of 1)	31% (21 of 67)	**100% (3 of 3)**	70%
Midge 10-d B	70	6.15	6.37	48% (32 of 66)	**100% (4 of 4)**	54%	100% (1 of 1)	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	70	6.15	6.37	70% (46 of 66)	**100% (4 of 4)**	34%	100% (1 of 1)	70% (47 of 67)	**100% (3 of 3)**	33%
OT-Four Endpoints[3]	70	6.15	6.37	39% (26 of 66)	**100% (4 of 4)**	63%	100% (1 of 1)	40% (27 of 67)	**100% (3 of 3)**	61%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
PW-TU $_{COPPER}$										
Amphipod 28-d S	70	0.0391	0.0533	34% (22 of 64)	33% (2 of 6)	63%	0% (0 of 1)	34% (22 of 65)	40% (2 of 5)	64%
Amphipod 28-d B	70	0.0391	0.0533	22% (14 of 64)	33% (2 of 6)	74%	0% (0 of 1)	22% (14 of 65)	40% (2 of 5)	76%
Mussel 28-d S	42	0.0391	0.0533	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	0.0391	0.0533	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	0.0391	0.0533	33% (21 of 64)	50% (3 of 6)	66%	0% (0 of 1)	32% (21 of 65)	**60% (3 of 5)**	67%
Midge 10-d B	70	0.0391	0.0533	50% (32 of 64)	**67% (4 of 6)**	51%	0% (0 of 1)	49% (32 of 65)	**80% (4 of 5)**	53%
OT-Six Endpoints[2]	70	0.0391	0.0533	72% (46 of 64)	**67% (4 of 6)**	31%	0% (0 of 1)	71% (46 of 65)	**80% (4 of 5)**	33%
OT-Four Endpoints[3]	70	0.0391	0.0533	44% (28 of 64)	33% (2 of 6)	54%	0% (0 of 1)	43% (28 of 65)	40% (2 of 5)	56%
PW-TU $_{LEAD}$										
Amphipod 28-d S	70	0.248	0.542	24% (14 of 59)	**91% (10 of 11)**	79%	86% (6 of 7)	30% (20 of 66)	**100% (4 of 4)**	71%
Amphipod 28-d B	70	0.248	0.542	**12% (7 of 59)**	**82% (9 of 11)**	**87%**	71% (5 of 7)	**18% (12 of 66)**	**100% (4 of 4)**	**83%**
Mussel 28-d S	42	0.248	0.542	29% (10 of 34)	**75% (6 of 8)**	71%	60% (3 of 5)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	0.248	0.542	**9% (3 of 34)**	50% (4 of 8)	**83%**	40% (2 of 5)	**13% (5 of 39)**	**67% (2 of 3)**	**86%**
Midge 10-d S	70	0.248	0.542	29% (17 of 59)	**64% (7 of 11)**	70%	57% (4 of 7)	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	0.248	0.542	47% (28 of 59)	**73% (8 of 11)**	56%	57% (4 of 7)	48% (32 of 66)	**100% (4 of 4)**	54%
OT-Six Endpoints[2]	70	0.248	0.542	68% (40 of 59)	**91% (10 of 11)**	41%	86% (6 of 7)	70% (46 of 66)	**100% (4 of 4)**	34%
OT-Four Endpoints[3]	70	0.248	0.542	34% (20 of 59)	**91% (10 of 11)**	70%	86% (6 of 7)	39% (26 of 66)	**100% (4 of 4)**	63%
PW-TU $_{NICKEL}$										
Amphipod 28-d S	70	0.0871	0.0889	34% (22 of 65)	40% (2 of 5)	64%	0% (0 of 1)	33% (22 of 66)	50% (2 of 4)	66%
Amphipod 28-d B	70	0.0871	0.0889	22% (14 of 65)	40% (2 of 5)	76%	0% (0 of 1)	21% (14 of 66)	50% (2 of 4)	77%
Mussel 28-d S	42	0.0871	0.0889	33% (13 of 39)	**100% (3 of 3)**	69%	100% (1 of 1)	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	0.0871	0.0889	**13% (5 of 39)**	**67% (2 of 3)**	**86%**	0% (0 of 1)	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	0.0871	0.0889	32% (21 of 65)	**60% (3 of 5)**	67%	100% (1 of 1)	33% (22 of 66)	50% (2 of 4)	66%
Midge 10-d B	70	0.0871	0.0889	51% (33 of 65)	**60% (3 of 5)**	50%	0% (0 of 1)	50% (33 of 66)	**75% (3 of 4)**	51%
OT-Six Endpoints[2]	70	0.0871	0.0889	71% (46 of 65)	**80% (4 of 5)**	33%	100% (1 of 1)	71% (47 of 66)	**75% (3 of 4)**	31%
OT-Four Endpoints[3]	70	0.0871	0.0889	42% (27 of 65)	**60% (3 of 5)**	59%	100% (1 of 1)	42% (28 of 66)	50% (2 of 4)	57%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
PW-TU $_{ZINC}$										
Amphipod 28-d S	70	1.62	3.35	22% (13 of 58)	**92% (11 of 12)**	**80%**	86% (6 of 7)	29% (19 of 65)	**100% (5 of 5)**	73%
Amphipod 28-d B	70	1.62	3.35	**10% (6 of 58)**	**83% (10 of 12)**	**89%**	71% (5 of 7)	**17% (11 of 65)**	**100% (5 of 5)**	**84%**
Mussel 28-d S	42	1.62	3.35	31% (11 of 36)	**83% (5 of 6)**	71%	67% (2 of 3)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	1.62	3.35	**6% (2 of 36)**	**83% (5 of 6)**	**93%**	67% (2 of 3)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
Midge 10-d S	70	1.62	3.35	22% (13 of 58)	**92% (11 of 12)**	**80%**	86% (6 of 7)	29% (19 of 65)	**100% (5 of 5)**	73%
Midge 10-d B	70	1.62	3.35	43% (25 of 58)	**92% (11 of 12)**	63%	86% (6 of 7)	48% (31 of 65)	**100% (5 of 5)**	56%
OT-Six Endpoints[2]	70	1.62	3.35	66% (38 of 58)	**100% (12 of 12)**	46%	100% (7 of 7)	69% (45 of 65)	**100% (5 of 5)**	36%
OT-Four Endpoints[3]	70	1.62	3.35	33% (19 of 58)	**92% (11 of 12)**	71%	86% (6 of 7)	38% (25 of 65)	**100% (5 of 5)**	64%
PW-TU $_{ZINC(DOC)}$										
Amphipod 28-d S	70	0.00076	0.00121	26% (16 of 61)	**89% (8 of 9)**	76%	83% (5 of 6)	31% (21 of 67)	**100% (3 of 3)**	70%
Amphipod 28-d B	70	0.00076	0.00121	**13% (8 of 61)**	**89% (8 of 9)**	**87%**	83% (5 of 6)	**19% (13 of 67)**	**100% (3 of 3)**	**81%**
Mussel 28-d S	42	0.00076	0.00121	32% (12 of 38)	**100% (4 of 4)**	71%	100% (2 of 2)	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	0.00076	0.00121	**8% (3 of 38)**	**100% (4 of 4)**	**93%**	100% (2 of 2)	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	0.00076	0.00121	26% (16 of 61)	**89% (8 of 9)**	76%	83% (5 of 6)	31% (21 of 67)	**100% (3 of 3)**	70%
Midge 10-d B	70	0.00076	0.00121	46% (28 of 61)	**89% (8 of 9)**	59%	83% (5 of 6)	49% (33 of 67)	**100% (3 of 3)**	53%
OT-Six Endpoints[2]	70	0.00076	0.00121	67% (41 of 61)	**100% (9 of 9)**	41%	100% (6 of 6)	70% (47 of 67)	**100% (3 of 3)**	33%
OT-Four Endpoints[3]	70	0.00076	0.00121	36% (22 of 61)	**89% (8 of 9)**	67%	83% (5 of 6)	40% (27 of 67)	**100% (3 of 3)**	61%
ΣPW-TU $_{METALS}$										
Amphipod 28-d S	70	30.2	30.8	33% (22 of 67)	**67% (2 of 3)**	67%	No Data	33% (22 of 67)	**67% (2 of 3)**	67%
Amphipod 28-d B	70	30.2	30.8	21% (14 of 67)	**67% (2 of 3)**	79%	No Data	21% (14 of 67)	**67% (2 of 3)**	79%
Mussel 28-d S	42	30.2	30.8	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	30.2	30.8	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	30.2	30.8	33% (22 of 67)	**67% (2 of 3)**	67%	No Data	33% (22 of 67)	**67% (2 of 3)**	67%
Midge 10-d B	70	30.2	30.8	51% (34 of 67)	**67% (2 of 3)**	50%	No Data	51% (34 of 67)	**67% (2 of 3)**	50%
OT-Six Endpoints[2]	70	30.2	30.8	72% (48 of 67)	**67% (2 of 3)**	30%	No Data	72% (48 of 67)	**67% (2 of 3)**	30%
OT-Four Endpoints[3]	70	30.2	30.8	42% (28 of 67)	**67% (2 of 3)**	59%	No Data	42% (28 of 67)	**67% (2 of 3)**	59%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
***ΣPW-TU** $_{DIVALENT\ METALS}$*										
Amphipod 28-d S	70	4	7.12	27% (17 of 63)	**100% (7 of 7)**	76%	100% (2 of 2)	29% (19 of 65)	**100% (5 of 5)**	73%
Amphipod 28-d B	70	4	7.12	**14% (9 of 63)**	**100% (7 of 7)**	**87%**	100% (2 of 2)	**17% (11 of 65)**	**100% (5 of 5)**	**84%**
Mussel 28-d S	42	4	7.12	32% (12 of 38)	**100% (4 of 4)**	71%	100% (1 of 1)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	4	7.12	**8% (3 of 38)**	**100% (4 of 4)**	**93%**	100% (1 of 1)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
Midge 10-d S	70	4	7.12	27% (17 of 63)	**100% (7 of 7)**	76%	100% (2 of 2)	29% (19 of 65)	**100% (5 of 5)**	73%
Midge 10-d B	70	4	7.12	46% (29 of 63)	**100% (7 of 7)**	59%	100% (2 of 2)	48% (31 of 65)	**100% (5 of 5)**	56%
OT-Six Endpoints[2]	70	4	7.12	68% (43 of 63)	**100% (7 of 7)**	39%	100% (2 of 2)	69% (45 of 65)	**100% (5 of 5)**	36%
OT-Four Endpoints[3]	70	4	7.12	37% (23 of 63)	**100% (7 of 7)**	67%	100% (2 of 2)	38% (25 of 65)	**100% (5 of 5)**	64%
Basis for T_{10}/T_{20} Values: 28-d *L. siliquoidea* Biomass										
***PW-TU** $_{CADMIUM}$*										
Amphipod 28-d S	70	0.723	1.25	30% (19 of 64)	**83% (5 of 6)**	71%	0% (0 of 1)	29% (19 of 65)	**100% (5 of 5)**	73%
Amphipod 28-d B	70	0.723	1.25	**17% (11 of 64)**	**83% (5 of 6)**	**83%**	0% (0 of 1)	**17% (11 of 65)**	**100% (5 of 5)**	**84%**
Mussel 28-d S	42	0.723	1.25	34% (13 of 38)	**75% (3 of 4)**	67%	0% (0 of 1)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	0.723	1.25	**11% (4 of 38)**	**75% (3 of 4)**	**88%**	0% (0 of 1)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
Midge 10-d S	70	0.723	1.25	30% (19 of 64)	**83% (5 of 6)**	71%	0% (0 of 1)	29% (19 of 65)	**100% (5 of 5)**	73%
Midge 10-d B	70	0.723	1.25	47% (30 of 64)	**100% (6 of 6)**	57%	100% (1 of 1)	48% (31 of 65)	**100% (5 of 5)**	56%
OT-Six Endpoints[2]	70	0.723	1.25	69% (44 of 64)	**100% (6 of 6)**	37%	100% (1 of 1)	69% (45 of 65)	**100% (5 of 5)**	36%
OT-Four Endpoints[3]	70	0.723	1.25	39% (25 of 64)	**83% (5 of 6)**	63%	0% (0 of 1)	38% (25 of 65)	**100% (5 of 5)**	64%
***PW-TU** $_{COPPER}$*										
Amphipod 28-d S	70	0.048	0.0563	34% (22 of 64)	33% (2 of 6)	63%	0% (0 of 1)	34% (22 of 65)	40% (2 of 5)	64%
Amphipod 28-d B	70	0.048	0.0563	22% (14 of 64)	33% (2 of 6)	74%	0% (0 of 1)	22% (14 of 65)	40% (2 of 5)	76%
Mussel 28-d S	42	0.048	0.0563	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	0.048	0.0563	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	0.048	0.0563	33% (21 of 64)	50% (3 of 6)	66%	0% (0 of 1)	32% (21 of 65)	**60% (3 of 5)**	67%
Midge 10-d B	70	0.048	0.0563	50% (32 of 64)	**67% (4 of 6)**	51%	0% (0 of 1)	49% (32 of 65)	**80% (4 of 5)**	53%
OT-Six Endpoints[2]	70	0.048	0.0563	72% (46 of 64)	**67% (4 of 6)**	31%	0% (0 of 1)	71% (46 of 65)	**80% (4 of 5)**	33%
OT-Four Endpoints[3]	70	0.048	0.0563	44% (28 of 64)	33% (2 of 6)	54%	0% (0 of 1)	43% (28 of 65)	40% (2 of 5)	56%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				<T_{10} Value	≥T_{10} Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	≤T_{20} Value	>T_{20} Value	Correct Class. Rate for T_{20}
PW-TU $_{LEAD}$										
Amphipod 28-d S	70	0.281	0.477	25% (15 of 61)	**100% (9 of 9)**	79%	100% (5 of 5)	30% (20 of 66)	**100% (4 of 4)**	71%
Amphipod 28-d B	70	0.281	0.477	**11% (7 of 61)**	**100% (9 of 9)**	**90%**	100% (5 of 5)	**18% (12 of 66)**	**100% (4 of 4)**	**83%**
Mussel 28-d S	42	0.281	0.477	31% (11 of 36)	**83% (5 of 6)**	71%	67% (2 of 3)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	0.281	0.477	**8% (3 of 36)**	**67% (4 of 6)**	**88%**	67% (2 of 3)	**13% (5 of 39)**	**67% (2 of 3)**	**86%**
Midge 10-d S	70	0.281	0.477	28% (17 of 61)	**78% (7 of 9)**	73%	80% (4 of 5)	32% (21 of 66)	**75% (3 of 4)**	69%
Midge 10-d B	70	0.281	0.477	46% (28 of 61)	**89% (8 of 9)**	59%	80% (4 of 5)	48% (32 of 66)	**100% (4 of 4)**	54%
OT-Six Endpoints[2]	70	0.281	0.477	67% (41 of 61)	**100% (9 of 9)**	41%	100% (5 of 5)	70% (46 of 66)	**100% (4 of 4)**	34%
OT-Four Endpoints[3]	70	0.281	0.477	34% (21 of 61)	**100% (9 of 9)**	70%	100% (5 of 5)	39% (26 of 66)	**100% (4 of 4)**	63%
PW-TU $_{LEAD(DOC)}$										
Amphipod 28-d S	70	0.0000735	0.0000866	27% (16 of 60)	**80% (8 of 10)**	74%	33% (1 of 3)	27% (17 of 63)	**100% (7 of 7)**	76%
Amphipod 28-d B	70	0.0000735	0.0000866	**13% (8 of 60)**	**80% (8 of 10)**	**86%**	33% (1 of 3)	**14% (9 of 63)**	**100% (7 of 7)**	**87%**
Mussel 28-d S	42	0.0000735	0.0000866	31% (11 of 36)	**83% (5 of 6)**	71%	0% (0 of 1)	30% (11 of 37)	**100% (5 of 5)**	74%
Mussel 28-d B	42	0.0000735	0.0000866	**8% (3 of 36)**	**67% (4 of 6)**	**88%**	0% (0 of 1)	**8% (3 of 37)**	**80% (4 of 5)**	**90%**
Midge 10-d S	70	0.0000735	0.0000866	28% (17 of 60)	**70% (7 of 10)**	71%	33% (1 of 3)	29% (18 of 63)	**86% (6 of 7)**	73%
Midge 10-d B	70	0.0000735	0.0000866	45% (27 of 60)	**90% (9 of 10)**	60%	100% (3 of 3)	48% (30 of 63)	**86% (6 of 7)**	56%
OT-Six Endpoints[2]	70	0.0000735	0.0000866	67% (40 of 60)	**100% (10 of 10)**	43%	100% (3 of 3)	68% (43 of 63)	**100% (7 of 7)**	39%
OT-Four Endpoints[3]	70	0.0000735	0.0000866	37% (22 of 60)	**80% (8 of 10)**	66%	33% (1 of 3)	37% (23 of 63)	**100% (7 of 7)**	67%
PW-TU $_{NICKEL}$										
Amphipod 28-d S	70	0.0919	0.0923	33% (22 of 66)	50% (2 of 4)	66%	No Data	33% (22 of 66)	50% (2 of 4)	66%
Amphipod 28-d B	70	0.0919	0.0923	21% (14 of 66)	50% (2 of 4)	77%	No Data	21% (14 of 66)	50% (2 of 4)	77%
Mussel 28-d S	42	0.0919	0.0923	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	0.0919	0.0923	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	0.0919	0.0923	33% (22 of 66)	50% (2 of 4)	66%	No Data	33% (22 of 66)	50% (2 of 4)	66%
Midge 10-d B	70	0.0919	0.0923	50% (33 of 66)	**75% (3 of 4)**	51%	No Data	50% (33 of 66)	**75% (3 of 4)**	51%
OT-Six Endpoints[2]	70	0.0919	0.0923	71% (47 of 66)	**75% (3 of 4)**	31%	No Data	71% (47 of 66)	**75% (3 of 4)**	31%
OT-Four Endpoints[3]	70	0.0919	0.0923	42% (28 of 66)	50% (2 of 4)	57%	No Data	42% (28 of 66)	50% (2 of 4)	57%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
PW-TU $_{ZINC}$										
Amphipod 28-d S	70	1.23	1.95	21% (12 of 57)	**92% (12 of 13)**	**81%**	83% (5 of 6)	27% (17 of 63)	**100% (7 of 7)**	76%
Amphipod 28-d B	70	1.23	1.95	**9% (5 of 57)**	**85% (11 of 13)**	**90%**	67% (4 of 6)	**14% (9 of 63)**	**100% (7 of 7)**	**87%**
Mussel 28-d S	42	1.23	1.95	29% (10 of 35)	**86% (6 of 7)**	74%	75% (3 of 4)	33% (13 of 39)	**100% (3 of 3)**	69%
Mussel 28-d B	42	1.23	1.95	**6% (2 of 35)**	**71% (5 of 7)**	**90%**	50% (2 of 4)	**10% (4 of 39)**	**100% (3 of 3)**	**90%**
Midge 10-d S	70	1.23	1.95	23% (13 of 57)	**85% (11 of 13)**	79%	67% (4 of 6)	27% (17 of 63)	**100% (7 of 7)**	76%
Midge 10-d B	70	1.23	1.95	42% (24 of 57)	**92% (12 of 13)**	64%	83% (5 of 6)	46% (29 of 63)	**100% (7 of 7)**	59%
OT-Six Endpoints[2]	70	1.23	1.95	65% (37 of 57)	**100% (13 of 13)**	47%	100% (6 of 6)	68% (43 of 63)	**100% (7 of 7)**	39%
OT-Four Endpoints[3]	70	1.23	1.95	32% (18 of 57)	**92% (12 of 13)**	73%	83% (5 of 6)	37% (23 of 63)	**100% (7 of 7)**	67%
PW-TU $_{ZINC(DOC)}$										
Amphipod 28-d S	70	0.00039	0.000606	22% (13 of 58)	**92% (11 of 12)**	**80%**	100% (3 of 3)	26% (16 of 61)	**89% (8 of 9)**	76%
Amphipod 28-d B	70	0.00039	0.000606	**10% (6 of 58)**	**83% (10 of 12)**	**89%**	67% (2 of 3)	**13% (8 of 61)**	**89% (8 of 9)**	**87%**
Mussel 28-d S	42	0.00039	0.000606	31% (11 of 36)	**83% (5 of 6)**	71%	50% (1 of 2)	32% (12 of 38)	**100% (4 of 4)**	71%
Mussel 28-d B	42	0.00039	0.000606	**6% (2 of 36)**	**83% (5 of 6)**	**93%**	50% (1 of 2)	**8% (3 of 38)**	**100% (4 of 4)**	**93%**
Midge 10-d S	70	0.00039	0.000606	22% (13 of 58)	**92% (11 of 12)**	**80%**	100% (3 of 3)	26% (16 of 61)	**89% (8 of 9)**	76%
Midge 10-d B	70	0.00039	0.000606	43% (25 of 58)	**92% (11 of 12)**	63%	100% (3 of 3)	46% (28 of 61)	**89% (8 of 9)**	59%
OT-Six Endpoints[2]	70	0.00039	0.000606	66% (38 of 58)	**100% (12 of 12)**	46%	100% (3 of 3)	67% (41 of 61)	**100% (9 of 9)**	41%
OT-Four Endpoints[3]	70	0.00039	0.000606	33% (19 of 58)	**92% (11 of 12)**	71%	100% (3 of 3)	36% (22 of 61)	**89% (8 of 9)**	67%
ΣPW-TU $_{METALS}$										
Amphipod 28-d S	70	26.9	27.7	33% (22 of 67)	**67% (2 of 3)**	67%	No Data	33% (22 of 67)	**67% (2 of 3)**	67%
Amphipod 28-d B	70	26.9	27.7	21% (14 of 67)	**67% (2 of 3)**	79%	No Data	21% (14 of 67)	**67% (2 of 3)**	79%
Mussel 28-d S	42	26.9	27.7	35% (14 of 40)	**100% (2 of 2)**	67%	No Data	35% (14 of 40)	**100% (2 of 2)**	67%
Mussel 28-d B	42	26.9	27.7	**13% (5 of 40)**	**100% (2 of 2)**	**88%**	No Data	**13% (5 of 40)**	**100% (2 of 2)**	**88%**
Midge 10-d S	70	26.9	27.7	33% (22 of 67)	**67% (2 of 3)**	67%	No Data	33% (22 of 67)	**67% (2 of 3)**	67%
Midge 10-d B	70	26.9	27.7	51% (34 of 67)	**67% (2 of 3)**	50%	No Data	51% (34 of 67)	**67% (2 of 3)**	50%
OT-Six Endpoints[2]	70	26.9	27.7	72% (48 of 67)	**67% (2 of 3)**	30%	No Data	72% (48 of 67)	**67% (2 of 3)**	30%
OT-Four Endpoints[3]	70	26.9	27.7	42% (28 of 67)	**67% (2 of 3)**	59%	No Data	42% (28 of 67)	**67% (2 of 3)**	59%

Table 11. Predictive ability of the pore-water toxicity thresholds (PWTTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca*, and the fat mucket, *Lampsilis siliquoidea* (Endpoints: survival and biomass).[1]

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate STT	n	T_{10} Value	T_{20} Value	Incidence of Toxicity						
				$<T_{10}$ Value	$\geq T_{10}$ Value	Correct Class. Rate for T_{10}	T_{10}-T_{20} Value	$\leq T_{20}$ Value	$>T_{20}$ Value	Correct Class. Rate for T_{20}
ΣPW-TU DIVALENT METALS										
Amphipod 28-d S	70	2.38	3.79	23% (14 of 60)	**100% (10 of 10)**	**80%**	100% (2 of 2)	26% (16 of 62)	**100% (8 of 8)**	77%
Amphipod 28-d B	70	2.38	3.79	**10% (6 of 60)**	**100% (10 of 10)**	**91%**	100% (2 of 2)	**13% (8 of 62)**	**100% (8 of 8)**	**89%**
Mussel 28-d S	42	2.38	3.79	28% (10 of 36)	**100% (6 of 6)**	76%	100% (2 of 2)	32% (12 of 38)	**100% (4 of 4)**	71%
Mussel 28-d B	42	2.38	3.79	**6% (2 of 36)**	**83% (5 of 6)**	**93%**	50% (1 of 2)	**8% (3 of 38)**	**100% (4 of 4)**	**93%**
Midge 10-d S	70	2.38	3.79	25% (15 of 60)	**90% (9 of 10)**	77%	50% (1 of 2)	26% (16 of 62)	**100% (8 of 8)**	77%
Midge 10-d B	70	2.38	3.79	43% (26 of 60)	**100% (10 of 10)**	63%	100% (2 of 2)	45% (28 of 62)	**100% (8 of 8)**	60%
OT-Six Endpoints[2]	70	2.38	3.79	67% (40 of 60)	**100% (10 of 10)**	43%	100% (2 of 2)	68% (42 of 62)	**100% (8 of 8)**	40%
OT-Four Endpoints[3]	70	2.38	3.79	33% (20 of 60)	**100% (10 of 10)**	71%	100% (2 of 2)	35% (22 of 62)	**100% (8 of 8)**	69%

d = day; S = survival; B = biomass; n = number of samples; COPC = chemical of potential concern; Class. = classification; PW-TU = pore-water toxic units; NB = No Benchmark; DOC = dissolved organic carbon; OT = overall toxicity.

[1]Bolded results indicate that the toxicity threshold met the individual evaluation criteria for the T_{10} value, T_{20} value, or correct classification rate.

[2]Based on the results of all three toxicity tests (six endpoints).

[3]Based on the results of the amphipod and mussel toxicity tests (four endpoints).

Table 12. Predictive ability of the sediment toxicity thresholds (STTs) that were derived based on the results of 28-day toxicity tests with the amphipod, *Hyalella azteca* (Endpoint: survival), when cadmium, lead, and zinc are used together to evaluate sediment quality conditions.[1]

Toxicity Test Endpoint Used to Evaluate STT	n	Incidence of Toxicity: All Three Metals Less Than the T Value	Incidence of Toxicity: One or More of the Three Metals Greater Than the T Value	Correct Classification Rate
Predictive Ability of the T_{10} values [2]				
Amphipod 28-d S	76	**7% (3 of 41)**	**60% (21 of 35)**	78%
Amphipod 28-d B	76	**2% (1 of 41)**	43% (15 of 35)	72%
Mussel 28-d S	48	20% (5 of 25)	**61% (14 of 23)**	71%
Mussel 28-d B	48	**4% (1 of 25)**	26% (6 of 23)	63%
Midge 10-d S	70	22% (8 of 37)	48% (16 of 33)	64%
Midge 10-d B	70	35% (13 of 37)	**70% (23 of 33)**	67%
OT-Six Endpoints[3]	76	54% (22 of 41)	89% (31 of 35)	66%
OT-Four Endpoints[4]	76	20% (8 of 41)	71% (25 of 35)	76%
Predictive Ability of the T_{20} values [5]				
Amphipod 28-d S	76	**10% (5 of 49)**	**70% (19 of 27)**	**83%**
Amphipod 28-d B	76	**4% (2 of 49)**	**52% (14 of 27)**	**80%**
Mussel 28-d S	48	23% (7 of 30)	**67% (12 of 18)**	**85%**
Mussel 28-d B	48	**3% (1 of 30)**	33% (6 of 18)	60%
Midge 10-d S	70	25% (11 of 44)	50% (13 of 26)	66%
Midge 10-d B	70	39% (17 of 44)	**73% (19 of 26)**	66%
OT-Six Endpoints[3]	76	59% (29 of 49)	89% (24 of 27)	58%
OT-Four Endpoints[4]	76	22% (11 of 49)	81% (22 of 27)	79%

-d S = -day survival; -d B = -day biomass; n = number of samples; OT = overall toxicity.

[2]The T_{10} values for Cd = 11.1 mg/kg DW; Pb = 150 mg/kg DW; Zn = 2083 mg/kg DW.

[3]Based on the results of all three toxicity tests (six endpoints).

[4]Based on the results of the amphipod and mussel toxicity tests (four endpoints).

[5]The T_{20} values for Cd = 17.3 mg/kg DW; Pb = 219 mg/kg DW; Zn = 2949 mg/kg DW.

Table 13. Predictive ability of the generic sediment quality guidelines for (ΣSEM-AVS)/f_{OC} and mean PEC-$Q_{METALS(1\%OC)}$ (USEPA 2000; 2005)[1].

COPC/COPC Mixture: Toxicity Test Endpoint Used to Evaluate SQGs	n	SQG_L	SQG_H	Incidence of Toxicity						
				<SQG_L	≥SQG_L	Correct Classification Rate for SQG_L	SQG_L-SQG_H	≤SQG_H	>SQG_H	Correct Classification Rate for SQG_H
(ΣSEM-AVS)/f_{OC}										
Amphipod 28-d S	76	130	3000	**12% (3 of 25)**	41% (21 of 51)	57%	21% (7 of 34)	**17% (10 of 59)**	**82% (14 of 17)**	**83%**
Amphipod 28-d B	76	130	3000	**4% (1 of 25)**	29% (15 of 51)	51%	18% (6 of 34)	**12% (7 of 59)**	**53% (9 of 17)**	**80%**
Mussel 28-d S	48	130	3000	22% (4 of 18)	50% (15 of 30)	60%	30% (6 of 20)	26% (10 of 38)	**90% (9 of 10)**	77%
Mussel 28-d B	48	130	3000	**6% (1 of 18)**	20% (6 of 30)	48%	10% (2 of 20)	**8% (3 of 38)**	40% (4 of 10)	**81%**
Midge 10-d S	70	130	3000	**19% (4 of 21)**	41% (20 of 49)	53%	28% (9 of 32)	25% (13 of 53)	**65% (11 of 17)**	73%
Midge 10-d B	70	130	3000	24% (5 of 21)	**63% (31 of 49)**	67%	59% (19 of 32)	45% (24 of 53)	**71% (12 of 17)**	59%
OT-Six Endpoints[2]	76	130	3000	48% (12 of 25)	**80% (41 of 51)**	71%	71% (24 of 34)	61% (36 of 59)	**100% (17 of 17)**	53%
OT-Four Endpoints[3]	76	130	3000	28% (7 of 25)	**51% (26 of 51)**	58%	32% (11 of 34)	31% (18 of 59)	**88% (15 of 17)**	74%
Mean PEC-$Q_{METAL(1\%OC)}$										
Amphipod 28-d S	76	0.1	5.0	**10% (1 of 10)**	35% (23 of 66)	42%	23% (12 of 53)	21% (13 of 63)	**85% (11 of 13)**	**80%**
Amphipod 28-d B	76	0.1	5.0	**10% (1 of 10)**	23% (15 of 66)	32%	15% (8 of 53)	**14% (9 of 63)**	**54% (7 of 13)**	**80%**
Mussel 28-d S	48	0.1	5.0	20% (1 of 5)	42% (18 of 43)	46%	30% (10 of 33)	29% (11 of 38)	**80% (8 of 10)**	73%
Mussel 28-d B	48	0.1	5.0	20% (1 of 5)	14% (6 of 43)	21%	9% (3 of 33)	**11% (4 of 38)**	30% (3 of 10)	77%
Midge 10-d S	70	0.1	5.0	**13% (1 of 8)**	37% (23 of 62)	43%	31% (15 of 49)	28% (16 of 57)	**62% (8 of 13)**	70%
Midge 10-d B	70	0.1	5.0	**13% (1 of 8)**	**56% (35 of 62)**	60%	55% (27 of 49)	49% (28 of 57)	**62% (8 of 13)**	53%
OT-Six Endpoints[2]	76	0.1	5.0	40% (4 of 10)	**74% (49 of 66)**	72%	70% (37 of 53)	65% (41 of 63)	**92% (12 of 13)**	45%
OT-Four Endpoints[3]	76	0.1	5.0	30% (3 of 10)	45% (30 of 66)	49%	34% (18 of 53)	33% (21 of 63)	**92% (12 of 13)**	71%

SQG = sediment quality guideline; SQG_L = SQG that identifies COPC concentrations with a low probability of being associated with toxicity to benthic invertebrates; SQG_H = SQG that identifies COPC concentrations with a high probability of being associated with toxicity to benthic invertebrates.

d = day; S = survival; B = biomass; n = number of samples; COPC = chemical of potential concern; PEC-Q = probable effect concentration-qotients; OC = organic carbon; ΣSEM-AVS = sum simultaneously extracted metals minus acid volatile sulfides; f_{OC} = fraction organic carbon.

[1]Bolded results indicate that the SQG met the individual evaluation criteria for the SQG_L, SQG_H, or correct classification rate.

[2]Based on the results of all three toxicity tests (six endpoints).

[3]Based on the results of the amphipod and mussel toxicity tests (four endpoints).

Table 14. Biological responses that occur within the two risk categories to the toxicity test organisms at the Tri-State Mining District site, identified using selected site-specific sediment toxicity thresholds (STTs).

Sediment Toxicity Threshold (STT)/ Sediment Toxicity Test	Endpoint Measured	Reference Samples mean (n)	Control-Adjusted Survival or Biomass: Low Risk mean ± SD (n)	Control-Adjusted Survival or Biomass: High Risk mean ± SD (n)
Cadmium (Toxicity Threshold of 11.1 mg/kg DW; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	100% ± 5.81% (45)	59.1% ± 42.4% (31)
28-d *Hyalella azteca*	Biomass	112.9% (10)	96.6% ± 32.4% (45)	61.6% ± 49.2% (31)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.3% ± 5.00% (28)	84.7% ± 23.5% (20)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.0% ± 19.1% (28)	73.0% ± 28.4% (20)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 10.6% (41)	92.7% ± 12.6% (29)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	84.6% ± 26.5% (41)	66.5% ± 24.5% (29)
Lead (Toxicity Threshold of 150 mg/kg DW; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	101% ± 5.91% (45)	59.1% ± 42.3% (31)
28-d *Hyalella azteca*	Biomass	112.9% (10)	98.6% ± 31.1% (45)	58.6% ± 48.0% (31)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	98.9% ± 5.21% (27)	85.8% ± 23.4% (21)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	90.9% ± 19.5% (27)	74.1% ± 27.9% (21)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 10.3% (41)	92.6% ± 12.9% (29)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	85.4% ± 26.8% (41)	65.5% ± 23.3% (29)
Zinc (Toxicity Threshold of 2083 mg/kg DW; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	99.5% ± 7.21% (53)	47.1% ± 42.7% (23)
28-d *Hyalella azteca*	Biomass	112.9% (10)	97.2% ± 32.5% (53)	47.9% ± 46.3% (23)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	97.8% ± 8.89% (32)	83.9% ± 24.7% (16)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.2% ± 18.3% (32)	68.1% ± 29.1% (16)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 9.94% (48)	90.1% ± 13.2% (22)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.3% ± 25.8% (48)	63.7% ± 25.4% (22)
Zinc (Toxicity Threshold of 2949 mg/kg DW; T_{20} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	99.5 ± 7.21 (53)	47.1 ± 42.7 (23)
28-d *Hyalella azteca*	Biomass	112.9% (10)	97.2 ± 32.5 (53)	47.9 ± 46.3 (23)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	97.8 ± 8.89 (32)	83.9 ± 24.7 (16)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.2 ± 18.3 (32)	68.1 ± 29.1 (16)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101 ± 9.94 (48)	90.1 ± 13.2 (22)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.3 ± 25.8 (48)	63.7 ± 25.4 (22)

Table 14. Biological responses that occur within the two risk categories to the toxicity test organisms at the Tri-State Mining District site, identified using selected site-specific sediment toxicity thresholds (STTs).

Sediment Toxicity Threshold (STT)/ Sediment Toxicity Test	Endpoint Measured	Reference Samples mean (n)	Control-Adjusted Survival or Biomass: Low Risk mean ± SD (n)	Control-Adjusted Survival or Biomass: High Risk mean ± SD (n)
ΣSEM-AVS (Toxicity Threshold of 13.7 µmol/g DW; T_{20} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	99.0 ± 9.72 (51)	52.3 ± 43.5 (25)
28-d *Hyalella azteca*	Biomass	112.9% (10)	95.1 ± 31.5 (51)	56.3 ± 52.5 (25)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.5 ± 4.81 (31)	81.7 ± 24.4 (17)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.3 ± 18.6 (31)	69.4 ± 28.7 (17)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101 ± 9.96 (47)	89.4 ± 12.2 (23)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.6 ± 25.8 (47)	63.9 ± 25.2 (23)
Mean PEC-Q (Toxicity Threshold of 0.556; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	100% ± 6.10% (47)	56.7% ± 42.7% (29)
28-d *Hyalella azteca*	Biomass	112.9% (10)	97.4% ± 31.3% (47)	57.9% ± 49.3% (29)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	98.7% ± 4.56% (28)	85.5% ± 24.2% (20)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	88.6% ± 15.8% (28)	76.4% ± 32.8% (20)
10-d *Chironomus dilutus*	Survival	104.7% (8)	100% ± 10.0% (44)	92.4% ± 13.6% (26)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	84.7% ± 26.2% (44)	64.3% ± 23.9% (26)
Mean PEC-Q $_{METAL}$ (Toxicity Threshold of 1.11; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	101% ± 5.65% (45)	59.0% ± 42.3% (31)
28-d *Hyalella azteca*	Biomass	112.9% (10)	97.2% ± 31.9% (45)	60.7% ± 48.9% (31)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.3% ± 5.08% (27)	85.3% ± 23.1% (21)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.1% ± 19.4% (27)	73.8% ± 27.8% (21)
10-d *Chironomus dilutus*	Survival	104.7% (8)	100% ± 10.2% (41)	93.3% ± 13.4% (29)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	85.9% ± 26.0% (41)	64.8% ± 23.8% (29)
ΣPEC-Q $_{Cd,Pb,Zn}$ (Toxicity Threshold of 7.92; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	100% ± 5.71% (48)	55.0% ± 42.5% (28)
28-d *Hyalella azteca*	Biomass	112.9% (10)	96.2% ± 31.4% (48)	58.6% ± 50.8% (28)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.3% ± 4.91% (29)	83.9% ± 23.9% (19)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	90.6% ± 18.9% (29)	72.8% ± 29.1% (19)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 10.3% (44)	91.4% ± 12.6% (26)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.6% ± 26.6% (44)	66.2% ± 24.5% (26)

Table 14. Biological responses that occur within the two risk categories to the toxicity test organisms at the Tri-State Mining District site, identified using selected site-specific sediment toxicity thresholds (STTs).

Sediment Toxicity Threshold (STT)/ Sediment Toxicity Test	Endpoint Measured	Reference Samples mean (n)	Control-Adjusted Survival or Biomass	
			Low Risk mean ± SD (n)	High Risk mean ± SD (n)
ΣSTT-Q $_{Cd,Cu,Pb,Zn}$ (Toxicity Threshold of 2.97; T_{10} Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	100% ± 6.08% (47)	56.6% ± 42.6% (29)
28-d *Hyalella azteca*	Biomass	112.9% (10)	97.5% ± 31.2% (47)	57.7% ± 49.2% (29)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.1% ± 5.07% (29)	84.2% ± 24.0% (19)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	90.6% ± 18.9% (29)	72.7% ± 29.1% (19)
10-d *Chironomus dilutus*	Survival	104.7% (8)	100% ± 10.1% (43)	92.9% ± 13.6% (27)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	85.7% ± 25.6% (43)	63.5% ± 23.9% (27)
T_{10} Values (derived using H. azteca Survival) for Cd, Pb, Zn used together [1]				
28-d *Hyalella azteca*	Survival	98.5% (10)	101% ± 5.42% (41)	63.1% ± 41.4% (35)
28-d *Hyalella azteca*	Biomass	112.9% (10)	99.1% ± 32.4% (41)	62.6% ± 46.7% (35)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	99.2% ± 5.24% (25)	86.7% ± 22.5% (23)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	91.5% ± 20.1% (25)	74.9% ± 26.8% (23)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 10.6% (37)	93.7% ± 12.6% (33)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	86.3% ± 26.9% (37)	66.8% ± 23.7% (33)
T_{20} Values (derived using H. azteca Survival) for Cd, Pb, Zn used together [1]				
28-d *Hyalella azteca*	Survival	98.5% (10)	100% ± 5.98% (49)	53.6% ± 42.7% (27)
28-d *Hyalella azteca*	Biomass	112.9% (10)	98.8% ± 32.8% (49)	52.4% ± 44.7% (27)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	97.7% ± 9.14% (30)	85.7% ± 23.8% (18)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	90.7% ± 18.6% (30)	71.6% ± 29.5% (18)
10-d *Chironomus dilutus*	Survival	104.7% (8)	100% ± 10.0% (44)	92.4% ± 13.6% (26)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	84.7% ± 26.2% (44)	64.3% ± 23.9% (26)

SD = standard deviation; n = number of samples; d = day.

[1]If the concentrations of all three metals were less than the T_{10}/T_{20} value samples were designated as low risk; if the concentrations of one or more of the metals was greater than the T_{10}/T_{20} value samples were designated as high risk.

Table 15. Biological responses that occur within the two risk categories to the toxicity test organisms at the Tri-State Mining District site, identified using selected site-specific pore-water toxicity thresholds (PWTTs).

Pore-water Toxicity Threshold (PWTT)/ Sediment Toxicity Test	Endpoint Measured	Reference Samples mean (n)	Control-adjusted Survival or Biomass	
			Low Risk mean ± SD (n)	High Risk mean ± SD (n)
PW-TU $_{ZINC}$ (Toxicity Threshold of 0.581; T $_{10}$ Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	98.8% ± 9.72% (52)	35.1% ± 39.4% (18)
28-d *Hyalella azteca*	Biomass	112.9% (10)	93.8% ± 32.2% (52)	38.1% ± 44.2% (18)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	98.8% ± 4.11% (31)	77.6% ± 27.7% (11)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	87.4% ± 15.7% (31)	61.6% ± 31.7% (11)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 9.51% (52)	86.4% ± 12.1% (18)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.0% ± 24.8% (52)	60.1% ± 26.8% (18)
PW-TU $_{ZINC}$ (Toxicity Threshold of 0.638; T $_{10}$ Value for H. azteca Survival)				
28-d *Hyalella azteca*	Survival	98.5% (10)	98.1% ± 10.4% (54)	29.4% ± 37.8% (16)
28-d *Hyalella azteca*	Biomass	112.9% (10)	94.4% ± 32.5% (54)	29.1% ± 35.7% (16)
28-d *Lampsilis siliquoidea*	Survival	100.7% (5)	98.7% ± 4.11% (32)	75.9% ± 28.5% (10)
28-d *Lampsilis siliquoidea*	Biomass	83.4% (5)	87.6% ± 15.5% (32)	58.4% ± 31.5% (10)
10-d *Chironomus dilutus*	Survival	104.7% (8)	101% ± 9.61% (54)	85.6% ± 12.1% (16)
10-d *Chironomus dilutus*	Biomass	105.7% (8)	83.6% ± 24.5% (54)	55.4% ± 24.6% (16)

SD = standard deviation; n = number of samples; d = day.

Figures

Figure 1. Map of the Tri-State Mining District study area.

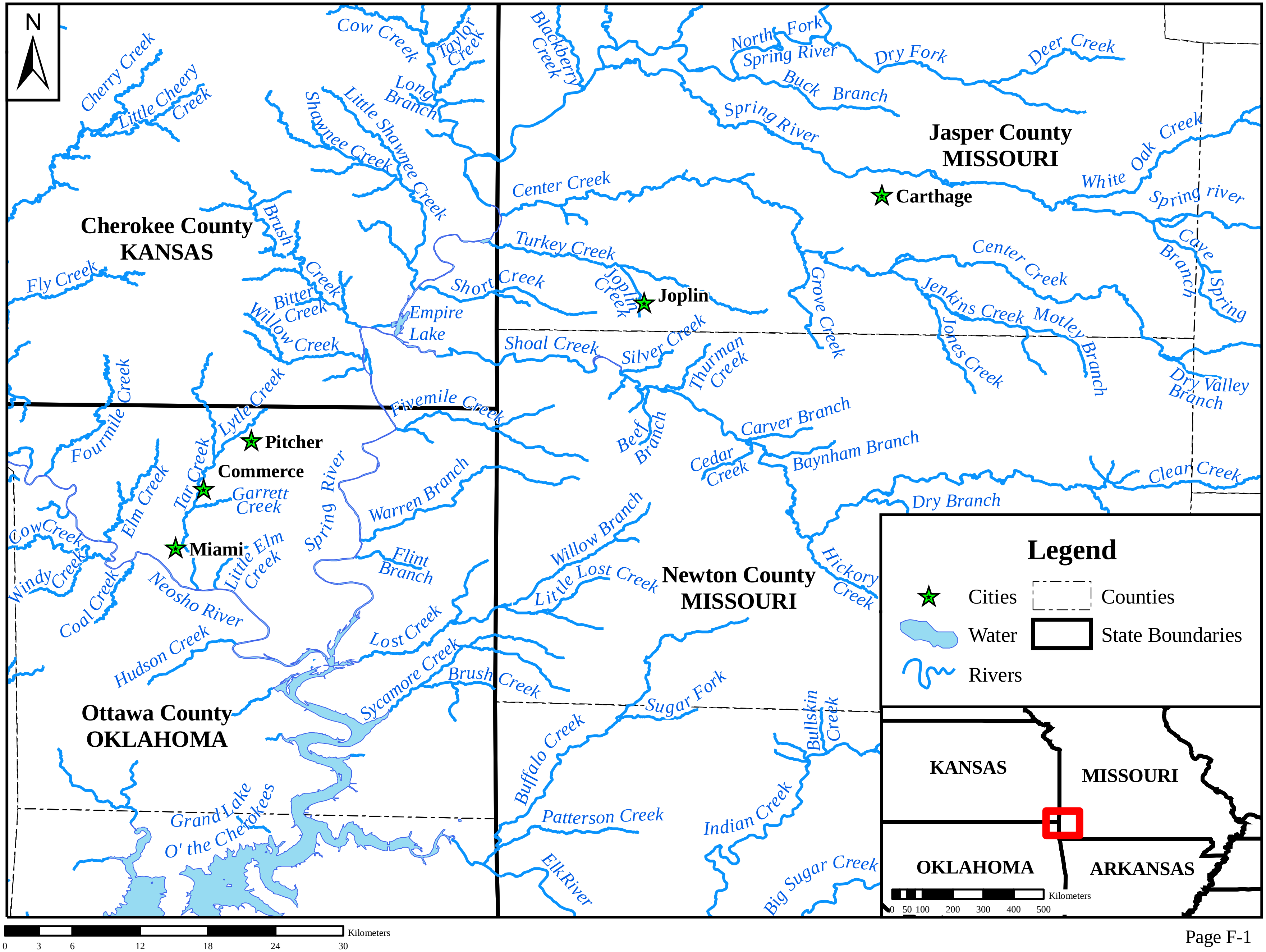


Figure 2. The framework for ecological risk assessment (modified from USEPA 1997).

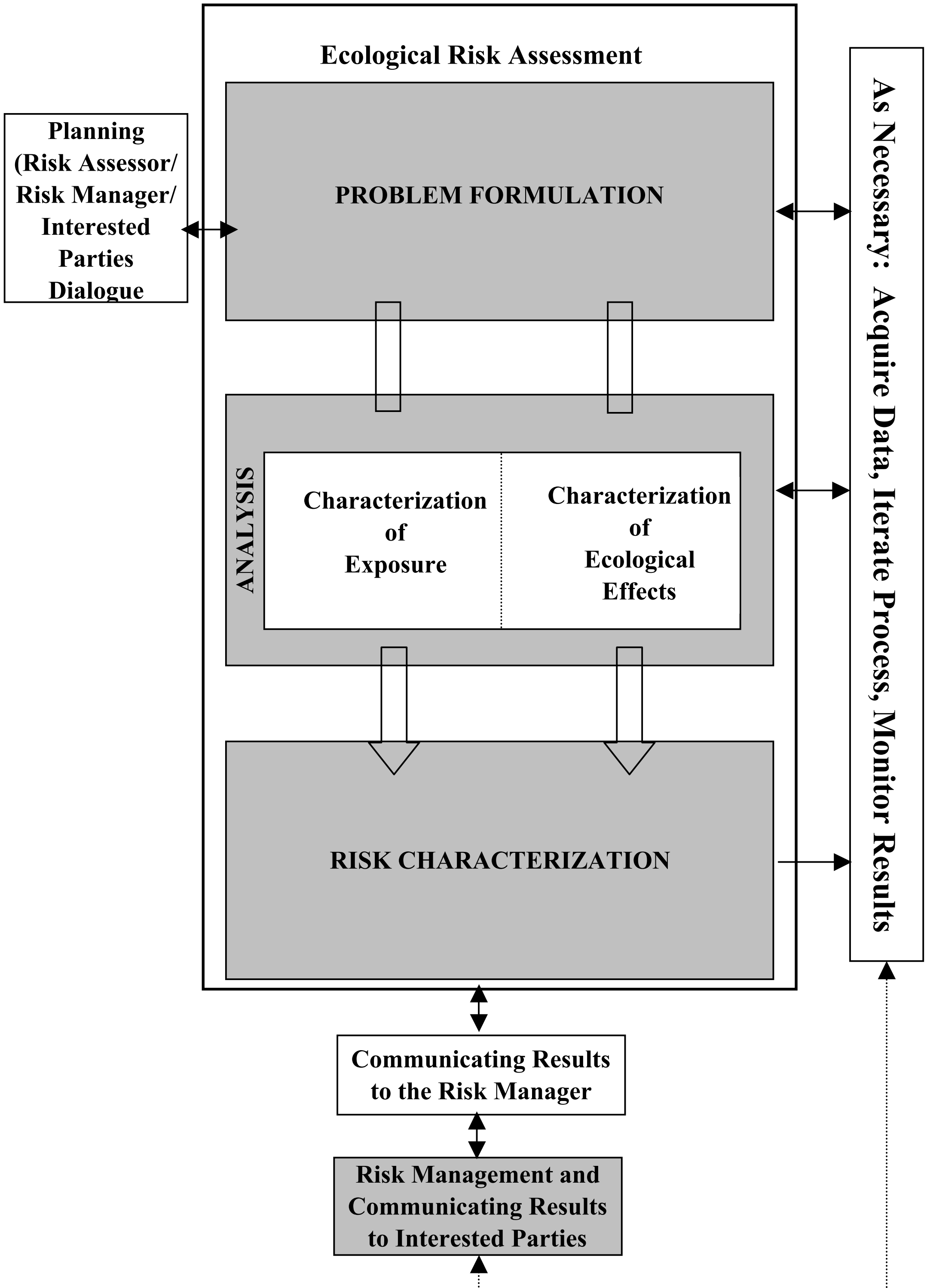
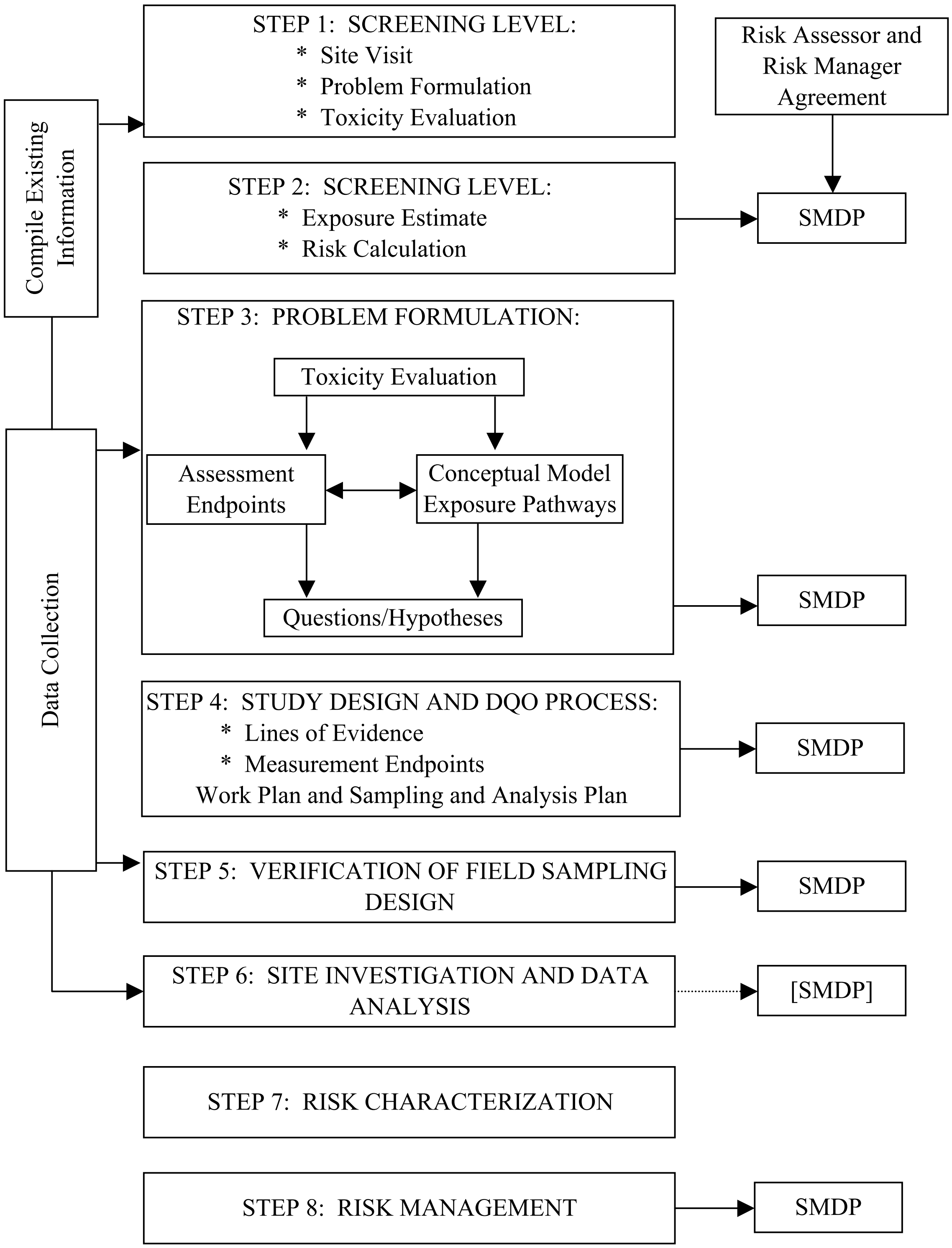


Figure 3. Eight-step ecological risk assessment process for Superfund (USEPA 1997).



SMDP = Scientific/Management Decision Point

Figure 4. Map of the Tri-State Mining District, showing the locations of the sediment samples selected to reflect reference conditions.

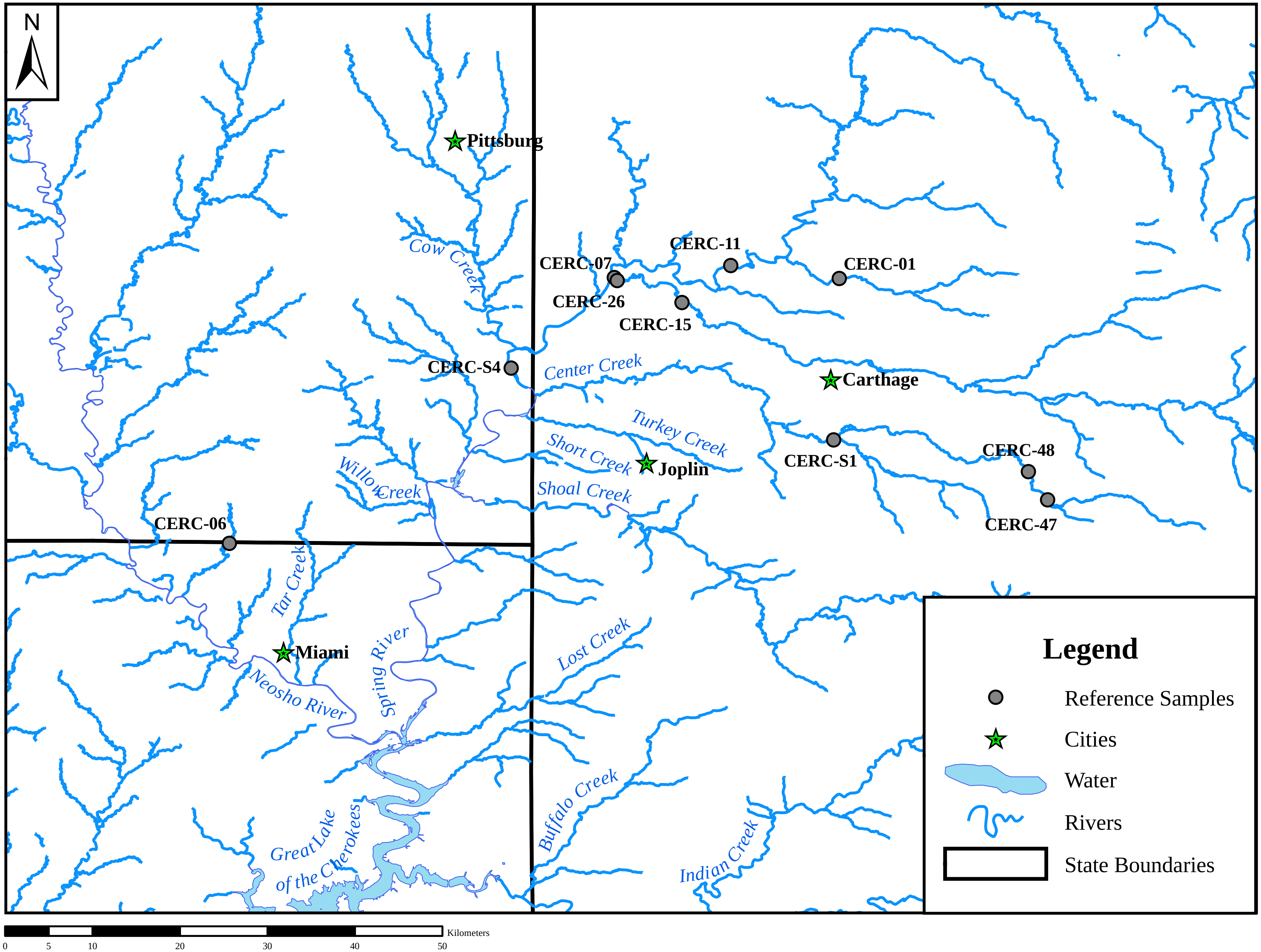


Figure 5. Plot illustrating the relationship between the concentration of cadmium (mg/kg DW) in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d expsoures to sediment samples from the Tri-State Mining District.

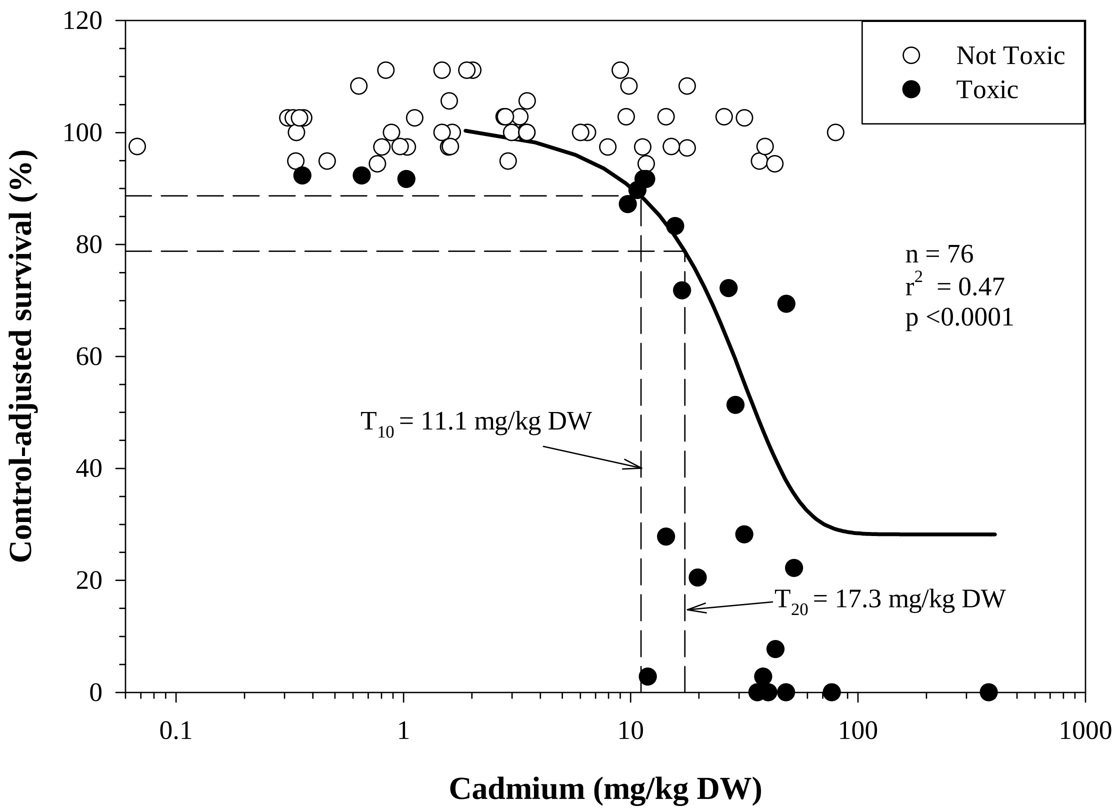


Figure 6. Plot illustrating the relationship between the concentration of lead (mg/kg DW) in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d expsoures to sediment samples from the Tri-State Mining District.

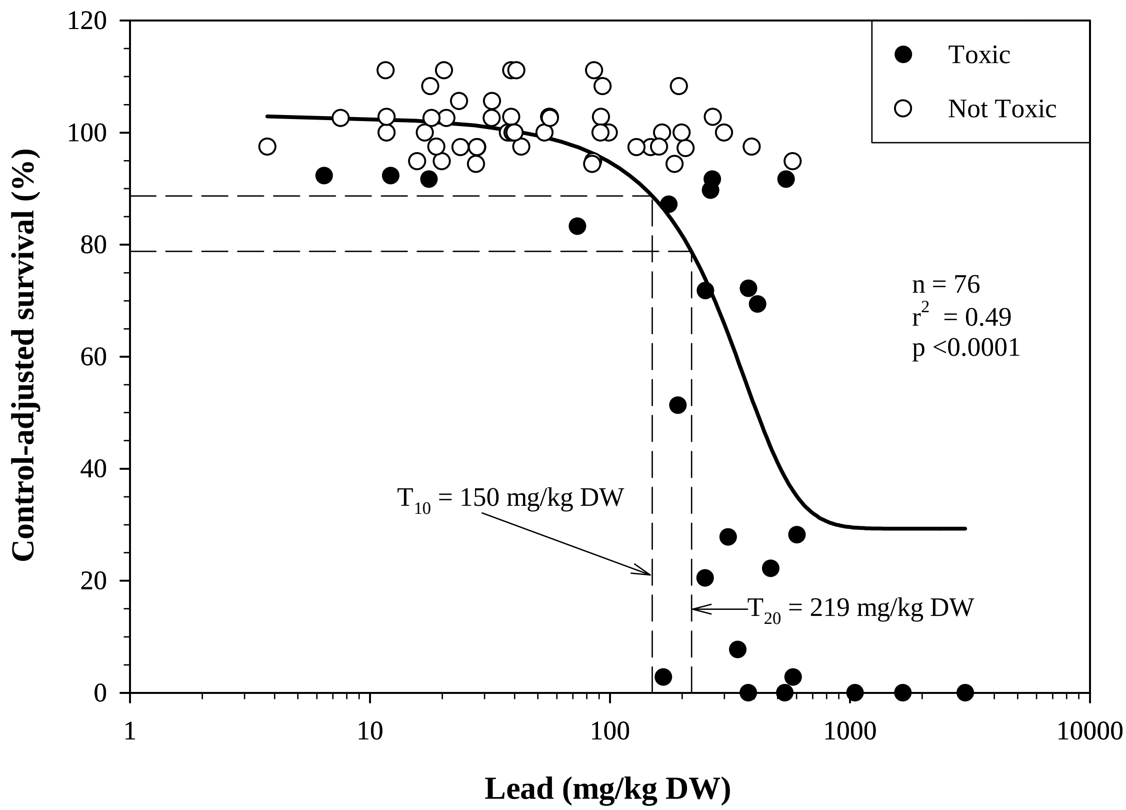


Figure 7. Plot illustrating the relationship between the concentration of zinc (mg/kg DW) in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d expsoures to sediment samples from the Tri-State Mining District.

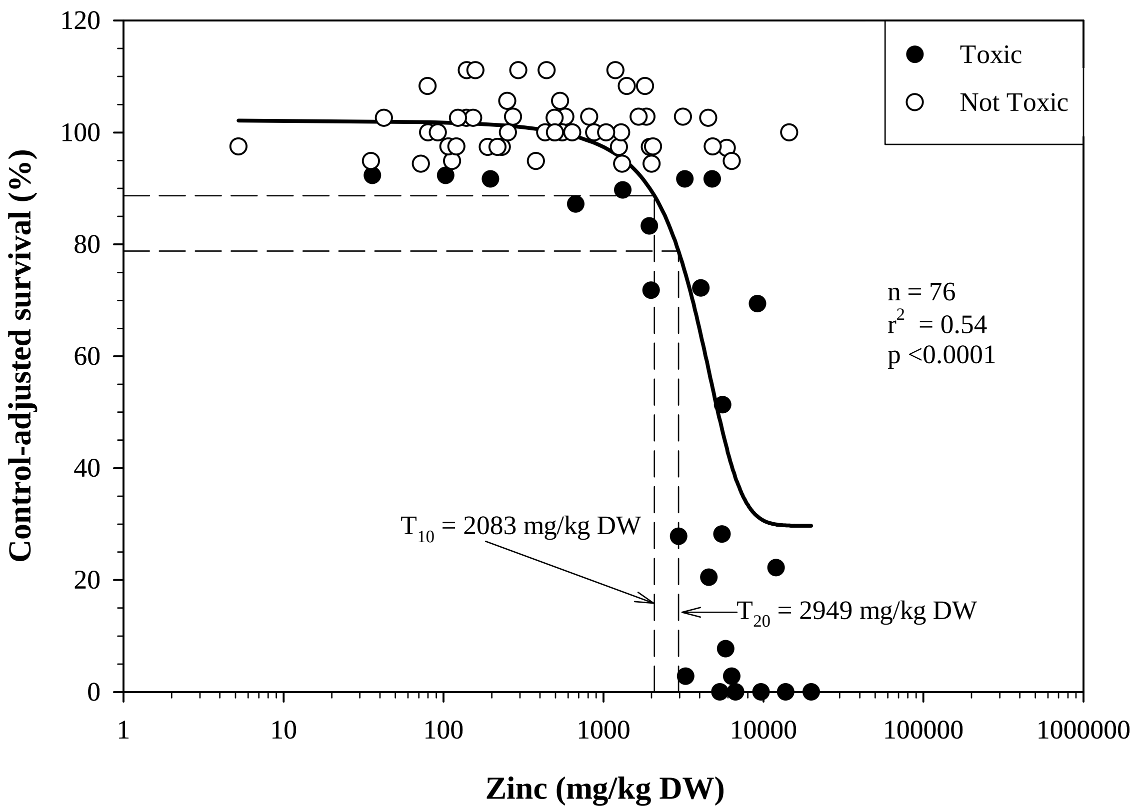


Figure 8. Plot illustrating the relationship between the concentration of ΣSEM-AVS (µmol/g DW) in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

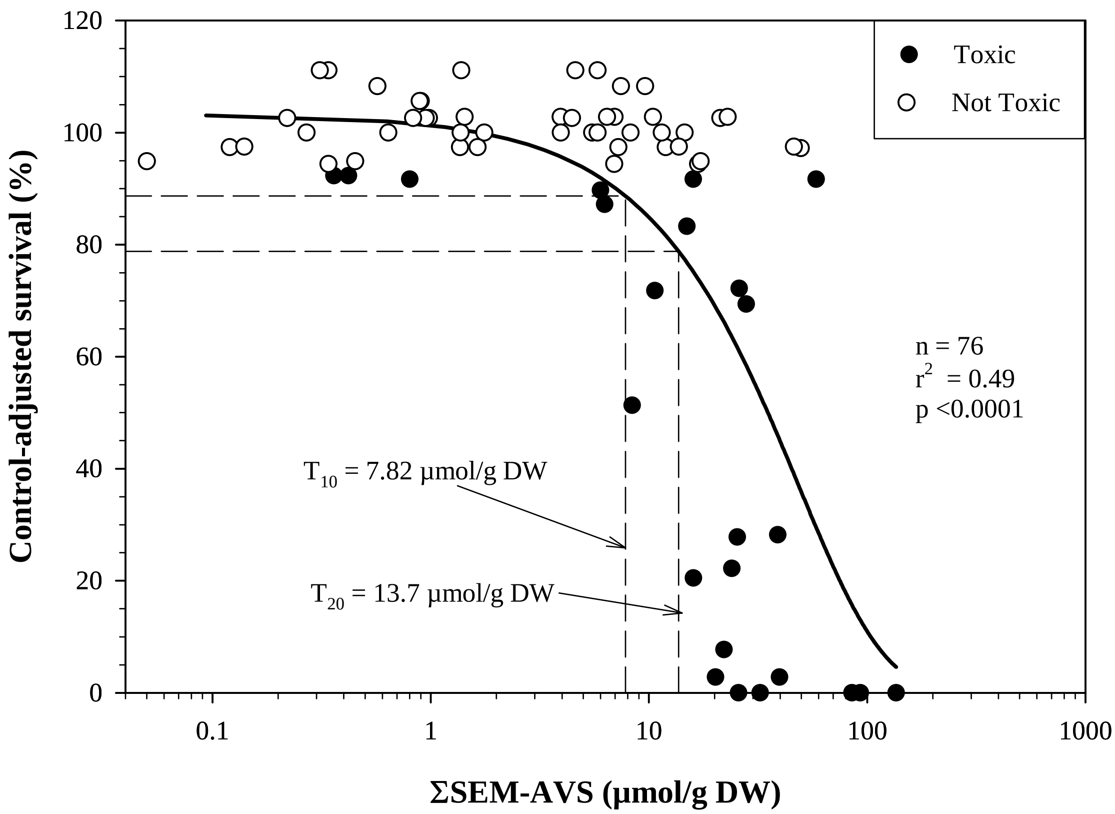


Figure 9. Plot illustrating the relationship between the concentration of mean PEC-Q in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

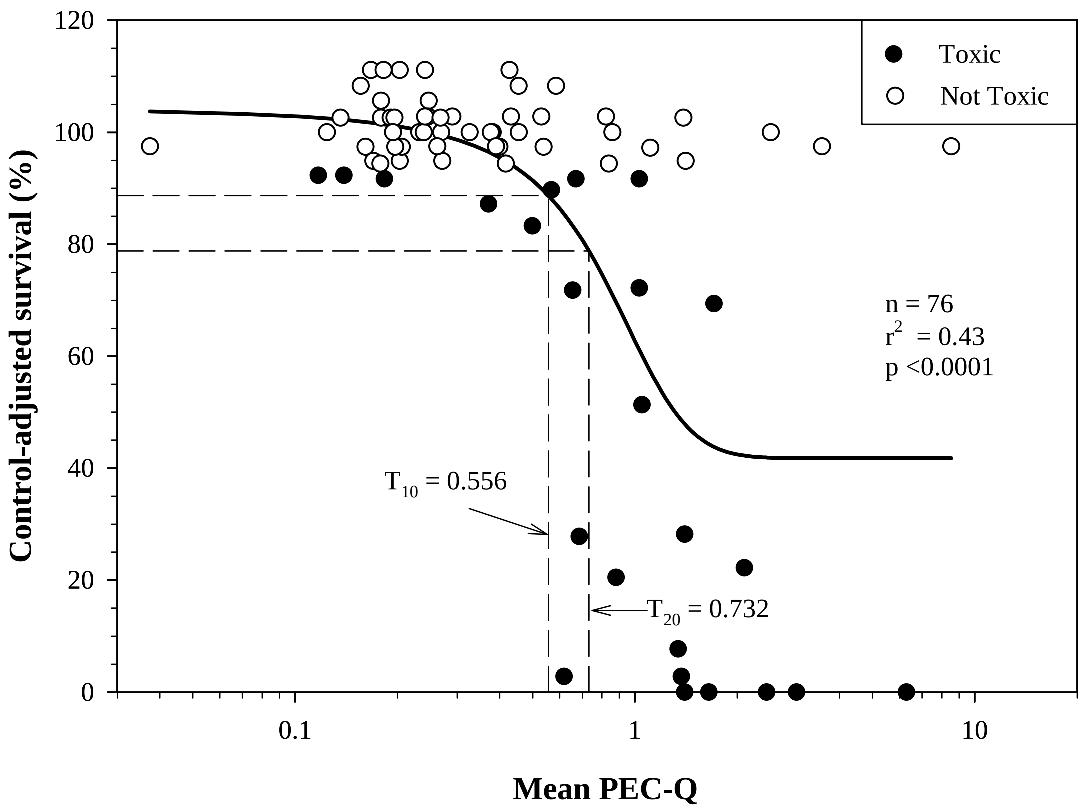


Figure 10. Plot illustrating the relationship between the concentration of mean PEC-Q_{METALS} in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-state Mining District.

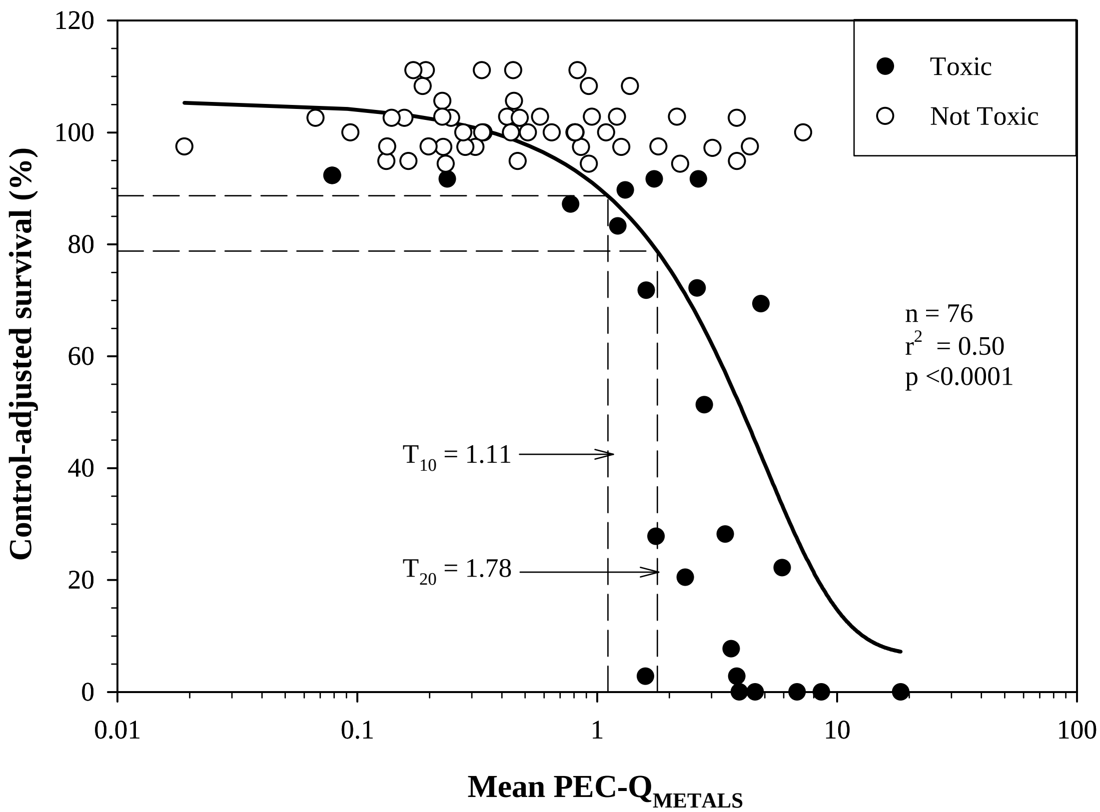


Figure 11. Plot illustrating the relationship between the concentration of $\Sigma PEC\text{-}Q_{Cd,Pb,Zn}$ in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyallela azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

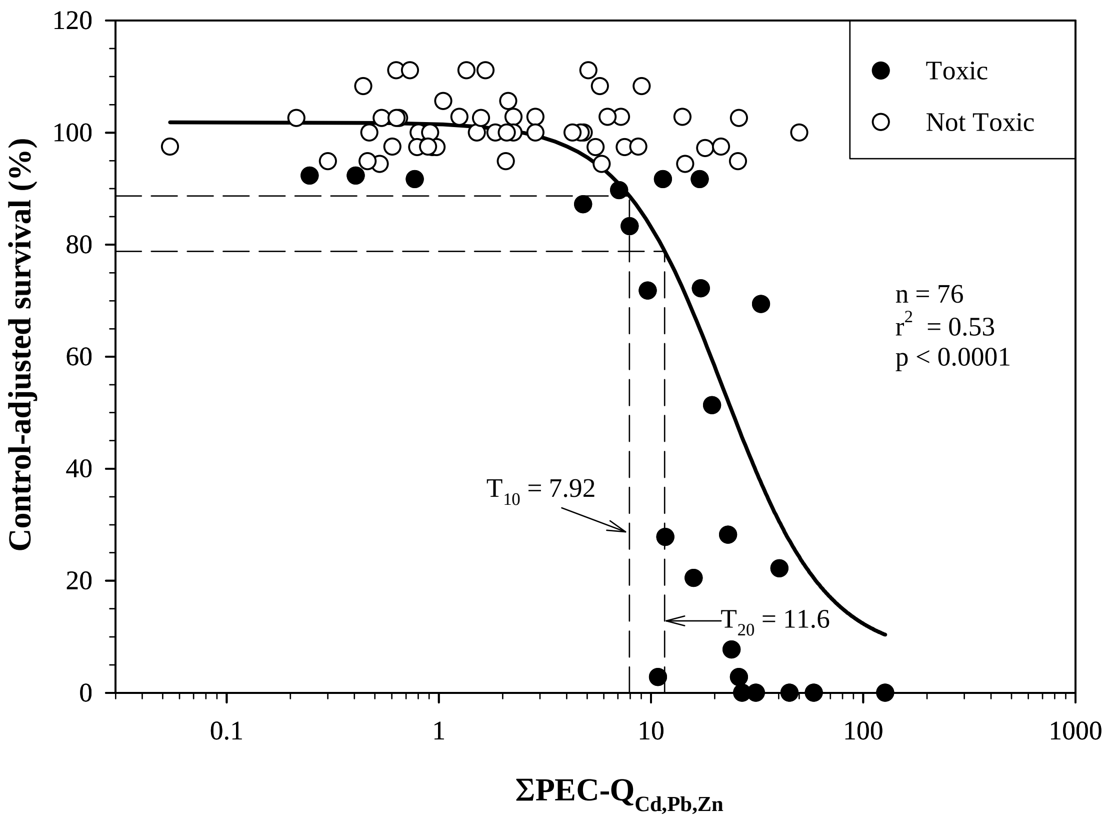


Figure 12. Plot illustrating the relationship between the concentration of $\Sigma STT\text{-}Q_{Cd,Cu,Pb,Zn}$ in sediment (<2 mm) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

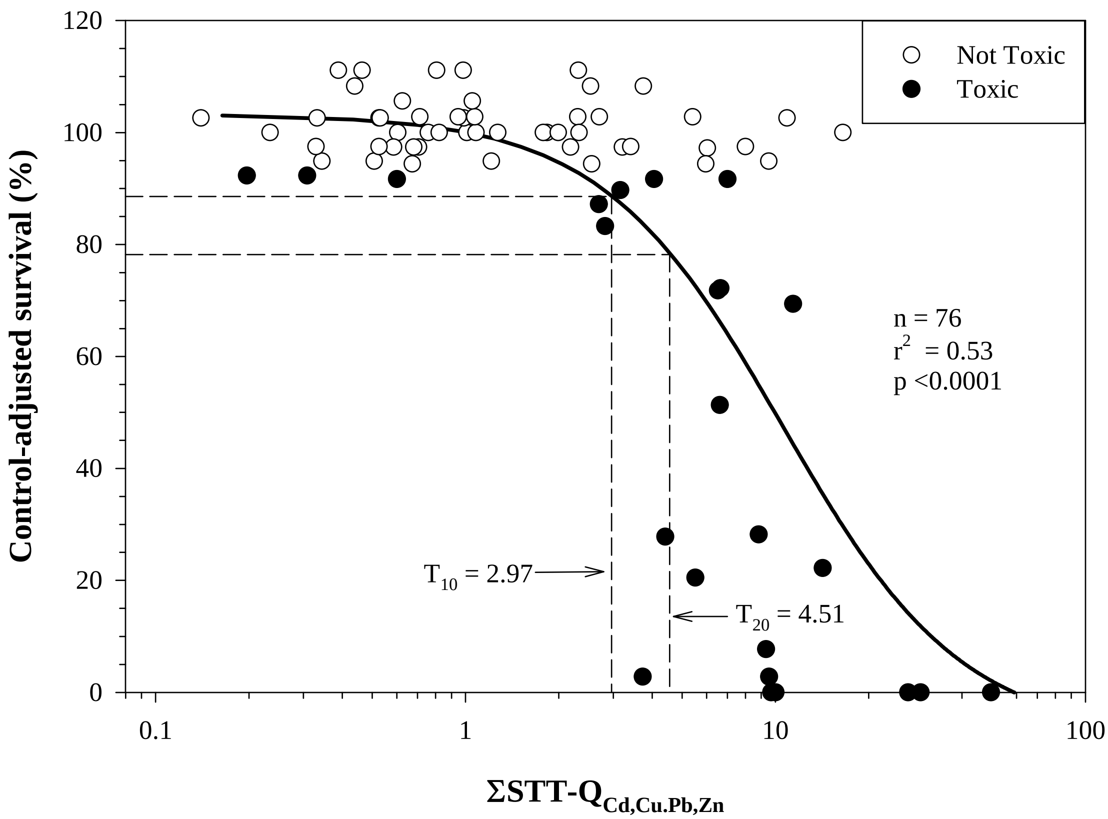


Figure 13. Plot illustrating the relationship between the concentration of copper (mg/kg DW) in sediment (<2 mm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

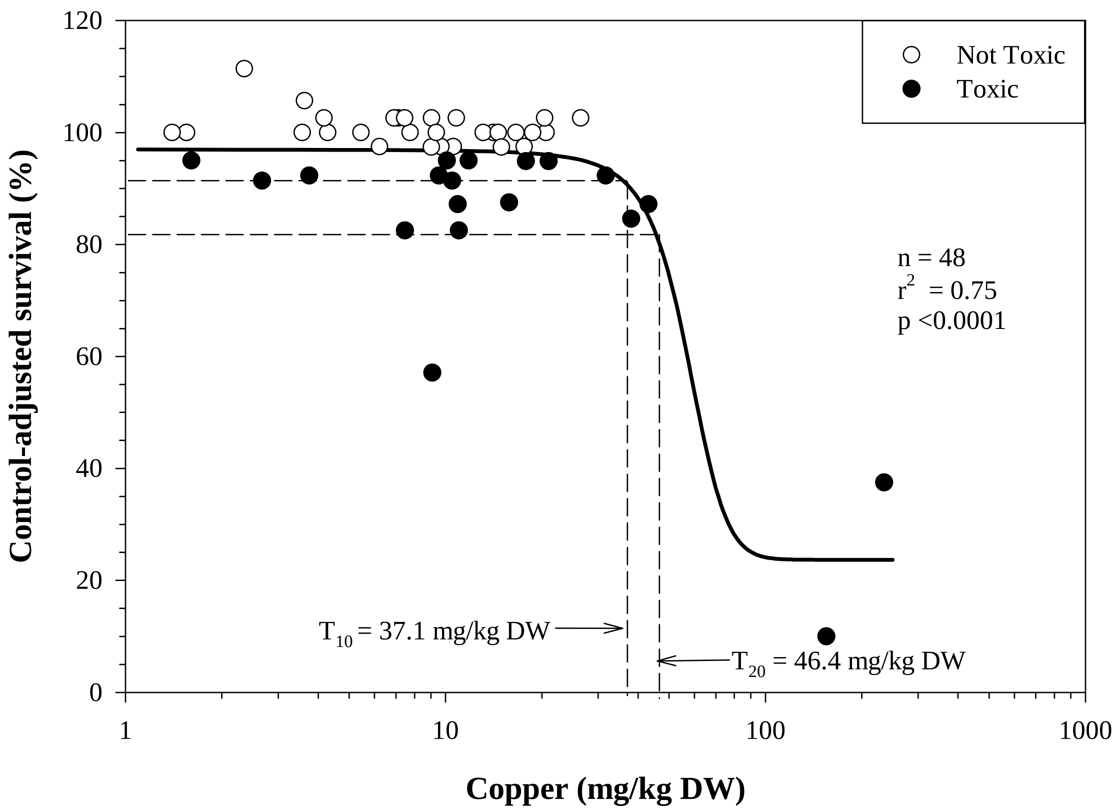


Figure 14. Plot illustrating the relationship between the concentration of lead (mg/kg DW) in sediment (<2 mm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

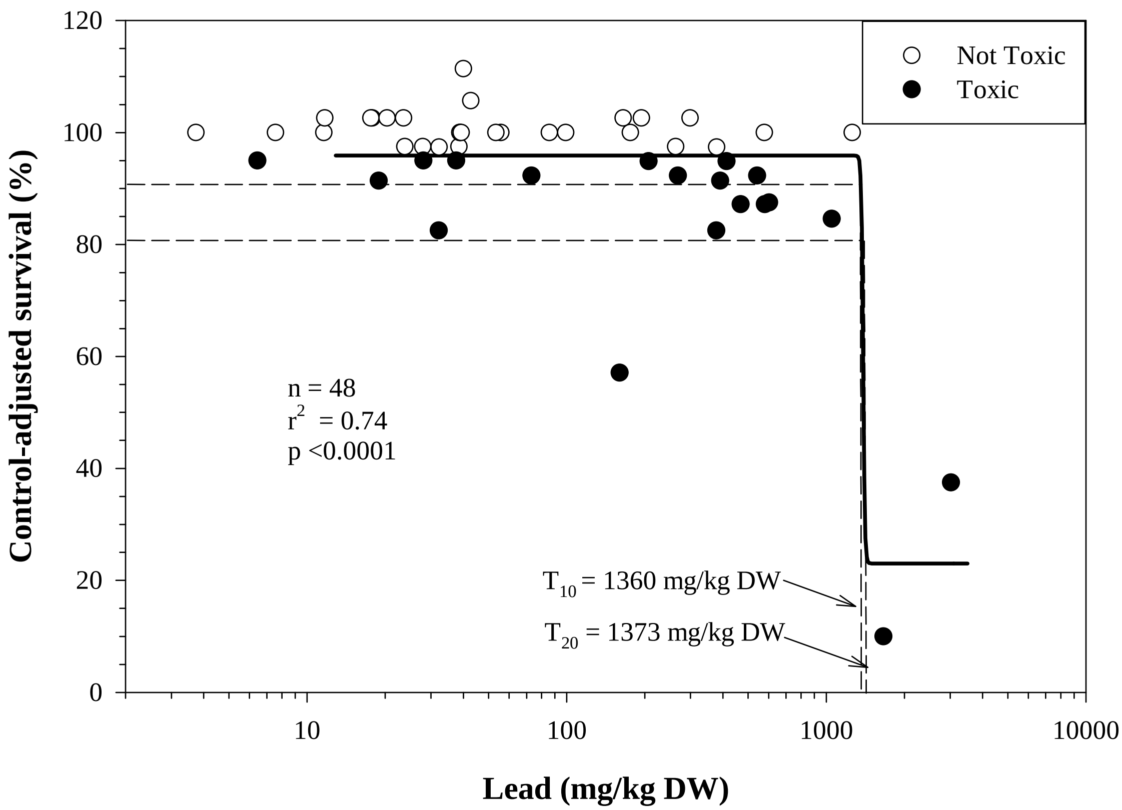


Figure 15. Plot illustrating the relationship between the concentration of ΣSEM-AVS (µmol/g DW) in sediment (<2 mm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

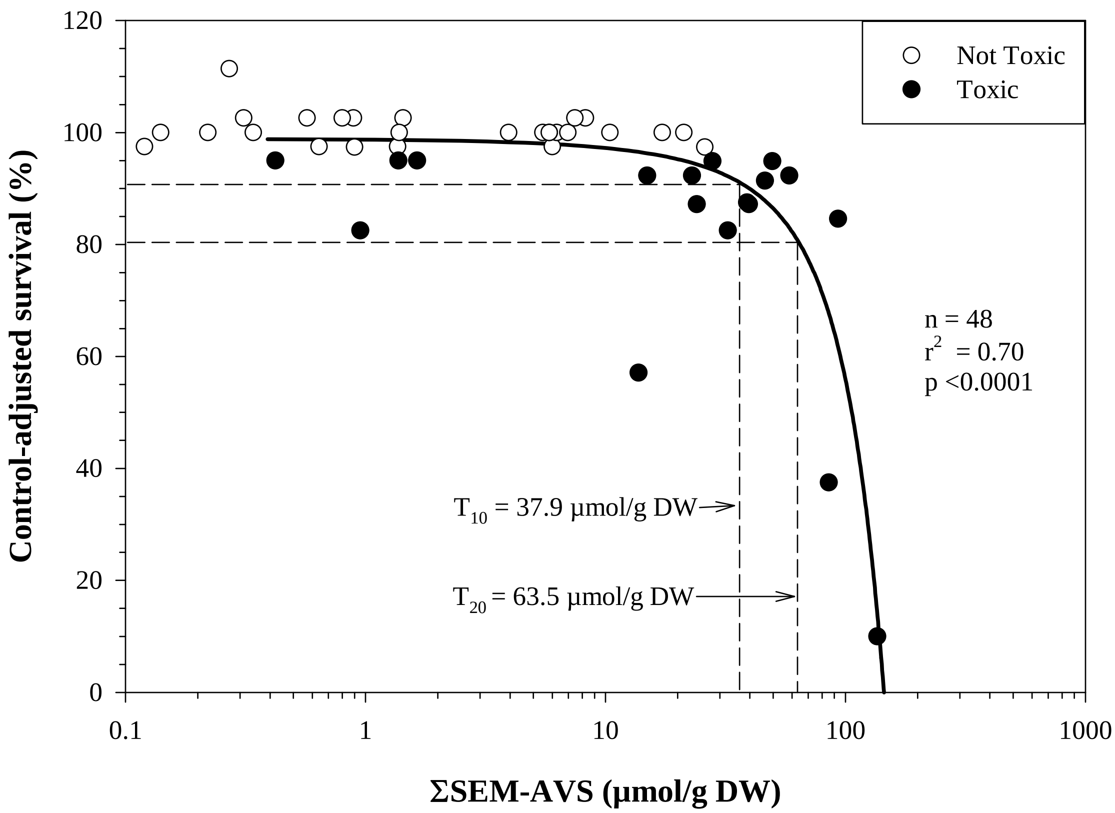


Figure 16. Plot illustrating the relationship between the concentration of copper (mg/kg DW) in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

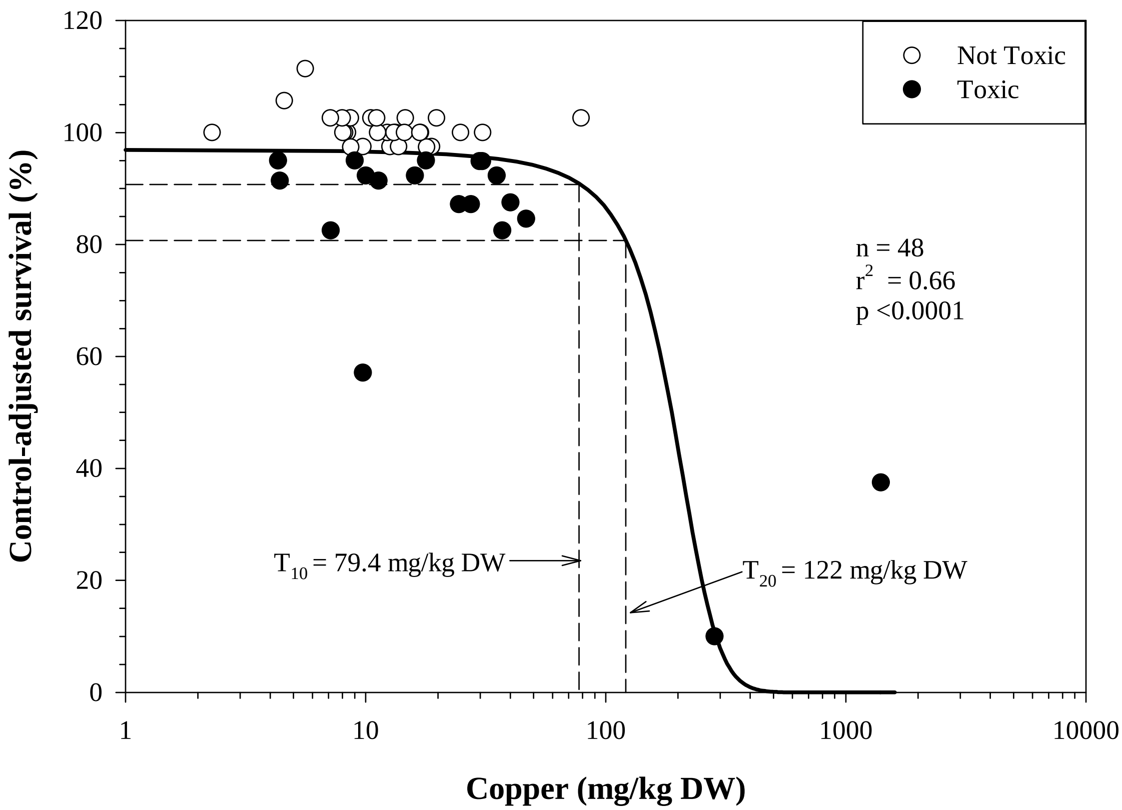


Figure 17. Plot illustrating the relationship between the concentration of zinc (mg/kg DW) in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

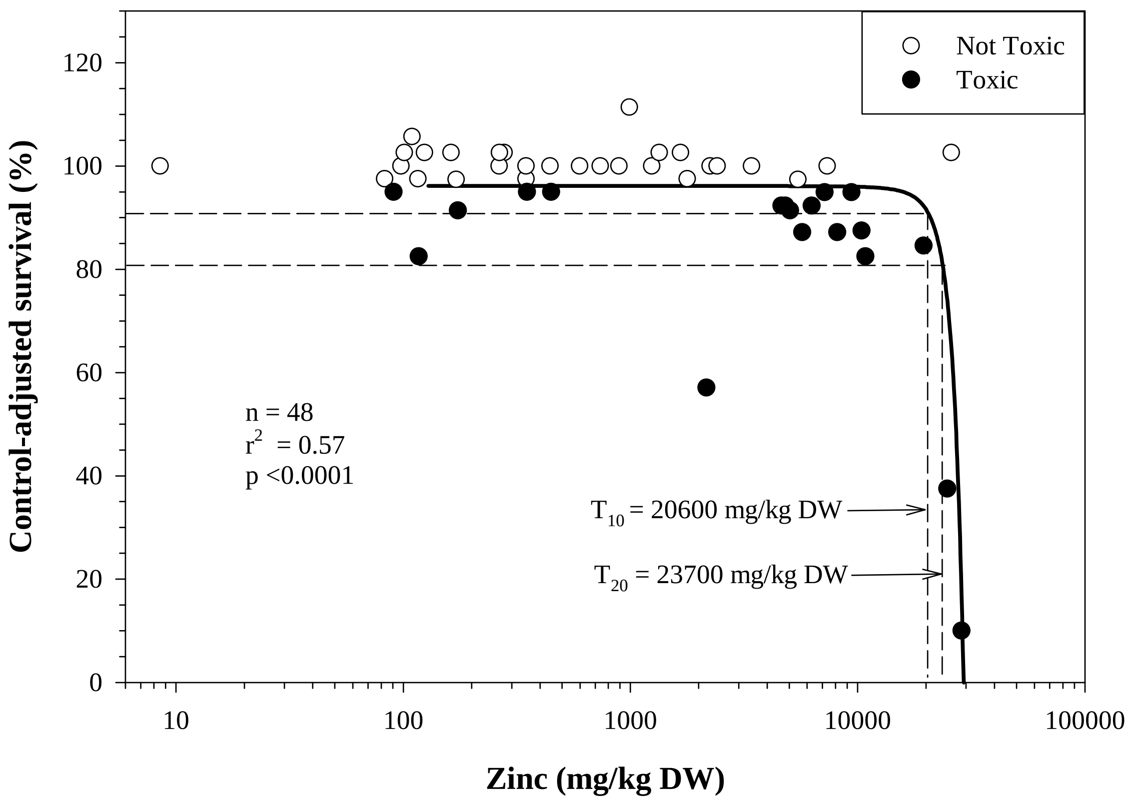


Figure 18. Plot illustrating the relationship between the concentration of ΣSEM-AVS (µmol/g DW) in sediment (<2 mm and <250 µm size fraction; see Table 4 for additional details) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

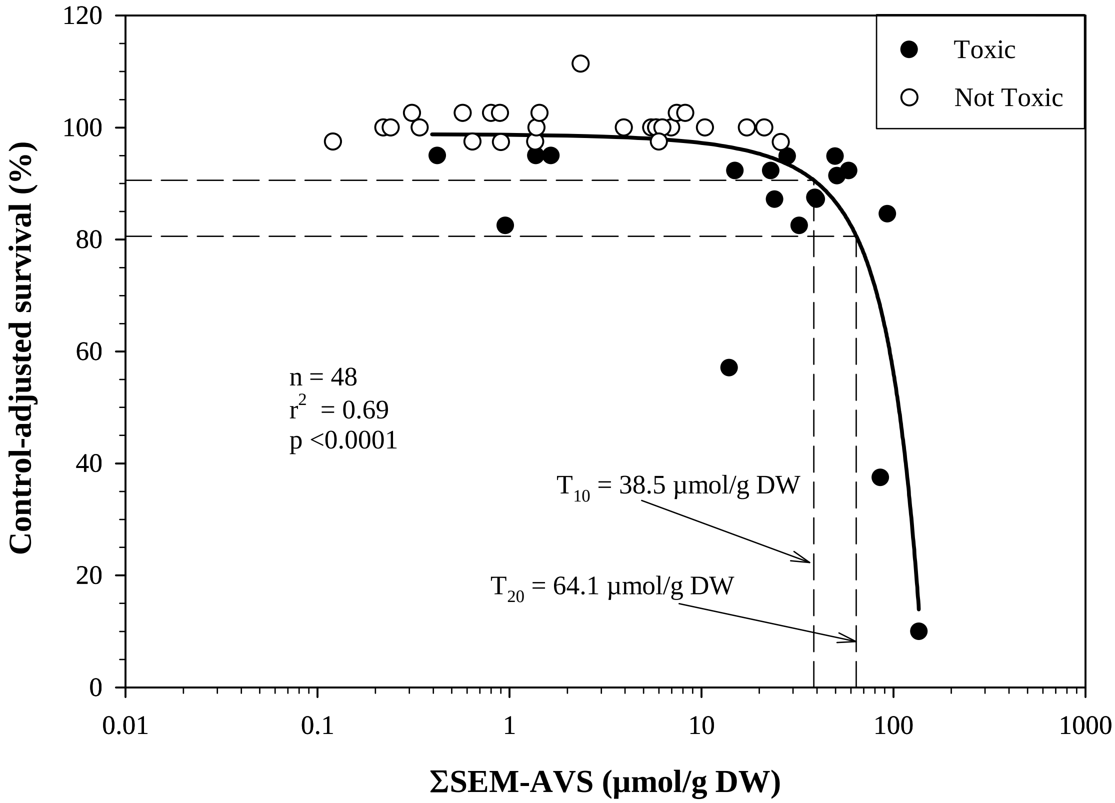


Figure 19. Plot illustrating the relationship between the concentration of mean PEC-Q_{METALS} in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

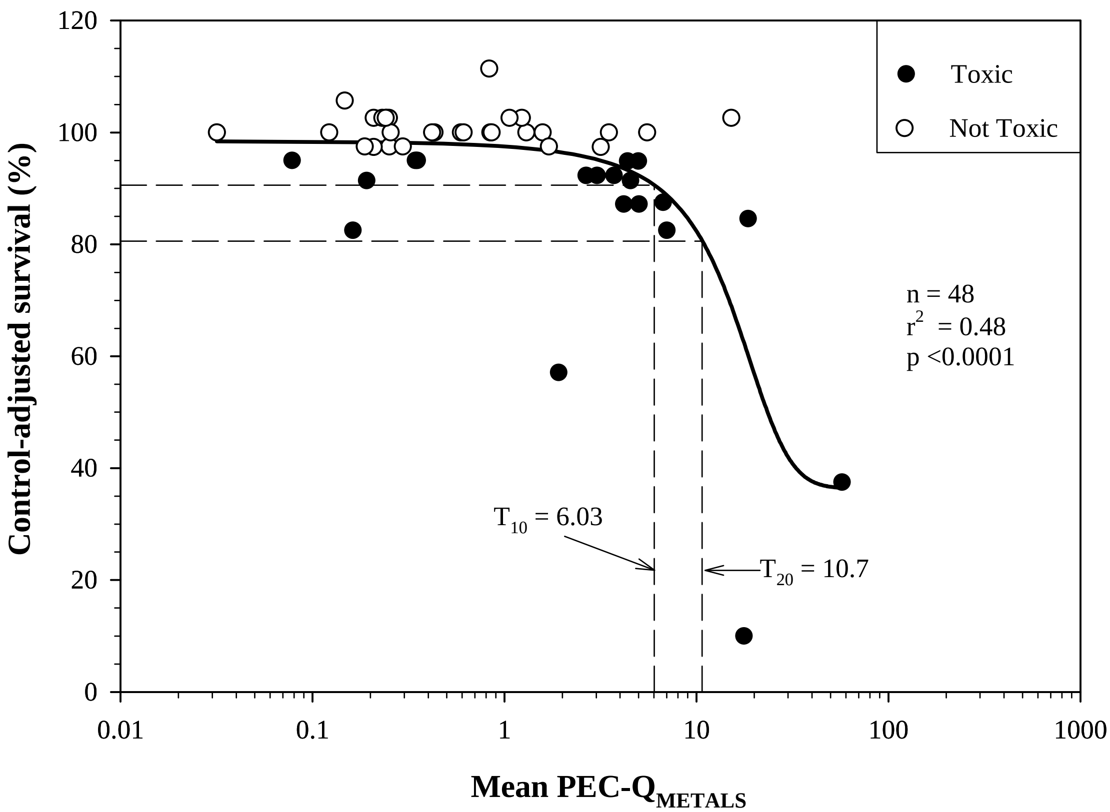


Figure 20. Plot illustrating the relationship between the concentration of mean PEC-$Q_{METALS(1\%OC)}$ in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

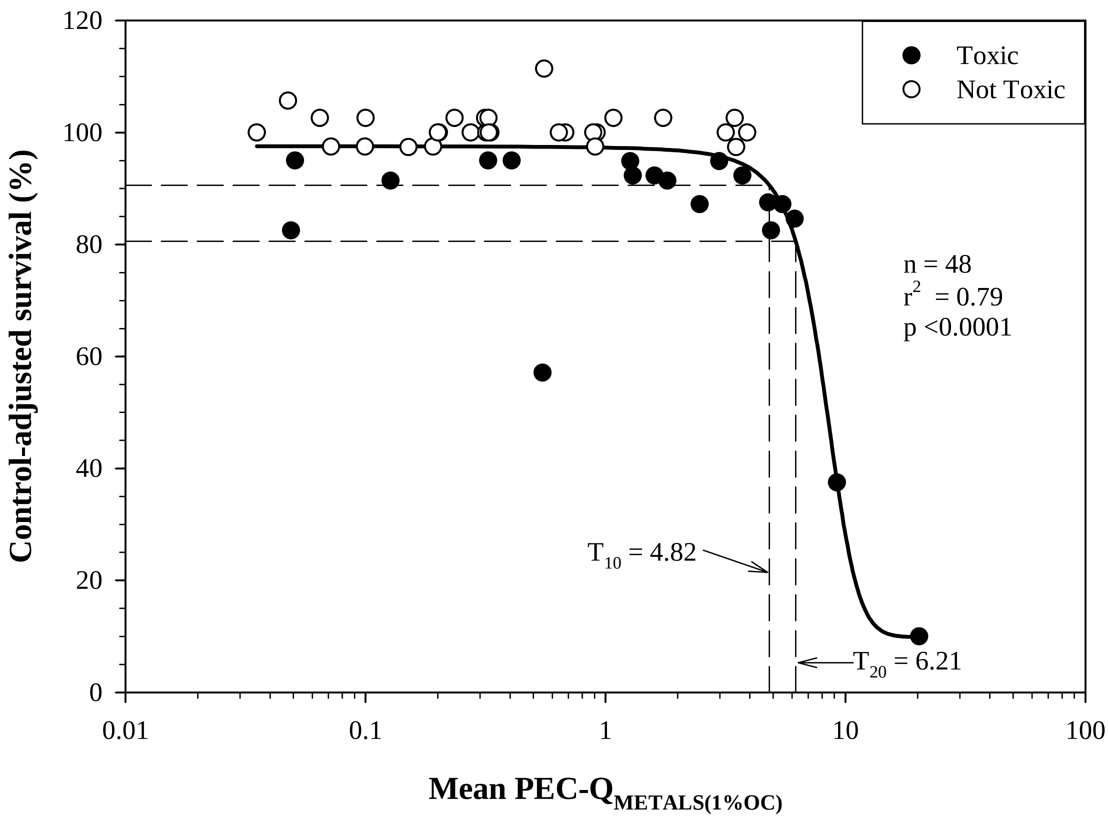


Figure 21. Plot illustrating the relationship between the concentration of ΣPEC-$Q_{Cd,Pb,Zn}$ in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsillis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

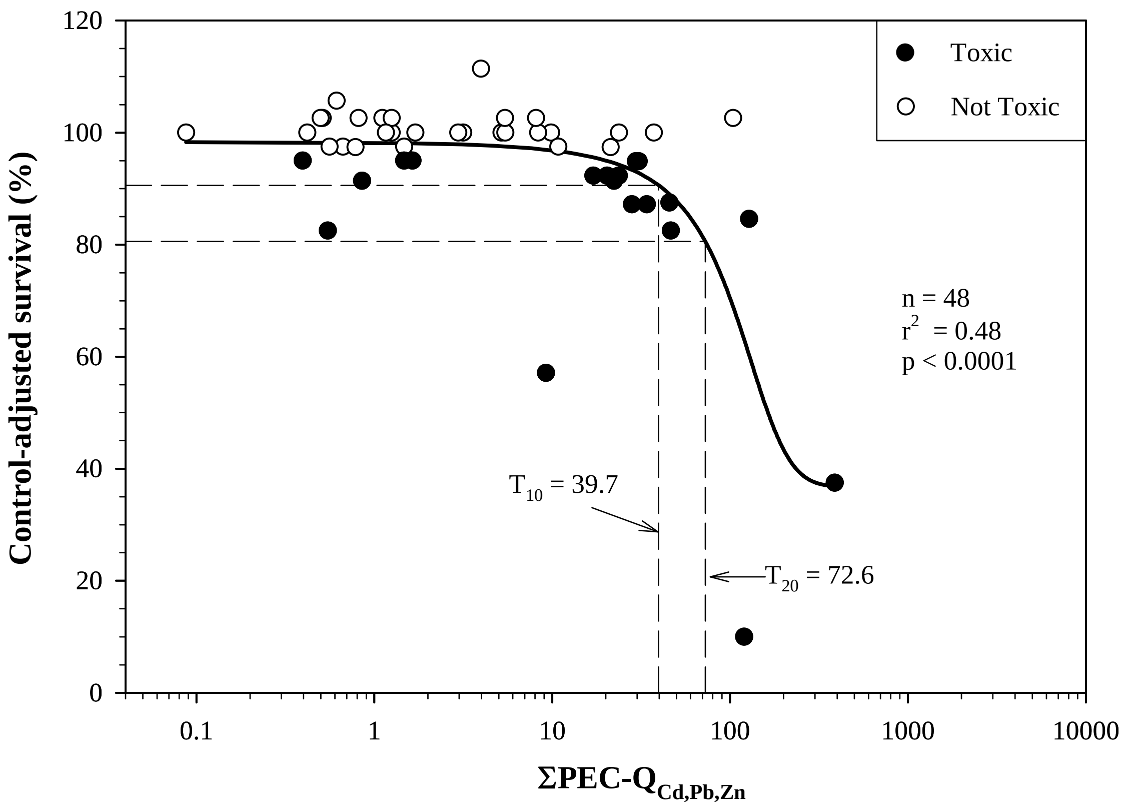


Figure 22. Plot illustrating the relationship between the concentration of ΣSTT-$Q_{Cd,Cu,Pb,Zn}$ in sediment (<250 µm) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

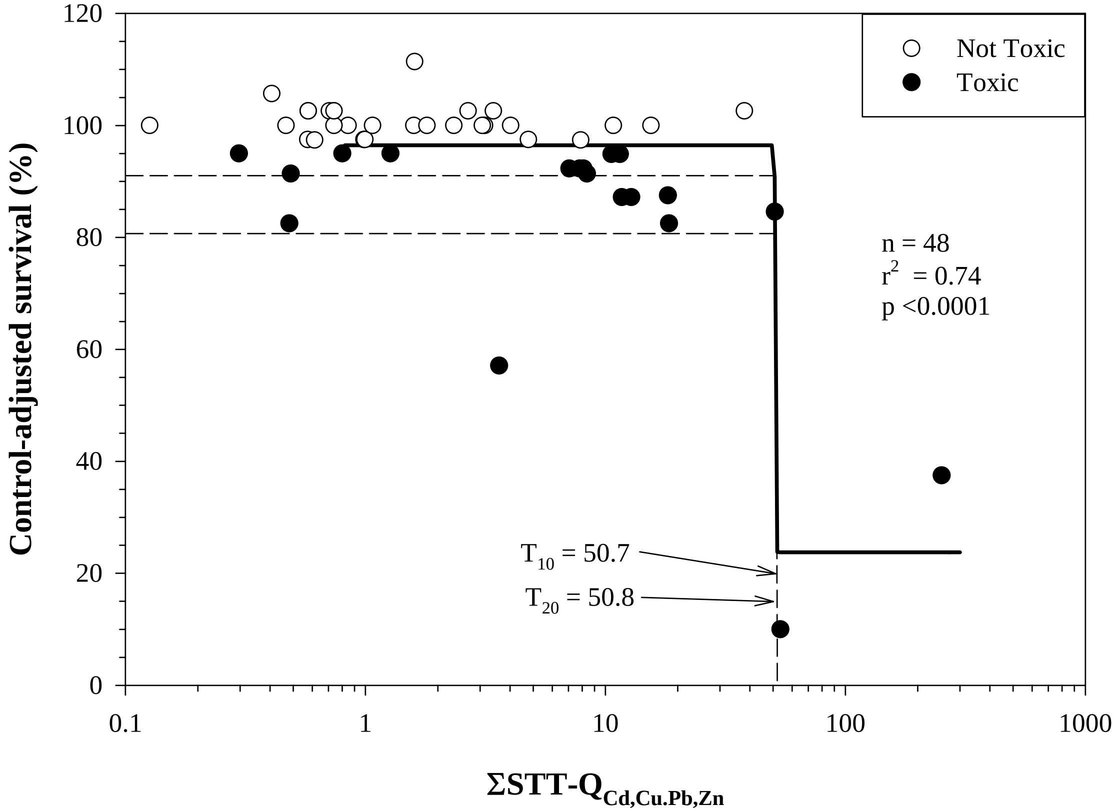


Figure 23. Plot illustrating the relationship between the concentration of copper (mg/kg DW) in sediment (<2 mm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

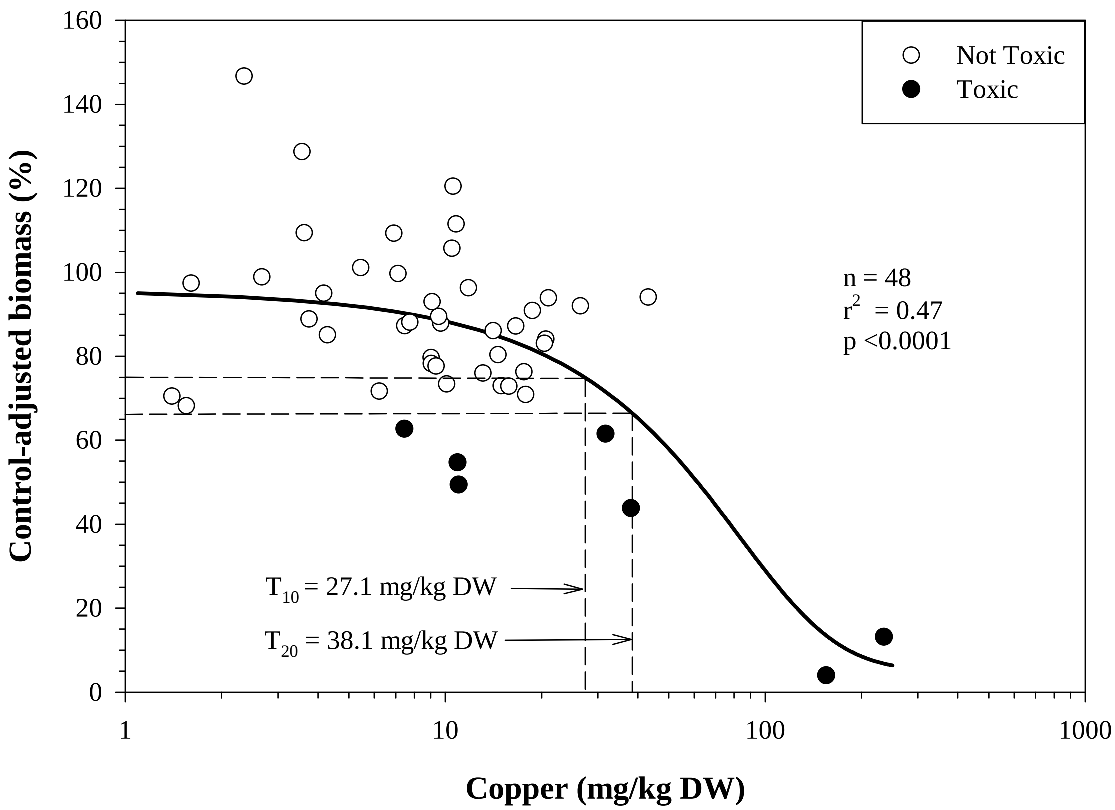


Figure 24. Plot illustrating the relationship between the concentration of lead (mg/kg DW) in sediment (<2 mm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

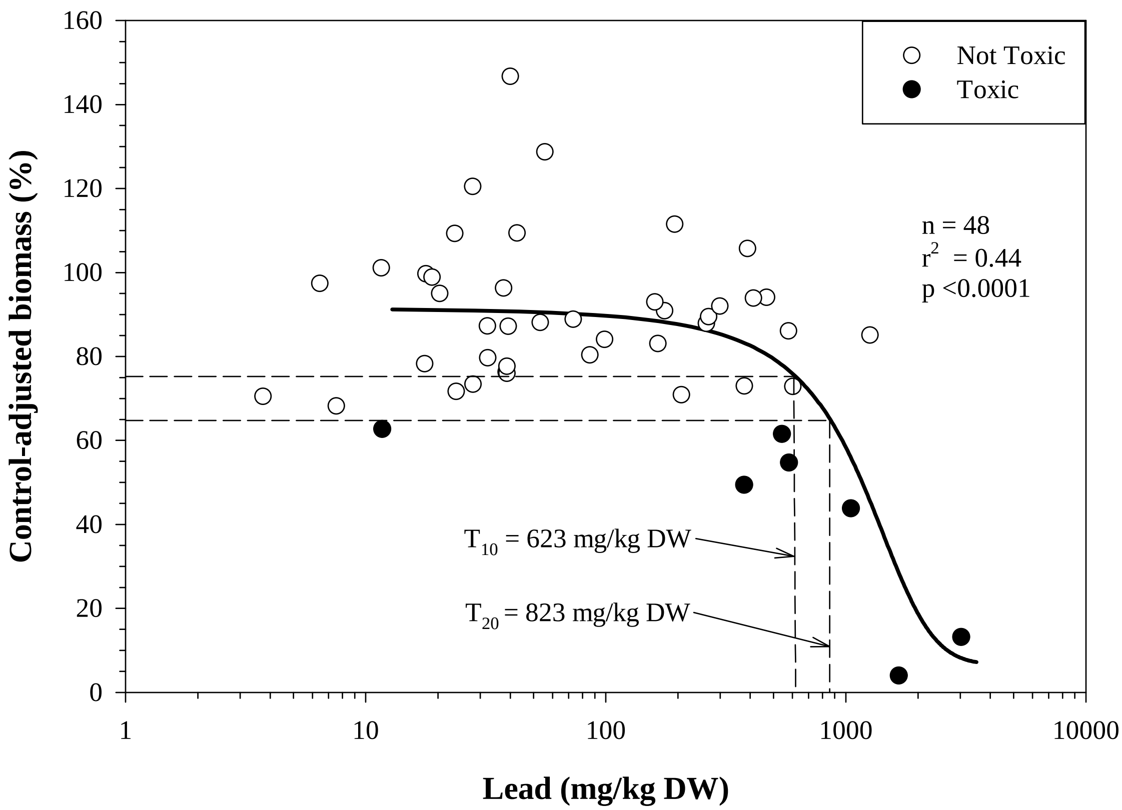


Figure 25. Plot illustrating the relationship between the concentration of ΣSEM-AVS (µmol/g DW) in sediment (<2 mm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

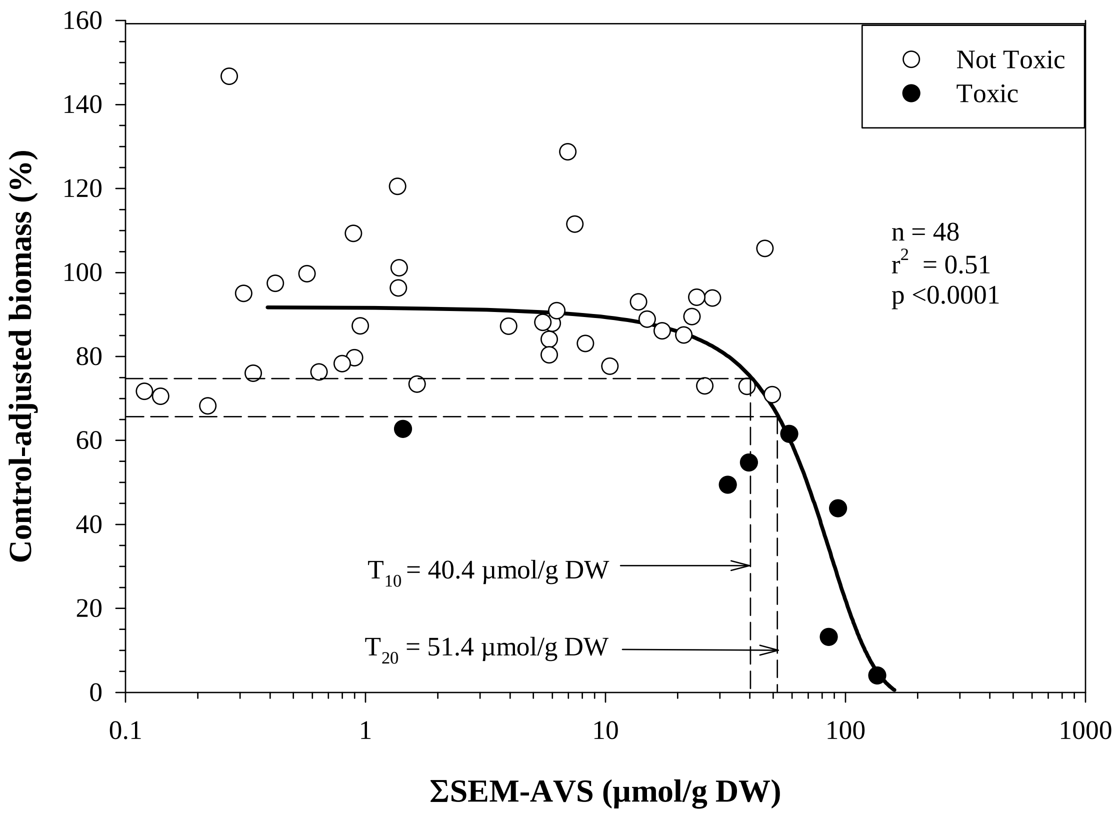


Figure 26. Plot illustrating the relationship between the concentration of $\Sigma STT\text{-}Q_{Cd,Cu,Pb,Zn}$ in sediment (<2 mm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

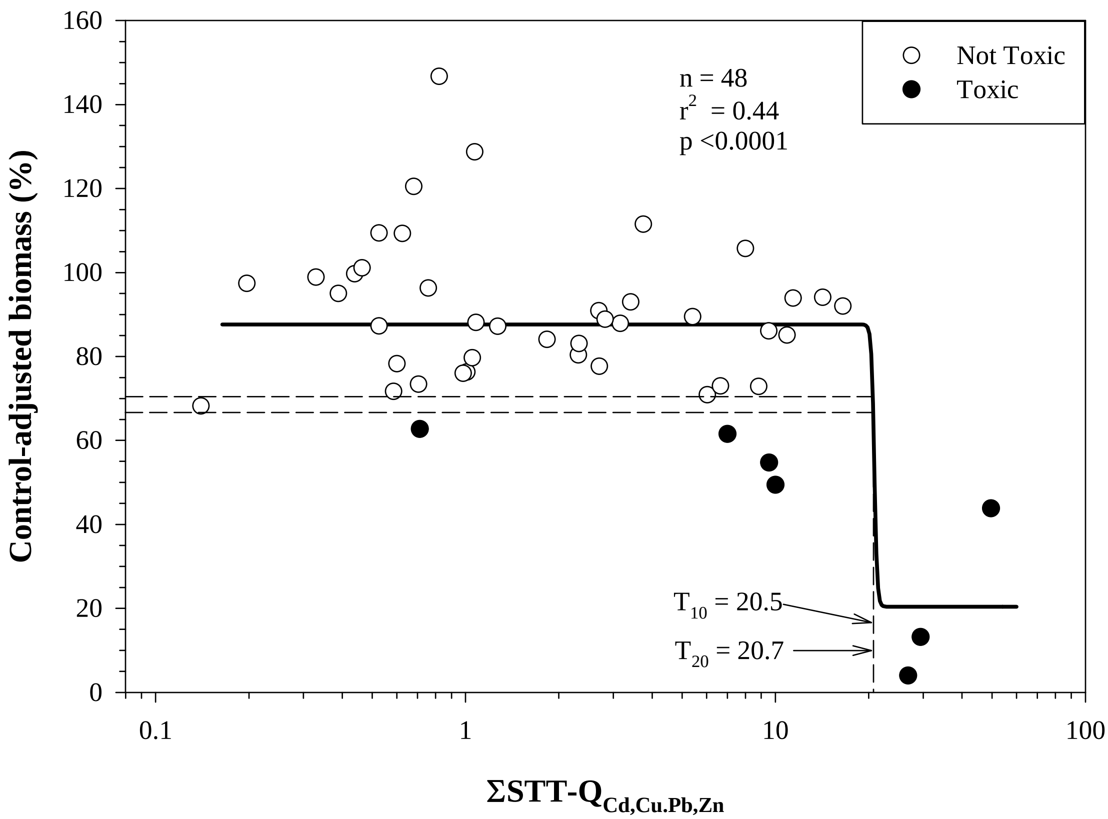


Figure 27. Plot illustrating the relationship between the concentration of copper (mg/kg DW) in sediment (<250 µm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

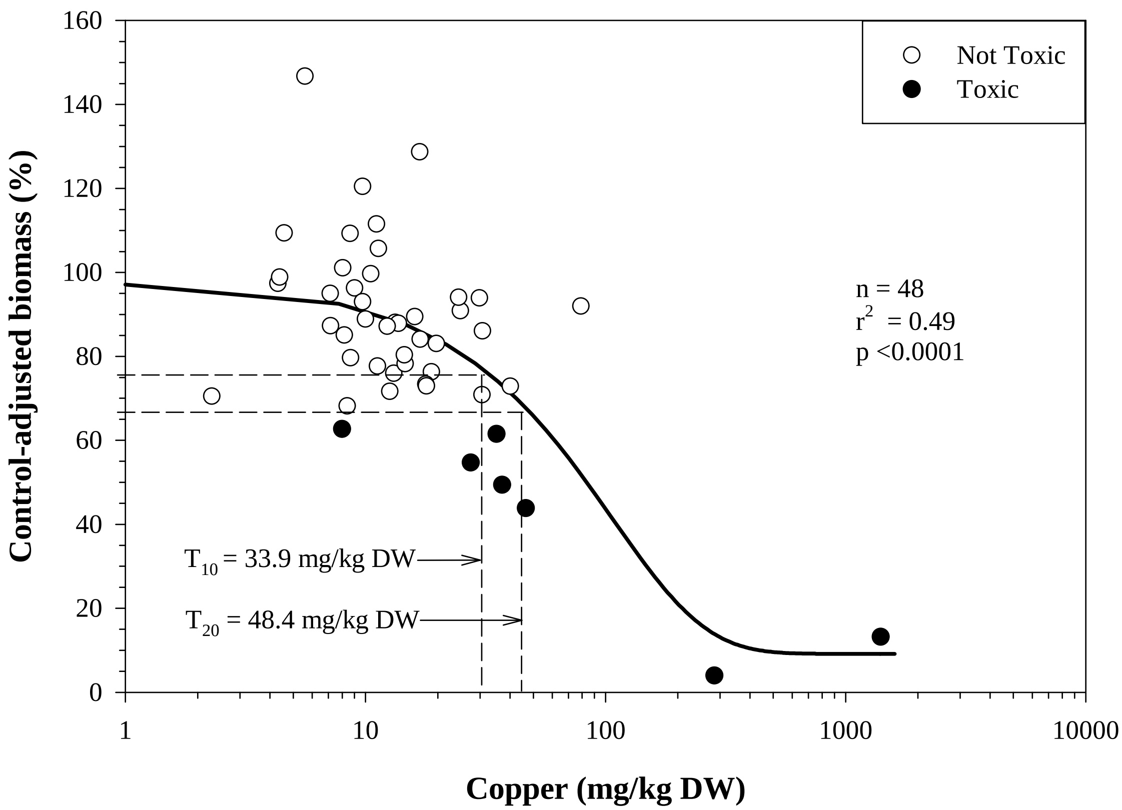


Figure 28. Plot illustrating the relationship between the concentration of lead (mg/kg DW) in sediment (<250 µm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

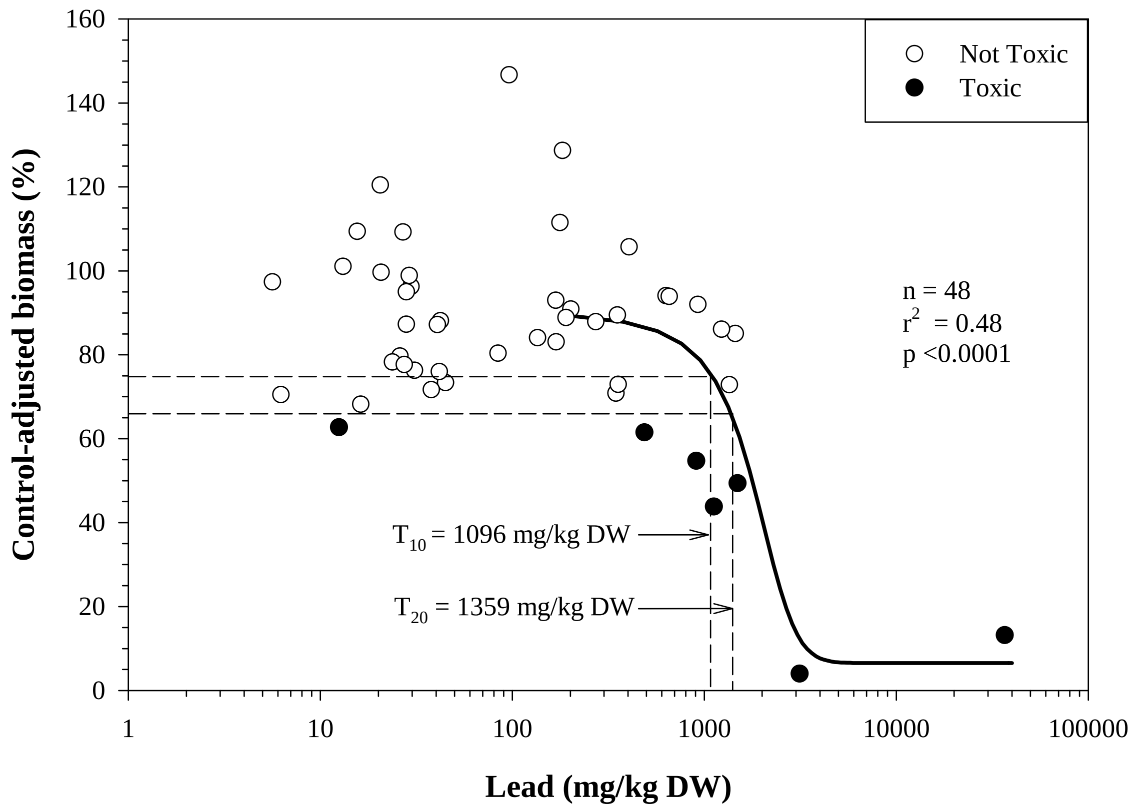


Figure 29. Plot illustrating the relationship between the concentration of ΣSEM-AVS (µmol/g DW) in sediment (<2 mm and <250 µm size fraction; see Table 4 for additional details) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

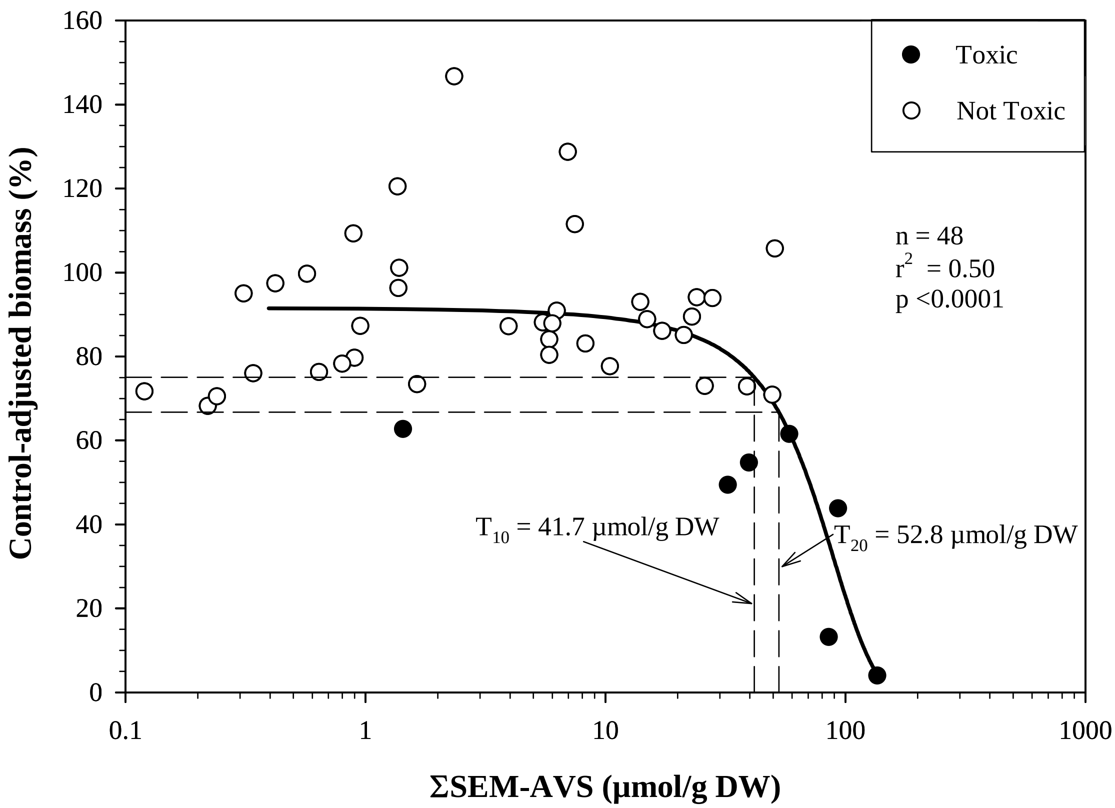


Figure 30. Plot illustrating the relationship between the concentration of mean PEC-Q_{METALS} in sediment (<250 µm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

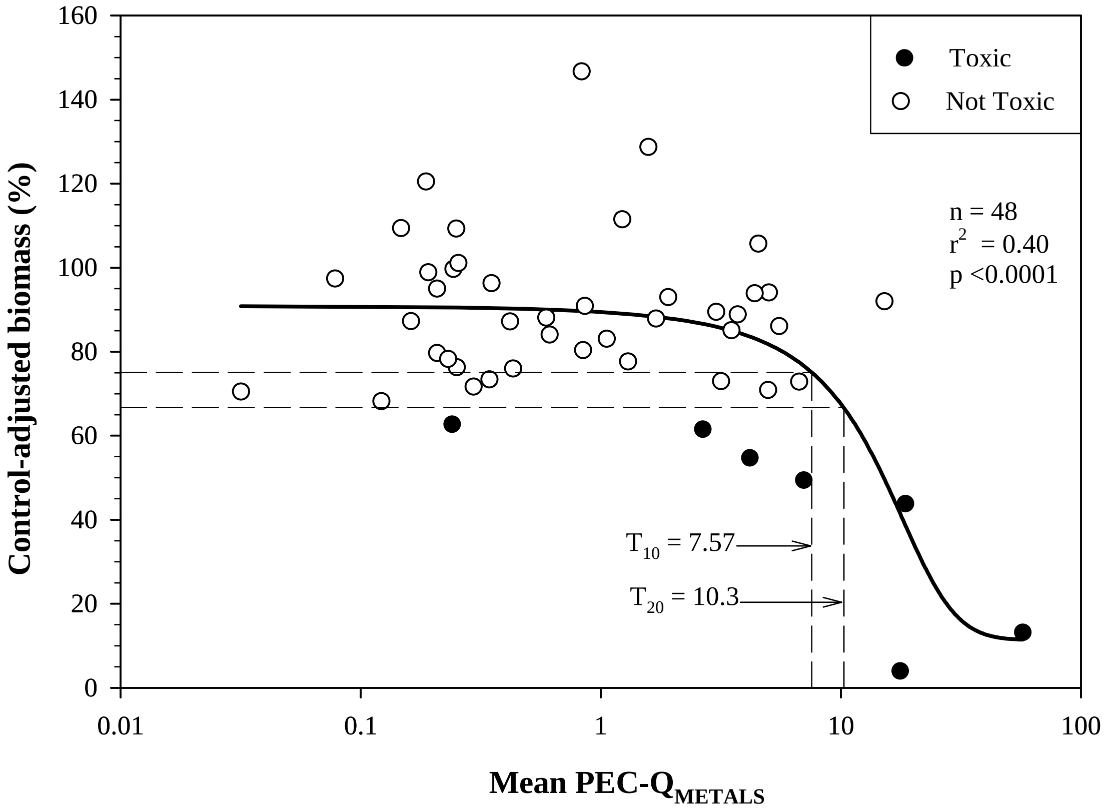


Figure 31. Plot illustrating the relationship between the concentration of mean PEC-$Q_{METALS(1\%OC)}$ in sediment (<250 µm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

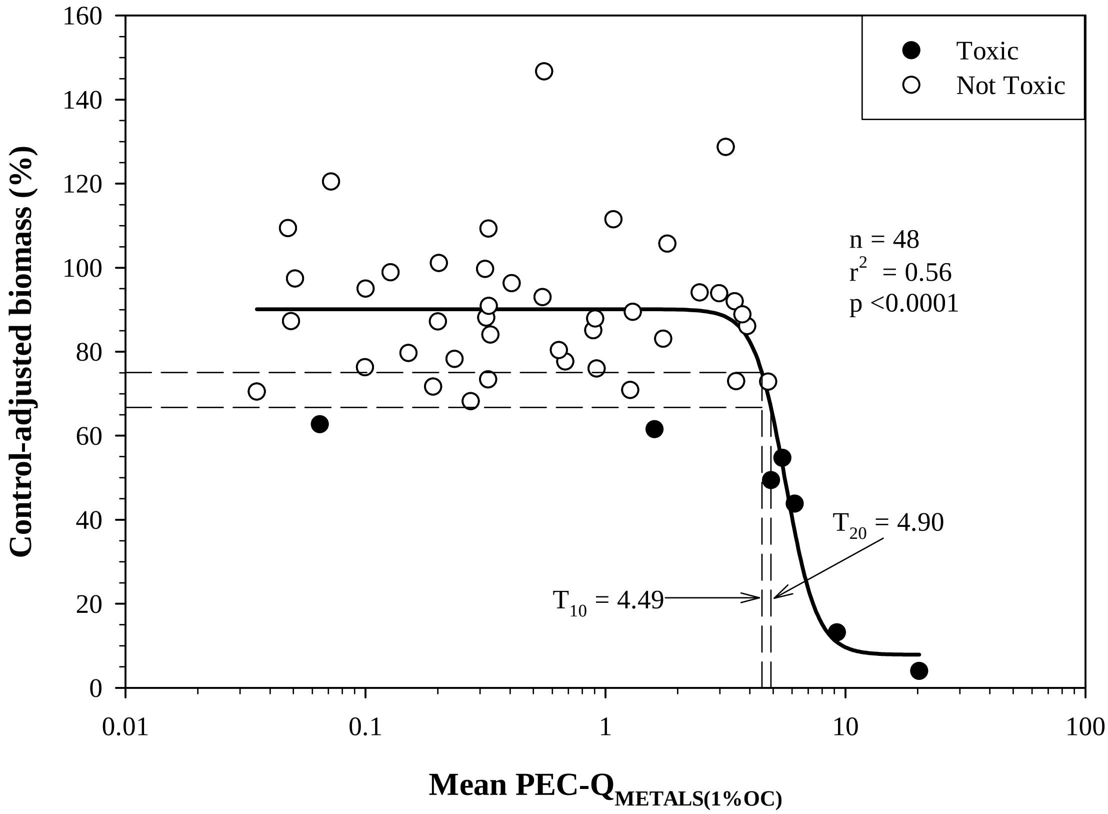


Figure 32. Plot illustrating the relationship between the concentration of ΣSTT-$Q_{Cd,Cu,Pb,Zn}$ in sediment (<250 µm) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

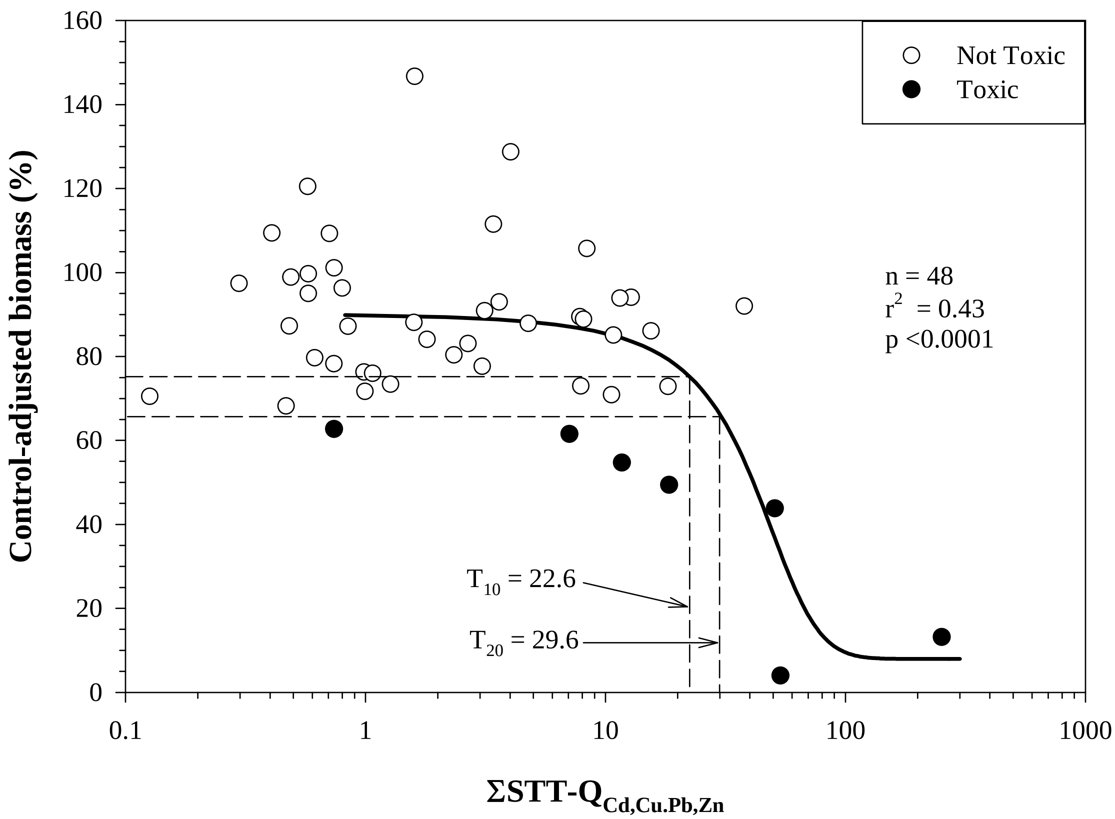


Figure 33. Plot illustrating the relationship between the concentration of cadmium in pore water ($PW\text{-}TU_{CADMIUM}$) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

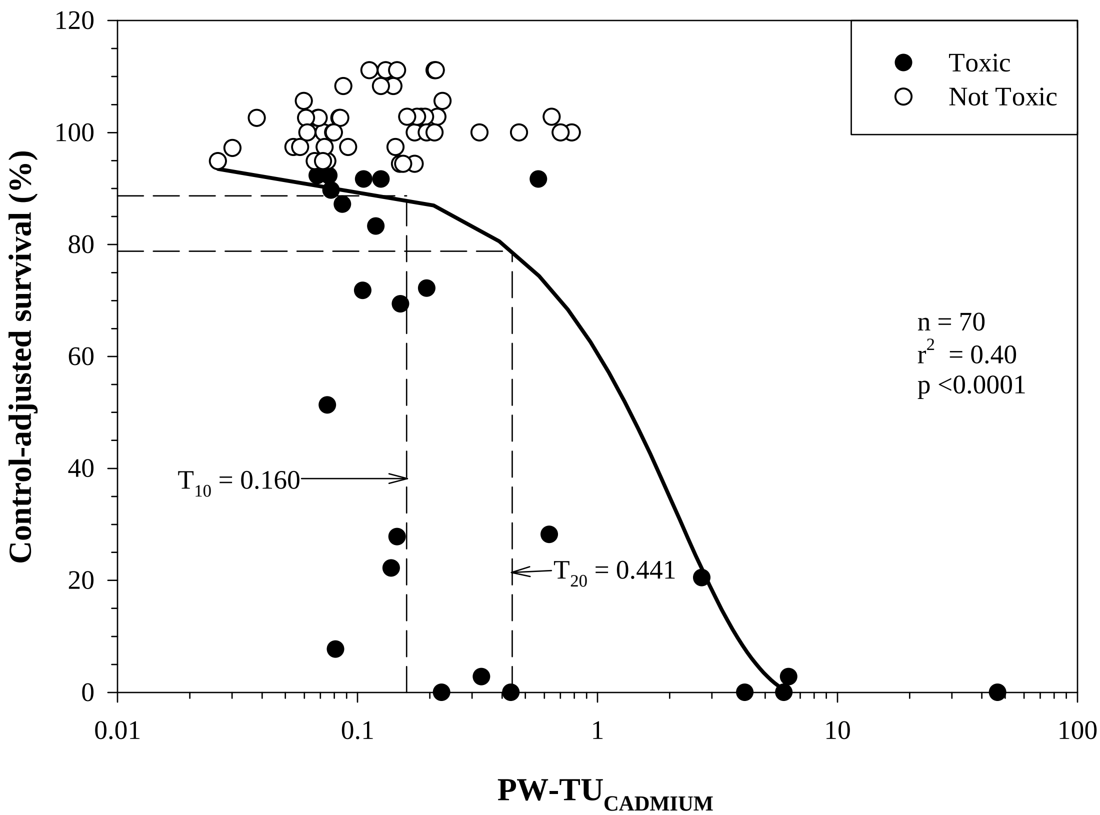


Figure 34. Plot illustrating the relationship between the concentration of lead in pore water ($PW\text{-}TU_{LEAD}$) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

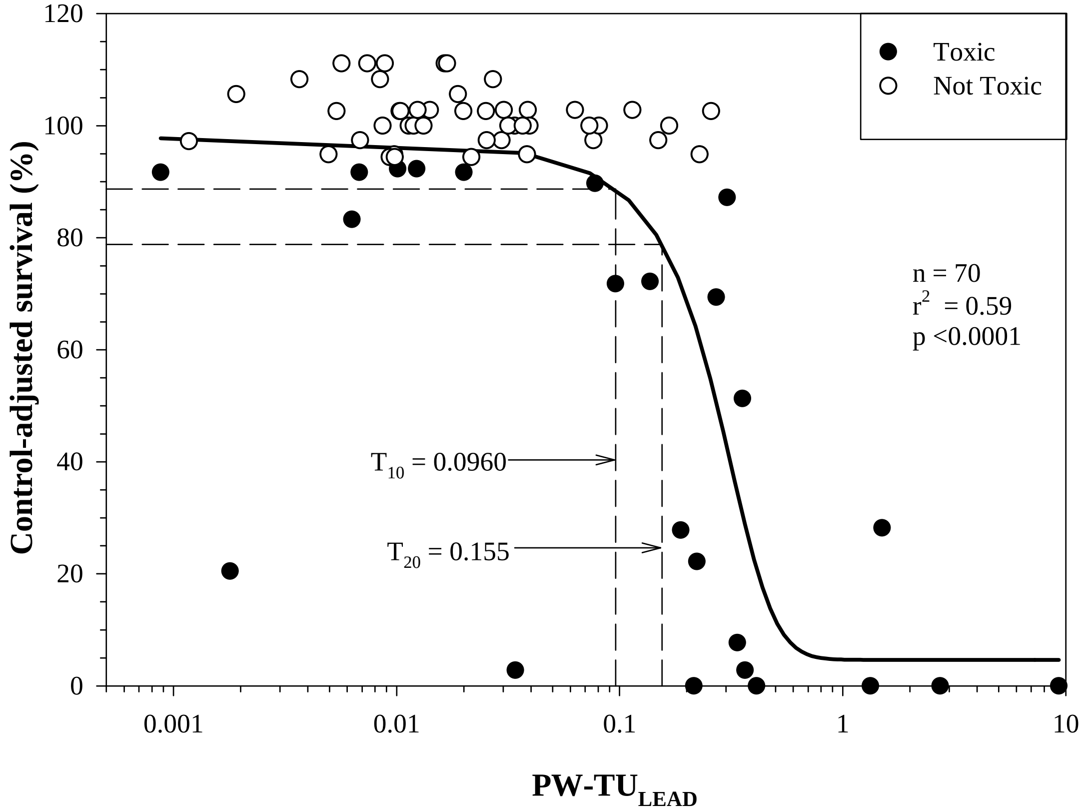


Figure 35. Plot illustrating the relationship between the concentration of lead in pore water, normalized to dissolved organic carbon [PW-TU$_{LEAD(DOC)}$], and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

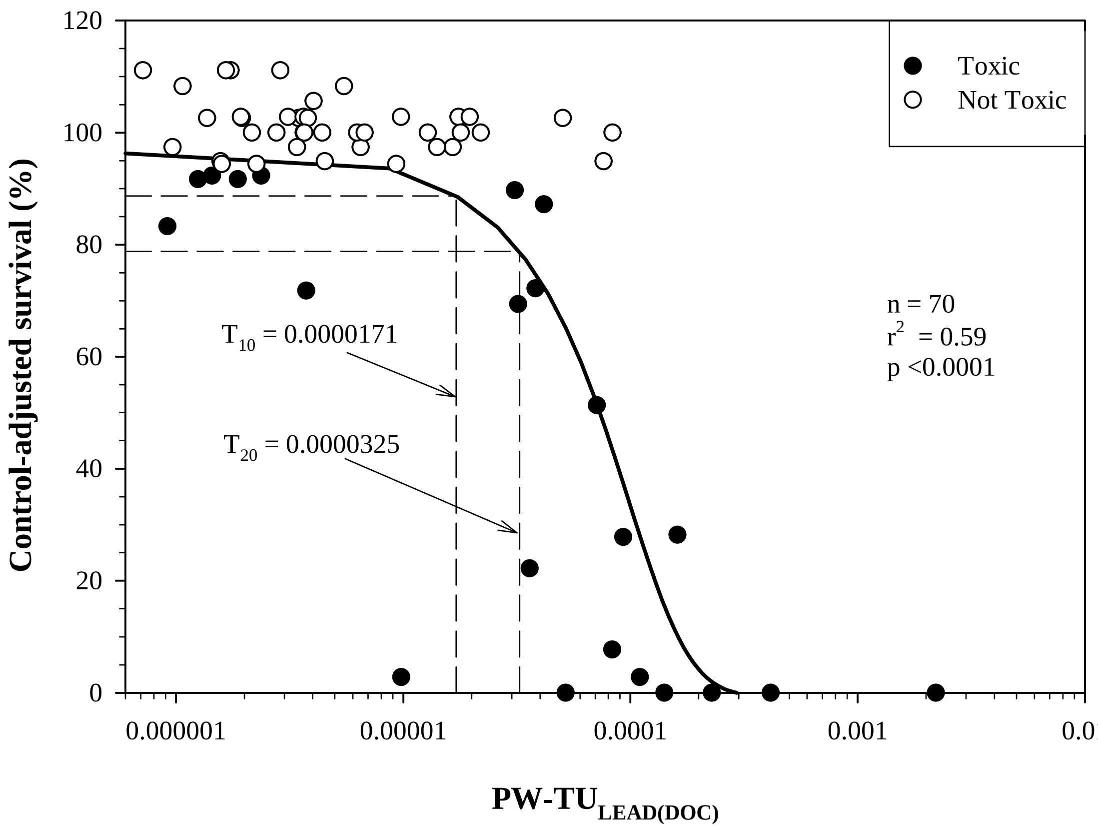


Figure 36. Plot illustrating the relationship between the concentration of zinc in pore water ($PW\text{-}TU_{ZINC}$) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

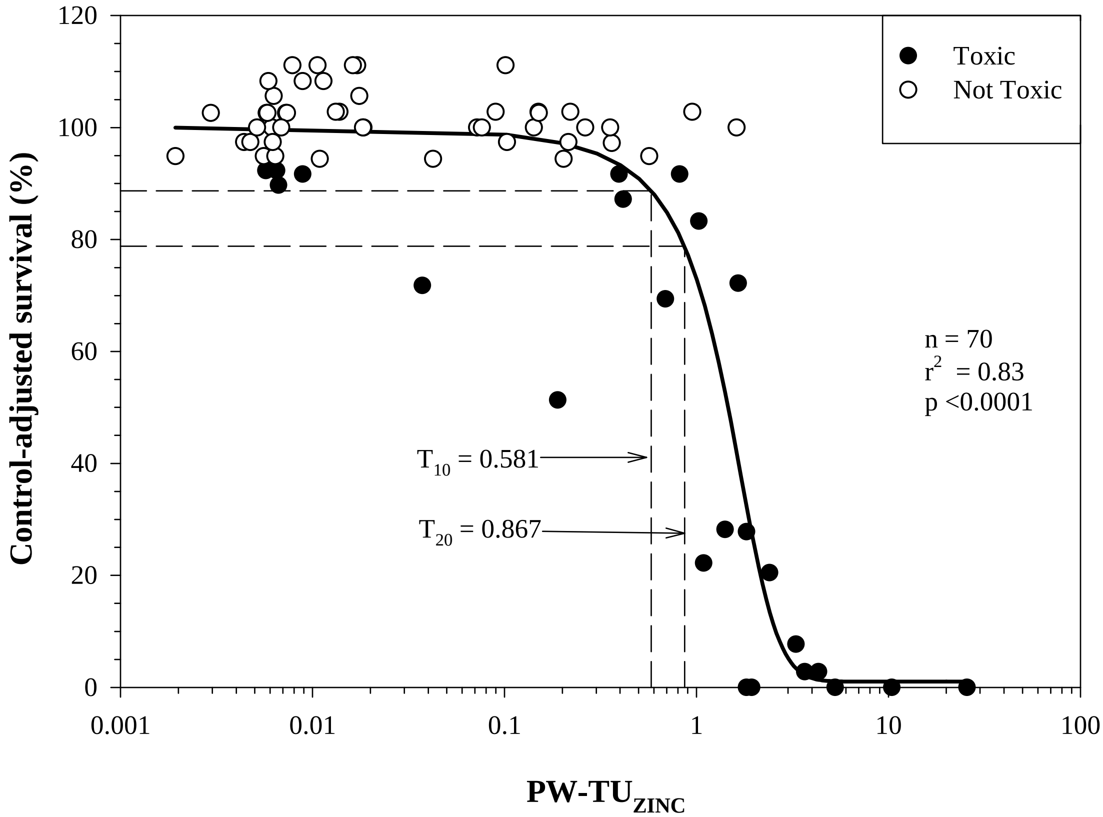


Figure 37. Plot illustrating the relationship between the concentration of zinc in pore water, normalized to dissolved organic carbon [PW-TU$_{ZINC(DOC)}$], and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

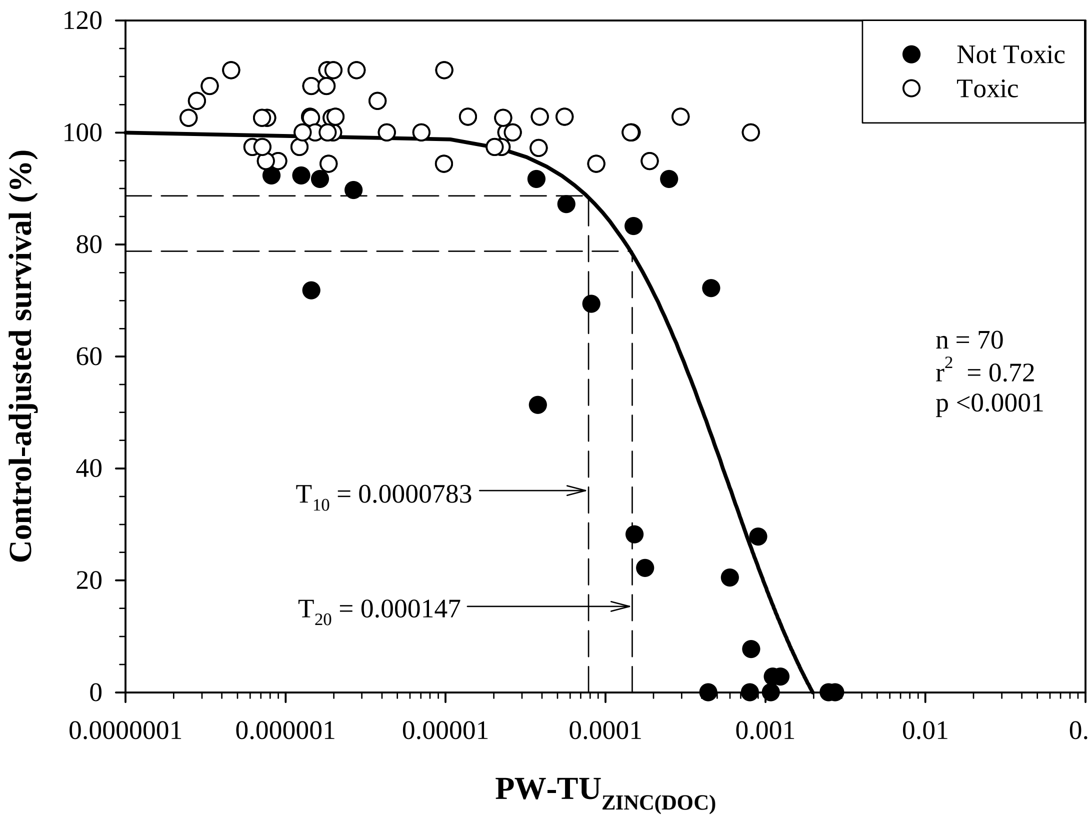


Figure 38. Plot illustrating the relationship between the concentration of divalent metals in pore water (ΣPW-TU$_{DIVALENT\ METALS}$) and the control-adjusted survival of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

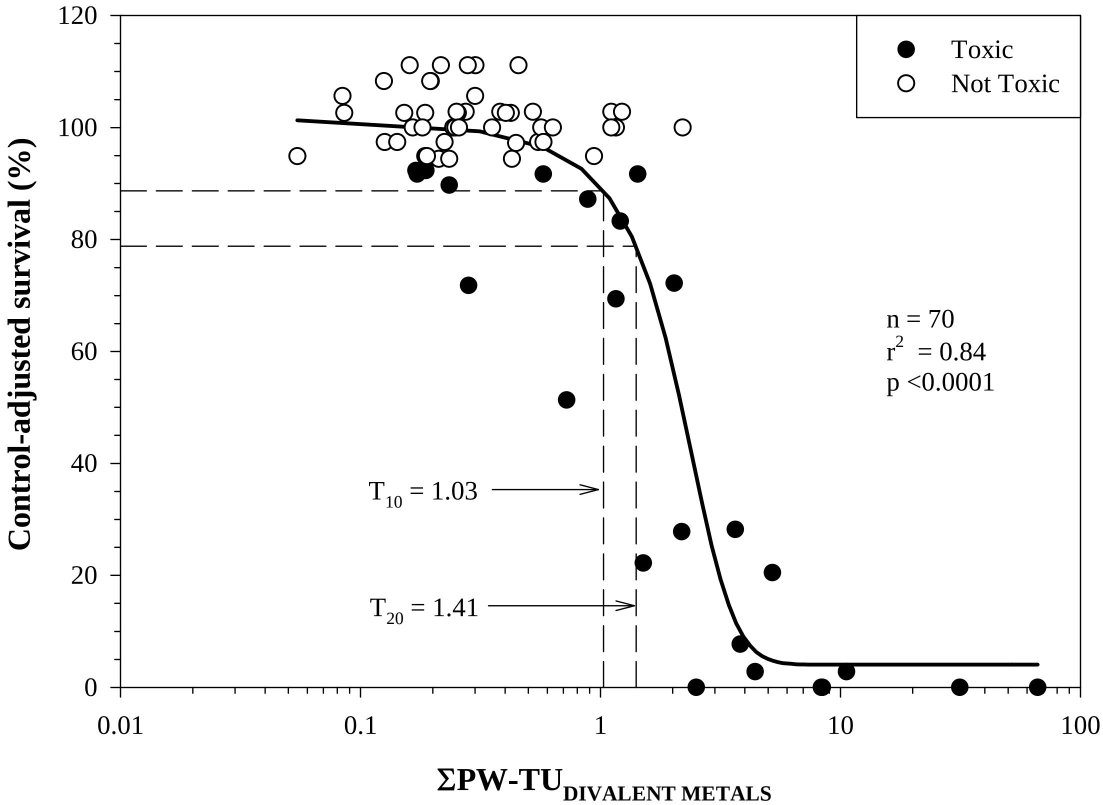


Figure 39. Plot illustrating the relationship between the concentration of lead in pore water ($PW\text{-}TU_{LEAD}$) and the control-adjusted biomass of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

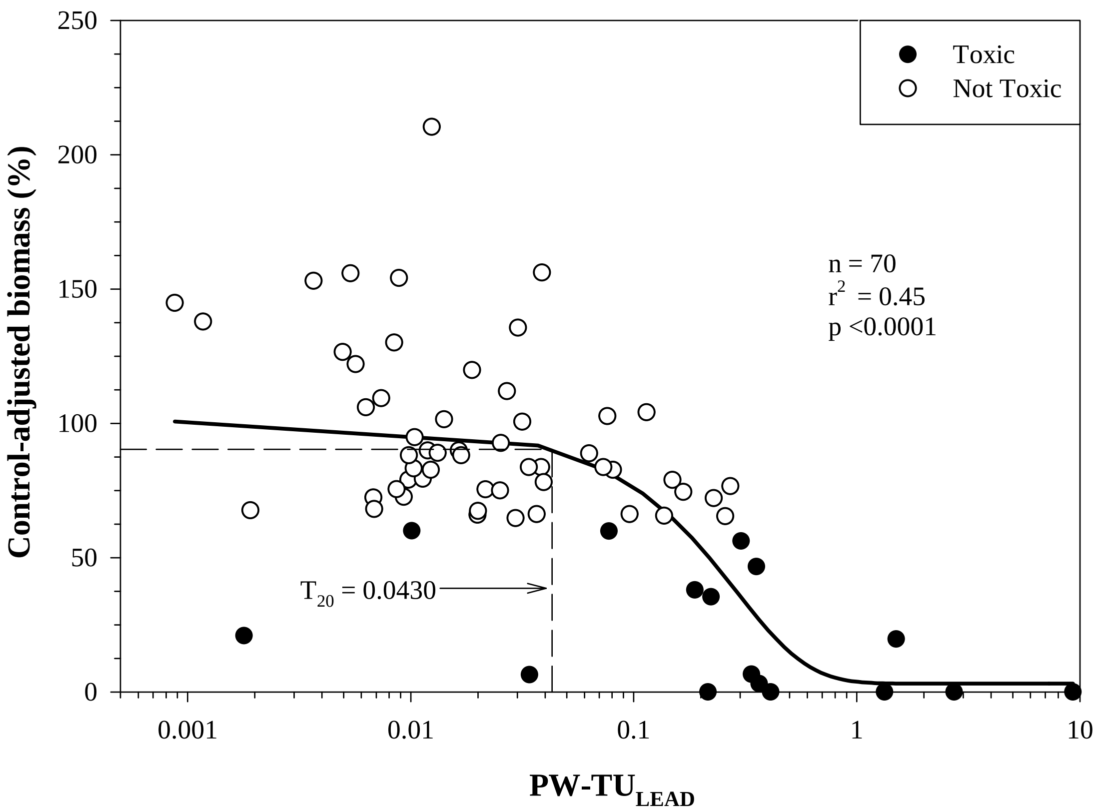


Figure 40. Plot illustrating the relationship between the concentration of lead in pore water, normalized to dissolved organic carbon [PW-TU$_{LEAD(DOC)}$], and the control-adjusted biomass of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

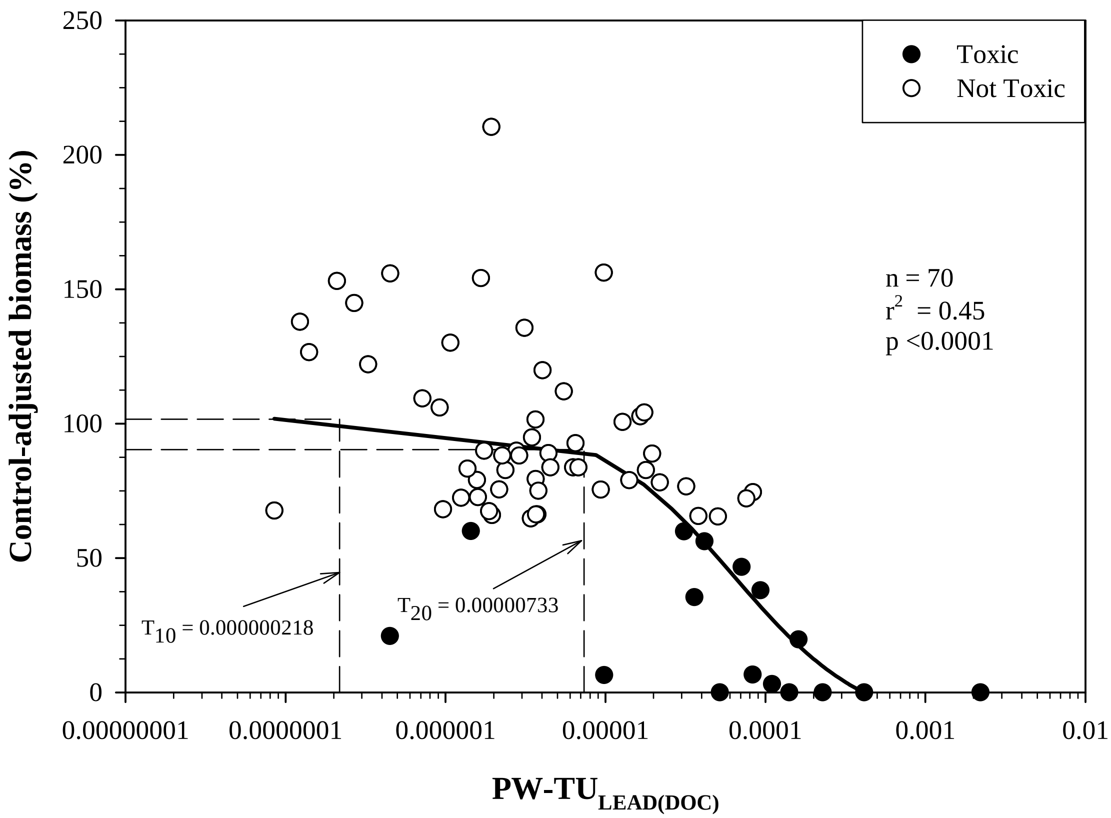


Figure 41. Plot illustrating the relationship between the concentration of zinc in pore water ($PW\text{-}TU_{ZINC}$) and the control-adjusted biomass of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

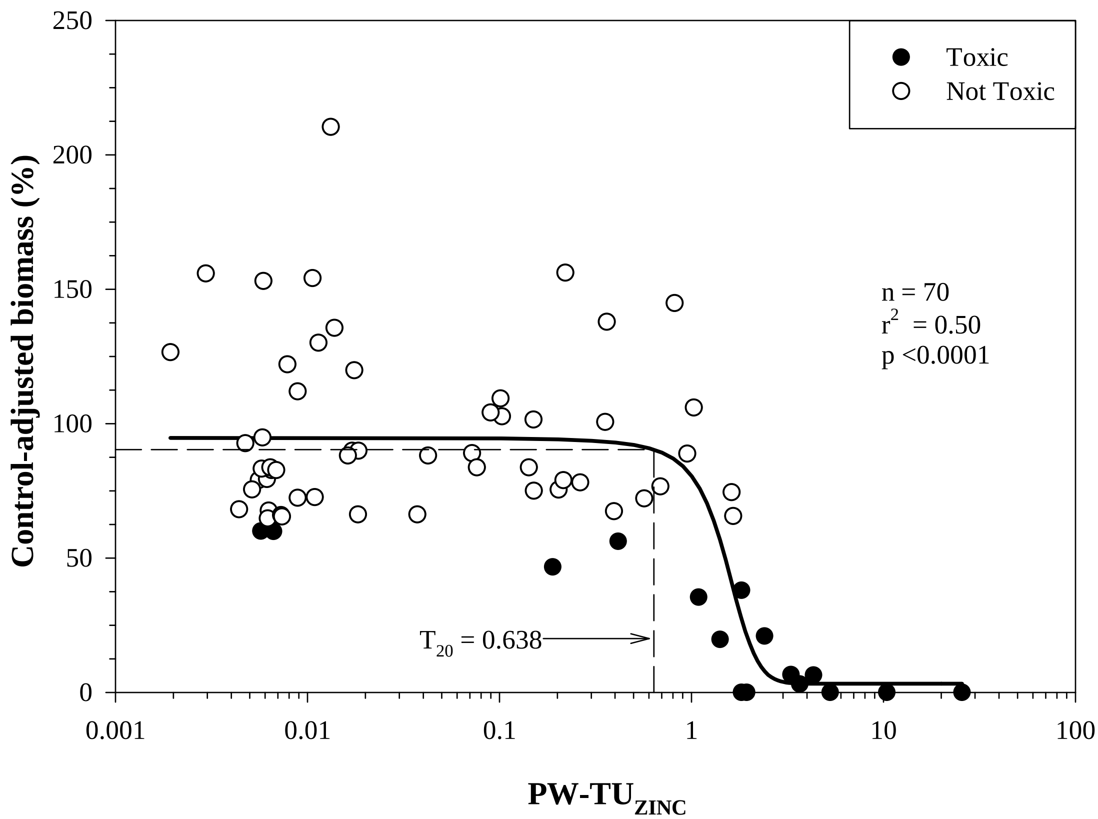


Figure 42. Plot illustrating the relationship between the concentration of zinc in pore water, normalized to dissolved organic carbon [PW-$TU_{ZINC(DOC)}$], and the control-adjusted biomass of amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

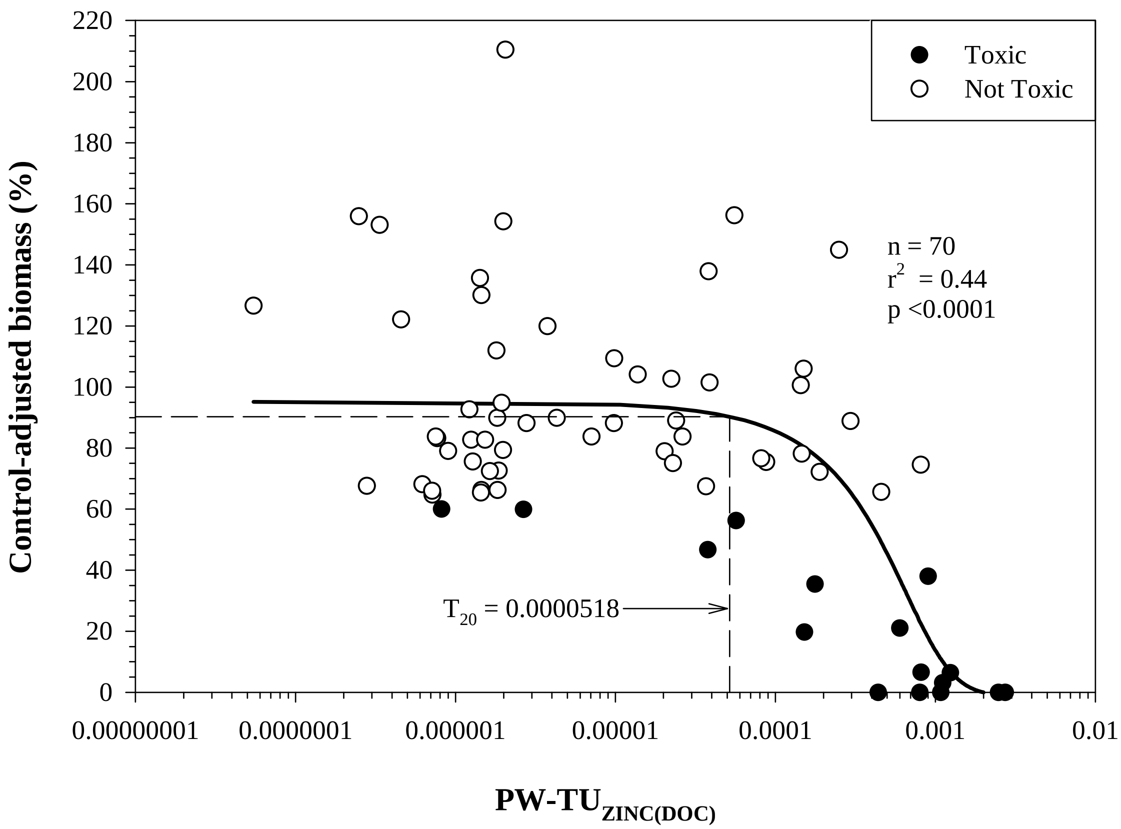


Figure 43. Plot illustrating the relationship between the concentration of divalent metals in pore water (ΣPW-TU$_{DIVALENT\ METALS}$) and the control-adjusted biomass of amphipods amphipods (*Hyalella azteca*) in 28-d exposures to sediment samples from the Tri-State Mining District.

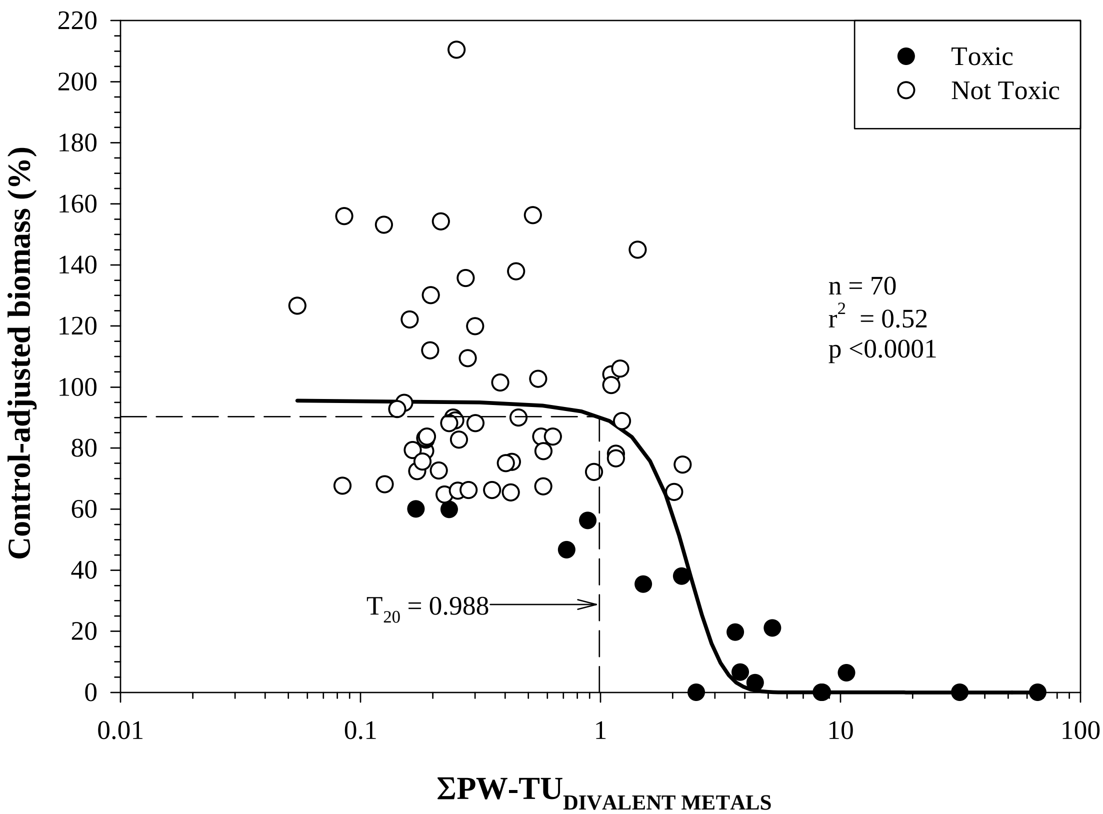


Figure 44. Plot illustrating the relationship between the concentration of cadmium in pore water (PW-$TU_{CADMIUM}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

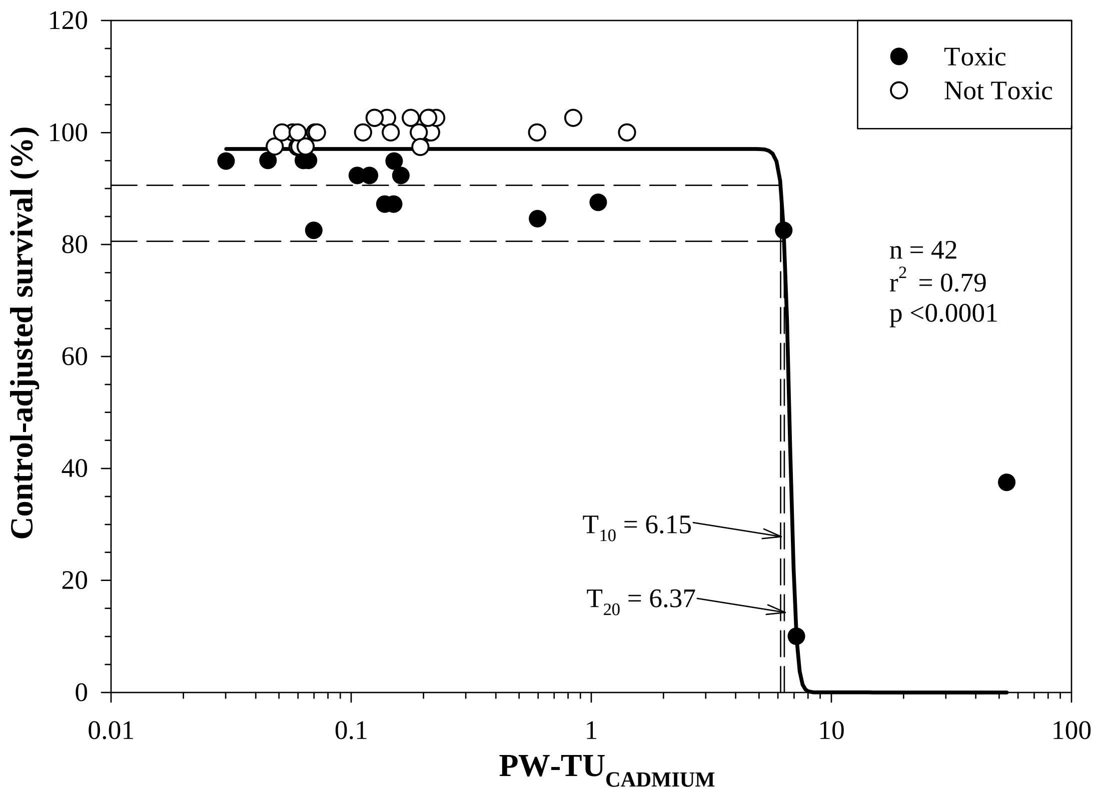


Figure 45. Plot illustrating the relationship between the concentration of copper in pore water ($PW\text{-}TU_{COPPER}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

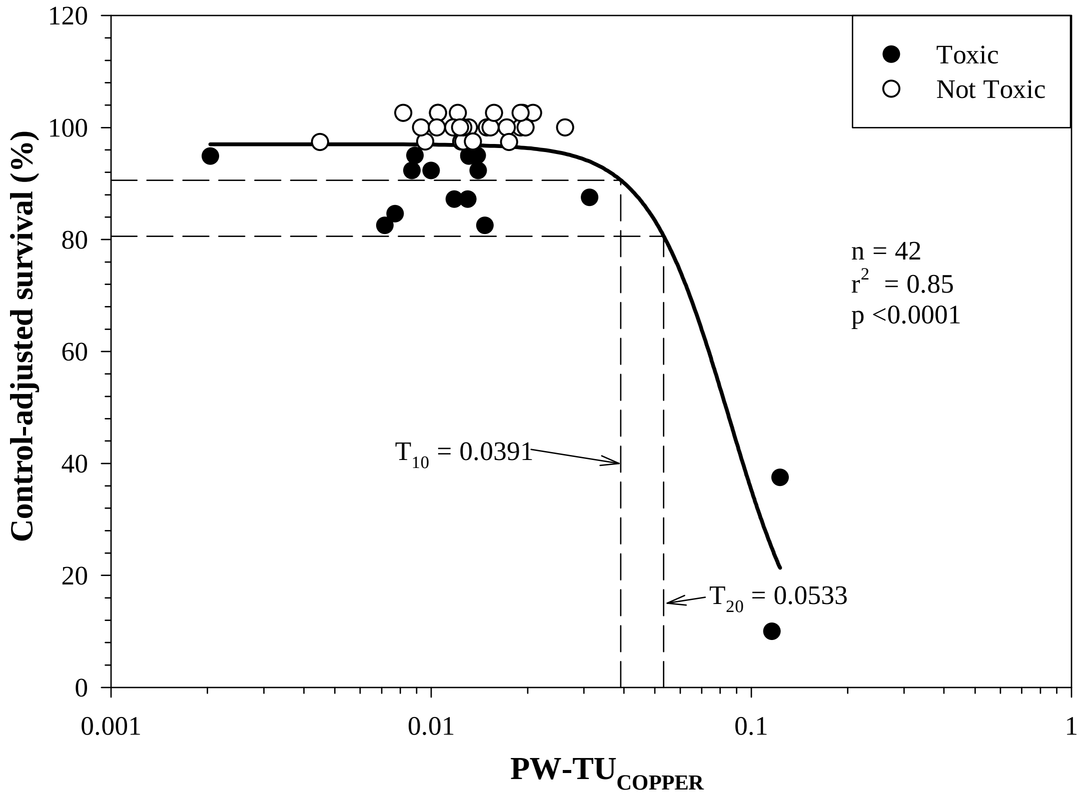


Figure 46. Plot illustrating the relationship between the concentration of lead in pore water ($PW\text{-}TU_{LEAD}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

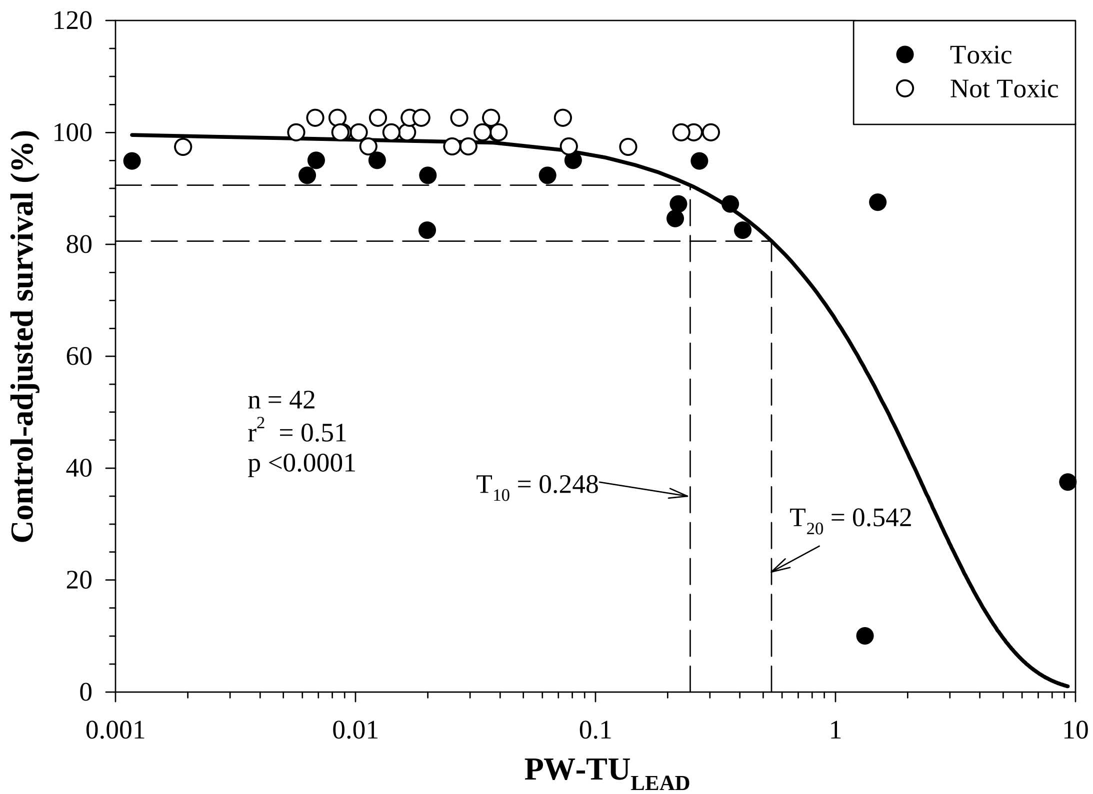


Figure 47. Plot illustrating the relationship between the concentration of nickel in pore water ($PW\text{-}TU_{NICKEL}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

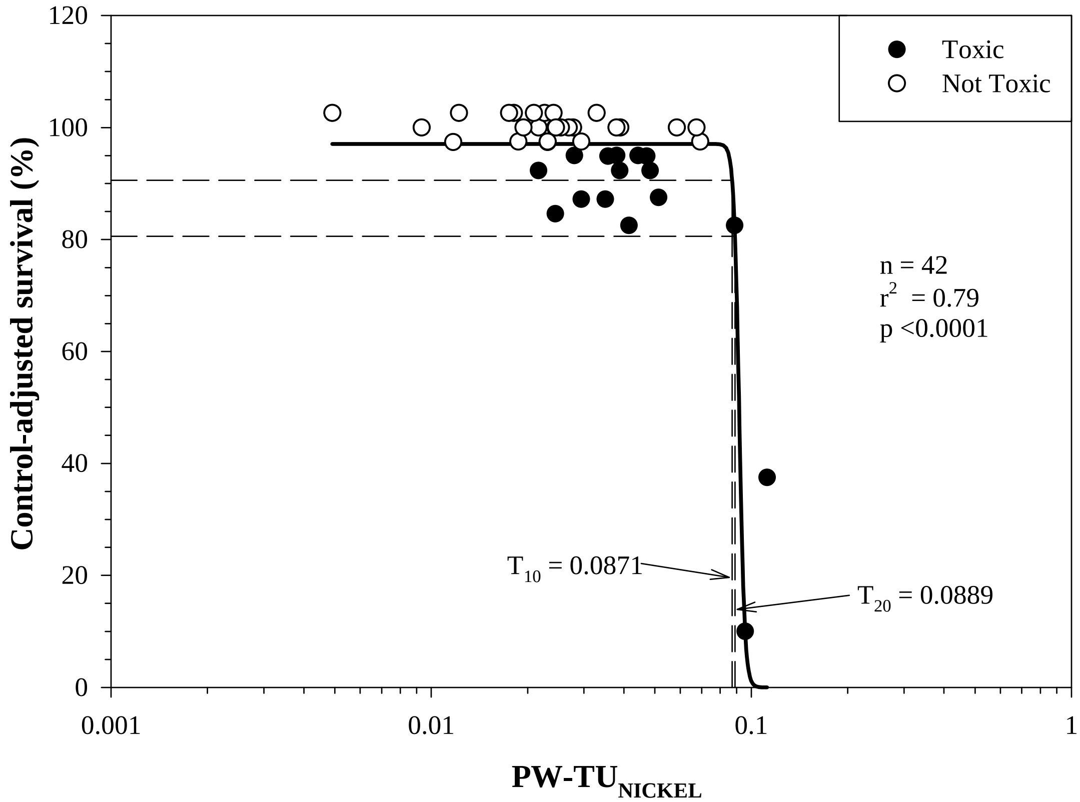


Figure 48. Plot illustrating the relationship between the concentration of zinc in pore water ($PW\text{-}TU_{ZINC}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

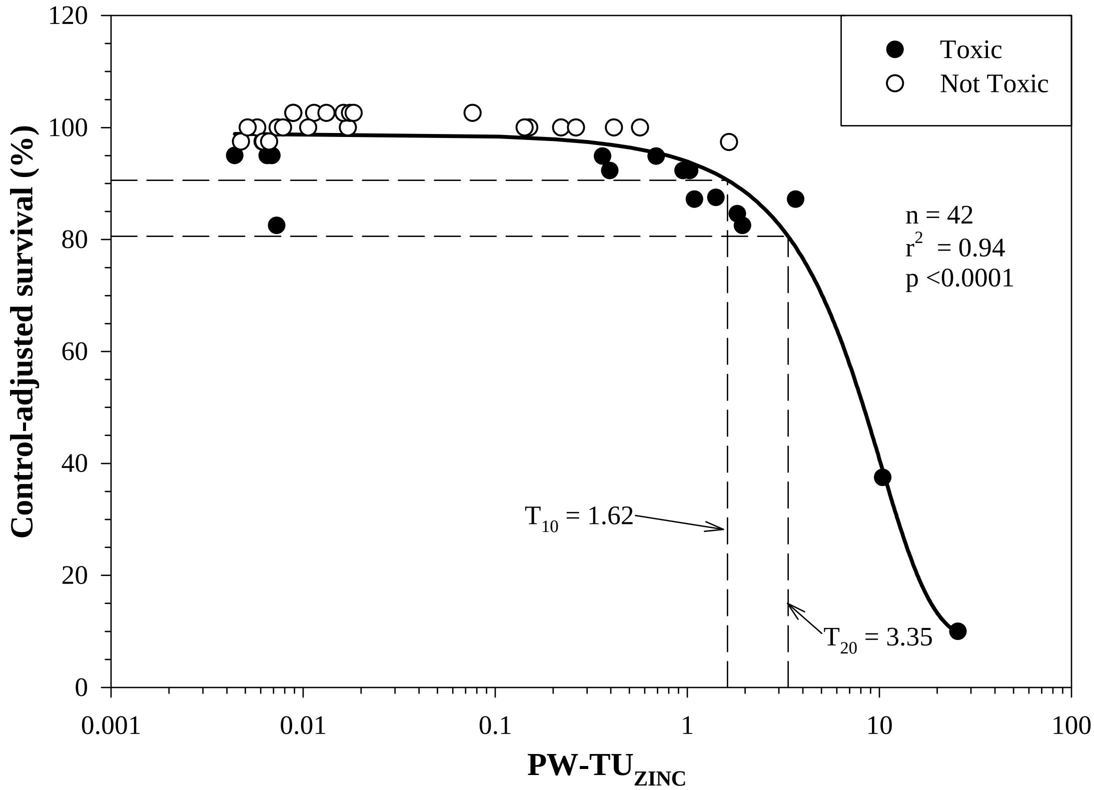


Figure 49. Plot illustrating the relationship between the concentration of zinc in pore water, normalized to dissolved organic carbon [PW-$TU_{ZINC(DOC)}$], and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

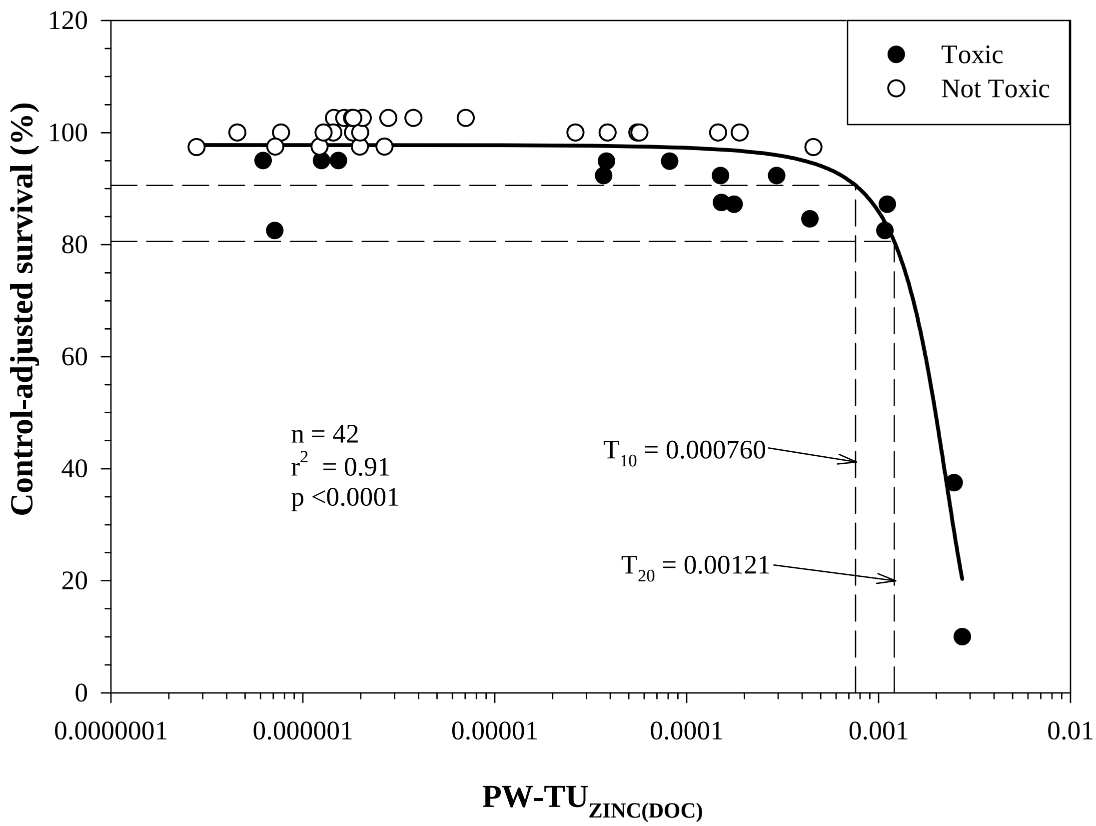


Figure 50. Plot illustrating the relationship between the concentration of metals in pore-water (ΣPW-TU$_{METALS}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

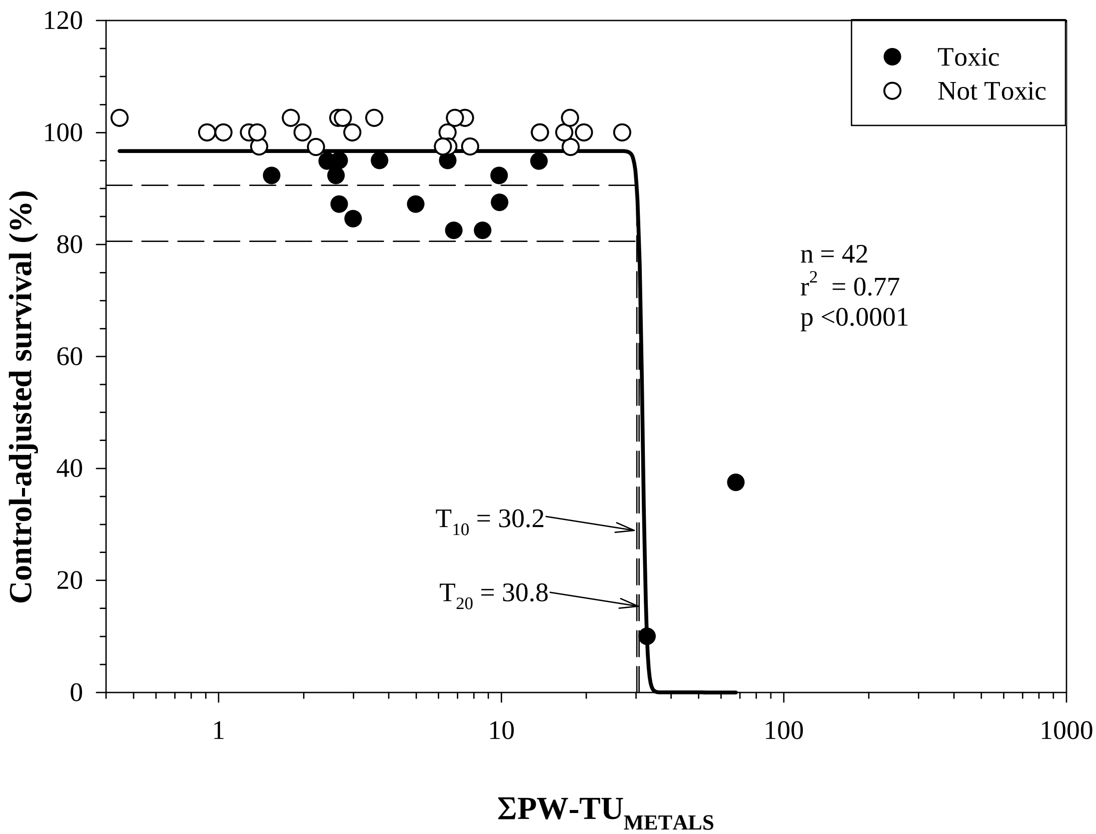


Figure 51. Plot illustrating the relationship between the concentration of divalent metals in pore water (ΣPW-TU$_{\text{DIVALENT METALS}}$) and the control-adjusted survival of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

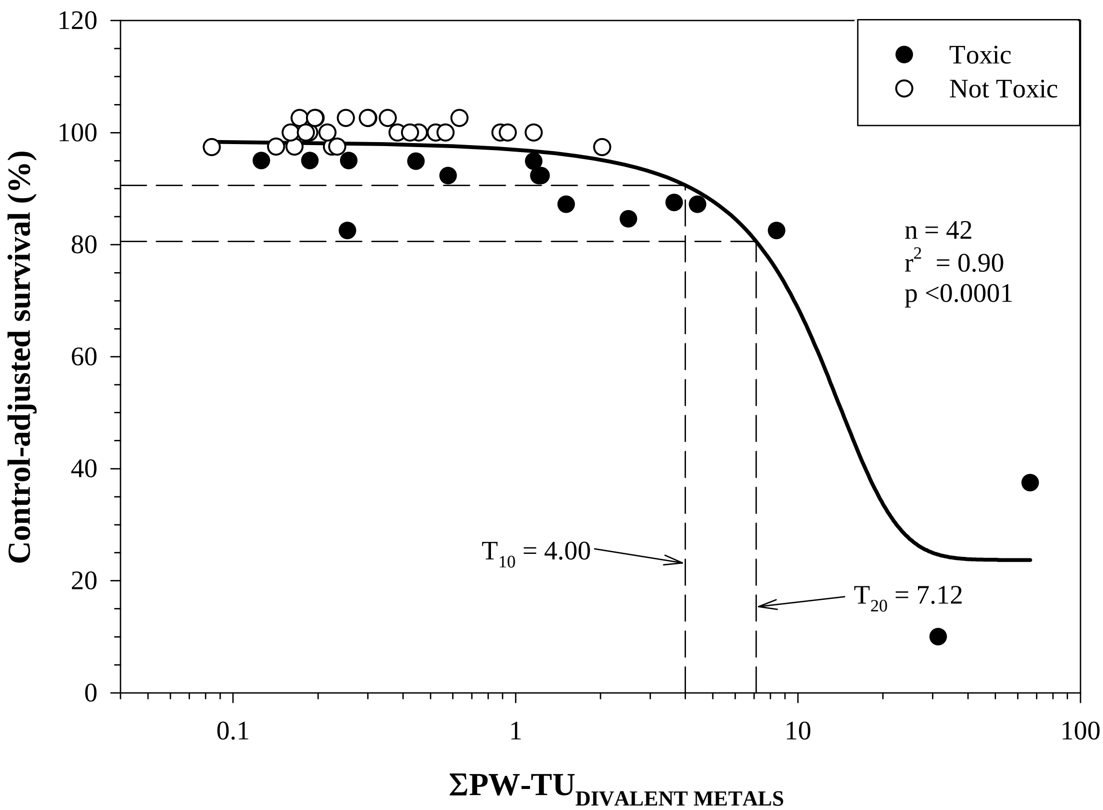


Figure 52. Plot illustrating the relationship between the concentration of cadmium in pore water ($PW\text{-}TU_{CADMIUM}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

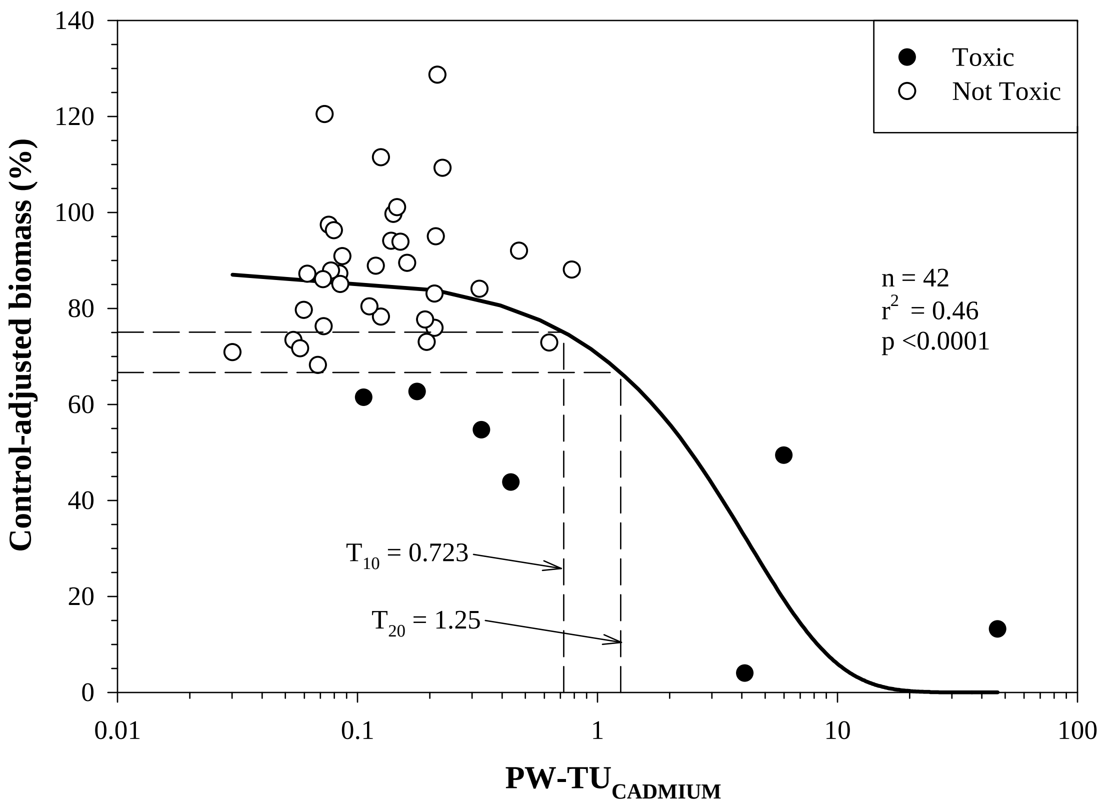


Figure 53. Plot illustrating the relationship between the concentration of copper in pore water ($PW\text{-}TU_{COPPER}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

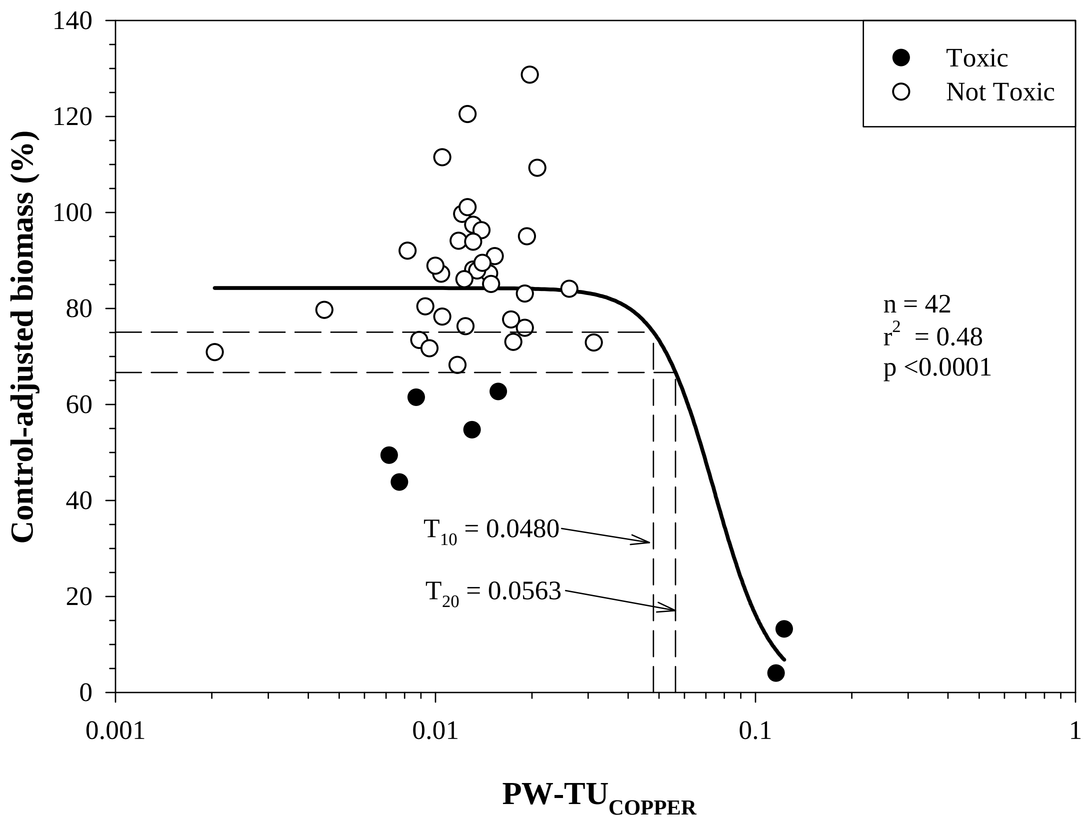


Figure 54. Plot illustrating the relationship between the concentration of lead in pore water ($PW\text{-}TU_{LEAD}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

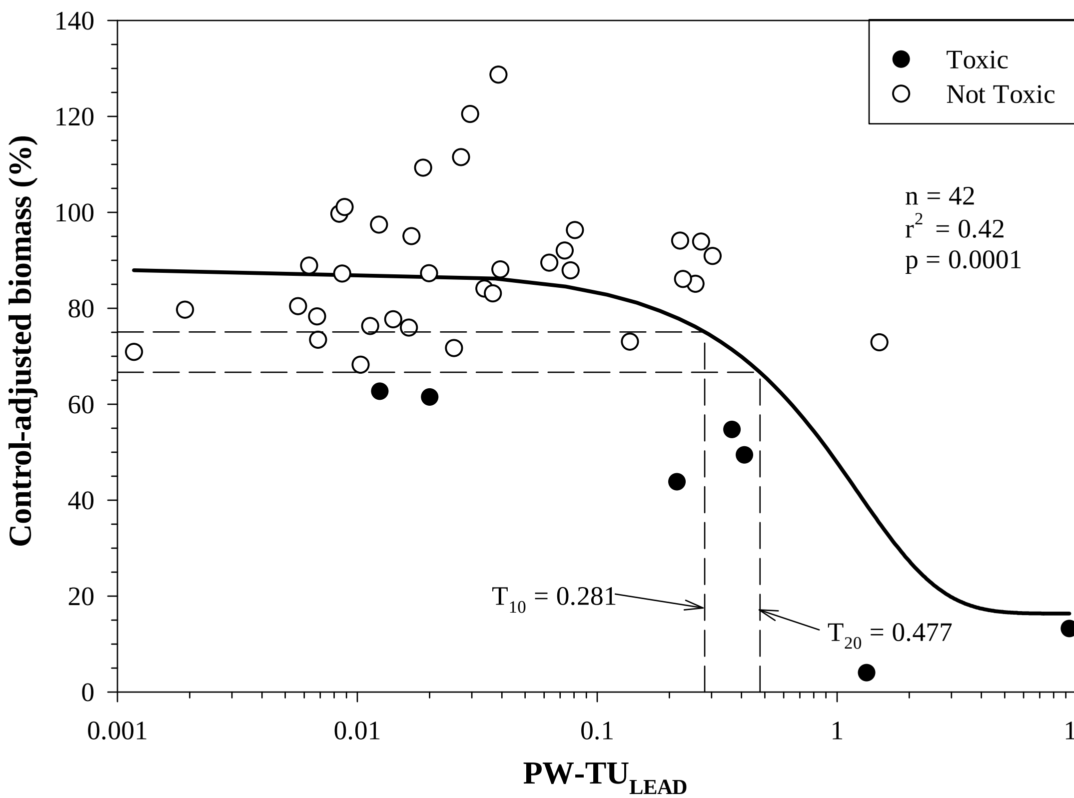


Figure 55. Plot illustrating the relationship between the concentration of lead in pore water, normalized to dissolved organic carbon [PW-TU$_{LEAD(DOC)}$], and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

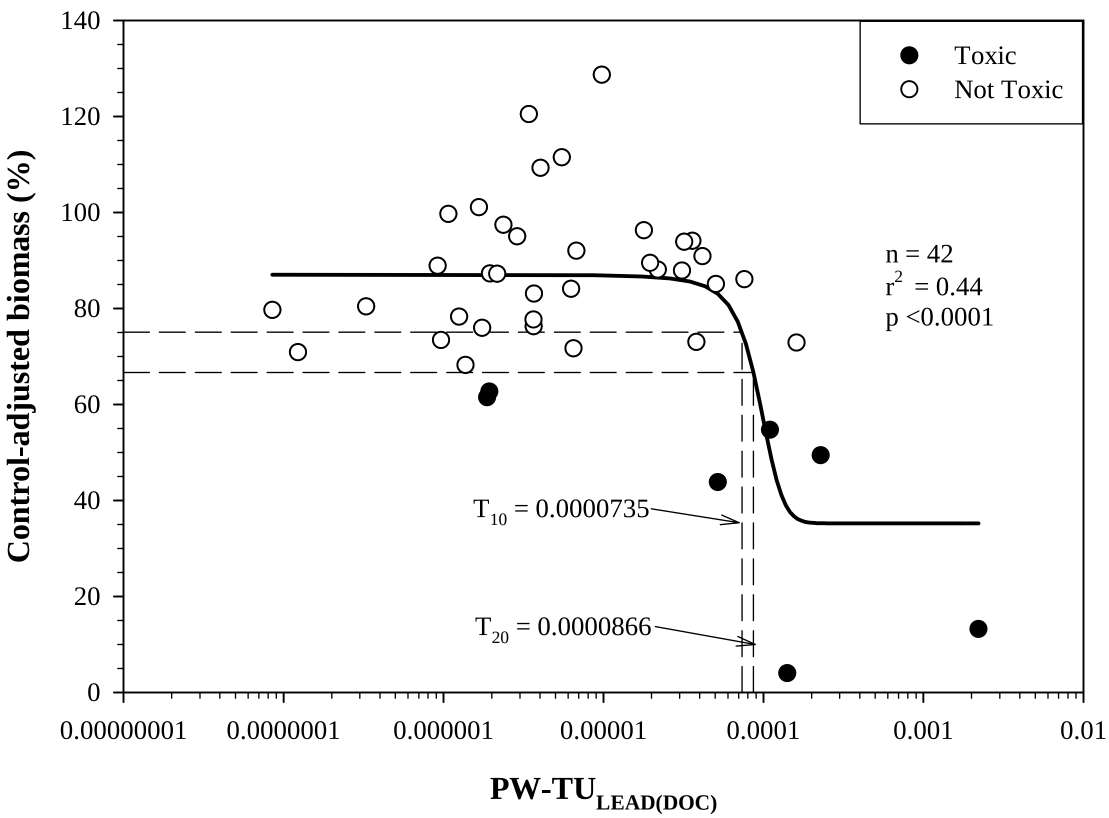


Figure 56. Plot illustrating the relationship between the concentration of nickel in pore water ($PW\text{-}TU_{NICKEL}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

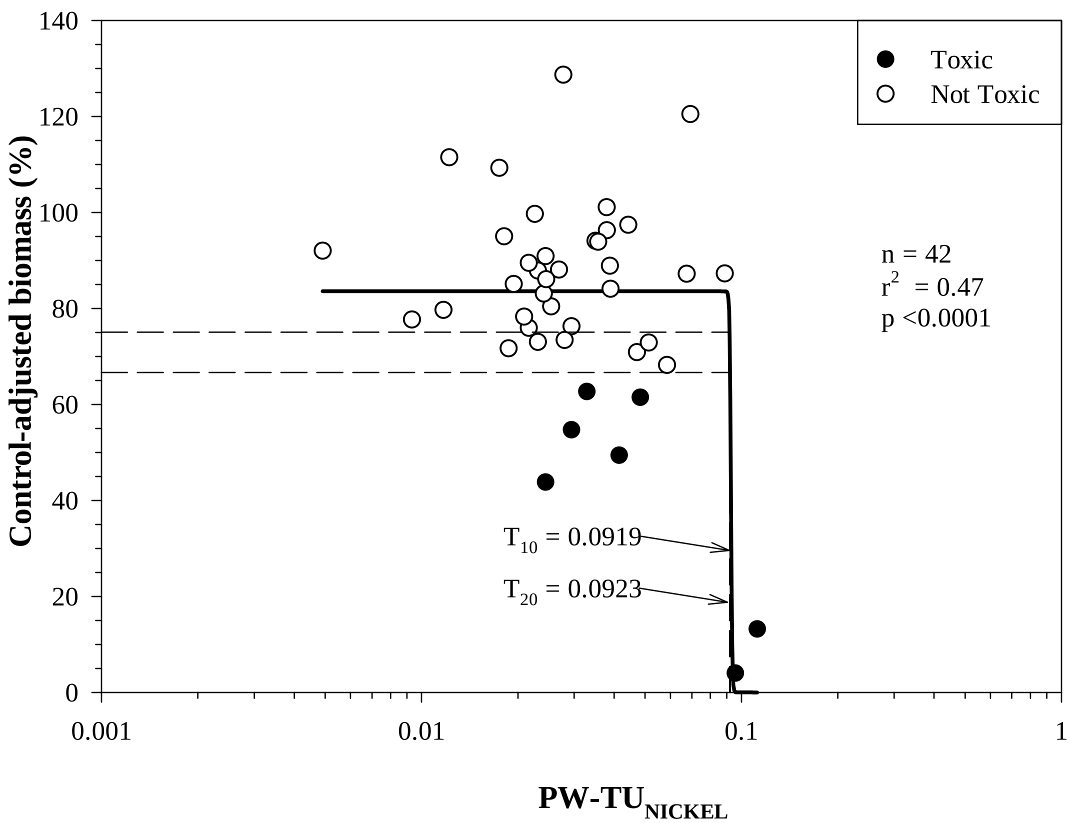


Figure 57. Plot illustrating the relationship between the concentration of zinc in pore water ($PW\text{-}TU_{ZINC}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

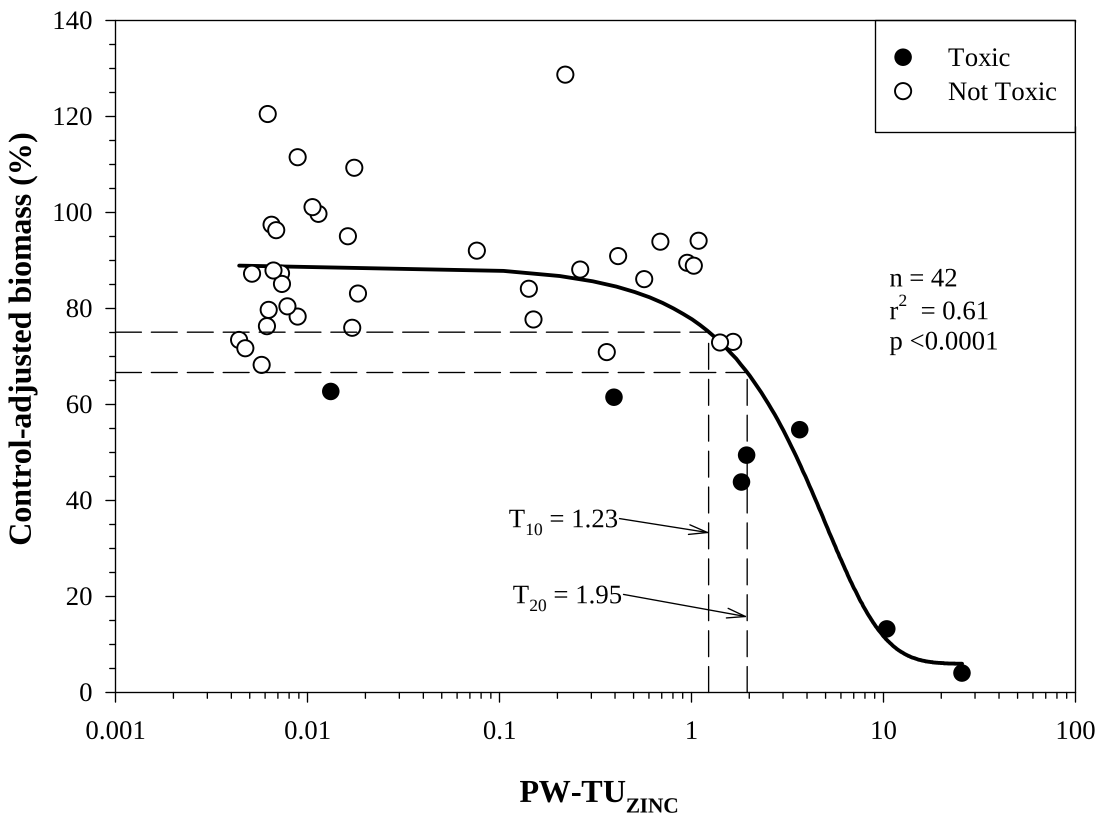


Figure 58. Plot illustrating the relationship between the concentration of zinc in pore water, normalized to dissolved organic carbon [PW-$TU_{ZINC(DOC)}$], and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

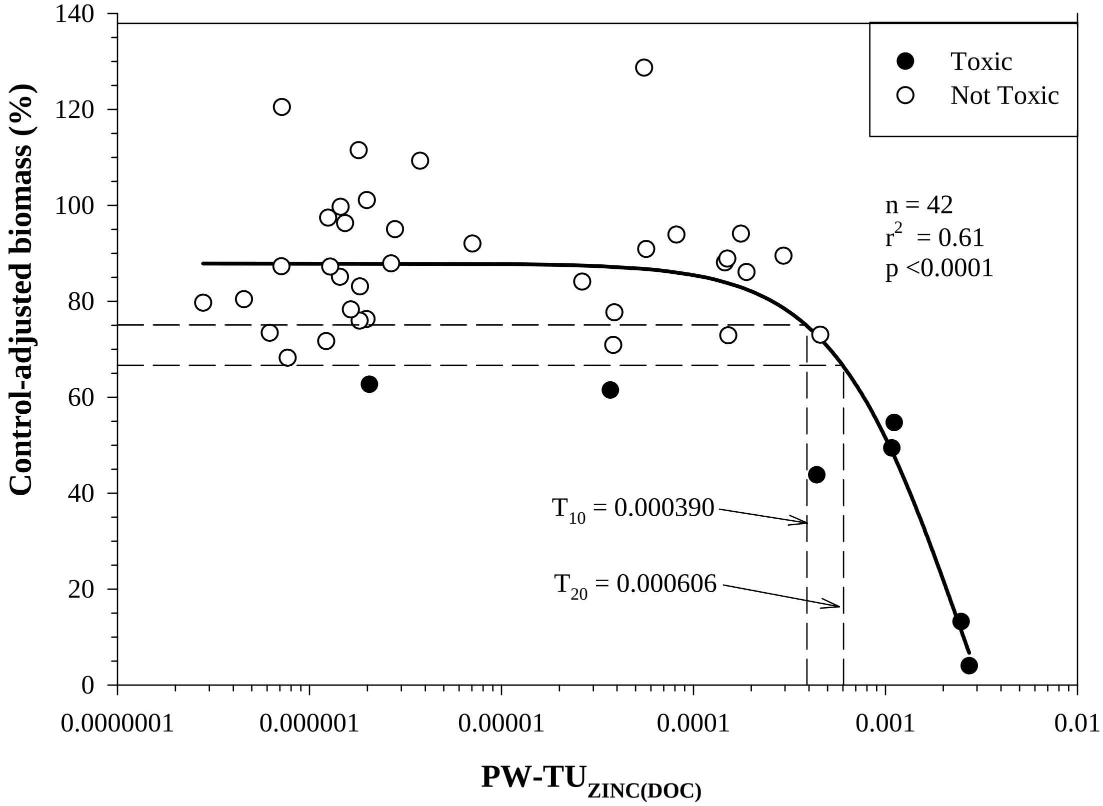


Figure 59. Plot illustrating the relationship between the concentration of metals in pore water (ΣPW-TU$_{METALS}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

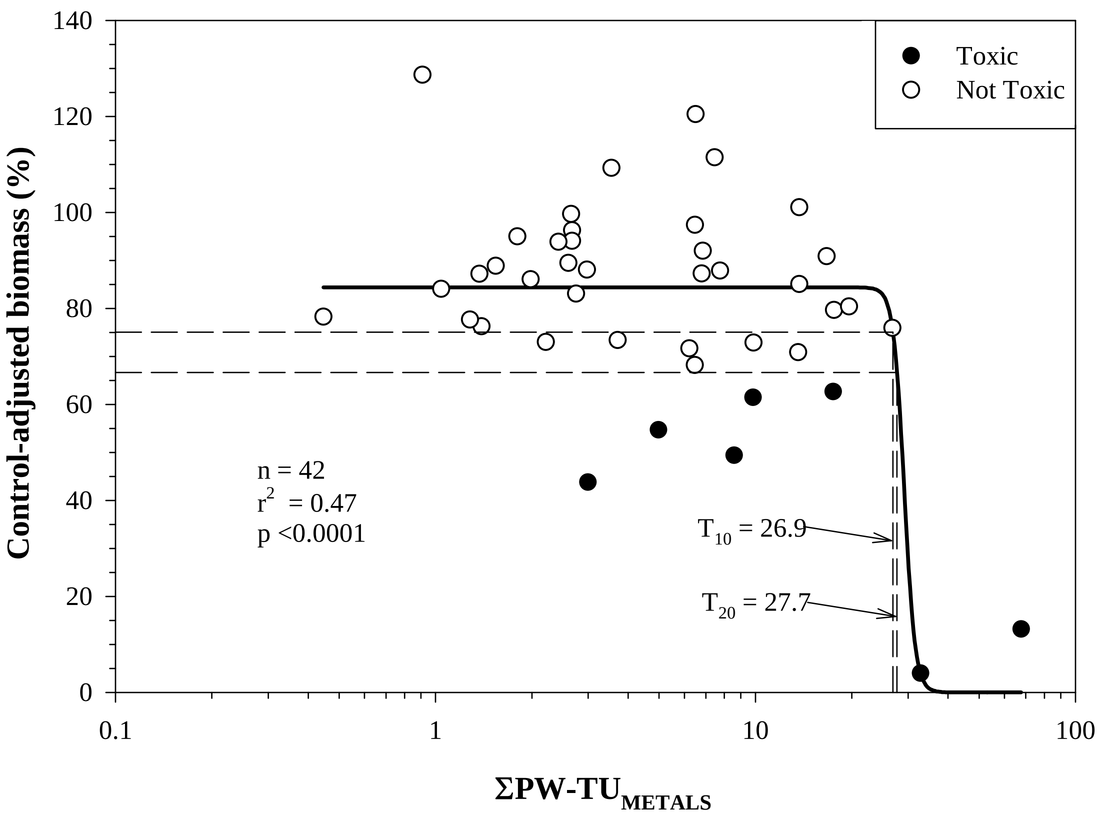


Figure 60. Plot illustrating the relationship between the concentration of divalent metals in pore water ($\Sigma PW\text{-}TU_{DIVALENT\ METALS}$) and the control-adjusted biomass of mussels (*Lampsilis siliquoidea*) in 28-d exposures to sediment samples from the Tri-State Mining District.

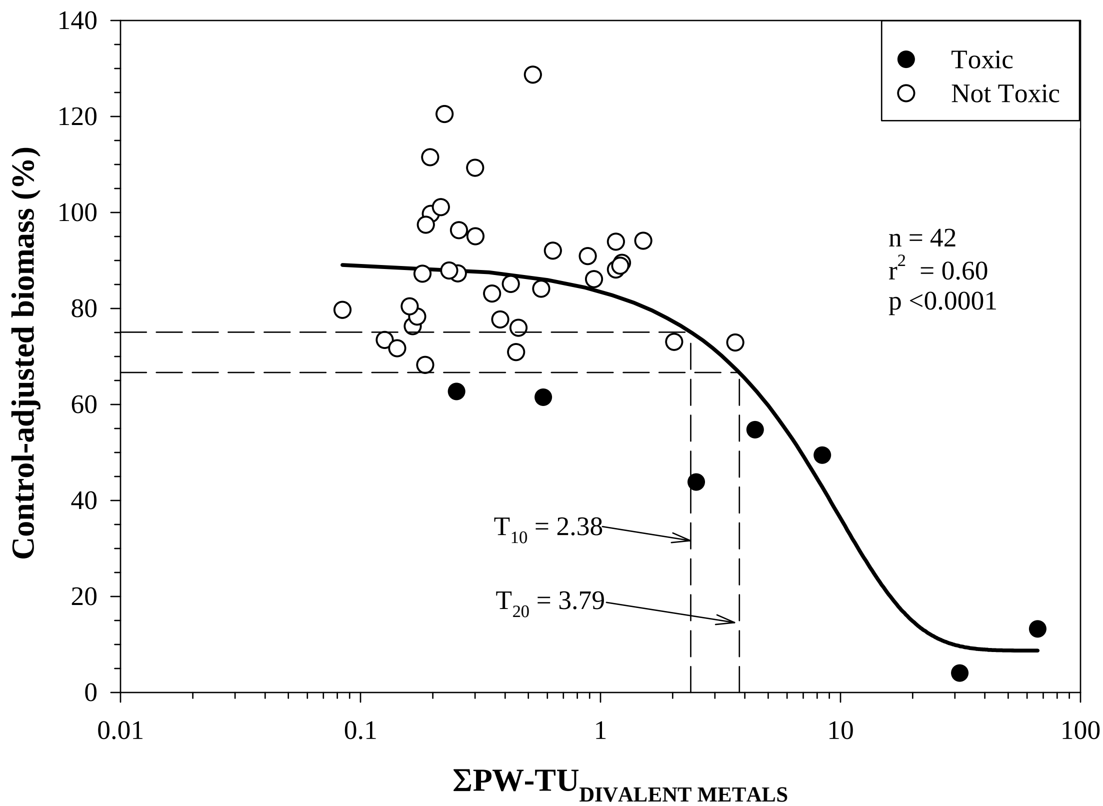


Figure 61. Scatter plot showing the relationship between amphipod (*Hyalella azteca*; HA) survival and biomass (n = 76).

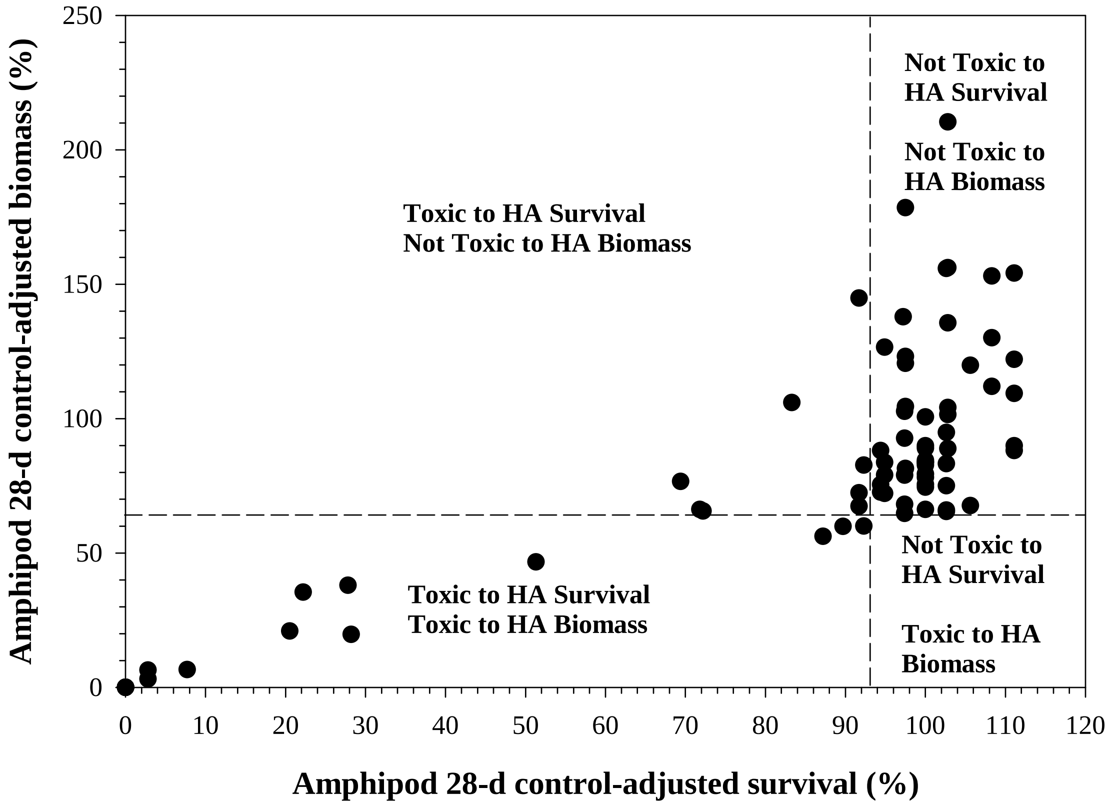


Figure 62. Scatter plot showing the relationship between amphipod (*Hyalella azteca*; HA) survival and mussel (*Lampsilis siliquoidea*; LS) survival (n = 48).

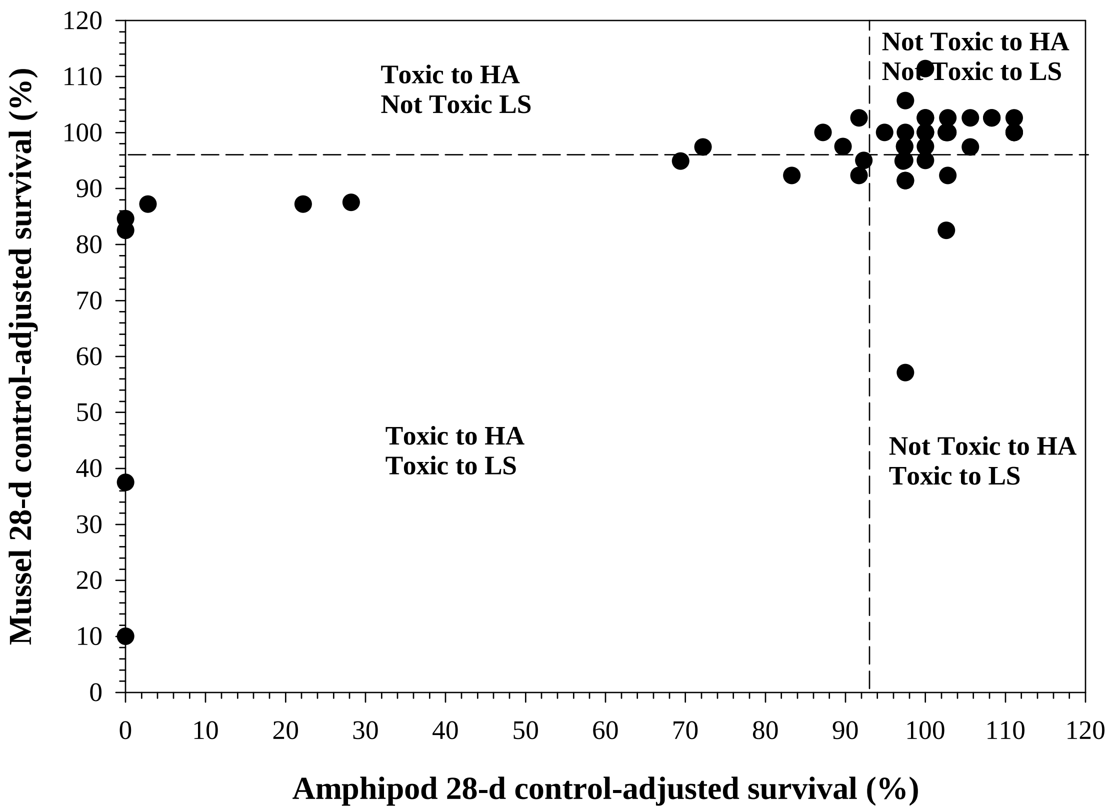


Figure 63. Scatter plot showing the relationship between amphipod (*Hyalella azteca*; HA) survival and mussel (*Lampsilis siliquoidea*; LS) biomass (n = 48).

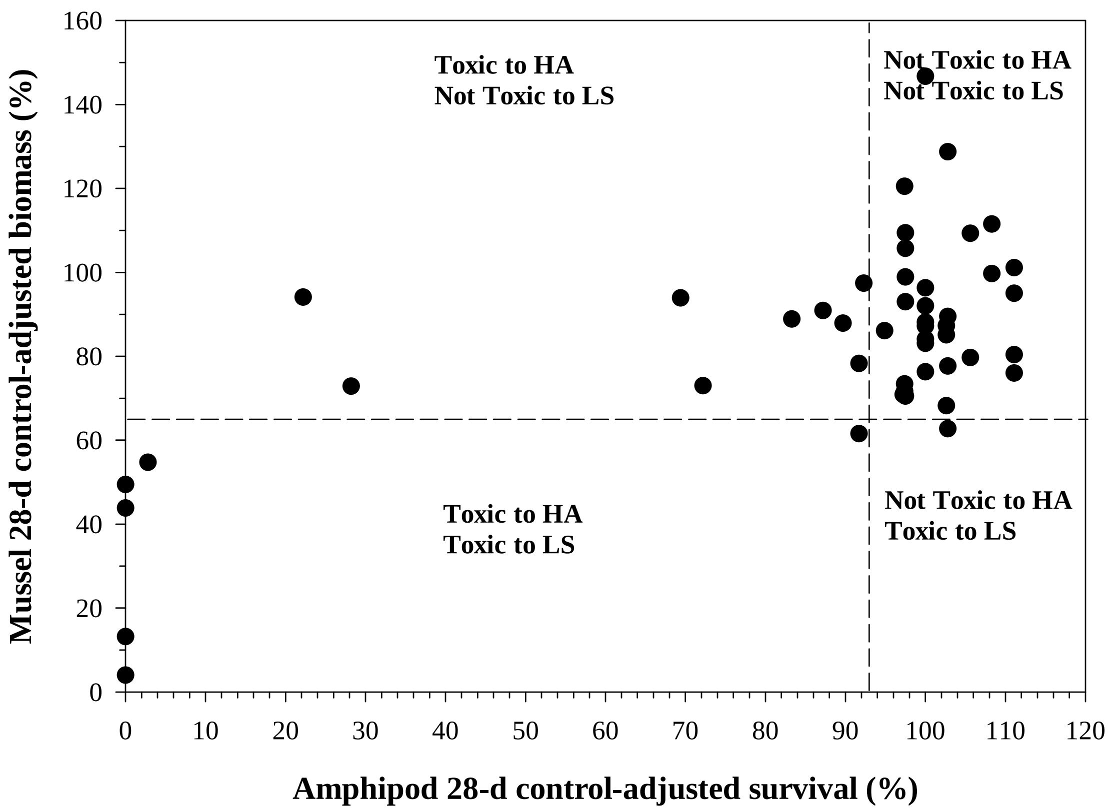


Figure 64. Scatter plot showing the relationship between amphipod (*Hyalella azteca*; HA) survival and midge (*Chironomus dilutus*; CD) survival (n = 76).

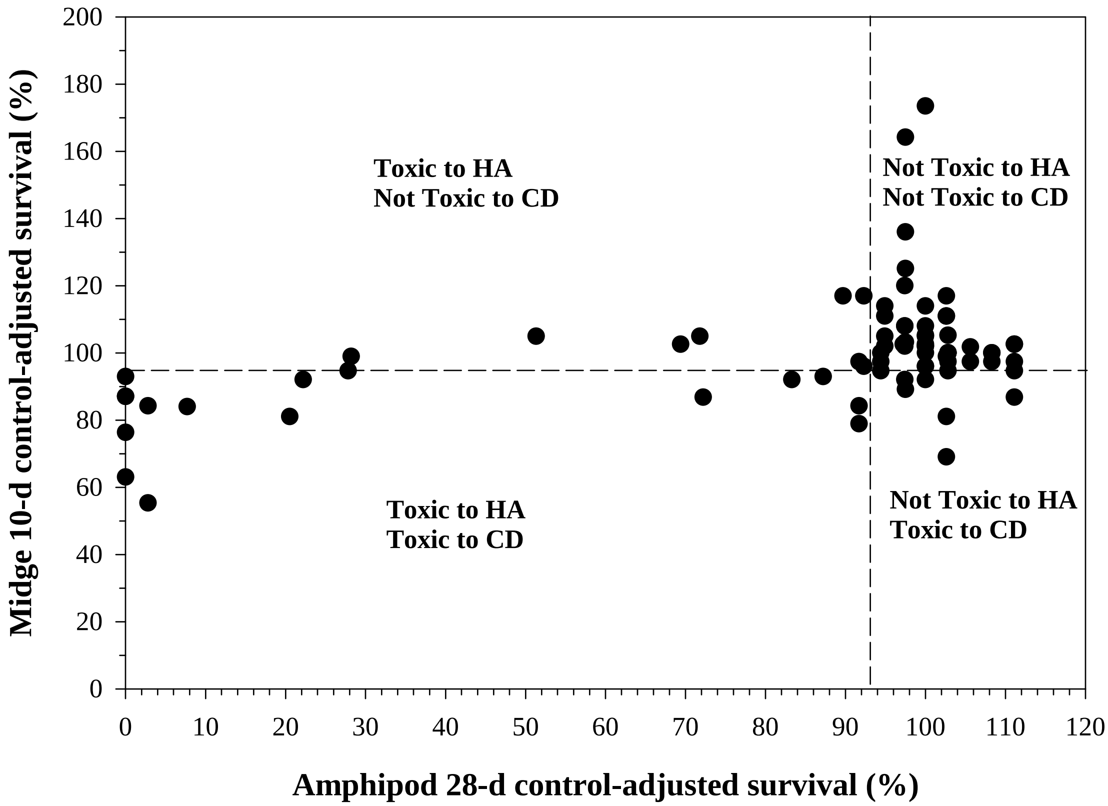


Figure 65. Scatter plot showing the relationship between amphipod (*Hyalella azteca*; HA) survival and midge (*Chironomus dilutus*; CD) biomass (n = 76).