BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED SITE SPECIFIC	)	
RULE FOR SANITARY DISTRICT	)	R14-24
OF DECATUR FROM 35 ILL. ADM.	)	(Site Specific Rule – Water)
CODE SECTION 302.208(e).	)	

PRE-FILED TESTIMONY OF KENT NEWTON
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

The Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Kent Newton in Support of Proposed Site Specific Rule for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF KENT NEWTON

I. INTRODUCTION

My name is Kent Newton, and I am the Executive Director and Chief Financial Officer of the District in Decatur, Illinois, a position I have held since April 2016. As Executive Director and Chief Financial Officer, I have overall responsibility for the District, its operations, and its compliance with laws and regulations, including Illinois water quality standards. Prior to serving in my present capacity, I served as the District's Director of Administration from December 2009. My resume is attached as Exhibit A. My testimony today concerns the District's Main Plant and consultations with the Illinois Environmental Protection Agency ("Illinois EPA") and the United States Environmental Protection Agency ("USEPA") on the development of the District's site specific rule.

Before I address those topics, I would first like to express the District's appreciation for the Illinois Pollution Control Board's ("Board") consideration of our proposed site-specific rule

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and for holding this hearing in the City of Decatur, Macon County, Illinois. I would also like to express our appreciation to the Illinois EPA and USEPA for their cooperation and assistance in working with us as we have pursued numerous efforts to resolve our nickel issue over the past several years. As a result of that collaboration, the District believes it has proposed a site specific chronic water quality standard ("WQS") for nickel that not only is equally protective of the environment but also ensures that compliance with the nickel WQS is technically feasible and economically reasonable for the District and its many users and stakeholders.

Further, we note that the site specific WQS, while providing appropriate relief from the Illinois general use chronic WQS for nickel, is still considerably more stringent than USEPA's National Recommended Water Quality Criteria (chronic) for nickel. Based on the District's Amended Petition for Site Specific Rule ("Amended Petition") and exhibits filed with the Board and our testimony being provided today, the District requests that the Board move forward to adopt our site specific rule.

II. MAIN PLANT

Located in Macon County, the District treats wastewater for the City of Decatur, the Villages of Forsyth, Mt. Zion, Oreana, and Argenta, and for industrial and commercial users in the Decatur, Illinois, metropolitan area. The District formed in 1917 and completed the original Main Plant, located at 501 Dipper Lane, Decatur, Illinois, in 1924. The District made major expansions and plant upgrades in 1928, 1957, 1964, and 1976, and completed the current plant in 1990. Numerous plant improvements to increase reliability and efficiency have been completed since 2002, and upgrades are ongoing. The District employs approximately 55 full-time employees and serves approximately 32,000 active billing accounts, including 25 significant industrial users ("SIUs"), and 2,400 other industrial and commercial users.

The Main Plant processes an average flow of approximately 28 million gallons per day ("MGD"), which is then discharged into the Sangamon River. The Main Plant has a design average flow of 41.0 MGD and a design maximum flow of 125.0 MGD. Treatment at the Main Plant consists of screening, grit removal, primary clarification, activated sludge, secondary clarification, disinfection, dechlorination, discharge to surface water, anaerobic digestion, sludge thickening, and land application of sludge on area farmland. The District has an approved pretreatment program with 13 noncategorical SIUs and 11 categorical SIUs.

Two industrial users, Archer Daniels Midland Company ("ADM") and Tate & Lyle Ingredients Americas, Inc. ("Tate & Lyle"), contribute a large portion of the flow to the Main Plant. These companies process grain (corn and soybeans) and produce a variety of products. On an annual average basis, ADM and Tate & Lyle discharge approximately 10 MGD and 5 MGD, respectively, and constitute an average of approximately 45% of the District's flow. This percentage increases to as much as 56% of the District's flow during extended dry weather periods.

The Main Plant's main discharge is via Outfall 001 to the Sangamon River at 39° 49' 56" North Latitude, 89° 0' 7" West Longitude. At the discharge point, the Sangamon River is designated as a General Use Water under Section 303.201 of the Board's rules.

III. CONSULTATIONS WITH ILLINOIS EPA AND USEPA

The District has worked cooperatively with Illinois EPA and USEPA in preparing the proposed site specific standard with the intent that it not only meet the Board's standards for site specific approval, but also be consistent with federal law, supported by Illinois EPA, and approvable by USEPA. In 2007, at the suggestion of Illinois EPA and USEPA, the District began investigating the potential usefulness of approaches based on a Water Effect Ratio

("WER") and/or Biotic Ligand Model ("BLM") and whether those might apply to the District's situation. In 2009, the District retained its consultant, Mr. Robert Santore of Windward Environmental, LLC in East Syracuse, New York, to evaluate the applicability of the BLM and WER based on available data. Since then, the District has continued developing the WER and BLM and submitting information to Illinois EPA and USEPA for review.

Over the years, the District has participated in a number of telephone conference calls with personnel from Illinois EPA, USEPA Region 5, USEPA's Duluth Research Laboratory, and USEPA Headquarters and has diligently addressed all follow-up questions and comments received from the agencies. The District has continued to work closely with Illinois EPA and USEPA and provided the additional information requested by the agencies for support and approval of the District's proposed site specific rule. And, again, the District appreciates the time and effort of Illinois EPA and USEPA throughout this process.

IV. CONCLUSION

The information discussed today supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

<signature on following page>

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Exhibit A

KENT D. NEWTON, CPFO

4342 Bentonville Road, Decatur, IL 62521
Phone (217) 422-6931
kentn@sddcleanwater.org

EXPERIENCE

Sanitary District of Decatur, Decatur, IL - 2009 – Present
Executive Director / CFO – 2015-Present
Responsible for providing the overall leadership and strategic vision for the District by working with the Board of Trustees and the Executive Management team. Manage the operation of the facilities and ensure compliance with all state and federal permit regulations, including Illinois water quality standards as well as coordination of all policy enactments legislated by the Board.

Director of Administration – 2009-2015
Manage financial, personnel and risk management functions for local government. Accountable for tax levy, annual budget and appropriation ordinance, annual financial report, fund balance analysis, monthly board report, debt issuance and revenue and expense forecasting under the direction of the Executive Director.

Park District of Oak Park, Oak Park, IL - 2000-2009
Superintendent of Business Operations
Manage financial, personnel, information technology and risk management functions for local government under the direction of the Executive Director.

Morton Grove Park District, Morton Grove, IL - 1998·2000
Superintendent of Finance
Manage financial, personnel, information technology and risk management functions for local government under the direction of the Executive Director.

Park Ridge Recreation and Park District, Park Ridge, IL - 1995-1998
Finance Coordinator
Manage financial and information technology for local government under the direction of the Superintendent of Finance and Administration.

EDUCATION AND TRAINING

B.S. Accounting *Purdue University West Lafayette, IN* 1994
Revenue School *National Recreation Park Association* 2000
Municipal Engineering Fundamentals for Non-Engineers *University of Wisconsin*-Madison 2015

CERTIFICATIONS AND AWARDS

Certified Public Finance Officer *Governmental Finance Officers Association (GFOA)*

MEMBERSHIPS

Water Environment Federation, Central States Water Environment Association, Illinois Water Environment Association, Illinois Association of Wastewater Agencies GFOA, Illinois GFOA

PAPERS

Hunter, G., Dunlap, P., Ratzki, T., Bunch, D., Kluge, T., **Newton, K.,** Miller, D. (2015) *NITROGEN, PHOSPHORUS, AND INDUSTRY- A MATCH MADE IN HEAVEN,* WEFTEC

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

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PROPOSED SITE SPECIFIC	)	
RULE FOR SANITARY DISTRICT	)	R14-24
OF DECATUR FROM 35 ILL. ADM.	)	(Site Specific Rule – Water)
CODE SECTION 302.208(e).	)	

PRE-FILED TESTIMONY OF TIMOTHY R. KLUGE
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

The Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Timothy R. Kluge in Support of Proposed Site Specific Rule for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF TIMOTHY R. KLUGE

I. INTRODUCTION

My name is Timothy R. Kluge and I was previously employed as Technical Director by the District in Decatur, Illinois, a position I held from 2007 to 2015. My duties as Technical Director were to direct activities and performance of the Operations, Instrumentation and Controls, and Laboratory Departments, including the industrial pretreatment program. Also, I was responsible for the District's compliance with all environmental regulations and served as the District's liaison with regulatory agencies in such matters. Prior to July 2007, I was employed by the Illinois Environmental Protection Agency ("Illinois EPA") for approximately 31 ½ years, where I held positions including Field Operations Section Manager, Industrial Permit Unit Manager and Field Engineer, all within the Division of Water Pollution Control. I received a Bachelor of Science in Chemical Engineering from the University of Illinois, Champaign-

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Urbana and a Masters of Science in Thermal and Environmental Engineering from Southern Illinois University at Carbondale. My resume is attached as Exhibit A.

My testimony today addresses and supports those portions of the District's Amended Petition for Site Specific Rule ("Amended Petition") that concern the District's National Pollutant Discharge Elimination System ("NPDES") permit and its limits; the District's investigations of nickel sources; the District's investigation of nickel treatment and industrial pretreatment options; the District's nickel water quality standard investigations; receiving stream impacts; and a summary of the District's proposed site specific standard.

II. NPDES PERMIT

The District's current NPDES Permit (No. IL0028321) was issued by Illinois EPA on April 20, 2007, effective on July 1, 2007, modified on July 1, 2009, and originally set to expire on June 30, 2012. However, because the District submitted a timely application for renewal of its NPDES permit on December 21, 2011, the District's NPDES permit is administratively continued pursuant to 35 Ill. Admin. Code § 309.104(a).

As issued on April 20, 2007, Special Condition 18 of the NPDES permit included a nickel effluent limit that Illinois EPA calculated using the general use water quality standard formula in Section 302.208(e). Specifically, the permitted nickel effluent limit was 0.011 mg/L measured as a monthly average with no daily maximum concentration limit stated.

The permit included a two-year compliance schedule and a provision for conducting a translator study, intended to gather data that would allow for possible recalculation based on additional hardness and soluble/insoluble metal analyses. The District performed the translator study during the summer and fall of 2007 and submitted a report to Illinois EPA. Based on the report, Illinois EPA determined that the hardness used to calculate the permit limit could be revised, and that a slightly different total metal adjustment was warranted. The calculated nickel limit was revised from 0.011 mg/L to 0.015 mg/L.

Accordingly, Illinois EPA modified the District's NPDES permit on July 1, 2009. Among other revisions made to the NPDES permit, Illinois EPA changed the permitted nickel limit based on the metals translators. Illinois EPA also extended the existing compliance schedule for nickel from two years to three years, to June 30, 2010, explaining that the work performed to date had not allowed achievement of numeric limitations for nickel. The additional time would be used to investigate other treatment techniques that would include electro-coagulation and methods to break the gluten-nickel chelate bond.

III. INVESTIGATIONS OF NICKEL SOURCES

When the 2007 NPDES permit was issued, the District also began an investigation of the sources of nickel in the wastewater received by the District. Several of the larger pumping stations in the District's collection system handle primarily from residential areas, and these were sampled to provide an indication of domestic contributions of nickel. Analysis of 24 samples collected over a ten-month period in 2007 and 2008 found an average nickel concentration from domestic sources below the detection limit.

Metals analyses of the large industrial discharges had been ongoing prior to the 2007 permit issuance. Data from 2003 through mid-2008 showed Archer Daniels Midland Company's ("ADM's") discharge to contain an average of 0.056 mg/L of nickel and Tate & Lyle's discharge an average nickel concentration below the detection limit. After considering these domestic and industrial results, the District determined that the most significant source of nickel in the District's wastewater was ADM's pretreated industrial flow.

IV. INVESTIGATION OF NICKEL TREATMENT AND PRETREATMENT OPTIONS

The District and ADM have investigated numerous alternatives over the past several years, but no treatment option has been identified that can consistently meet the required nickel limit and is also both technically feasible and economically reasonable.

The District's Amended Petition provides a detailed discussion of both the District's and ADM's efforts to mitigate nickel, and for brevity I will not repeat that discussion here, other than to direct the Board's attention specifically to all the mitigation efforts described at pages 20 through 29 and 52 through 58 of the Amended Petition. I actively participated in the review of the District's mitigation efforts and was consulted and regularly updated on ADM's efforts, and I would be happy to respond to any questions the Board or its staff may have on those reviews. I also know that ADM's efforts are further described in Mr. Paul Bloom's testimony and that he can speak more particularly to ADM's work.

V. NICKEL WATER QUALITY STANDARD INVESTIGATIONS

Beginning in late 2007, the District also consulted a number of times with Illinois EPA personnel regarding its nickel permit limit. In the course of those discussions, Illinois EPA noted that the recently-developed national water quality criterion for copper used a Biotic Ligand Model ("BLM") to assist in predicting impacts of the metal on aquatic organisms. Subsequently, the District found that a BLM had been developed for nickel and described in a report by the Water Environment Research Foundation (Wu, K. Benjamin, Paul R. Paquin, Valerie Navab, Rooni Mathew, Robert C. Santore, and Dominic M. Di Toro, 2003. Development of a Biotic Ligand Model for Nickel: Phase I Report 01-ECO-10T, Water Environment Research Foundation, Alexandria VA). The District contacted one of the authors of this report and requested an evaluation of using this approach to develop a proposal for a site-specific nickel water quality standard applicable to the portion of the Sangamon River receiving the District's treated discharge. The development process for the District's proposed site-specific standard is described in Mr. Robert Santore's testimony.

VI. RECEIVING STREAM IMPACTS

The Sangamon River watershed comprises approximately 5,419 square miles, all in central Illinois, and practically all of it tillable and generally cultivated. The Sangamon River originates in central McLean County, east of Bloomington, flows generally southwesterly to Decatur, then westerly to Springfield, northwesterly to the confluence with Salt Creek near Oakford, and then joins the Illinois River north of Beardstown. Its total length is about 250 miles.

Since 1998, the District has contracted with personnel from Eastern Illinois University to perform biotic assessments of the Sangamon River in the vicinity of the District's discharge. These studies include evaluations of fish and macroinvertebrate populations as well as water chemistry upstream and downstream of the District's Main Plant. The studies and results will be described in the testimony of Dr. Robert Colombo.

Treated wastewater from the District's Main Plant discharges to the Sangamon River. The District's discharge is located about three miles downstream from the dam impounding Lake Decatur, the primary water source for the City of Decatur. Because the lake is managed as a water supply, the volume of water discharged from the dam varies widely during different seasons and weather conditions. The U.S. Geological Survey ("USGS") maintains a stream flow measurement station at the Illinois Route 48 bridge crossing over the Sangamon River, approximately one mile downstream from the dam, providing continuous river flow data upstream of the District's discharge. USGS' website provides flow data from this stream measurement station from October 1, 1982, to the present.

The Illinois State Water Survey ("ISWS") has mapped the seven-day, ten-year low flow ("7Q10") of Illinois' streams, including the Sangamon River, its tributaries, and wastewater plant flows. The 7Q10 flow is important because Illinois EPA uses this flow to establish water quality-based effluent limits. The ISWS map for the Sangamon River Region shows a 7Q10 flow of zero below the Lake Decatur dam and upstream of the District's discharge point, meaning that on average, over a period of ten years, the stream will have no flow for at least one period of seven consecutive days. The ISWS Map for the Sangamon River Region (Apr. 2002) was attached to the Amended Petition filed on November 30, 2017, as Exhibit 31.

The District performed Ecological Compliance Assessment Tool ("EcoCAT") searches of the Illinois Natural Heritage Database and found no records of State-listed threatened or endangered species, Illinois Natural Area Inventory sites, dedicated Illinois Nature Preserves, or registered Land and Water Reserves in the vicinity of the project location. A copy of the EcoCAT Report dated November 29, 2017, was attached to the Amended Petition filed on November 30, 2017, as Exhibit 41.

VII. SUMMARY OF DISTRICT'S PROPOSED SITE SPECIFIC STANDARD

The District's discharge exceeds the current water quality standard for nickel due to the influent contributions primarily from one industrial user. A different numeric standard that considers the bioavailability of nickel to aquatic life would provide equivalent protection of the Sangamon River and its designated uses. Utilizing a Water Effect Ratio based on dissolved organic material in the Sangamon River as described in Mr. Robert Santore's testimony, supplemented by additional evidence provided by an extensive literature review and calculation of a BLM-based value, a proposed Water Effect Ratio factor of 2.50 applied to the statewide chronic standard for nickel is justified. The proposed standard has been met the majority of the time in the past, and studies of the aquatic life in the river indicate that at current discharge levels, no water quality concerns attributed to nickel have been noted.

VIII. CONCLUSION

The information discussed today supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Melissa.Brown@heplerbroom.com

Exhibit A

Timothy R. Kluge

Education

Bachelor of Science, Chemical Engineering, University of Illinois at Urbana-Champaign (1975)

Master of Science, Thermal and Environmental Engineering, Southern Illinois University Carbondale (1981)

Numerous seminars and short courses providing technical training and management skills development

Professional Experience

2007 - 2015: Sanitary District of Decatur, Technical Director. Directed activities and performance of the Operations, Instrumentation and Controls, and Laboratory Departments including the Industrial Pretreatment Program; responsible for District compliance with all environmental regulations and acted as District liaison with regulatory agencies in such matters.

1993 - 2007: Illinois Environmental Protection Agency, Division of Water Pollution Control, Field Operations Section Manager. Responsible for planning and implementing an inspection program to identify and respond to violations of state and federal water pollution control laws, assuring technical quality, consistency, and productivity in the field program for the Division's seven regional offices, and ensuring coordination of field activities with other Agency programs.

1983 - 1993: Illinois Environmental Protection Agency, Division of Water Pollution Control, Industrial Permit Unit Manager. Responsible for review of industrial discharge permit applications, construction and operating permit applications for industrial wastewater, and management of the industrial pretreatment program.

1975 - 1983: Illinois Environmental Protection Agency, Division of Water Pollution Control, Springfield Regional Office. Responsible for field inspections and compliance activities at assigned municipal and industrial wastewater treatment facilities, assistance and training for plant operators, and response to citizen complaints and environmental emergency incidents.

Professional Registration and Activities

Licensed Professional Engineer (Illinois)
Water Environment Federation (Life Member)
Illinois Water Environment Association, (President 1998-1999; Delegate 2011-2014)

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

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PRE-FILED TESTIMONY OF ROBERT E. COLOMBO II, PH.D.
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

The Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Dr. Robert E. Colombo II in Support of Proposed Site Specific Rule for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF ROBERT E. COLOMBO II, PH.D.

I. INTRODUCTION

My name is Dr. Robert E. Colombo II, and I am an Associate Professor in the Biology Department at Eastern Illinois University ("EIU"), a position I have held since 2013. Prior to serving in my present capacity, I served as Assistant Professor of Fisheries Biology at EIU from 2009 through 2013, and a Histology Instructor at Southern Illinois University School of Medicine from 2007 through 2009. I received my Ph.D. from the Fisheries and Illinois Aquaculture Center and Department of Zoology at Southern Illinois University in Carbondale, Illinois, in 2007. I also have a Master of Science degree in Zoology and a Bachelor of Science degree in Biology.

As a professor at EIU, I teach courses in Fisheries Management, General Ecology, Ichthyology, Population Ecology, and Endocrinology. My research focuses on how fish populations respond to anthropogenic impacts. Specifically, I am interested in the responses of

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native fishes to harvest, invasive species and habitat alterations. Most of my research focuses on commercially or ecologically important species in lotic (flowing) water systems. My Curriculum Vitae is attached as Exhibit A.

My testimony today concerns EIU's assessments conducted on the stretch of the Sangamon River beginning just below the Lake Decatur Dam and extending downstream to incorporate the discharges of the District.

II. EIU'S ASSESSMENTS OF THE SANGAMON RIVER STUDY AREA

Researchers from EIU have studied the overall impact of the District's discharge on water quality and biology in the Sangamon River from 1998 to the present and reported the study's results on an annual basis. I have been directly involved with these studies since 2009. These biological studies continue to document similar or improved water quality conditions downstream of the District's discharge point, as compared to upstream, based on various assessments.

EIU has regularly concluded that the higher concentrations of soluble nickel occurring in the Sangamon River downstream of the District's effluent discharge do not appear to be affecting fish or macroinvertebrate communities. Regarding the most recently completed annual assessment for 2016, EIU assessed physical parameters using a modified Ohio's Quality Habitat Evaluation Index ("QHEI") for seven sites. At the sites, EIU measured substrate type and depth and estimated the percent of each instream cover type, the channel morphology, the amount of riparian zone and bank erosion, the pool and riffle quality, and gradient. Higher QHEI scores were typical of sites downstream of the District's discharge. EIU observed that the consistent flow downstream of the District's outfall during periods of low discharge from the Lake Decatur reservoir may help maintain the physical habitat quality while the upstream reach becomes disconnected pools. These results are further discussed in EIU's May 2017 report attached as Exhibit 32 to the District's Amended Petition for Site Specific Rule filed in this proceeding on November 30, 2017 ("Amended Petition").

When assessing macroinvertebrates, EIU's studies have regularly documented similar or improved conditions downstream of the District's discharge point, as compared to upstream. For example, during the most recently completed annual sampling period, a total of 58 different taxa were identified from the seven sites sampled. When comparing overall assemblages, there was no significant difference for Simpson's Diversity ($p = 0.159$) between the reaches upstream and downstream of the District's main outfall. However, estimated abundance; richness; percent Ephemeroptera, Plecoptera, and Trichoptera ("EPT") taxa; EPT richness; and macroinvertebrate index of biotic integrity ("MBI") were significantly higher (lower for MBI) downstream of the District's main outfall (estimated abundance $p = 0.006$, richness $p = <0.001$, percent EPT $p = <0.001$, EPT richness $p = <0.001$, MBI $p = <0.001$). These results are further discussed in EIU's May 2017 report attached as Exhibit 32 to the District's Amended Petition.

EIU also sampled macroinvertebrates in the summer of 2014, as well as the fall of 2015, in the upstream and downstream reaches. EIU found no significant difference between the two reaches either year for estimated relative abundance, total taxa richness, and EPT richness. However, percent EPT was significantly higher in the downstream reach in both years, and Simpson's Diversity was higher downstream in 2015. Based on these results, EIU concluded that there are very few differences in macroinvertebrate communities between reaches, all differences indicate higher quality communities in the downstream reach of the study area, and macroinvertebrate communities in the study area are impacted more by habitat type and quality than by water quality and concentrations of soluble nickel. These results are further discussed in EIU's May 2015 report attached as Exhibit 33 to the District's Amended Petition.

EIU sampled fish using pulsed DC electrofishing to determine if fish communities are affected by water quality upstream and downstream of the District's effluent discharge. EIU used catch-per-unit-effort ("CPUE") to calculate the relative density of fish and determined that, for 2016, CPUE was highest in the upstream reach and lowest in the downstream reach. However, previous years of studies have regularly determined that there was no significant difference in the number of fish caught per hour between reaches upstream and downstream of the District's main outfall. These results are further discussed in EIU's May 2017 and May 2015 reports attached as Exhibit 32 and Exhibit 33 to the District's Amended Petition.

EIU has also measured diversity of the fish community in each reach using Simpson's Diversity Index. This measure of diversity showed no difference between reaches upstream and downstream of the District's main outfall. Based on these results, EIU concluded that fish communities are not different between reaches and did not appear to be affected by soluble nickel within the study area. These results are further discussed in EIU's May 2015 report attached as Exhibit 33 to the District's Amended Petition.

Similarly, EIU's study results have regularly reported that fish species diversity in the Sangamon River study area is comparable to other Midwestern streams, with Steelcolor Shiner and Spotfin Shiner being the most numerically abundant non-game species and Bluegill being the most abundant sportfish species. These results are further discussed in EIU's May 2015 report attached as Exhibit 33 to the District's Amended Petition.

In addition to the May 2017 and May 2015 reports, EIU's annual assessment reports from previous years are attached for reference as Exhibits 34 – 40 to the District's Amended Petition.

III. CONCLUSION

The information discussed today supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Daniel L. Siegfried
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Exhibit A

Robert Edward Colombo II

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Department of Biological Sciences
College of Sciences
Eastern Illinois University
Charleston, Illinois 61920
recolombo@eiu.edu
Work: 217-581-3011

I. Education

12/2007 Ph.D., Fisheries and Illinois Aquaculture Center and Department of Zoology, Southern Illinois University, Carbondale

Dissertation Title: Population Demographics and the Ecological Role of the Channel Catfish (*Ictalurus punctatus*) in Commercially Exploited and Unexploited Reaches of the Wabash River with Implications for the Flathead Catfish (*Pylodictus olivaris*). Major advisors: James E. Garvey, Ph.D. and Roy C. Heidinger, Ph.D.

2004 M.S., Zoology, Fisheries and Illinois Aquaculture Center and Department of Zoology, Southern Illinois University, Carbondale

Thesis Title: Reproductive Demographics and Early Life History of the Shovelnose Sturgeon (*Scaphirhynchus platorynchus*)
Major advisor: James E. Garvey, Ph.D.

1998 B.S., *magna cum laude*, Biology 1998, SUNY Environmental Science and Forestry, Syracuse, New York

Major advisor: Neal Ringler, Ph.D.

II. Employment History

2016-Present Coordinator, Environmental Biology Program, Department of Biological Sciences , Eastern Illinois University, Charleston, Illinois.

2013-Present Associate Professor, Department of Biological Sciences, Eastern Illinois University, Charleston, Illinois.

2009-2013 Assistant Professor, Department of Biological Sciences, Eastern Illinois University, Charleston, Illinois.

2008-Present Adjunct Assistant Professor, Department of Zoology, Southern Illinois University, Carbondale.

2008 Zoology Instructor, Department of Zoology, Southern Illinois University, Carbondale.

2007-2009 Histology Instructor, Department of Anatomy, School of Medicine, Southern Illinois University, Carbondale, IL.

2007-2009 Problem Based Learning Facilitator / Tutor, School of Medicine, Southern Illinois University, Carbondale, IL.

III. Research Experience

Ph.D. Population Demographics and the Ecological Role of the Channel Catfish (*Ictalurus punctatus*) in Commercially Exploited and Unexploited Reaches of the Wabash River with Implications for the Flathead Catfish (*Pylodictus olivaris*).

M.S. Reproductive Demographics and Early Life History of the Shovelnose Sturgeon (*Scaphirhynchus platorynchus*)
Tools Used:

SIUC R.A. Current Status of the Pallid Sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River

Habitat Use and Movement of the Bighead and Silver Carp in the Illinois River

Undergraduate: Lake Sturgeon Population Demographics in the St. Lawrence River, NY.

IV. Fields of Research

Fish physiology, histology, embryology, fish parasitology and pathology, impacts of commercial exploitation on inland fisheries stocks, fisheries modeling and population dynamics, analysis of mark recapture data, analysis of telemetry data, endangered species conservation, exotic species management, genetic stock structure, sturgeon ecology and conservation, large river fisheries, basic and applied fish biology, husbandry.

V. Teaching Experience

Associate Professor (Eastern Illinois University 2009-Present)

- General Biology BIO1100* (Fall 2009)
- Human Anatomy BIO2200* (Summer 2010, 2012, & 2014)
- Principles of Ecology BIO3800* (Fall 2009 – Spring 2016)

- Fisheries Ecology and Management BIO4812* (Fall 2010, 2012, 2014, & 2016)
- Ichthyology BIO4950* (Spring 2010, 2012, 2014, 2016, and 2018)
- Population Ecology BIO5208* (Fall 2011, 2013, 2017)
- Graduate Seminar BIO5150* (Spring 2011, Fall 2014 & 2015)
- Fish and Wildlife Techniques BIO3960/5372* (Fall 2012)
- Anatomy and Physiology I* (Summer 2015)
- Functional Comparative Anatomy* (Fall 2015)

Instructor (SIUC School of Medicine, 2007 to 2009)
- Embryology Curriculum Director (2008)
- Histology (2007 to 2009)*
- Problem Based Learning Tutor (2007 to 2009)*

Zoology Instructor (SIUC)
- Comparative Vertebrate Histology, *Zool 409* (2008)

Graduate Teaching Assistant (SIUC):
- Comparative Vertebrate Histology, *Zool 409* (2006 & 2007)*
    - Winner of the Foote and Foote Award for Outstanding Teaching Assistant in Zoology 2006
- Comparative Endocrinology, *Zool 426* (2006 & 2007)

***Student appraisal available**

VI. Extramural Grants (>$3 million)

1. **Colombo, R.E.** 2016. Assessment of the Fish Community in Six Mile and Money Creeks. The Nature Conservancy. $42,000

2. **Colombo, R.E.,** S. Meiners and E.K Bollinger. 2017-2018. Long Term River Monitoring Program of the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $285,000

3. **Colombo, R.E**. 2016-2017. Assessment of the recruitment abilities of Asian Carp in tributaries of the Illinois River. U.S. Fish and Wildlife Service. $40,000.

4. **Colombo, R.E.,** S. Meiners and E.K Bollinger. 2016-2017. Long Term River Monitoring Program of the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $322,135

5. **Colombo, R.E.**, and A.P. Porreca. 2016-2017. Biological and water quality studies on the Lake of Egypt. Southern Illinois Power Cooperative. $120,000

6. **Colombo, R.E.**, J. Laursen, and C. Pederson. 2015-2019. Ecological condition of the Sangamon River receiving effluent form the Sanitary District of Decatur:

Focusing on water chemistry, qualitative habitat assessment, and the mussel, macroinvertebrate, and fish assemblages. $290,000

7. **Colombo, R.E.,** S. Meiners and E.K Bollinger. 2015-2016. Long Term River Monitoring Program of the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $357,135

8. Smith, S., D. Keeney, and **R. Colombo**. 2015-2016. Impact of Dams on the Genetic Structure of Fish Populations. Illinois Water Resource Center. $8158

9. **Colombo, R.E.** and A. Resende da Maia. 2014-2016. Monitoring to Support Embarras River Watershed plan and Support, Evaluate Restoration Activities in Kickapoo Creek. $140,000. Illinois Environmental Protection Agency

10. **Colombo, R.E.,** S. Meiners and E.K Bollinger. 2014-2015. Long Term River Monitoring Program of the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $375,932

11. **Colombo, R.E.,** D. Keeney and S. Meiners. 2014-2017. Impacts of Dam Removals on Fish and Macroinvertebrate Community Assemblage. US Fish and Wildlife State Wildlife Initiative Grant. $44,000.

12. **Colombo, R.E.,** S. Meiners and E.K Bollinger. 2013-2014. Long Term River Monitoring Program of the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $375,933

13. **Colombo, R.E.** and E. Bollinger. 2012-2013. Demographics of Catfish Populations in the Wabash River. U.S. Fish and Wildlife Service, Federal Aid in Sportfish Restoration. $84,000

14. **Colombo, R.E.** and A. Schrey. 2010-2014. Monitoring the populations of sportfish in an Illinois power cooling lake. AMEREN Electrical Generation Co. $176,000

15. **Colombo, R.E.**, J. Laursen, and C. Pederson. 2010-2015. Biotic assessment of water quality in a stretch of the Sangamon River. Sanitary District of Decatur. $328,943

16. **Colombo, R.E.** 2010-2016. Assessment of Asian Carp Recruitment in the Illinois River. Illinois Natural History Survey. $180,000

17. **Colombo, R.E.** 2010-2015. Sportfish movement on the Wabash River. Illinois Department of Natural Resources. $50,000

18. **Colombo, R.E.** 2010-2013. Demographics of flathead catfish on the Wabash River. Illinois Natural History Survey. $54,000

19. Pederson, C.P. and **R.E. Colombo**. 2010-2012. Lake/Reservoir Phytoplankton Biocriteria. Illinois Environmental Protection Agency. $22,000

20. **Colombo, R.E.** 2009-2011. Restoration of Kickapoo Creek. Illinois Department of Natural Resources. $20,000

VII. Peer-Reviewed Manuscripts

1. *Boone, E.C., J.R. Laursen, **R.E. Colombo**, S.J. Meiners, M.J. Romani, and D.B. Keeney. *Accepted.* Infection patterns and molecular data reveal host and tissue specificity of Posthodiplostomum species in centrarchid hosts. Parasitology

2. Sullivan, C.J., C.A. Camacho, D.H. Wahl, Q.E. Phelps, **R.E. Colombo**, C.L. Pierce, and M.J. Weber. *Accepted.* Factors regulating year-class strength of Silver Carp throughout the Mississippi River basin. Transactions of the American Fisheries Society

3. *Moody, C.J., G. Sass, E.K. Bollinger, L. Frankland, and **R.E. Colombo**. 2017. Demographics of flathead catfish, Pylodictis olivaris, in the Wabash River, Illinois/Indiana, USA. North American Journal of Fisheries Management

4. *Sotola, V.A., A.W. Schrey, L. Frankland, E.K. Bollinger, and **R.E. Colombo**. 2017. Genetic stock structure of age-0 Channel (*Ictalurus punctatus*) and Blue (*I. furcatus*) Catfish in a large unimpounded Midwestern U.S. river. Transactions of the American Fisheries Society.

5. *Smith. S., S. Meiners, R. Hastings, T. Thomas, and **R. Colombo.** 2017. Low-Head Dam Impacts on Habitat and the Functional Composition of Fish Communities. River Research and Applications. doi: 10.1002/rra.3128

6. *Hastings, R.S., S. Meiners, T. Thomas, and **R.E. Colombo**. 2016. Contrasting impacts of dams on the metacommunity structure of fish and macroinvertebrate assemblages. North American Journal of Fisheries Management 36: 1358-1367.

7. *Nepal K.C., V., C.R. Jansen, and **R.E. Colombo.** 2016. Seasonal Patterns in Diet Composition of Adult Shovelnose Sturgeon in a Free-flowing River. Journal of Freshwater Ecology.

8. Hintz, W.D., D.C. Glover, K.J. Kilgore, D.P. Herzog, T.W. Spier, **R.E. Colombo**, R.A. Hrabik, and J.E. Garvey. 2016. Status and Habitat Use of Scaphirhynchus Sturgeons in an Important Fluvial Corridor: Implications for River Habitat Enhancement. Transactions of the American Fisheries Society 145: 386-399.

9. Mulhollem, J.J., **R.E. Colombo**, and D. H. Wahl. 2016. Effects of heated effluent on Midwestern U.S. lakes: Implications for future Climate Change. Aquatic Sciences. DOI 10.1007/s00027-016-0466-3

10. *Hastings, R. S. Meiners, T. Thomas, and **R. Colombo**. 2015. When to Sample: Flow Mediates Low-head in Dam Effects on Fish Assemblages. Journal of Freshwater Ecology DOI:10.1080/02705060.2015.1079560#sthash.nyZHZ1dU.dpuf

11. *Martinez, E., A.P. Porreca, **R.E. Colombo**, and M.A. Menze. 2015. Tradeoffs of Warm Adaptation in Aquatic Ectotherms: Live Fast Die Young. Comparative Biochemistry and Physiology. DOI: 10.1016/j.cbpa.2015.07.014

12. *Nepal KC, V., L.D. Frankland, and **R.E. Colombo**. 2015. Demographics of the Shovelnose Sturgeon in the Lower Wabash River. North American Journal of Fisheries Management. 35:835-844.

13. *Stuck, J., A. Porreca, D. Wahl and **R. Colombo**. 2015. Contrasting population demographics of invasive Silver Carp Hypopthalmicthys molitrix between an impounded and free flowing river. North American Journal of Fisheries Management. 35:114-122.

14. *Porreca, A.P., C.L. Pederson, J.R. Laursen, and **R.E. Colombo**. 2013. A Comparison of Electrofishing Methods and Fyke Netting to Produce Reliable Abundance and Size Metrics. Journal of Freshwater Ecology. 28: 585-590.

15. *Koch, B, R.C. Brooks, A. Oliver, D. Herzog, J.E. Garvey, R. Hrabik, **R. Colombo**, Q. Phelps, and T. Spier. 2011. Habitat Selection and Movement of Naturally Occurring Pallid Sturgeon in the Mississippi River. Transactions of the American Fisheries Society 141:112-120.

16. *Shuangying, Y., R.S. Holbrook, D.W. Sparling, and **R.E. Colombo**. 2011. Metal Accumulation and evaluation of effects in a freshwater turtle. Ecotoxicology 20: 1801-1812.

17. ***Colombo, R.E.,** Q.E. Phelps, C.M Miller, J.E. Garvey, R.C. Heidinger, and N.S. Richardson. 2010. Comparison of channel catfish age estimates and resulting population demographics using two common structures. North American Journal of Fisheries Management 30: 305-308.

18. Schrey, A., **R. Colombo**, J. Garvey, and E. Heist. 2009. Stock Structure of the Shovelnose Sturgeon from the Mississippi River Drainage. Journal of Applied Ichthyology 25: 625-631.

19. Phelps, Q.P., D.P. Herzog, R.C. Brooks, V.A. Barko, D.E. Ostendorf, J.W. Ridings, S.J. Tripp, **R.E. Colombo**, J.G. Garvey, and R.A. Hrabick. 2009.

Seasonal Comparison of Catch Rates and Size Structure Using Three Gear Types to Sample Sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management 29: 1487-1495.

20. Tripp, S.J., **R.E. Colombo**, and J.E. Garvey. 2009. Declining Recruitment and Growth of Shovelnose Sturgeon in the Middle Mississippi River: Implications for Conservation. Transactions of the American Fisheries Society 138: 416-422.

21. Tripp, S.J., **R.E. Colombo**, and J.E. Garvey, B.M. Burr, D.P. Herzog, and R.A. Hrabik. 2009. Assessing the life history strategy of the shovelnose sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management.

22. **Colombo, R.E.**, Q.E. Phelps, J.E.Garvey, R.C. Heidinger, and T. Stefanavage. 2008. Gear-Specific Population Demographics of Channel Catfish in a Large Un-impounded Midwestern River. North American Journal of Fisheries Management 28: 241-246.

23. DeGrandchamp, K.L., J.E. Garvey, and **R.E. Colombo**. 2008. Using habitat selection to predict establishment of invasive Asian carps in a large river. Transactions of the American Fisheries Society 137: 45-56.

24. **Colombo, R.E.**, J.E. Garvey, N.D. Jackson, R. Brooks, D.P. Herzog, R.A. Hrabik, and T.W. Spier. 2007. Harvest of Mississippi River sturgeon drives abundance and reproductive success: a harbinger of collapse? Journal of Applied Ichthyology. 23: 444-451.

25. **Colombo, R.E.**, J.E. Garvey, and P.S.Wills. 2007. A Guide to the embryologic development of the shovelnose sturgeon (*Scaphirhynchus platorhynchus*) reared at constant temperature. Journal of Applied Ichthyology 23: 402-419.

26. **Colombo, R.E.**, J.E. Garvey, and P.S.Wills. 2007. Gonadal development and sexual demographics of the shovelnose sturgeon, *Scaphirhyncus platorhynchus*, in the Middle Mississippi River. Journal of Applied Ichthyology 23: 420-427.

27. Jackson, N.D., J.E. Garvey, and **R.E. Colombo**. 2007. Comparing aging precision of calcified structures in shovelnose sturgeon. Journal of Applied Ichthyology. 23: 525-528.

28. **Colombo, R.E.**, P.S. Wills and J.E. Garvey. 2004. Use of ultrasound imaging to determine the sex of shovelnose sturgeon from the Middle Mississippi River. North American Journal of Fish Management 24: 322-326.

*** STUDENT COAUTHOR**

VIIa. Peer-Reviewed Manuscripts (In Prep or In Review)

1. *Smith, S., D. B. Keeney, T. Thomas, and **R. Colombo.** *In Review.* Submitted August 2017. Population Genetics of Three Fish Species in Fragmented Habitats. Submitted to Journal of Applied Ichthyology

2. *Boone, E.C., S.J. Meiners, L. Frankland, J.R. Laursen, and **R.E.** Colombo. *In Prep.* Fixed versus Random Sampling in a Low Density Population of Spotted Bass. Submitted to North American Journal of Fisheries Management.

3. Huck, S.M., L.D. Frankland, and **R.E. Colombo-** In Prep. Diel Movement and Habitat Use of Flathead Catfish *Pylodictis olivaris* in a Large Unimpounded Midwestern River. Submitted to Transactions of the American Fisheries Society

4. Bollinger, E.K. and **R.E. Colombo**. In Prep. Long-term Comparison of Benthic Macroinvertebrate Assemblages in Two Illinois Creeks. To be submitted to American Midland Naturalist

5. *Wildenberg, A., J.R. Larson, C.L. Pederson, C.J. Moody, and **R.E. Colombo**. In Prep. Effect of treated wastewater effluent on mussel community composition in a Midwestern River. Submitted to Freshwater Science

VIII. Technical Reports

1. ***Colombo, R.** and A. Porreca. 2013. Monitoring the Sportfish Assemblages of Coffeen Lake: A Final Report. Submitted to AMEREN Energy Generating Company.

2. **Colombo, R.**, J. Laursen, and C. Pederson. 2012. Biotic assessment of water quality in a stretch of the Sangamon River Receiving Effluent from the Sanitary District of Decatur: Focusing on qualitative habitat assessment, mussel assemblage, tiered-aquatic life use, and the sport fishery. Submitted to the Sanitary District of Decatur. Final Report

3. ***Colombo, R.** and A. Porreca. 2012. Monitoring the Sportfish Assemblages of Coffeen Lake: Year 2-2011 Annual Progress Report. Submitted to AMEREN Energy Generating Company.

4. ***Colombo, R.E.** and J. West. 2012. Impacts of Restoration on Fish and Macroinvertebrate Communities in Kickapoo Creek near Charleston, IL. Submitted to Illinois Department of Natural Resources. Final Report

5. ***Colombo, R.** and A. Porreca. 2011. Monitoring the Sportfish Assemblages of Coffeen Lake: Year 1-2010 Annual Progress Report. Submitted to AMEREN Energy Generating Company.

6. ***Colombo, R.** and J. West. 2011. Restoration of Kickapoo Creek near Charleston, IL. Submitted to Illinois Department of Natural Resources.

7. **Colombo, R.**, J. Laursen, and C. Pederson. 2011. Biotic assessment of water quality in a stretch of the Sangamon River Receiving Effluent from the Sanitary District of Decatur: Focusing on qualitative habitat assessment, mussel assemblage, tiered-aquatic life use, and the sport fishery. Submitted to the Sanitary District of Decatur.

8. **Colombo, R.E.**, J.E. Garvey, N.D. Jackson, R. Brooks, D.P. Herzog, R.A. Hrabik, and T.W. Spier. 2006. Harvest of Mississippi River sturgeon drives abundance and reproductive success: a harbinger of collapse? Chapter 6, in Current status of the pallid sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River. A Final Report Submitted to the U.S. Army Corps of Engineers, St. Louis district.

9. **Colombo, R.E.**, J.E. Garvey, and P.S.Wills. 2006. Gonadal development and sexual demographics of the shovelnose sturgeon, *Scaphirhynchus platorhynchus*, in the Middle Mississippi River. Chapter 7, in Current status of the pallid sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River. A Final Report Submitted to the U.S. Army Corps of Engineers, St. Louis district.

10. **Colombo, R.E.**, J.E. Garvey, and P.S.Wills. 2006. A Guide to the embryologic development of the shovelnose sturgeon (*Scaphirhynchus platorhynchus*) reared at constant temperature. Chapter 9, in Current status of the pallid sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River. A Final Report Submitted to the U.S. Army Corps of Engineers, St. Louis district.

11. Jackson, N.D., J.E. Garvey, and **R.E. Colombo**. 2006. Comparing aging precision of calcified structures in shovelnose sturgeon. Chapter 10, in Current status of the pallid sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River. A Final Report Submitted to the U.S. Army Corps of Engineers, St. Louis district.

12. **Colombo, R.E.**, J. E. Garvey, and R. C. Heidinger. 2005. Wabash river catfish population demographics and management implications. A Final Report Submitted to the Indiana Department of Natural Resources.

13. Heidinger, R., J.E. Garvey, and **R.E. Colombo**. 2005. The Wabash River Catfish Project. Year 4. Indiana Department of Natural Resources.

14. Heidinger, R., J.E. Garvey, **R.E. Colombo**, and P. Beck. 2004. The Wabash River Catfish Project. Year 3. Indiana Department of Natural Resources.

15. Heidinger, R., J.E. Garvey, and **R.E. Colombo**. 2003. The Wabash River Catfish Project. Year 2. Indiana Department of Natural Resources.

16. Heidinger, R., R.J. Sheehan, J.E. Garvey, C.J. Williamson and **R.E. Colombo**. 2002. The Wabash River Catfish Project. Year 1. Indiana Department of Natural Resources.

17. Heidinger, R., R.J. Sheehan, P.S. Wills, N. Jackson, **R. Colombo** and A. Miller. 2002. Middle Mississippi River Pallid Sturgeon Habitat Use Project. Year 6. Annual Progress Report.

*** STUDENT COAUTHOR**

IX. Presentations

1. *Hoster, B., and **R.E. Colombo**. Caudal fin abnormalities influence a condition index for Catstomid species from the Sangamon River. 55th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Moline, IL. February 2017. **STATE**

2. *Pesik, J., D. Roth, S. Meiners, D. Wahl, and R.E. **Colombo**. Differing spatiotemporal trends in larval fish communities in tributaries of two large river systems. 55th Annual Illinois Chapter of the American Fisheries Society Meeting, Moline, IL. February 2017. **STATE**

3. *Roth, D., J. Pesik, D. Wahl., **R.E. Colombo**. Spatial, temporal, and abiotic factors influencing Asian carp reproduction in large river tributaries. Oral Presentation. Illinois Chapter of the American Fisheries Society Annual Meeting. Moline, IL. February 2017. **STATE**

4. *Thornton, J.L., L.D. Frankland, J. Hirst, C. Jansen, V. Nepal KC, **R.E. Colombo**. Monitoring demographics of a commercially exploited population of Shovelnose Sturgeon (*Scaphirhynchus platorynchus*). 55th Annual Illinois Chapter of the American Fisheries Society Meeting, Moline, IL. February 2017. **STATE**

5. *Hoster, B., K. Gaines, A. Maia, E.K. Bollinger, and **R.E. Colombo**. Reproductive health of three Catostomid species in a wastewater treatment effluent impacted river. 77th Midwest Fish and Wildlife Conference, Lincoln, NE. February 2017. **REGIONAL**

6. *Pesik, J., D. Roth, S. Meiners, D. Wahl, and **R.E. Colombo**. Larval fish assemblages differ spatially and temporally among tributaries of two large river systems. 77th Annual Midwest Fish and Wildlife Conference, Lincoln, NE. February 2017. **REGIONAL**

7. *Pesik, J., V.A. Sotola, S. Rayford, and **R.E. Colombo**. Larval fish populations differ spatiotemporally on a large unimpounded river. 77th Annual Midwest Fish and Wildlife Conference, Lincoln, NE. February 2017. **REGIONAL**

8. *Roth, D. J. Pesik, D. Wahl, **R.E. Colombo**. Monitoring Invasive Bigheaded Carp Reproduction in Large River Tributaries with Larval Sampling Gear Comparison. Oral Presentation. 77th Midwest Fish and Wildlife Conference. Lincoln, NE. February 2017. **REGIONAL**

9. *Thornton, J.L., L.D. Frankland, J. Hirst, C. Jansen, V. Nepal KC, **R.E. Colombo**. Population demographics of Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) in the Wabash River. 77th Annual Midwest Fish and Wildlife Conference, Lincoln, NE. February 2017. **REGIONAL**

10. *Favata C.A., **R.E. Colombo**, A. Maia. Managing structural rehabilitation: Ecological monitoring and factors driving community structure in a restored stream. Contributed symposium paper, American Fisheries Society Annual Meeting, Kansas City, MO. August 2016. **NATIONAL**

11. *Hoster, B., and **R.E. Colombo**. Effects of wastewater treatment effluent on fish communities in an Illinois River tributary: condition of three Catostomid species. 46th Annual Meeting of the American Fisheries Society: Kansas, City, MO. August, 2016. **NATIONAL**

12. *Pesik, J., V.A. Sotola, S. Rayford, and **R.E. Colombo**. Larval fish assemblages differ spatially and temporally on a large river. American Fisheries Society Annual Meeting, Kansas City, MO. August 2016. **NATIONAL**

13. Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, D.B. Keeney and **R. Colombo**. Implications of low-head dams: from habitat quality to population genetics. *Oral Presentation.* 146th Annual Meeting of the American Fisheries Society, Kansas City, MO. August 2016. **NATIONAL**

14. Roth, D., E. Boone, C. Moody-Carpenter, L. Frankland, **R.E. Colombo**. Temporal and river discharge effects on silver carp abundance and size structure in the Wabash River. Oral Presentation. 146th Annual Meeting of the American Fisheries Society: Kansas, City, MO. August, 2016. **NATIONAL**

15. Boone, E., L. Frankland, D. Keeney, J. Laursen, **R.E. Colombo**. White Grub in Centrarchidae from the Ohio River Drainage. *Platform Presentation.* Illinois Chapter of the American Fisheries Society: Springfield, IL. March 1, 2016. **STATE**

16. Favata C.A., **R.E. Colombo**, D.R. Roseboom, T.D. Straub, A.Maia. Community structure in a restored stream: what is driving dissimilarity? Oral presentation, Illinois Chapter of American Fisheries Society Annual Meeting, Springfield, IL. February 2016. **STATE**

17. Kruckman, H.G., L. Frankland, S.J. Meiners, **R.E. Colombo**. Seasonal habitat use and fin-scale movements of channel catfish in the lower Wabash River. Oral Presentation. Illinois Chapter of the American Fisheries Society Annual Meeting. Springfield, IL. February 2016. **STATE**

18. Mitchell Z.A., C. Moody-Carpenter, L. Frankland, E.K. Bollinger, **R.E. Colombo**. Population status and potential impacts of harvest regulations on three exploited species of Catfish in the Wabash River, IL. Oral Presentation 54th Annual meeting of the Illinois American Fisheries Society, Springfield, IL. February 2016. **STATE**

19. Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, D.B. Keeney and **R. Colombo**. Effects of low-head dams on river ecosystems: from habitat quality to population genetics. *Oral Presentation.* 54th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Springfield, IL. March 2016. **STATE**

20. Sotola, V.A., A. Schrey, E. Bollinger, L. Frankland, **R.E. Colombo**. Genetic population structure and diversity of adult channel and blue catfish in the Wabash and Ohio Rivers. Oral Presentation Illinois Chapter of the American Fisheries Society Conference, Springfield, IL. March 2016. **STATE**

21. Boone, E., L. Frankland, D. Keeney, **R.E. Colombo**, and J. Laursen. White Grub in Centrarchidae from the Ohio River Drainage. *Platform Presentation.* 76th Midwest Fish and Wildlife Conference: Grand Rapids, MI. January 27, 2016. **REGIONAL**

22. Favata C.A., **R.E. Colombo**, D.R. Roseboom, T.D. Straub, A. Maia. Factors driving fish assemblages in a restored stream. Oral presentation, Midwest Fish and Wildlife Annual Conference, Grand Rapids, MI. January 2016. **REGIONAL**

23. Kruckman, H.G., L. Frankland, S.J. Meiners, **R.E. Colombo**. Assessment of channel catfish habitat use and fine-scale movement in the Wabash River using acoustic telemetry. Oral Presentation. Midwest Fish and Wildlife Conference. Grand Rapids, MI. January 2016. **REGIONAL**

24. Mitchell Z.A., C. Moody-Carpenter, L. Frankland, E.K. Bollinger, **R.E. Colombo**. Demographics and harvest of three commercially exploited species of Catfish in a large Midwestern river. Oral Presentation. 76th Midwest Fish & Wildlife Conference, Grand Rapids, MI. January 2016. **REGIONAL**

25. Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, D.B. Keeney and **R. Colombo**. Habitat and fish guild variation and the lack of genetic differentiation in the presence of two low-head dams. *Oral Presentation.* 76th Annual Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 2016. **REGIONAL**

26. Sotola, V.A., A. Schrey, E. Bollinger, L. Frankland, **R.E. Colombo**. Genetic population structure and genetic diversity of adult channel and blue catfish in two large Midwestern rivers. Oral Presentation. Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 2016. **REGIONAL**

27. Favata C.A., **R.E. Colombo**, D.R. Roseboom, T.D. Straub, A. Maia. Ecomorphology and swimming energetics of longear sunfish Lepomis megalotis in turbulent flow. Oral presentation, Society of Integrative and Comparative Biology Annual Meeting, Portland, OR. January 2016. **NATIONAL**

28. *Kruckman H.G., L. Frankland, S.J. Meiners, **R.E. Colombo**. Habitat use and movement of channel catfish in a large Midwestern river using acoustic telemetry. 4th Biennial Symposium of the International Society for River Science- La Crosse, WI. August 2015. **INTERNATIONAL**

29. *Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, and **R. Colombo**. Impacts of low-head dams on habitat, fish assemblages, and population genetics in two Illinois Rivers. International Society of River Science 4th Biennial Symposium 2015, La Crosse, WI. August 2015. **INTERNATIONAL**

30. *Sotola V.A., Schrey A., Bollinger E.K., Frankland L.D., **Colombo R.E.** Genetic stock structure of age-0 channel and blue catfish in the Wabash River. 4th Biennial Symposium of the International Society for River Science- La Crosse, WI. August 2015. **INTERNATIONAL**

31. *Boone, E., L. Frankland, J. Laursen, and **R.E. Colombo**. Population characteristics and Parasite Burdens of Spotted Bass in the Wabash River. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon. August 2015. **NATIONAL**

32. *Kruckman H.G., L. Frankland, S.J. Meiners, **R.E. Colombo**. Habitat use and movement of channel catfish in a Midwestern river using acoustic telemetry. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon. August 2015. **NATIONAL**

33. *Favata C.A., **Colombo R.E.**, Roseboom D.R., Straub T.D., and Maia A. Ecomorphology of fish assemblages in an East-Central Illinois stream. Lectern, American Fisheries Society Annual Meeting, Portland, OR. August 2015. **NATIONAL**

34. *Mitchell Z.A., Moody-Carpenter C., Frankland L.D., Bollinger E.K., **Colombo R.E.** Seasonal effects of DC pulse frequency on collection of fish in the Wabash River, IL. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon. August 2015. **NATIONAL**

35. *Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, and **R. Colombo**. Impacts of low-head dams on habitat, fish assemblages, and population genetics in two Illinois Rivers. 145th Annual Meeting of the American Fisheries Society, Portland, OR. August 2015. **NATIONAL**

36. *Sotola V.A., Schrey A., Bollinger E.K., Frankland L.D., **Colombo R.E.** Genetic stock structure of age-0 channel and blue catfish in a large unimpounded river. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon. August 2015. **NATIONAL**

37. *Boone, E., L. Frankland, J. Laursen, and **R.E. Colombo**. Demographics and Parasite Burdens of Spotted Bass in the Wabash River. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

38. Moody-Carpenter, C.J., L.D Frankland, T. Edison and **R.E. Colombo**. The Long-Term Fish Population Monitoring Program for the Wabash River. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

39. *Kruckman, H.G., L. Frankland, S.J. Meiners, and **R.E. Colombo**. Habitat use and movement of channel catfish in the lower Wabash River using acoustic telemetry. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

40. *Sotola, V.A., A. Schrey, E. Bollinger, S. Rayford, L. Frankland, and **R.E. Colombo**. Age-0 growth, timing of spawning events, and genetic stock structure of channel and blue catfish in the Wabash River. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

41. *Morgeson, C., L. Solomon, R. Pendleton, D. Wahl, and **R. Colombo**. Changes in Asian carp demographics in Illinois River tributaries. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **(Winner of the Lewis L. Osborne Best Student Presentation Award) STATE**

42. *Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, and **R. Colombo**. Effects of dams on fish assemblages and habitat in the Vermilion River. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

43. *Mitchell, Z., E. Bollinger, C. Carpenter, L. Frankland, and **R.E. Colombo**. Effects of DC pulse frequency on the collection of fish in the Wabash River. 53rd Annual Meeting of the Illinois Chapter of the American Fisheries Society, Grafton, IL. March 2015. **STATE**

44. *Morgeson, C., L. Solomon, R. Pendleton, D. Wahl, and **R. Colombo**. Comparing Asian carp between the Illinois River and its tributaries. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014. **INTERNATIONAL**

45. *Morgeson, C., R. Hastings, D. Wahl, and **R. Colombo**. Asian carp populations in four Illinois River tributaries. 52ndAnnual Meeting of the Illinois Chapter of the American Fisheries Society, Bloomington, IL. March 2014. **STATE**

46. *Huck, S. M., C. Moody-Carpenter, L. Frankland, and **R. E. Colombo**. Assessment of Habitat Use, Range, and Movement Patterns of Flathead Catfish in the Wabash River using Ultrasonic Telemetry. Midwest Fish and Wildlife Annual Conference, Kansas City, MO. January 2014. **REGIONAL**

47. *Pant, M., V. Nepal KC, J.L. West, T. Thomas, and **R.E. Colombo**. Habitat Restoration Leads to Increased Fish Diversity and Relative Density of fishes in a Small Midwestern Stream. 74th Midwest Fish and Wildlife Conference, Kansas City, MO. January 2014. **REGIONAL**

48. *Rayford, S.V., C.W. Morgeson, L.D. Frankland, and **R.E. Colombo**. Tracking Young of Year Assemblages Using an Electrified Mini-Missouri Trawl. 74th Annual Midwest Fish and Wildlife Conference, Kansas City, MO. January 2014. **REGIONAL**

49. *Hastings, R., S. J. Meiners, T. Thomas and **R. E. Colombo**. 2014. Seasonal Shifts in Dam Effects on Fish Assemblages in a High Quality Illinois River. Annual meeting of the Midwest Fish and Wildlife Society. Kansas City, MO. **REGIONAL**

50. *Hastings, R., S. J. Meiners, T. Thomas and **R. E. Colombo**. 2013. Effects of dams on community assemblages prior to removal in a high quality river system in Vermilion County, Illinois. National meeting of the American Fisheries Society. Little Rock, AR. **NATIONAL**

51. *Huck, S. M., C. Moody, L. Frankland, and **R. E. Colombo**. Assessment of Habitat, Range and Movement of Flathead Catfish (Pylodictis olivaris) in a Midwestern River using Ultrasonic Telemetry. National American Fisheries Society Annual Meeting, Little Rock, AK. September 2013. **NATIONAL**

52. *Pant, M., V. Nepal KC, J.L. West, T. Thomas, and **R.E. Colombo**. Impacts of Restoration on Fishes, Macroinvertebrates and Physical Habitat at Kickapoo Creek, Charleston IL. 143rd Annual Meeting of the American Fisheries Society, Little Rock, AR. September 2013. **NATIONAL**

53. *Nepal KC, V., L.D. Frankland, and **R.E. Colombo**. Demographics of a Commercially Exploited Population of Shovelnose Sturgeon in the Lower

Wabash River, IL. 51st Annual meeting of the Illinois American Fisheries Society, Rend Lake, IL. March 2013. **(Winner of the Lewis L. Osborne Best Student Presentation Award) STATE**

54. *Moody, C.J., L.D. Frankland, G.G. Sass, and **R.E. Colombo**. Demographics of a Commercially Exploited Population of Flathead Catfish in the Wabash River. 51st Annual meeting of the Illinois American Fisheries Society, Rend Lake, IL. March 2013. **STATE**

55. *Wildenberg, A.J. C.J. Moody, J.R. Laursen, C.L. Pederson, and **R.E. Colombo**. Mussel Community Response to Wastewater Effluent in a Midwestern River. 51st Annual meeting of the Illinois American Fisheries Society, Rend Lake, IL. March 2013. **STATE**

56. *Hastings, R., S. J. Meiners, T. Thomas and **R. E. Colombo**. 2013. Assessment of fish assemblages in the Vermilion River prior to dam removal. Annual meeting of the Illinois Chapter of the American Fisheries Society, Rend Lake, IL. **STATE**

57. *Huck, S. M., E. McCallen, L. Frankland, and **R. E. Colombo**. Assessment of Habitat, Range, and Movement of Flathead Catfish (Pylodictis olivaris) in the Wabash River using Ultrasonic Telemetry. Illinois American Fisheries Society Annual Meeting, Rend Lake, IL. March 2013. **STATE**

58. *Porreca, A., and **R.E. Colombo**. Evaluating the Impact of Thermal Effluent on Sportfish Abundance in a Midwestern Cooling Lake. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

59. *Stuck, J.G., L. Frankland, D.H. Wahl, and **R.E. Colombo**. Demographic Differences of Silver Carp, *Hypophthalmichthys molitrix*, Populations between Impacted and Unimpacted Midwestern River Ecosystems. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

60. †Hughes, M., N. Camp, M. Krick, A.P. Porreca, C. Phillips, **R.E. Colombo**, and M. Menze. Life in Hot Waters: Live Fast, Die Young. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

61. *Moody, C.J., L. Frankland, G.G. Sass, and **R.E. Colombo**. A Tale of the Wabash River Flathead Catfish: Sampling Inefficiencies and Demographics. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

62. *Wildenberg, A., C.J. Moody, J.R. Laursen, C.L. Pederson, and **R.E. Colombo**. Mussel Community Response to Wastewater Effluent in a Midwestern River. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

63. *Mulhollem, J. D.H. Wahl, C.D. Suski, and **R.E. Colombo**. Individual Species and Community Level Consequences of Thermal Effluent on Midwestern Reservoirs. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

64. *†Wildenberg, A. J.; J. R. Laursen, C. J. Moody, S. M. Huck, T. J. Park, and **R. E. Colombo.** Effect of wastewater effluent on mussel species composition in a Midwestern River. 2012 National Meeting Society of Freshwater Science. Louisville KY. May 2012. **NATIONAL**

65. *Porreca, A. P. and **R. E. Colombo.** Distribution and Abundance of Sportfishes in an Illinois Power Cooling Reservoir. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

66. *Stuck, J., L. Frankland, G. Sass, D. Wahl, and **R. Colombo**. Population Demographics of the Invasive Silver Carp in the Illinois and Wabash River Ecosystems. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

67. *Wildenberg, A., C. Moody, J. Laursen, C.L. Pederson, and R.E. Colombo. Impacts of Waste Water Effluent on Freshwater Mussel Populations. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

68. *Moody, C., L. Frankland, G. Sass, and **R Colombo**. Demographics of an exploited population of flathead catfish in the Wabash River. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

69. *West, J., T. Thomas, and **R. Colombo**. Habitat Restoration Leads to Increased Diversity and Density in Fish Communities. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

70. *Porreca, A. P. and **R. E. Colombo.** Seasonal Densities of Sportfish in a Thermally-Altered Environment. Lectern. 72nd Midwest Fish & Wildlife Conference, Des Moines, IA. December 2011. **REGIONAL**

71. *Stuck, J., L. Frankland, G. Sass, D. Wahl, and **R. Colombo**. Differences in Population Demographics of Silver Carp Between Impacted and Unimpacted River Ecosystems. 72nd Midwest Fish and Wildlife Conference, Des Moines, IA. December 2011. **REGIONAL**

72. *Moody, C., L. Frankland, G. Sass, and **R Colombo**. Demographics of an exploited population of flathead catfish in the Wabash River. Wabash River Consortium Meeting. Terre Haute, IN. November 2011. **REGIONAL**

73. ***Colombo, R.E.**, John West, and Trent Thomas. Seasonal Differences in the Diversity and Relative Abundance of Fishes in a Small Midwestern Stream.

Lectern. 141st Annual Meeting of the American Fisheries Society, Seattle, WA. September 2011. **NATIONAL**

74. *Miller, C. M., G. King, S. Thompson, and **R. E. Colombo**. Assessment of Crappie Population Demographics in Three Midwestern Reservoirs. 141st Annual Meeting of the American Fisheries Society, Seattle, WA. September 2011. **NATIONAL**

75. ***Colombo, R.E.**, John West, and Trent Thomas. Effects of Habitat Restoration on Stream Fish Assemblages in a Midwestern Stream. Lectern. 2011 Joint Meeting of Ichthyologists and Herpetologists, Minneapolis, MN. July 2011. **NATIONAL**

76. *Miller, C., **R. Colombo**, and C. Pederson. Comparative fish assemblages of the Lake Decatur Watershed. 140th American Fisheries Society Meeting. Pittsburgh, PA. September 2010. **NATIONAL**

77. *Miller, C., Q. Phelps, **R.E. Colombo**, J. Garvey, and R. Heidinger. Predicting the impact of harvest on the yield of channel and flathead catfish in the Wabash River using population modeling. 2nd International Catfish Symposium. St. Louis, MO. 2010. **INTERNATIONAL**

78. **Colombo, R.E.,** S.J Tripp, and J.E. Garvey. Harvest Impacts on the Shovelnose Sturgeon. 70th Midwest Fish and Wildlife Conference. Springfield, IL. December 2009. **REGIONAL**

79. **Colombo, R. E.** and 12 coauthors. Status of the shovelnose sturgeon. 138th Annual Meeting of the American Fisheries Society. Nashville, TN. September 2009. **NATIONAL**

80. Heist, E. P. Braaten, **R. Colombo**, A. Delonay, J. Garvey, P. Hartfield, D. Herzog, G. Jordan, K. Kappenman, and Molly Webb. Status of the Pallid Sturgeon. 138th Annual Meeting of the American Fisheries Society. Nashville, TN. September 2009. **NATIONAL**

81. Garvey, J.E., and **R.E. Colombo**. Comparative fish stock assessments of the Wabash and Mississippi Rivers. Annual Meeting of the Illinois Chapter of the American Fisheries Society, Lake Shelbyville, IL. March 2007. **STATE**

82. Brooks, R., J. Garvey, **R. Colombo**, S. Bauer, D. Herzog and R. Hrabik. Fish Movement in Large Rivers. 67th Midwest Fish and Wildlife Conference. Omaha, NE. December 2006. **REGIONAL**

83. **Colombo, R.E.**, J.E. Garvey, D. Herzog, R. Hrabik, N.D. Jackson. Harvest of Shovelnose Sturgeon Influences Year Class Strength and Adult Abundance: Are

We Moving Towards Collapse? 136th Annual Meeting of the American Fisheries Society, Lake Placid, NY. September 2006. **NATIONAL**

84. **Colombo, R.E.**, J.E. Garvey, D. Herzog, R. Hrabik, N.D. Jackson. Potential Impact of Commercial Harvest on the Shovelnose Sturgeon Population in the Middle Mississippi River. Annual Meeting of the Mississippi River Research Consortium, LaCrosse, WI. April 2006. **(Winner of the Best Lectern Presentation Award). REGIONAL**

85. **Colombo, R.E.**, J.E. Garvey, D. Herzog, R. Hrabik, N.D. Jackson. Harvest of Shovelnose Sturgeon Influences Year Class Strength and Adult Abundance: A Harbinger of Collapse? Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rend Lake, IL. March 2006. **STATE**

86. **Colombo, R.E.**, J.E. Garvey, and R.C. Heidinger. Comparing the Demographics of Channel Catfish in Fished and Un-fished Reaches of the Wabash River. 135th Annual Meeting of the American Fisheries Society, Anchorage, AK, September 2005. **NATIONAL**

87. **Colombo, R.E.**, J.E. Garvey, and R.C. Heidinger. Harvest Induced Impacts on the Demographics of Channel Catfish in the Wabash River. Annual Meeting of the Illinois Chapter of the American Fisheries Society Meeting. Moline, IL. March 2005. **(Winner of the Lewis L. Osborne Best Student Presentation Award). STATE**

88. **Colombo, R.E.**, P.S. Wills, and J.E. Garvey. A Guide to the Gonadal Development of the Shovelnose Sturgeon. Scaphirhynchus Symposium. St. Louis, MO. January, 2005. **NATIONAL**

89. Spier, T., J.E. Garvey, R. Brooks and **R.E. Colombo**. Movement and Habitat Use by the Pallid and Shovelnose Sturgeon in the Middle Mississippi River. Scaphirhynchus Symposium. St. Louis, MO. January, 2005. **NATIONAL**

90. **Colombo, R.E.**, J.E. Garvey, and R.C. Heidinger. Assessing the Impacts of Commercial Exploitation on the Demographics of Channel Catfish in a Large River. 65th Midwest Fish and Wildlife Conference. Indianapolis, IN. December 2004. **REGIONAL**

91. Schrey, A., **R.E. Colombo**, E. Heist, and J.E. Garvey. Spatial Stock Structure of the Shovelnose Sturgeon. 134th Annual Meeting of the American Fisheries Society, Madison, WI. August 2005. **NATIONAL**

92. **Colombo, R.E.**, J.E. Garvey, and R.C. Heidinger. Comparing the Demographics of Channel Catfish in Fished and Un-fished Reaches of the Wabash River. 64th Midwest Fish and Wildlife Conference. Kansas City, MO. December 2003. **REGIONAL**

93. **Colombo, R.E.**, J.E. Garvey, R.H. Heidinger and R.J. Sheehan. Age, Growth and Mortality of Channel Catfish in the Wabash River. Indiana American Fisheries Society Fish and Wildlife Conference. Indianapolis, IN. March 2003. **STATE**

94. **Colombo, R.E.**, J.E. Garvey, R.H. Heidinger and R.J. Sheehan. Population Demographics of Channel Catfish, *Ictaluris punctatus,* in the Wabash River. Annual Meeting of the Illinois Chapter of the American Fisheries Society Meeting. Rend Lake, IL. February 2003. **STATE**

95. **Colombo, R.E**. Sturgeon Research at Southern Illinois University. Georgia American Fisheries Society Meeting. Rome, GA. January 2003. **STATE**

***STUDENT COAUTHOR**
† UNDERGRADUATE COAUTHOR

X. Invited Presentations

1. **Colombo, R.E.** Stress in Flowing Waters: Anthropogenic Impacts on Lotic Systems. University of Illinois, Natural Resources and Environmental Science Seminar Series. October 2013

2. ***Colombo, R.E.**, M. Pant, J. West, and T. Thomas. Impacts of restoration on the fish community assemblage in a small Midwestern River. 73rd Midwest Fish and Wildlife Conference, Wichita, KS. December 2012. **REGIONAL**

3. **Colombo, R.E.** and 13 coauthors. Distribution, life history and population status of the shovelnose sturgeon. 138th Annual Meeting of the American Fisheries Society. Nashville, TN. September 2009. **NATIONAL**

4. **Colombo, R.E.**, J.E. Garvey, S.J. Tripp, and C.J. Williamson. Impacts of commercial exploitation of riverine fish stocks with implications to different life histories. Southern Illinois University, Ecology Center Seminar Series. **UNIVERSITY**

5. **Colombo, R.E.**, J.E. Garvey, D. Herzog, R. Hrabik, N.D. Jackson. Harvest induced impacts on the demographics of shovelnose sturgeon with implications to the pallid sturgeon. MICRA Sturgeon and Paddlefish Meeting. St. Louis, MO. January 2007. **REGIONAL**

6. **Colombo, R.E.**, J.E. Garvey, and R.C. Heidinger. Influence of a reserve on the catfish populations in the Wabash River. Ohio River Fisheries Management Program Meeting. Winslow, IN. May 2004. **REGIONAL**

XI. Poster Presentations

1. *Hine, E.C., C. Moody-Carpenter, E. Boone, L.D. Frankland, S. Meiners, T. Edison, **R.E. Colombo**. Spatial and Temporal Trends in Fish Communities of the Lower Wabash River. Poster Presentation. Illinois Chapter of the American Fisheries Society Annual Meeting. Moline, IL. February 2017. **STATE**

2. *Hine, E.C., C. Moody-Carpenter, E. Boone, L.D. Frankland, S. Meiners, T. Edison, **R.E. Colombo**. Variation in Fish Communities of the Lower Wabash River. Poster Presentation. 77th Midwest Fish and Wildlife Annual Conference, Lincoln, NE. February 2017. **REGIONAL**

3. *Boone, E., L. Frankland, D. Keeney, J. Laursen, **R.E. Colombo**. White Grub in Centrarchidae from the Ohio River Drainage. Poster Presentation. Annual Meeting of the American Fisheries Society: Kansas City, MO. August, 2016. **NATIONAL**

4. *Favata, C.A., S.C.F Smith, **R.E. Colombo**, A. Maia. Length-weight relationships and relative condition for Illinois stream fish. Poster presentation. Midwest Fish and Wildlife Annual Conference, Grand Rapids, MI. January 2016. **REGIONAL**

5. *Roth, D., E. Boone, C. Carpenter, L. Frankland, **R.E. Colombo**. Temporal effects of river discharge on Asian carp abundance and size structure in the Wabash River.Poster Presentation. Illinois Chapter of the American Fisheries Society Annual Meeting: Springfield, IL. February 2015. **STATE**

6. *Roth. D., C. Morgeson, D.Wahl, **R.E. Colombo**. Larval fish assemblages of four major tributaries of the Illinois River. Poster Presentation. 76th Midwest Fish and Wildlife Conference: Grand Rapids, Michigan, January 2016. **REGIONAL**

7. *Pesik, J., E. Boone, C. Carpenter, T. Edison, L. Frankland, and **R.E. Colombo**. Relative abundance of Catostomids influenced by physical parameters in a large river. 54th Annual Illinois Chapter of the American Fisheries Society Meeting, Springfield, IL. February 2016. **STATE** (poster)

8. *Pesik, J., V.A. Sotola, S. Rayford, and **R.E. Colombo**. Larval fish assemblages above and below a major tributary confluence differ spatially and temporally on a large river. 76th Annual Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 2016. **REGIONAL** (poster)

9. †Forbus, K, S.C.F. Smith, T. Thomas, S. Meiners and **R. Colombo**. Use of Macroinvertebrate Assemblages and Habitat Assessments as Bioindicators of River Health. 76th Annual Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 2016. (Poster) **REGIONAL**

10. *Boone, E., C.J. Moody-Carpenter, M. White, and R.E. Colombo. Demographics of a Recreationally Important Population of Spotted Bass in the Wabash River, Illinois. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014. **INTERNATIONAL**

11. *Boone, E., L. Frankland, J. Laursen, and R.E. Colombo. Demographics of a Recreationally Important Parasitized Population of Spotted Bass in the Wabash River, Illinois. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

12. *Moody-Carpenter, C.J., L.D Frankland, and R.E. Colombo. Age and Growth of Channel and blue catfish in the Wabash River. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

13. *Huck, S., H. Kruckman, C.J. Moody-Carpenter, L. Frankland, and R.E. Colombo. Assessment and habitat use, range, and diel movement patterns of flathead catfish in a Midwestern river using ultrasonic telemetry. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014. **INTERNATIONAL**

14. *Kruckman, H.G., A. Porreca, L. Frankland, S.J. Meiners, and R.E. Colombo. Using Electrosedation as an Alternative to Chemical Anesthetics When Surgically Implanting Acoustic Transmitters in Channel Catfish. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

15. *Petry, D.W., J.L. Larsen, C.L. Pederson, and R.E. Colombo. Comparison of agency and volunteer stream assignments using macroinvertebrate assemblages. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

16. *Favata,C.A., R.E. Colombo, D.P. Roseboom, T.D. Straub, and A.Maia. Ecomorphology of fish assemblages in an east-central Illinois stream. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

17. *Sotola, V.A., A. Schrey, E. Bollinger, S. Rayford, L. Frankland, and R.E. Colombo. Age-0 growth, timing of spawning events, and genetic stock structure of channel and blue catfish in the Wabash River. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

18. *Rayford, S., V.A. Sotola, E. Bollinger, L. Frankland, and R.E. Colombo. Estimation of Small Bodied Fish Community Assemblages in a Large Unimpounded River Using a Novel Gear. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014. **INTERNATIONAL**

19. *Morgeson, C., D. Wahl, and R. Colombo. Larval fish assemblages in four Illinois River tributaries. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

20. *Smith, S.C.F., R. Hastings, T. Thomas, S. Meiners, and R. Colombo. Impacts of dams on fish assemblages and habitat. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

21. *Moody-Carpenter, C., Z. Mitchell, E. Bollinger, L. Frankland, and R.E. Colombo. Effects of DC pulse frequency on the collection of Catfish in the Wabash River. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014. **INTERNATIONAL**

22. *Mitchell, Z., E. Bollinger, C. Carpenter, L. Frankland, and R.E. Colombo. Effects of DC pulse frequency on the collection of fish in the Wabash River. 75th Annual Midwest Fish and Wildlife Conference, Indianapolis, IN. February 2015. **REGIONAL**

23. *Morgeson, C., R. Hastings, D. Wahl, and **R. Colombo.** Demographics of Asian Carps in Four Illinois River Tributaries. Annual meeting of the Midwest Fish and Wildlife Society. Kansas City, MO. **REGIONAL**

24. *Rayford, S.V., C.W. Morgeson, L.D. Frankland, and R.E. Colombo. Larval Fish Movement: Active or Passive in a Large Unimpounded River? 74th Annual Midwest Fish and Wildlife Conference, Kansas City, MO. January 2014. **REGIONAL**

25. *White, M. W., J. R. Laursen, and **R. E. Colombo**. Parasites of bluegill in the Sangamon River: Impact of sewage effluent and seasonality on infection parameters and correlation with fish condition. 74th Annual Meeting of the Midwest Fish and Wildlife Conference, Kansas City, MO. January 2014. **REGIONAL**

26. Morgeson, C., R. Hastings, D. Wahl, and R. Colombo. Demographics of Asian carps in four Illinois River tributaries. 74th Annual Midwest Fish and Wildlife Conference, Kansas City, MO. January 2014. **REGIONAL**

27. *Rayford, S.V., C.J. Moody, L.D. Frankland, and R.E. Colombo. Population Demographics of Channel and Blue Catfish in the Wabash River Using a Multi-gear Approach. 143rd Annual meeting of the American Fisheries Society, Little Rock, AR. September 2013. **NATIONAL**

28. Huck, S. M., L. Frankland, and **R. E. Colombo**. Assessment of Range, Habitat, and Movement of Flathead Catfish (Pylodictis olivaris) in the Wabash River using Ultrasonic Telemetry. Eastern Illinois University Science Fest, Charleston IL. 2013. **UNIVRESITY**

29. *Rayford, S.V., C.J. Moody, L.D. Frankland, and R.E. Colombo. Population Demographics of Channel and Blue Catfish in the Wabash River Using a Multi-

gear Approach. 51st Annual meeting of the Illinois American Fisheries Society, Rend Lake, IL. March 2013. **STATE**

30. *Huck, S., J. Laursen, C. Pederson, and **R. Colombo**. Demographics of a Lightly Exploited Channel Catfish Population in the Sangamon River. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

31. *Pant, M., J.L. West, T. Thomas, and R.E. Colombo. Habitat Restoration Leads to Higher Diversity and Density of fishes in a Small Midwestern Stream. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

32. *Nepal K.C., V., L. Frankland, and R.E. Colombo. Demographics of the Commercially Exploited Shovelnose Sturgeon Population in the Wabash River, Illinois. 142nd Annual Meeting of the American Fisheries Society, St. Paul, MN. September 2012. **NATIONAL**

33. *Huck, S., J. Laursen, C. Pederson, and **R. Colombo**. Demographics of a Lightly Exploited Channel Catfish Population in the Sangamon River. 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

34. †Krick, M., A. Porreca, M. Menze, and **R. Colombo**. Comparison of Bluegill (*Lepomis macrochirus*) Population Demographics between a Thermally Altered and an Ambient Lake Environment 50th Meeting of the Illinois American Fisheries Society. February 2012. **STATE**

35. *Porreca, A. P., M. Pant, C. L. Pederson, and **R. E. Colombo**. Evaluating the Effects of an Altered Thermal Regime on Sportfish Species. Poster. 141st Annual Meeting of The American Fisheries Society, Seattle, WA. September 2011. **NATIONAL**

36. *Stuck, J., L. Frankland, G. Sass, D. Wahl, and **R. Colombo**. Population Status of Silver Carp, Hypophthalmichthys molitrix, on the Illinois River. Poster. 141st Annual Meeting of the American Fisheries Society, Seattle, WA. September 2011. **NATIONAL**

37. *Moody, C., L. Frankland, G. Sass, and **R Colombo**. Demographics of a exploited population of flathead catfish in the Wabash River. 141st Annual Meeting of the American Fisheries Society, Seattle, WA. September 2011. **NATIONAL**

38. *West, J. L., T. Thomas, and **R.E. Colombo**. Habitat Restoration of Kickapoo Creek. 71st Midwest Fish and Wildlife Conference. Minneapolis, MN. December 2010. **REGIONAL**

39. *Miller, C., **R. Colombo**, and C. Pederson. Diversity of Ichthyofauna in tributary streams of the Sangamon River. 71st Midwest Fish and Wildlife Conference. Minneapolis, MN. December 2010. **REGIONAL**

40. *Miller, C., **R. Colombo**, and C. Pederson. Comparative fish assemblages of the Lake Decatur Watershed. 70th Midwest Fish and Wildlife Conference. Springfield, IL. December 2009. **REGIONAL**

41. Phelps, Q.E., **R.E. Colombo**, J.E. Garvey and R.C. Heidinger. Comparison of channel catfish age estimates and resulting population demographics using two common structures. 138th Annual Meeting of the American Fisheries Society, Ottawa, Can, August 2008. **NATIONAL**

42. Phelps, Q.E., **R.E. Colombo**, J.E. Garvey and R.C. Heidinger. Gear Specific Population Demographics of Channel Catfish in a Large River. 67th Midwest Fish and Wildlife Conference. Omaha, NE. December 2006. **REGIONAL**

43. Tripp, S.J., **R.E. Colombo**, J.E. Garvey and Q.E. Phelps. Using Sex-specific Population Demographics to Predict Responses of Shovelnose Sturgeon to Harvest. 67th Midwest Fish and Wildlife Conference. Omaha, NE. December 2006. **REGIONAL**

44. Spier, T.W., J.E. Garvey, R. Brooks and **R.E. Colombo**. Movement and Habitat Use by the Pallid and Shovelnose Sturgeon in the Middle Mississippi River. 134th Annual Meeting of the American Fisheries Society, Madison, WI. August 2005. **NATIONAL**

45. **Colombo, R.E.**, P.S. Wills, and J.E. Garvey. A Guide to the Embryological Development of the Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) Reared at a Constant Temperature. 2004 Joint Meeting of Ichthyologists and Herpetologists. Norman, OK. May 2004. **NATIONAL**

***STUDENT COAUTHOR**
†UNDERGRADUATE COAUTHOR

XII. Internal Grants

1. **Colombo, RE**. 2010. College of Science Early Research Grant. Eastern Illinois University. $300

2. **Colombo, R.E.** and M. Menze. 2012. Life in Hot Water. Council on Faculty Research. Eastern Illinois University. $4800

3. Menze, M., **Colombo, R.E.**, G. Bulla, K. Gaines, K. Hung, and J. Novack. 2011. Using Inquiry-based Learning Modules to Vertically Integrate Core Biological

Concepts in the Biology Majors Curriculum. Proposal Initiative Fund. Eastern Illinois University. $7000

XIII. Graduate Students

1. Candice Miller: Population demographics of white and black crappie central Illinois Reservoirs. Graduated December 2011. Current: Biologist Oklahoma Conservation Commission.

2. Anthony Porreca: Impacts of hot water effluent on sportfish communities. Graduated December 2012. Current: Ph.D. student Southern Illinois University, Carbondale.

3. Jason Stuck: Comparison of Asian carp demographics in the Wabash and Mississippi Rivers. Graduated December 2012. Current: Shellfish Biologist South Carolina Fish and Game.

4. John West: Impacts of stream habitat restoration on fish and macroinvertebrate assemblages. Graduated December 2013. Current: Fish Biologist Missouri Department of Conservation.

5. Cassi Moodi-Carpenter: Demographics of flathead catfish in the Wabash River. Graduated December 2013. Current Research Biologist Eastern Illinois University.

6. Sarah Huck: Channel Catfish Population dynamics in two Midwestern rivers. Graduated May 2014. Current Fisheries Research Biologist Illinois Natural History Service.

7. Manisha Pant: Long-term impacts of habitat restoration on fish and macroinvertebrates. Graduated May 2014. Current Fisheries Research Biologist Virginia Institute of Marine Science

8. Vaskar Nepal KC: Population demographics of shovelnose sturgeon in the lower 200 miles of the Wabash River. Graduated August 2014. Current Ph.D. Student Virginia Institute of Marine Science

9. Ryan Hastings. Impact of Dam Removal on Fish and Macroinvertebrate Community Assemblage. Graduated May 2014. Current: Fish Biologist Maryland Department of Natural Resources.

10. Sharon Rayford. Habitat associations of young of the year fishes in a large unimpounded river. Graduated May 2014. Current: Fisheries Biologist, US Fish and Wildlife Service, CA.

11. Clint Morgeson. Population Demographics of Asian Carps in tributaries of the Illinois River. Graduation May 2015

12. Evan Boone. Population Demographics and Parasite Load of Spotted Bass in the Wabash River. Expected Graduation May 2016. Current: Fisheries Biologist, US Fish and Wildlife Service, WI

13. Zach Mitchell. Population Demographics of Blue and Channel Catfish in the Lower Wabash River. Expected Graduation May 2016. Current: Ph.D., Candidate University of South Texas

14. V. Alex Sotola. Recruitment Dynamics and Genetic Stock Structure of the Channel Catfish in the Wabash River. Expected Graduation May 2016. Current: Ph.D., Candidate University of South Texas

15. Hanna Kruckman. Habitat Use and Movement of the Channel Catfish in the Lower Wabash River. Graduation December 2016. . Current: Fisheries Biologist, US Fish and Wildlife Service, MN

16. Shannon Smith. Genetic Implications of Dams on Fishes with differing life histories. Graduation August 2016. Current: Research Fisheries Biologist University of Arkansas Pine Bluff

XIV. Student Awards

A. University
   1. Outstanding Thesis Award
      a. 2017 – Shannon Smith
      b. 2014 – Vaskar Nepal KC
   2. Distinguished Graduate Student
      a. 2012 – Anthony Porreca
      b. 2013 – Cassi Moody
      c. 2014 – Vaskar Nepal KC
   3. Hamand Scholar
      a. 2012 – Anthony Porreca
      b. 2013 – Cassi Moody
      c. 2014 – Vaskar Nepal KC
   4. Graduate School Showcase 2012 – Anthony Porreca
   5. Williams Travel Award
      a. Candice Miller ($500)
      b. John West x2 ($400)
      c. Jason Stuck ($400)
      d. Anthony Porreca ($500)
      e. Manisha Pant ($250)
      f. Vaskar Nepal KC ($250)
      g. Ryan Hastings ($250)

6. Provost Research Assistantship 2011 – Anthony Porreca ($9000)
7. Graduate School Investigator Award
    a. 2011 – Cassi Moody ($250)
    b. 2012 – Jason Stuck ($250)
    c. 2013 – Manisha Pant ($250)
    d. 2013 – Sarah Huck ($250)
    e. 2013 – Amanda Wildenberg ($250)
    f. 2015 – Clint Morgenson ($250)
    g. 2016 – Shannon Smith ($250)
    h. 2016 – Zach Mitchell ($250)
8. Research/Creative Activity Award
    a. Candice Miller, spring 2010 - $1000
    b. John West, spring 2010 - $1000, 2011 - $875
    c. Jason Stuck, spring 2011 - $875,spring 2012 - $1000
    d. Cassi Moody, spring 2011 - $875, spring 2012 - $1000
    e. Sarah Huck, spring 2012 - $1000
    f. Ryan Hastings, fall 2012 - $400
    g. Vaskar Nepal KC, fall 2012 - $400, fall 2013 - $1000
    h. Manisha Pant, fall 2012 - $400, fall 2013 - $1000
    i. Sharon Rayford, fall 2012 - $400
    j. Shannon Smith 2015
    k. Hanna Kruckman 2015
    l. Zach Mitchell 2015
    m. V. Alex Sotola 2015

B. State
1. Lewis L. Osborne best student presentation award. Illinois American Fisheries Society
    a. 2013 – Vaskar Nepal KC ($500)
    b. 2014 – Sarah Huck ($500)
    c. 2015 – Clint Morgenson ($500)
    d. 2016 – Shannon Smith ($500)
2. ILAFS Larimore Student Research Grant
    a. 2012 – Cassi Moody ($500)
    b. 2013 – Vaskar Nepal KC ($500)
    c. 2013 – Amanda Wildenberg ($500)
    d. 2013 – Sarah Huck ($500)
    e. 2014 – Manisha Pant ($500)
    f. 2016 – Hannah Kruckman ($500)
3. ILMA Student Research Grant
    a. 2012 – Anthony Porreca ($1000)
    b. 2014 – Sharon Rayford ($1000)
4. ISAS Student Research Grant 2012 – Amanda Wildenberg ($500)

C. Regional
1. Hillary Duff Student Travel Award

   a. 2010 – Candice Miller ($500)
   b. 2013 – Sharon Rayford ($500)
   c. 2014 – Zachary Mitchell ($500)
   d. 2015 – Hanna Kruckman ($500)
2. Janice Lee Fenske Memorial Award Finalist –
   a. 2014 – Vaskar Nepal KC
   b. 2015 – Hanna Kruckman
   c. 2015 – Clint Morgeson
   d. 2015 – Zach Mitchell
   e. 2015 – Alex Sotola
   f. 2016 – Hanna Kruckman
   g. 2016 – Shannon Smith

D. National
1. North American Sturgeon and Paddlefish Society Travel Award – Vaskar Nepal KC ($250)
2. Equal Opportunity Section of American Fisheries Society Award – Manisha Pant ($500)
3. Best Poster Presentation (Runner Up) American Fisheries Society – 2013 Sharon Rayford
4. Skinner Memorial Award – 2015 Hanna Kruckman ($800)

XV. Honors and Awards

- Commencement Marshal. Eastern Illinois University, fall 2014 commencement
- Faculty Marshal. Eastern Illinois University. spring 2014 commencement
- Rodney S. Ranes Outstanding Graduate Faculty Mentor Award, Eastern Illinois University, 2014
- College of Sciences Student Advisory Board Outstanding Faculty Award, Eastern Illinois University, 2014
- Achievement and Contribution Award (Service), Eastern Illinois University, 2013.
- Edwin L. "Bud" May Award, Outstanding Achievement in Research and Grants, Eastern Illinois University, 2012.
- Achievement and Contribution Award (Research), Eastern Illinois University, 2010.
- Faculty of the Year, Southern Illinois University, School of Medicine, 2007 & 2008
- Dissertation Research Assistantship Award, Southern Illinois University Carbondale, summer 2007. (University, $4,000)
- Foote and Foote Award for Outstanding Teaching Assistant in the Department of Zoology, 2006. Approximately 50 TAs in the Department. (University, $1,500)
- Best Lectern Presentation, Mississippi River Research Consortium Meeting. La Crosse, WI. 2006. (Regional, $500)
- Lewis L. Osborne Award for Best Student Presentation, Illinois Chapter of the American Fisheries Society, Quad Cities 2005. (Regional, $500)

- John E. Skinner Memorial Fund Award 2005. (National, $650)
- Illinois American Fisheries Society Travel Grant 2005 and 2006. (Regional, $250)

XVI. Professional Societies and Service

1. Memberships
    - Sigma Xi Research Society, 2011 – Present
    - American Fisheries Society, 2001 – Present
    - Illinois Chapter American Fisheries Society, 2003 – Present
    - Education Section of the American Fisheries Society, 2003 – Present
    - Phi Kappa Phi Honor Society, 2003 – Present
    - Management Section of the American Fisheries Society, 2003 – Present

2. Offices Held
    - Esocid Technical Committee, North Central Division AFS – 2010 – Present
    - Environmental Concerns Committee, IL AFS – 2011 – Present
    - Excellence Committee, Education Section of AFS, 2006-2010
    - Newsletter Editor, Management Section of the AFS, 2003 – 2006
    - President, Student Chapter, American Fisheries Society. SIUC, 2004
    - President, Student Chapter, American Fisheries Society. SUNY ESF. 1997

3. Professional Service
    - Judge, Student Poster Competition, American Fisheries Society, 2006
    - Reviewer, Journal of Fish Biology, 2008 - Present
    - Reviewer, American Fisheries Society Books, 2007-Present
    - Reviewer, North American Journal of Aquaculture, 2006-Present
    - Reviewer, North American Journal of Fisheries Management, 2005 – Present
    - Reviewer, Journal of Applied Ichthyology, 2006 - Present

XVII. University Service

- Chair, Graduate Student Investigator Award Committee, 2013
- Chair, Search Committee, Anatomist/Physiologist, 2012-2013
- Chair, Achievement and Contribution Awards Committee, 2012
- Member, Council on Faculty Research, 2012 – 2015
- Member, Graduate Student Investigator Committee, 2011 – 2013
- Member, Achievement and Contribution Awards Committee, 2011
- Member, Enrollment Management Committee, 2011 – 2013
- Member, Search Committee, Wildlife Ecologist/Mammologist, Eastern Illinois University, 2010
- Faculty Advisor, Phi Sigma Biological Sciences Honor Society, Eastern Illinois University, 2010-present
- Faculty advisor, Hunting and Fishing Club, Eastern Illinois University, 2009 - present

- Faculty advisor, Fisheries and Wildlife Club, Eastern Illinois University, 2009 - present
- Member, Faculty Fellows, Eastern Illinois University, 2009 – Present
- Member, Search Committee for Assistant Professor in the School of Medicine, Department of Anatomy, 2008
- Member, Search Committee for Assistant Professor in the College of Science, Department of Zoology, 2006
- Judge for Illinois Junior Academy of Science, Regional Science Fair, 2004 - Present

XVIII. Other Skills

- Proficient in FAST, FAMS, and FISHSTAT II fisheries modeling packages
- Proficient in R, SAS, SPSS, and JMP data analysis packages
- Proficient in the analysis of mark-recapture data and the program MARK
- SCUBA certified Open Water II
- Coast Guard Boat Safety

XIX. References

1. Dr. James Garvey
   Vice Chancellor for Research and Graduate Dean
   Southern Illinois University
   Director, Fisheries and Illinois Aquaculture Center
   618-536-7761
   ovcr@siu.edu

2. Dr. Eric Bollinger
   Professor
   Eastern Illinois University
   Department of Biological Sciences
   217-581-6653
   ekbollinger@eiu.edu

3. Dr. Dave Wahl
   Aquatic/Fisheries Biologist
   Director, Kaskaskia, Ridge Lake, and Sam Parr Biological Field Station
   Illinois Natural History Survey & University of Illinois
   Kaskaskia Biological Station
   217-728-4400
   d-wahl@illinois.edu

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF: PROPOSED SITE SPECIFIC RULE FOR SANITARY DISTRICT OF DECATUR FROM 35 ILL. ADM. CODE SECTION 302.208(e).	))))))	R14-24 (Site Specific Rule – Water)

PRE-FILED TESTIMONY OF ROBERT C. SANTORE
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

NOW COMES the Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Robert C. Santore for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF ROBERT C. SANTORE

I. INTRODUCTION

My name is Robert C. Santore and I am a Partner at Windward Environmental LLC, an environmental science and engineering consulting firm engaged by the District to support its efforts to obtain a site specific water quality standard ("WQS") for nickel from the Illinois Pollution Control Board ("Board"). I have been at Windward since May 2015. Prior to that time, I served as Senior Professional Associate and the Environmental Chemistry Section Manager from December 2010 to May 2015 for HDR Inc. Prior to that time I was an Associate with HydroQual, Inc. from September 1996 to December 2010. My Curriculum Vitae is attached as Exhibit A.

My testimony today addresses and supports those portions of the District's Amended Petition for Site Specific Rule ("Amended Petition") relating to the development of the site specific WQS for nickel for the Sangamon River that takes into account bioavailability effects

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using a Water Effect Ratio ("WER"). My testimony also provides larger context and explains that the District's proposed site specific WQS for nickel, while providing necessary relief from the Illinois general use chronic water quality standard for nickel, is still considerably more stringent than United States Environmental Protection Agency's ("USEPA's") National Recommended Water Quality Criteria for nickel (chronic) that applies in many areas of the country, as well as the standards that apply in Illinois' neighboring States of Iowa and Indiana.

II. SITE-SPECIFIC CHRONIC WATER QUALITY STANDARD FOR NICKEL

The District is seeking a site specific rule to establish an alternative chronic water quality standard for nickel from the point of its Main Plant discharge into the Sangamon River to the point of the confluence of the Sangamon River with the South Fork of the Sangamon River near Riverton.

The general use water quality standard for nickel, which is set forth in Section 302.208(e), is defined by a calculation for dissolved nickel based on stream hardness. 35 Ill. Admin. Code § 302.208(e). The acute standard ("AS") for nickel is defined as "exp[A+Bln(H)] X 0.998*, where A=0.5173 and B=0.8460," and the chronic standard ("CS") for nickel is defined as "exp[A+Bln(H)] X 0.997*, where A=-2.286 and B=0.8460." The AS for nickel "shall not be exceeded at any time," except as provided in Section 302.102. 35 Ill. Admin. Code § 302.208(a). The CS for nickel "shall not be exceeded by the arithmetic average of at least four consecutive samples collected over any period of at least four days," except as provided in Section 302.102. 35 Ill. Admin. Code § 302.208(b). No change is proposed for the general use acute water quality standard for nickel.

The site specific chronic water quality standard for nickel proposed by the District would provide as follows:

Section 303.410 Chronic Nickel Water Quality Standard for Segment of the Sangamon River

The general use chronic water quality standard for dissolved nickel contained in Section 302.208 shall not apply to the Sangamon River, which receives discharges from the Sanitary District of Decatur's Main STP, from the outfall of that facility 39° 49' 56" North Latitude, 89° 0' 7" West Longitude (the lat/long of Outfall 001) to the point of the confluence of the Sangamon River with the South Fork of the Sangamon River near Riverton. Instead, nickel levels in such waters shall meet a chronic water quality standard for dissolved nickel as follows:

Chronic Dissolved Nickel Standard = exp[A+Bln(H)] x 0.997* x WER, where A = -2.286, B = 0.846, ln(H) = natural logarithm of Hardness, * = conversion factor multiplier for dissolved metals, and WER = 2.50

The District's proposed site-specific chronic water quality standard for nickel is based on WER adjustment to the default Illinois hardness equation-based chronic nickel standards that is based on an equation that considers the impact of DOC on nickel toxicity. The WER is further supported by calculations using the Biotic Ligand Model ("BLM") which produce a very similar result. The BLM has been adopted by USEPA for determining the water quality criteria for copper (USEPA 2007), and versions for other metals including nickel have been developed. The nickel BLM is a predictive model that can also be used to account for nickel bioavailability and uses mechanistic information to estimate the anticipated effects of water quality factors on the bioavailability and toxicity of metals, including nickel. Chemical speciation calculations using the nickel BLM shows that natural organic matter in the Sangamon River (quantified as DOC) will reduce nickel bioavailability. This result provides an independent confirmation that organic matter is expected to reduce nickel toxicity and that the WER based on the DOC equation is reasonable.

Many factors can modify the bioavailability and toxicity of nickel, including hardness and natural organic matter (NOM). The Sangamon River chemistry is hard water with considerable amounts of organic matter. The Illinois nickel standard is based on hardness, so hardness effects are already addressed. However, the state standard does not consider ameliorative effects of NOM on nickel. The WER is an approach developed by USEPA to develop a site-specific standard that can account for toxicity modifying factors that affect the bioavailability of metals that are not otherwise addressed by the statewide standard. We have developed a WER for the Sangamon River which was derived to consider NOM. The WER, together with the hardness equation, will define a site specific standard that incorporates the effects of both NOM and hardness, which are the two primary factors that affect nickel bioavailability and toxicity.

Natural organic matter has been shown to reduce the bioavailability and toxicity of nickel. The effects of NOM are one of the primary reasons why a site-specific adjustment to the nickel standard is justified. The effects of NOM on nickel bioavailability were confirmed by chronic *C. dubia* toxicity tests performed at Oregon State University (OSU). OSU conducted these nickel toxicity tests to support the development of a WER for nickel in the Sangamon River. For these tests, the exposure conditions were designed to match the ionic composition of the Sangamon River with and without added NOM. Chronic toxicity tests with *C. dubia* were conducted to quantify nickel toxicity on survival and reproduction. The results of the OSU tests confirm that DOC reduces nickel bioavailability and toxicity. Ms. Allison Cardwell is present today and will testify to the process used in OSU's toxicity testing and can respond to any questions you have in that regard.

Water quality parameters used as input data to the BLM were determined at two downstream locations on two separate sampling events (at Rock Springs B and at Lincoln Homestead). The nickel BLM was used to predict nickel toxicity in site water and reference water. From this analysis, a WER of 2.63 was determined. *See* BLM Adjustment Report, Exhibit 14. This BLM-derived result further demonstrates that the DOC relationship-based WER of 2.50 is reasonable for the Sangamon River and protective for sensitive aquatic life.

III. SITE SPECIFIC STANDARD WELL BELOW NATIONAL RECOMMENDED WATER QUALITY CRITERIA FOR NICKEL

The preceding discussion focuses on establishing a site specific chronic water quality standard for nickel that is different from the Illinois general use chronic water quality standard established by Board rule at Section 302.208(e). Based on the Illinois EPA-determined critical hardness value of 359 mg/L and nickel translator value of 0.966, the proposed site specific rule would result in an anticipated National Pollutant Discharge Elimination System ("NPDES") permit limit of 38.20 µg/L (0.0382 mg/L) total nickel for the District.

For comparison purposes, USEPA has established its own nationally recommended water quality standards and has published a National Recommended Aquatic Life Criteria Table at the following website: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table.

As described by USEPA, the table contains the most up-to-date criteria for aquatic life ambient water quality criteria. Aquatic life criteria for toxic chemicals are the highest concentration of specific pollutants or parameters in water that are not expected to pose a significant risk to the majority of species in a given environment or a narrative description of the desired conditions of a water body being "free from" certain negative conditions. The table lists

USEPA's recommended aquatic life criteria. State and tribal governments may use these criteria or use them as guidance in developing their own. For nickel, the table provides as follows:

National Recommended Aquatic Life Criteria table

Pollutant (P=Priority Pollutant)	CAS Number	Freshwater CMC (acute) (µg/L)	Freshwater CCC (chronic) (µg/L)	Saltwater CMC (acute) (µg/L)	Saltwater CCC (chronic) (µg/L)	Publication Year	Notes
Nickel (P)	7440020	470	52	74	8.2	1995	Freshwater and saltwater criteria for metals are expressed in terms of the dissolved metal in the water column. See Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria. The freshwater criterion for this metal is expressed as a function of hardness (mg/L). The value given here corresponds to a hardness of 100 mg/L.

At a hardness value of 100 mg/L, EPA's chronic value is 52 µg/L, or 0.052 mg/L. Correcting for hardness in the Sangamon River, i.e., using 359 mg/L for hardness, the calculation would result in a recommended chronic criterion of approximately 153.81 µg/L (0.154 mg/L).

For further comparison purposes, we also surveyed the chronic water quality standards for nickel in the neighboring states of Iowa and Indiana. Iowa's chronic water quality standard for nickel, at a hardness 359 mg/L, would result in a value of 153.81 µg/L (0.154 mg/L).[1] And Indiana's chronic water quality standard for nickel, at a hardness of 359 mg/L, would result in a value of 464.89 µg/L (0.465 mg/L).[2] All of these chronic standards would still be converted to a

[1] 567 Iowa Adm. Code 61.3(3).
[2] 327 Indiana Adm. Code 2-1-6.

total nickel basis using the appropriate translator to determine permit limits. For these calculations, please see Exhibit 46, entitled "Nickel Calculator for Illinois, Indiana, Iowa and USEPA," which was attached to the District's Motion to File Revised Exhibits 14 and 28, New Exhibits 45 and 46, Revised Exhibit List, and Minor Revision to Proposed Subsection 303.410 filed on April 20, 2018.

Thus, for comparative purposes, applying the site-specific proposal, although the District's anticipated NPDES permit limit of 0.0382 mg/L would be somewhat higher than its current permit limit of 0.015 mg/L, it is still almost an order of magnitude below the anticipated permit limit resulting from USEPA's and Iowa's calculation of 0.154 mg/L. Moreover, the District's anticipated permit limit is much lower still than would be calculated under the Indiana regulation.

As a result, based on USEPA assessment, the District's site specific chronic water quality standard will not pose a significant risk to the majority of species in the Sangamon River, as has been established by the toxicity testing of OSU, and the District's site specific standard should be approvable by USEPA.

IV. CONCLUSION

The information discussed today supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

<signature on following page>

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Bob Santore
Partner

Summary of Expertise

Bob Santore is an environmental scientist with over 20 years' experience in environmental and aquatic chemistry, US Environmental Protection Agency (EPA) regulatory issues, site-specific criteria, water quality modeling, and chemical modeling. Mr. Santore's recent work has focused on developing mechanistic models to explain and predict the bioavailability and toxicity of metals in the environment. This work has included the development of the biotic ligand model (BLM), which has been used as the basis for the revision of the EPA ambient water quality criteria (AWQC) for copper. Mr. Santore has led efforts to develop BLMs for a variety of metals and environmental media, including freshwater BLMs for aluminum, cadmium, cobalt, copper, lead, nickel, silver, and zinc; marine BLMs for copper and zinc; soil BLMs for copper and nickel; and sediment BLMs for cadmium, copper, nickel, lead, and zinc. These efforts have produced a number of software packages that serve as easy-to-use tools for assessing metals bioavailability for setting site-specific water quality criteria (WQC) and assessing the ecological risk associated with metals in the environment. The BLM software is widely used by scientists, regulators, and academics.

Areas of Specialization

- Metals bioavailability
- Biotic ligand model application and development
- Water quality criteria development, including site-specific criteria
- Chemical equilibrium modeling
- Ecological risk

Education

- BA, Biology/Genetics, Cornell University, 1985
- MS, Hydrogeology, Syracuse University, 1991

Work History

- Partner, Windward Environmental LLC, 2015-present
- Senior Professional Associate/ Environmental Chemistry Department Manager, HDR, 2010-2015
- Associate, HydroQual 1996-2010

Memberships

- Society of Environmental Toxicology and Chemistry
- American Chemical Society

Bob Santore (*cont.*)
Partner

Project Experience

Development of a Model for the Prediction of the Fate, Transport, and Effects on Aquatic Biota of Mercury and Cadmium in New York/New Jersey Harbor

Mr. Santore served as senior project scientist for an effort to develop a quantitative model for predicting the fate and effects of heavy metal discharges to the New York/New Jersey (NY/NJ) harbor as part of a water quality, eutrophication, and sediment transport model developed for the Contaminant Assessment and Reduction Project for the Hudson River Foundation. The project included a thorough review of the state-of-the-science regarding mercury, including chemical speciation, environmental fate, and effects on biota. Efforts to assess biotic effects focused on the bioaccumulation and biomagnification of monomethylmercury, as well as the environmental conditions that determine the degree to which methylmercury is formed. As part of this effort, historical loads of mercury to sediment in NY/NJ harbor were characterized; the long-term effects of the contaminated sediment on future water quality were a key consideration. The mercury model was unique in that the mercury methylation rates were calculated as a result of sulfate reduction kinetics and mercury bioavailability. The ability to calculate methylation rates, rather than use methylation as a calibration parameter, allowed the model to predict how changes in water quality (such as changes in trophic state) might affect the methylation of mercury. The quantitative model would ultimately be used to assess the merits of different remediation and management alternatives for contaminant reduction in NY/NJ harbor.

Upper Columbia River Sediment Analysis

On behalf of Teck American, Mr. Santore worked to determine whether sediment bioassays conducted using Upper Columbia River sediment showed any evidence of reduced performance relative to reference samples and whether factors associated with reductions in performance were due to chemicals or other factors. The analyses included comparing bulk sediment chemistry to sediment quality benchmarks, as well as bioavailability-based benchmarks such as acid volatile sulfide-simultaneously extracted metals (AVS-SEM). In addition, metals concentrations in sediment porewater were analyzed using the BLM to determine if metals concentrations were high enough to be associated with toxicity. Biological measurements included growth endpoints for sensitive invertebrates (i.e., *Hyalella azteca* and chironomids). Physical factors such as grain size were evaluated using triangle diagrams that showed the distribution of sand, silt, and clay. The spatial trends of the chemical, physical, and biological data were examined using river mile plots and concentration gradient maps.

Upper Columbia River Analysis of Short-Term Sediment Toxicity Test Results

Mr. Santore was involved in an effort to analyze the results of short-term sediment toxicity tests conducted with sediment collected from the Upper Columbia River (UCR) to identify sediment that should be used in subsequent long-term toxicity tests. Sediment chemistry data (e.g., AVS-SEM, mean probable effects concentration quotient [mPECq], zinc to vanadium ratio, total organic carbon [TOC], BLM-calculated toxic units) and sediment toxicity data (e.g., survival and growth [using *Hyalella azteca* and *Chironomus dilutus*]) were evaluated. A combination of biological responses and sediment chemistry characteristics were used to select the subset of samples to be used in the long-term testing.

Review of USGS Upper Columbia River Sturgeon Report

Mr. Santore was involved in an effort to critically review a draft report prepared by the US Geological Survey (USGS) that described the results of acute and chronic toxicity tests conducted with white sturgeon and rainbow trout. The tests evaluated the toxicity of cadmium, copper, lead, and zinc in water-only exposures. During the project, each calculation presented in the draft report was repeated, and graphical summaries were prepared. All analyses were scripted and used data obtained directly from the project database.

Bob Santore *(cont.)*
Partner

Development of Aquatic Life Criteria Using the Marine Copper BLM

Mr. Santore served as the project manager for an effort to develop a WQC document for the US Environmental Protection Agency (EPA) that used the marine BLM to explain and predict the importance of exposure conditions on copper bioavailability to estuarine and marine organisms. The marine BLM was used with a normalized species sensitivity distribution to determine a concentration that would be protective of marine and estuarine aquatic life.

Elk Valley Cadmium Effects Characterization

Mr. Santore was involved in a project to evaluate the potential for effects due to cadmium in the Fording and Elk Rivers in British Columbia and to develop scientifically defensible site-specific water quality targets for cadmium at several compliance sites within the Elk Valley. A chronic cadmium BLM was developed for application during this project. Both BLM normalized and hardness-normalized species sensitivity distributions were developed to establish protective water quality targets and evaluate whether effects were likely under current exposure conditions. Targets determined using the BLM and the hardness equation were similar, and it was determined that cadmium was not a major driver for toxicity at the compliance sites evaluated.

Great Lakes Environmental Center – EPA Work Assignment: Fixed Monitoring Benchmark

Mr. Santore led an effort to describe the fixed monitoring benchmark (FMB) approach to implementation of site-specific (and temporally variable) WQC. The approach was developed for the implementation of BLM-based WQC for copper. The method integrated measured dissolved copper concentrations and BLM-predicted instantaneous WQC in a probability-based manner to provide a benchmark (i.e., the FMB) that represented a concentration that should not be exceeded with a frequency greater than a specified exceedance frequency (e.g., once in 3 years).

International Zinc Association Metal Mixture Modeling Evaluation

Mr. Santore served as project manager for an effort to develop a metal mixture BLM and evaluate the framework and model performance with several datasets. The project was a collaborative effort, and various modeling approaches were applied to the specified metal mixture toxicity datasets. Concepts related to concentration addition and independent action were evaluated and incorporated into a multi-biotic ligand site, multi-metal BLM. The results of the project were described in a special edition of the journal Environmental Toxicology and Chemistry.

Revision of the Ambient Water Quality Criteria for Copper

Mr. Santore served as project manager for an effort to develop a revision of the freshwater AWQC for copper that included site-specific bioavailability information using the BLM. This work provided EPA with the modeling and data analysis support they needed to release an update to the WQC for copper based on the BLM.

Development of a Marine BLM for Copper

Mr. Santore served as the project manager and was the primary code developer for an effort to develop a version of the copper BLM suitable for assessing the ecological risk and standards compliance of copper in saltwater environments. This project required the development of a general speciation model for copper, including organic matter interactions in marine waters. Biotic ligand parameters were developed for a number of sensitive marine invertebrates, including blue mussels (*Mytilus galloprovincialis*), purple sea urchins (*Strongylocentrotus purpuratus*), and oysters (*Crassostrea gigas*). The resulting model was validated with toxicity data from San Diego Bay and Pearl Harbor and used to estimate site specific WQC at these sites.

Bob Santore (*cont.*)
Partner

Upper Columbia River Phase 2 Sediment Study

Mr. Santore was involved in an effort to provide technical support during EPA's review of the draft quality assurance project plan (QAPP) for a sediment study on the Upper Columbia River. Specifically, the project investigated the magnitude and spatial patterns of metals contamination in Upper Columbia River sediment and used this information to design a sediment study to quantify potential risk to sensitive aquatic and benthic organisms from exposure to this sediment.

Development of Chronic BLM-Based Water Quality Guideline for Copper

On behalf of Environment Canada, Mr. Santore served as project manager for this effort to incorporate the chronic BLM for copper into a software package that automated the calculation of aquatic risks for copper using the water quality guideline approach approved by Environment Canada. The software automated the process of using the copper BLM to normalize chronic toxicity data and the production of a species sensitivity distribution (SSD) graph and calculated HC5. The copper database included with the software package incorporated toxicity data for aquatic invertebrates, fish, amphibians, plants, and algae into the HC5 and SSD. A variety of distributional models were used to select the best model based on goodness of fit with the SSD.

Review of Nickel Bioavailability Studies and Evaluation of Nickel BLM Performance

Mr. Santore served as project manager for this review of nickel literature to support a site-specific WQC study for Decatur, Illinois. EPA requested a comprehensive review of the nickel literature as a first step toward evaluating whether the nickel BLM could be used as a general approach for developing water quality guidelines. Acute and chronic nickel toxicity was reviewed for this project, and the major factors affecting nickel bioavailability and toxicity to aquatic organisms were identified. These data were then used to show that the nickel BLM was predictive of nickel toxicity over a wide range of chemical conditions and, therefore, could be used to develop nickel water quality guidelines.

Assessment of Copper Olfactory Impairment in Salmonid Fish in Marine Waters

On behalf of the US Navy Environmental Sustainability Development to Integration (NESDI) Program, Mr. Santore served as project manager for an effort to assess copper olfactory impairment in salmonid fish in marine waters. The possible impairment of the olfactory response in salmonids from exposure to copper has been the subject of considerable attention in recent studies by the National Oceanic and Atmospheric Administration (NOAA) and others. For this project, Mr. Santore evaluated whether the recently proposed marine WQC based on the BLM would be protective with regard to olfactory impairment in salmonids as well as copper toxicity for sensitive invertebrates such as *Mytilus* (blue mussel), *Crassostrea* (oyster), *Dendraster* (sand dollar), and *Strongylocentrotus* (purple sea urchin). The marine BLM was used to predict safe copper limits in San Diego Bay and Puget Sound, and these concentrations were compared with toxicity tests for select organisms and olfactory inhibition in salmonids.

Elk Valley Cross-Program Collaboration/Support for the Elk Valley Water Quality Plan

Mr. Santore was involved in a collaborative effort to support Teck Coal during the development of the Elk Valley water quality plan, with a focus on the effects characterizations for selenium, cadmium, nitrate, and sulfate. Much of the effort involved the review and discussion of material developed by the project team, followed by the presentation of materials to the technical advisory committee assembled to review the plan.

Assessment of a Site-Specific WQC for Nickel Using BLM

Mr. Santore served as project manager and provided support for an effort to derive a site-specific WQC for nickel in the receiving waters downstream of a municipal wastewater treatment plant (WWTP) in Decatur, Illinois. The national ambient water quality criteria (AWQC) are known to be overprotective for many metals. The nickel BLM was used to predict nickel effects in receiving waters downstream of the WWTP to show that

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an elevated WQC for nickel would be fully protective of sensitive aquatic organisms. The model results were used as a rationale in a petition for a site-specific rule based on an increased nickel criterion.

Revision of the Marine WQC for Copper Using the Marine BLM

On behalf of Computer Sciences Corp., Mr. Santore led an effort to use the marine BLM for copper to develop updated acute and chronic WQC for copper in marine systems. This work was conducted with oversight by and cooperation with EPA with the intent that the revised criteria would later be used by EPA to update the national criteria for copper in marine systems.

Copper Speciation in Marine and Estuarine Waters near an Active Copper Mine

Mr. Santore was involved in an analysis to determine the environmental factors that were likely responsible for determining the form and bioavailability of copper in the estuarine and marine waters bordering an active copper mine. The marine BLM was used to interpret copper titration data, and it was determined that natural organic matter (NOM) was controlling the lability of copper in these samples, as measured by stripping voltammetry. In addition to improving the interpretation of previous monitoring data, the results would be used to refine the future monitoring of copper, as well as factors that determined the ecological risk from copper at the site.

Elk Valley Cadmium Environmental Management-Level Review

Mr. Santore was involved in a project to provide an independent critical review of a draft report that described the derivation of environmental management levels (EMLs) for cadmium. This review assessed the adequacy of the data used and analyses described to support the EMLs. During the review, British Columbia Ministry of Environment (BC MOE) procedures for water quality guideline (WQG) derivation were considered. The review determined that the approach taken did not correspond to the conceptual model proposed. Hardness was used to normalize the toxicity database, whereas the conceptual model included other factors such as pH, and dissolved organic carbon (DOC) concentration. The EMLs developed for the Fording River might not have been protective of *Hyalella azteca* because they were removed from consideration under the assumption that they were not present in the Fording River. Due to the lack of evidence for their absence, it was suggested that removal of H. azteca from the species sensitivity distribution be reconsidered until field evidence could support the assumption.

Evaluation and Summary of Acute and Chronic Toxicity Data for White Sturgeon

Mr. Santore was involved in an effort to analyze chemistry and toxicity data from acute and chronic toxicity tests conducted using White Sturgeon exposed to copper, zinc, lead, and cadmium. Exposures were performed in laboratory water and in water taken from the Upper Columbia River. All data analyses were performed in an efficient and repeatable manner with scripts developed to work directly with the project database. Results of all analyses and data summaries included in a project data summary report.

Upper Columbia River - Ecology Sediment Report Review

Mr. Santore reviewed a report prepared by MacDonald Environmental Services, Limited (MESL) for Washington State Department of Ecology that presented a compilation of sediment exposure and toxicity data in an attempt to link the two. The approach used in the reviewed report was the "reference envelope" approach. This review identified three methodological flaws in the MESL analysis, including: inconsistent attribution of toxicity and underlying causative agents, unrepresentative reference stations, flawed application of the reference envelope approach.

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Feasibility Assessment of Bioavailability Considerations in Developing Predicted No-Effect Concentrations for Silver

Mr. Santore was involved in an effort to assess silver concentrations in surface water based on a large dataset of monitoring samples collected from sites across the European Union (EU). Many of the silver concentrations were greater than a proposed predicted no-effect concentration (PNEC) intended to serve as a safe limit for the entire EU. However, it was demonstrated that an alternative BLM-based result, which considered bioavailability effects from NOM and other substances in surface water, was much higher than the proposed PNEC and also higher than ambient silver concentrations, and therefore no risk from silver was expected in EU surface water. The report was delivered as a section to a chemical safety report that was part of a Registration, Evaluation, and Authorization of Chemical Substances (REACH) dossier.

Development of Risk Assessment Software Integrating BLM Calculations for Cobalt

On behalf of the Cobalt Development Institute, Mr. Santore led an effort to update the existing cobalt BLM and incorporate the chronic BLM for cobalt into a software package that automated the calculation of aquatic risk assessment for zinc using the risk assessment approach adopted by the EU.

Chemical Speciation Model for Copper in Marine Systems in Support of a Marine BLM

Mr. Santore served as project manager for a Copper Development Association (CDA) effort to develop a chemical speciation model that considered the effects of NOM on copper speciation in marine systems. Although many models had been developed to characterize NOM effects on copper speciation in freshwater environments, a systematic modeling effort had not occurred for marine water. The project used a large speciation dataset as well as published speciation measurements to develop the best overall model for predicting marine NOM effects on copper speciation. Ultimately, the speciation model would be used in a marine BLM for copper.

Development of a BLM for Metals Mixtures

On behalf of the CDA, Mr. Santore led an effort to incorporate mixtures effects into existing BLMs to allow the model to consider simultaneous effects from multiple metals. The model was tested using effects data from aquatic and benthic organisms. Laboratory toxicity studies used in model development and testing included binary and ternary mixtures of cadmium, copper, lead, and zinc. Field data were from a mining-impacted site where complex mixtures of these same metals occurred. The BLM was used to assess the controlled responses in laboratory exposures and then determine if similar mixture effects could explain toxicity patterns observed in the field.

Development of Acute and Chronic BLM for Aluminum

On behalf of the European Aluminum Association, Mr. Santore led an effort to develop a BLM for aluminum based on acute and chronic responses in sensitive fish and invertebrates. The aluminum BLM was then used to characterize predicted no-effect concentrations for aluminum in the EU under their REACH registration.

Development of a BLM for Lead

On behalf of the International Lead Zinc Research Organization (ILZRO), Mr. Santore led an effort to develop a BLM for lead in order to predict lead toxicity to sensitive fish and aquatic invertebrates.

Development of Risk Assessment Software Integrating BLM Calculations for Zinc

On behalf of the International Zinc Association (IZA), Mr. Santore led a project to incorporate the chronic BLM for zinc into a software package that automated the calculation of aquatic risk for zinc using the risk assessment approach adopted by the EU.

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Bioavailability Assessment of Metals-Contaminated Sediment and Development of a Sediment BLM

Mr. Santore led an effort to test a multi-metal sediment BLM using datasets from the literature that showed toxicity due to the exposure of sensitive aquatic invertebrates to metals-contaminated sediment.

Site-Specific Objectives for Copper, Lead, and Zinc in Chollas Creek

Mr. Santore provided technical review and oversight for the development of site-specific objectives for copper, lead, and zinc in Chollas Creek near San Diego, California.

Application of the BLM for Copper to the Protection of Freshwater Unionid Mussel Species

Mr. Santore served as project manager for a USGS project to calibrate a copper BLM for unionid mussels. As part of this work, Mr. Santore led an effort to confirm that bioavailability was important in understanding copper toxicity to unionids and that the BLM was appropriately taking factors such as hardness, pH, and the presence of NOM into account. The project determined that the existing acute copper criterion was adequately protective of unionids, including threatened and endangered species. The work provided sufficient information to allow unionids to be included in subsequent updates to the EPA copper criteria document.

Assessing the Bioavailability and Risk of Metals in Sediment to Benthic and Aquatic Life

Mr. Santore served as a project scientist for this assessment of metals-contaminated sediment. The distribution and variability of metals in freshwater sediment, as well as the distribution of factors affecting bioavailability (e.g., AVS, and sediment organic matter), were considered in conducting sediment BLM calculations to assess potential risks from metals.

Assessment of the Feasibility of Site-Specific Objectives for Cyanide in Los Angeles County Sanitation Districts

Mr. Santore served as project manager for this effort to evaluate the feasibility of developing a site-specific objective for cyanide for the Los Angeles County Sanitation District. Cyanide is often formed in WWTP effluent following chlorination and can often be in excess of the AWQC for free cyanide (5.2 μg/L). As a result, many municipal wastewater discharges exceed the AWQC for cyanide. A combination of approaches were used to evaluate whether an elevated cyanide criteria would be defensible in receiving waters for Los Angeles County Sanitation district discharges. The approaches included recalculation of the criteria excluding sensitive organisms non-native to Los Angeles County waters and an assessment of bioavailability factors using a modeling approach. The model could predict cyanide toxicity to a wide variety of aquatic organisms and determine if site-specific water chemistry justified an adjustment of the cyanide WQC.

Development of a Model of Acute Toxicity of Cadmium to Aquatic Life

Mr. Santore was involved in a review of the scientific understanding of the bioavailability and toxicity of cadmium in support of the development of a BLM application for cadmium based on EPA's announcement of its intention to use the BLM in the development of updated WQC for metals. During the same timeframe, EPA, the Water Environment Research Foundation (WERF), and the Electric Power Research Institute (EPRI) announced a cooperative effort to support similar work for the development of the BLM for other metals as well. The results of these efforts would be incorporated into updated WQC for other metals, including aluminum, cadmium, copper, lead, nickel, silver and zinc.

Development of a Model of Copper Fate and Bioavailability Downstream of a Copper Mine

Mr. Santore served as project engineer for the development of a model of copper fate and bioavailability for an active site impacted by mine tailings. The model included a comprehensive assessment of factors controlling copper, including copper released from tailings minerals, chemical speciation, and adsorption on suspended particles. A primary concern at this site was the oxidation of pyrite and chalcopyrite minerals and the subsequent formation of acid rock drainage (ARD), which may have contributed to elevated copper

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concentrations in runoff from the site. The model would be used as an aid for the management of the operational copper mine.

Development of a Risk Assessment Framework for Copper and Other Metals

Mr. Santore was involved in a project to develop a risk assessment framework for copper and other metals in aquatic systems. As part of this effort, he was responsible for summarizing information on the bioavailability and toxicity of copper and the development of the computer code for the BLM. The BLM was used to predict the speciation of copper in the water column and the level of accumulation of copper at the site of action of toxicity. The predicted metal concentration at the site of action (e.g., the fish gill) was used to assess the potential for toxicity. Although this work was focused on assessing the effects of copper on aquatic organisms, the framework is generally applicable to other metals.

Development of a Risk Assessment Framework for Silver

As part of his effort to develop modeling tools for use in exposure and risk assessments for metals, Mr. Santore developed a BLM for use in predicting the toxicity of silver. The approach used considered not only the total metal exposure level but the metal speciation and bioavailability, which was a key advantage. An integrated water column-sediment metal chemistry model was also developed for use in exposure and risk assessments as part of parallel development efforts for copper and silver. The model would be used to predict the level of metal and AVS in bedded sediment, key considerations in assessing metal bioavailability and toxicity in sediment.

Extant Criteria Evaluation – Arid West Water Quality Research

Mr. Santore was a member of a team of nationally recognized experts in the field of WQC assembled to evaluate the applicability of national AWQC to surface waters in the arid West. Project efforts were focused on evaluating the relevance of selected EPA AWQC to ephemeral and effluent-dependent watercourses in the arid West. Emphasis was placed on considering modifications to AWQC duration and frequency periods to better reflect the biotic and hydrologic conditions encountered in these systems. To test this approach, the team evaluated four AWQC as "models" representing several important contaminant classes of interest to dischargers in the arid West, which included copper, selenium, diazinon, and ammonia. The recently developed BLM offered a unique approach for evaluating site-specific WQC for metals such as copper, silver, zinc, and others. The project also offered an opportunity to test the predictive capability of the model in very high hardness conditions. The work provided critical validation of the model in these unique conditions and helped to support the use of the BLM as a general tool for WQC development across the entire United States.

Reassessment of Cyanide Criteria for the Protection of Aquatic Life and Wildlife

Mr. Santore served as project manager for an effort to re-evaluate the EPA AWQC for cyanide. An extensive literature review on the chemistry of cyanide and how chemical factors modify the bioavailability of cyanide to aquatic organisms was conducted. A key component of the modeling analysis was a test of the degree to which cyanide chemistry could be used to explain bioavailability and toxicity to aquatic organisms. The BLM was developed previously to predict the toxicity of metals to aquatic organisms under site-specific conditions.

Review of Models for Use in Exposure and Risk Assessments for Metals

Mr. Santore participated in a comprehensive review of fate and transport, bioaccumulation, and toxicity models for metals in aquatic systems. The review was completed in response to a request made to the sponsors of the project (i.e., ILZRO, ICA, and the Nickel Producers Environmental Research Association [NiPERA]) by the International Council on Metals in the Environment (ICME) for recommendations about models that could be used in exposure and risk assessments to evaluate the fate and effects of metals in aquatic systems. The work was summarized as part of the SETAC publication Metals in Aquatic Systems: A Review of Exposure, Bioaccumulation, and Toxicity Models.

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Use of the BLM to Revise EPA AWQC for Metals

WERF, EPA, and EPRI initiated a cooperative effort to use the BLM in the development of revised WQC for metals in aquatic environments. Mr. Santore played a key role in the development of the BLM and the application of the modeling framework to site-specific WQC. Efforts included a revision of the WQC for copper and silver.

Water Quality Model for New Croton and Muscoot Reservoirs

Mr. Santore served as the project engineer for the development of a eutrophication and water quality model of the New Croton and Muscoot reservoirs to investigate whether the Croton System water supply for New York City could attain target water objectives without full-scale filtration required by the Surface Water Treatment Rule. The model was developed to provide estimates of future water quality given nutrient load reductions in the watersheds and tributaries draining into the reservoirs. NOM concentrations and iron and manganese in anoxic hypolimnetic waters were of particular concern due to their contribution to taste, odor, and color problems in the drinking water supply. The modeling analysis provided a quantitative link between nutrient loads, productivity in the reservoirs, and sediment fluxes of nutrients and metals and their impact on drinking water quality. The model was also used to evaluate management alternatives, including load reductions, watershed best management practices (BMPs), alum treatment, and hypolimnetic aeration and their effect on reservoir water quality.

Workshops, Courses, and Panel Discussions

Supplemental Training Materials and Guidance Documents for Using the Copper BLM

Mr. Santore led an effort to develop additional training materials for the copper BLM. The materials were designed to aid users in understanding the mechanistic workings of the model and provided monitoring programs to support its use. Mr. Santore developed a 1 day BLM workshop and presented the workshop at EPA regional offices in Washington, DC; Denver, CO; Dallas, TX; and Raleigh, NC. Mr. Santore also developed online training materials, including a frequently asked questions (FAQ) document, to provide additional outreach to end users, regional EPA offices, states, and tribes interested in the BLM.

BLM Short Course

Mr. Santore was one of the developers of a 1-day short course designed to introduce non technical audiences to the BLM. The course included an explanation of the background reference literature, chemistry, bioaccumulation, and toxic effects of metals in aquatic environments and presented case studies of the use of the BLM in regulatory settings. The development and presentation of the course was funded by CDA, and the course was presented to audiences in the United States, Chile, Argentina, Canada, and Europe.

Argentum Conference Biological Processes Panel

Mr. Santore was invited to participate on the Biological Processes Panel for Silver at the Sixth International Argentum Conference on Fate and Effects of Silver in the Environment. The Biological Processes Panel was responsible for summarizing our current understanding of mechanisms that regulate the bioavailability and bioreactivity of silver in the environment.

Select Presentations

- Santore, RC, AC Ryan, K Brix, and D DeForest. 2014. A review of the bioavailability and toxicity of lead to aquatic organisms in acute and chronic exposures. SETAC North America Conference, Vancouver, BC. November 2014.
- Santore, RC, RM Santore, and DS Smith. 2014. Copper speciation and binding by natural organic matter in marine waters at ambient and acidified pH. SETAC North America Conference, Vancouver, BC. November 2014.

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- Smith, DS, KC Livingstone, W Chen, C Gueguen, RC Santore, and J McGeer. 2014. Influence of estuarine dissolved organic matter of variable source on Zn toxicity to hydra (*Eudendrium carneum*) and speciation measured by AGNES. SETAC North America Conference, Vancouver, BC. November 2014.
- Ryan, AC, RC Santore, M Hecker, and D Vardy. Evaluating the likelihood that early life stages of white sturgeon were affected by metals in sediment exposures. SETAC North America Conference, Vancouver, BC. November 2014.
- Santore, RC, RM Santore, and PR Paquin. 2014. Using the Biotic Ligand Model for determining water quality criteria for copper. Pacific Northwest Clean Water Association, Vancouver, WA. October 2014.
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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED SITE SPECIFIC	)	
RULE FOR SANITARY DISTRICT	)	R14-24
OF DECATUR FROM 35 ILL. ADM.	)	(Site Specific Rule – Water)
CODE SECTION 302.208(e).	)	

PRE-FILED TESTIMONY OF ALLISON CARDWELL
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

NOW COMES the Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Allison Cardwell for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF ALLISON CARDWELL

I. INTRODUCTION

My name is Allison Cardwell, and I served as the Study Director from the Oregon State University Aquatic Toxicology Laboratory for the District's Study of Chronic Toxicity of a Nickel-Spiked Simulated Effluent, With and Without Dissolved Organic Carbon (DOC) to the Cladoceran, *Ceriodaphnia dubia* ("OSU Toxicity Report"), which was attached as part of Exhibit 28 to the District's Motion to File Revised Exhibits 14 and 28, New Exhibits 45 and 46, Revised Exhibit List, and Minor Revision to Proposed Subsection 303.410 filed on April 20, 2018. My Curriculum Vitae is attached hereto as Exhibit A.

My testimony today addresses and supports those portions of the District's Amended Petition for Site Specific Rule ("Amended Petition") relating to the development of the site specific water quality standard for nickel for the Sangamon River, specifically the chronic toxicity testing component that was used by Mr. Robert Santore of Windward Environmental

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LLC in developing the site specific standard to account for bioavailability effects using a Water Effect Ratio ("WER").

II. CHRONIC TOXICITY TESTING

The purpose of the chronic toxicity testing was to determine the toxicity of nickel to an aquatic invertebrate, the cladoceran *Ceriodaphnia dubia*, when exposed in a laboratory-reconstituted water designed to simulate an effluent collected from the wastewater treatment facility in Decatur, Illinois. Tests were conducted both with and without the addition of dissolved organic carbon ("DOC"), to quantify the anticipated protective effects of DOC on nickel toxicity. The studies were conducted as seven-day chronic toxicity tests according to standard United States Environmental Protection Agency ("USEPA") testing methodology (USEPA 2002)[1] and WER guidance (USEPA 1994)[2], attached hereto as Exhibit B and Exhibit C, respectively. To determine chronic toxicity, survival and reproduction, and nickel concentrations in the water were assessed during the seven-day test period.

Due to the complex ionic makeup of the simulated effluent, the test organisms were acclimated for over a year to the high ionic composition (e.g., high hardness, high pH) of the water. Following many months of acclimation, starting from a very hard reconstituted water

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[1] USEPA. 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. EPA-821-R-02-013.Test Method 1002.0: Daphnid, *Ceriodaphnia dubia*, Survival and Reproduction Test Method. USEPA Office of Water, Washington, DC. (Select portions only. For the entire 350 page document, please see: https://www.epa.gov/sites/production/files/2015-08/documents/short-term-chronic-freshwater-wet-manual_2002.pdf).

[2] USEPA. 1994. Interim Guidance on Determination and Use of Water-Effect Ratios for Metals. EPA-823-B-94-001. Office of Water. Washington D.C. (Select portions only. For the entire 186 page document, please see: https://nepis.epa.gov/Exe/ZyNET.exe/20003QI5.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000011%5C20003QI5.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL)

culture, the *C. dubia* cultures were maintained successfully in the simulated effluent in order to use in the toxicity tests. *C. dubia* was selected as the test species because it is sensitive to nickel and is the most sensitive species in the Illinois water quality criteria for nickel.[3] The Illinois ambient water quality criteria for nickel are attached hereto as Exhibit D. Additionally, using a sensitive species for the toxicity testing provides protection for many other aquatic species.

Testing and documentation for the study were carried out in the spirit of Good Laboratory Practice ("GLP") standards. The study was conducted at the Oregon State University Aquatic Toxicology Laboratory (OSU AquaTox, Albany, OR, USA). Analytical measurements of the nickel concentrations were performed at the OSU W.M. Keck Plasma Spectrometry Laboratory (Corvallis, OR, USA). Chemical analyses of water quality parameters of the simulated effluent water were performed at CH2M Hill (Corvallis, OR, USA).

In two tests, one with the simulated effluent without DOC and one with the simulated effluent with DOC added, the test organism, *C. dubia*, was exposed to a series of nickel concentrations. The nickel spiked into the waters were at concentrations designed to elicit a biological response, based upon survival and reproduction of the organism, and quantified as 20% effect concentrations (EC_{20}). The EC_{20} is calculated from a dose response curve and corresponds to a nickel concentration where 20% of the organisms exhibited reduced survival and reproduction. The EC_{20} values were calculated for each test and compared to establish the differences between waters without DOC and with DOC. The results demonstrated that the addition of DOC to the simulated effluent had a protective effect on chronic nickel toxicity to a

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[3] Illinois Pollution Control Board. 2002. R02-11 (Rulemaking-Water); Water Quality Triennial Review: Amendments to 35 Ill. Adm. Code 302.105, 302.208(e)-(g), 302.504(a), 302.575(d), and 309.141(h) and Proposed 35 Ill. Adm. Code 301.267, 301.313, 301.413, 304.120, and 309.157, Exhibit V: Ambient Water Quality Criteria for Nickel: Water Quality Criteria Derivation Fact Sheet – Individual Substances, available at: http://www.ipcb.state.il.us/COOL/external/CaseView.aspx?referer=results&case=5188.

sensitive test organism, *C. dubia*. The protectiveness of DOC, and water hardness, on nickel toxicity has also been observed and reported in the literature for other species as well, including fish and other invertebrates. The results of the toxicity tests simulating the specific water quality conditions of the District effluent and Sangamon River provided the data for the calculation of a site specific water quality criteria, as detailed in Dr. Robert Santore's testimony.

III. CONCLUSION

The information discussed today and in the OSU Toxicity Report supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions you may have regarding the OSU Toxicity Report.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Exhibit A

Allison S. Cardwell

Curriculum Vitae

CONTACT	POSITION TITLE
Aquatic Toxicology Lab 34347 NE Electric Road Corvallis, OR 97333 541.788.0564 allison.cardwell@oregonstate.edu	Sr. Faculty Research Assistant/Laboratory Manager Aquatic Toxicology Lab Department of Environmental & Molecular Toxicology Oregon State University, Corvallis, OR, USA

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE	YEAR(s)	FIELD OF STUDY
University of Washington, Seattle, WA	BS	1994 -1998	Fisheries Biology

BIOGRAPHICAL SKETCH

Allison Cardwell has 20 years of experience conducting all facets of aquatic toxicity testing. She has worked in three laboratories: two commercial and one research. She began washing glassware, was promoted to culturing organisms for the tests, then promoted to conducting the tests of effluents, sediments, pure chemicals and mixtures of chemicals, then promoted to Laboratory Manager where she is in charge of study design and implementation of testing. For the past 8 years she has managed all aquatic toxicity testing at the Oregon State University Aquatic Toxicology Laboratory.

Her primary expertise involves designing and conducting the tests and analyzing and reporting the results. As well, she is responsible for all laboratory quality control, quality assurance, as well as conducting the training and managing all record keeping, most of which is subject to Good Laboratory Practice (21 CFR 58).

Much of her experience over the past 13 years has been determining the bioavailability and toxicity of metals, namely cobalt, aluminum, copper, iron, manganese, lead, and nickel in freshwater. Most of the work has been highly specialized, determining the influence on toxicity of differences in the composition of water from streams, rivers, ponds, and lakes.

RELEVANT EMPLOYMENT INFORMATION

2010 - current, Sr. Faculty Research Assistant/Laboratory Manager, Department of Environmental & Molecular Toxicology, Oregon State University, Corvallis, OR.
2008 - 2010, Laboratory Supervisor, Parametrix Environmental Research Laboratory (PERL), Albany, OR.
2005 - 2008, Associate Toxicologist, Parametrix Environmental Research Laboratory (PERL), Albany, OR.
2001 - 2004, Executive Director/Watershed Coordinator, Lamoille County Natural Resources Conservation District, Morrisville, VT.
1999 - 2001, Environmental Scientist, Heindel & Noyes, Burlington, VT.
1993 - 1998, Aquatic Toxicology Laboratory Technician, Parametrix, Inc., Kirkland, WA.

OTHER TRAINING EXPERIENCE

2014, Invited Guest: 2014 Aquatic Toxicology Symposium, Ft. Worden, WA.
2008, Good Laboratory Practices (GLP) Training, 40 CFR 160, Workshop.
2007, International Uniform Chemical Information Database (IUCLID) Training, TechniData America.
2007, Introductory GLP Training, West Coast Quality Training Institute.
2006, Biotic Ligand Model Workshop, Society of Environmental Toxicology and Chemistry.

RESEARCH EXPERIENCE

2013 - current, Evaluate the Aquatic Toxicity of Nickel to *Ceriodaphnia dubia* in a simulated effluent for the derivation of site-specific criteria.
2010 - current, Development of US. Ambient Water Quality Criteria, European Union Predicted No Effect Concentration, and a Biotic Ligand Model for Aluminum.
2012 - current, Development of US. Ambient Water Quality Criteria, European Union Predicted No Effect Concentration, and a Multiple Linear Regression Model for Iron.
2005 - current, Development of European Union Predicted No Effect Concentration and a Biotic Ligand Model for Cobalt.
2005 - 2008, Evaluate the Aquatic Toxicity of Manganese and Derivation of Water Quality Criteria.
2009, Update existing ecological and mammalian/human health IUCLID dossiers for several nickel compounds to support registration under the European Registration, Evaluation, Authorisation of Chemicals (REACH). Focus on the effects of nickel compounds in soils and in freshwater and marine environments.
2009, Validate Nickel Biotic Ligand Model (BLM) Predictions for Selected Non-standard Test Organisms.
2008, Evaluate the reliability of the biotic ligand model (BLM) to predict Cu toxicity in very hard surface water characteristic of the arid West, relative to current copper criteria methodologies.
2005 – 2007, Determine effects of water-soluble fractions of crude oil with the presence and absence of oil microdroplets on hatching, growth, and development of *Oncorhynchus gorbuscha* (Pink Salmon).
2005 - 2007, Determine the influence of pH and hardness on the toxicity of ammonia to aquatic organisms.

PROFESSIONAL MEMBERSHIPS

2006 - current, Society of Environmental Toxicology and Chemistry (SETAC)
2006 - 2009, 2018 Pacific Northwest Chapter - Society of Environmental Toxicology & Chemistry

PUBLICATIONS

Adams WJ, **Cardwell AS**, DeForest DK, Gensemer RW., Santore RC, Wang N, Nordheim E. 2018. Special Section: Aluminum Bioavailability and Toxicity to Aquatic Organisms. *Environ Toxicol Chem.* 37 (1): 34–35

Cardwell AS, Adams WJ, Gensemer RW, Nordheim E, Santore RC, Ryan AC, Stubblefield WA. 2018. Chronic toxicity of aluminum, at a pH of 6, to freshwater organisms: Empirical data for the development of international regulatory standards/criteria. *Environ Toxicol Chem*. 37 (1): 36–48.

Gensemer RW, Gondek JC, Rodriguez PH, Arbildua JJ, Stubblefield WA, **Cardwell AS**, Santore RC, Ryan AC, Adams WJ, Nordheim E. 2018. Evaluating the effects of pH, hardness, and dissolved organic carbon on the toxicity of aluminum to freshwater aquatic organisms under circumneutral conditions. *Environ Toxicol Chem*. 37 (1): 49–60.

Santore RC, Ryan AC, Kroglund F, Rodriguez P, Stubblefield WA, **Cardwell AS**, Adams WJ, Nordheim E. 2018. Development and application of a biotic ligand model for predicting the chronic toxicity of dissolved and precipitated aluminum to aquatic organisms. *Environ Toxicol Chem*. 37(1): 70–79.

Wang N, Ivey CD, Brunson EL, Cleveland D, Ingersoll CG, Stubblefield WA, **Cardwell AS**. 2018. Acute and chronic toxicity of aluminum to a unionid mussel (*Lampsilis siliquoidea* and amphipod (*Hyalella azteca*) in water-only exposures. *Environ Toxicol Chem*. 37(1): 61–69

Adams WJ, Rodriguez PH, **Cardwell AS**, Tear LM, Stubblefield WA, Brix KV, and DeForest DK. A multiple linear regression model to predict the influence of dissolved organic carbon, hardness, and pH on chronic iron toxicity to freshwater organisms. *In preparation.*

Stubblefield WA, Van Genderen EJ, **Cardwell AS**, DeSchamphelaere K. Acute and chronic toxicity of cobalt to freshwater organisms. *Environ Toxicol Chem. In preparation.*

Stubblefield WA, **Cardwell AS**, VanGenderen EJ, Santore RC, Ryan AC. Effect of water quality parameters and the development of a biotic ligand model for chronic cobalt toxicity to *Ceriodaphnia dubia* and fathead minnows (*Pimephales promelas*). *Environ Toxicol Chem. In preparation.*

PRESENTATIONS

Cardwell AS, Delbeke K, Baken S, Stubblefield WA. 2017. A pH-controlled flow-through system exposing fathead minnows and rainbow trout to copper under soft water conditions with added dissolved organic carbon. SETAC Europe, Brussels, Belgium (Poster Co-author).

Stubblefield WA, **Cardwell AS**. 2016. Acute and Chronic Toxicity of Metal Mixtures Containing Cobalt, Copper, and Nickel to *Ceriodaphnia dubia* and *Pimephales promelas.* SETAC North America Meeting, Orlando, FL, USA. (Poster Co-author).

Santore RC, Ryan AC, Adams WJ, Stubblefield WA, **Cardwell AS**, Gensemer RW, Nordheim E. 2013. Predicting aluminum toxicity as a mixture of effects from dissolved and precipitated metal. SETAC North America Meeting, Nashville, TN, USA. (Poster Co-author).

Gondek J, Gensemer RW, Stubblefield WA, **Cardwell AS**, Santore RC, Adams WJ, Nordheim E. 2013. A comparative analysis of aquatic HC_{05} values for aluminum using Biotic Ligand Model- vs. hardness-normalized toxicity data. SETAC North America Meeting, Nashville, TN, USA. (Poster Co-author).

Cardwell AS, Stubblefield WA, Adams WJ, Gensemer RW, Nordheim E, Santore RC. 2012. Evaluation of aluminum chronic toxicity to the fathead minnow and zebrafish using a flow-through pH-control toxicity test system. SETAC North America, Long Beach, CA, USA. (Poster Presenter).

Stubblefield WA, **Cardwell AS**, Adams WJ, Gensemer RW, Nordheim E, Santore RC. 2012. The toxicity of aluminum to 8 different aquatic species, at a pH of 6. SETAC North America, Long Beach, CA, USA. (Platform Co-author).

Adams, WJ, Rodriguez PH, **Cardwell AS**, Tear LM, Stubblefield WA, Brix KV, DeForest DK. 2012. Use of Multiple Linear Regression to Model the Influence of Water Chemistry on Chronic Iron Toxicity to Freshwater Organisms. SETAC North America, Long Beach, CA, USA. (Platform Co-author).

Gensemer RW, Canton SP, Adams WJ, Santore RC, Ryan AC, Stubblefield WA, **Cardwell AS**, Rodriguez P, DeForest D. 2010. Scientific Alternatives for Deriving Aquatic Life Criteria for Aluminum as a Function of pH, Hardness, and Dissolved Organic Carbon. SETAC North America, Portland, OR, USA. (Platform Co-author).

Cardwell AS, Smith CA, Gensemer R, Van Genderen E, Ramage K, Curley E. 2006. Influence of elevated hardness on ammonia toxicity to fish and aquatic invertebrates. SETAC Pacific Northwest Chapter Meeting, Port Townsend, WA, USA (Poster Presenter).

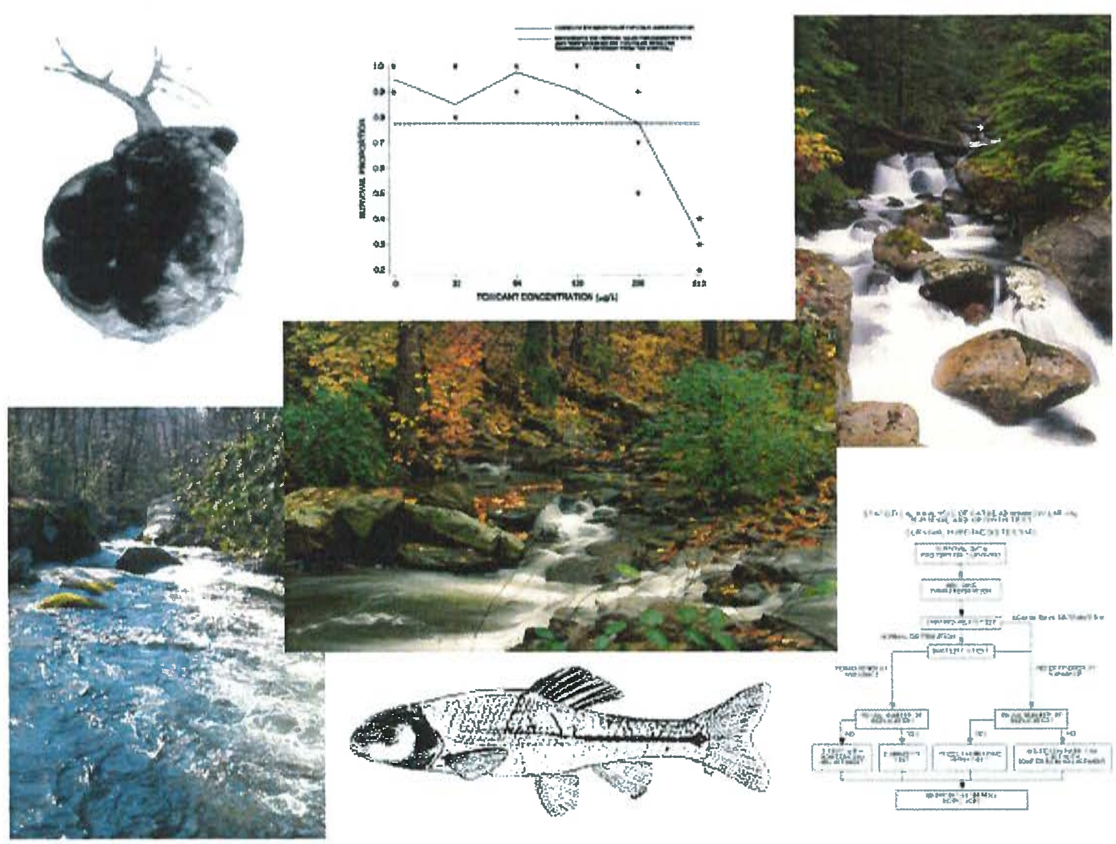
Exhibit B

United States
Environmental Protection
Agency

Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms

Fourth Edition

October 2002



U.S. Environmental Protection Agency
Office of Water (4303T)
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Washington, DC 20460

EPA-821-R-02-013

DISCLAIMER

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SECTION 12

SECTION 12 (Continued)

SECTION 13

SECTION 13 (Continued)

SECTION 14

SECTION 1

INTRODUCTION

1.1 This manual describes chronic toxicity tests for use in the National Pollutant Discharge Elimination System (NPDES) Permits Program to identify effluents and receiving waters containing toxic materials in chronically toxic concentrations. The methods included in this manual are referenced in Table IA, 40 CFR Part 136 regulations and, therefore, constitute approved methods for chronic toxicity tests. They are also suitable for determining the toxicity of specific compounds contained in discharges. The tests may be conducted in a central laboratory or on-site, by the regulatory agency or the permittee.

1.2 The data are used for NPDES permits development and to determine compliance with permit toxicity limits. Data can also be used to predict potential acute and chronic toxicity in the receiving water, based on the LC50, NOEC, IC50 or IC25 (see Section 9, Chronic Toxicity Endpoints and Data Analysis) and appropriate dilution, application, and persistence factors. The tests are performed as a part of self-monitoring permit requirements, compliance biomonitoring inspections, toxics sampling inspections, and special investigations. Data from chronic toxicity tests performed as part of permit requirements are evaluated during compliance evaluation inspections and performance audit inspections.

1.3 Modifications of these tests are also used in toxicity reduction evaluations and toxicity identification evaluations to identify the toxic components of an effluent, to aid in the development and implementation of toxicity reduction plans, and to compare and control the effectiveness of various treatment technologies for a given type of industry, irrespective of the receiving water (USEPA, 1988c; USEPA, 1989b; USEPA 1989c; USEPA, 1989d; USEPA, 1989e; USEPA, 1991a; USEPA, 1991b; and USEPA, 1992).

1.4 This methods manual serves as a companion to the acute toxicity test methods for freshwater and marine organisms (USEPA, 2002a), the short-term chronic toxicity test methods for marine and estuarine organisms (USEPA, 2002b), and the manual for evaluation of laboratories performing aquatic toxicity tests (USEPA, 1991c). In 2002, EPA revised previous editions of each of the three methods manuals (USEPA, 1993a; USEPA, 1994a; USEPA, 1994b).

1.5 Guidance for the implementation of toxicity tests in the NPDES program is provided in the Technical Support Document for Water Quality-based Toxics Control (USEPA, 1991a).

1.6 These freshwater short-term toxicity tests are similar to those developed for marine and estuarine organisms to evaluate the toxicity of effluents discharged to marine and estuarine waters under the NPDES permit program. Methods are presented in this manual for three species of freshwater organisms from three phylogenetic groups. The methods are all static renewal type seven-day tests except the green alga, ***Selenastrum capricornutum***, test which lasts four days.

1.7 The three species for which test methods are provided are the fathead minnow, ***Pimephales promelas***; the daphnid, ***Ceriodaphnia dubia***; and the green alga, ***Selenastrum capricornutum***.

1.7.1 Two of the methods incorporate the chronic endpoint of growth in addition to lethality and one incorporates reproduction. The fathead minnow, ***Pimephales promelas***, embryo-larval survival and teratogenicity test incorporates teratogenic effects in addition to lethality. The green alga, ***Selenastrum capricornutum***, growth test has the advantage of a relatively short exposure period (96 h).

1.8 The validity of the freshwater chronic methods in predicting adverse ecological impacts of toxic discharges was demonstrated in field studies (USEPA, 1984; USEPA, 1985b; USEPA, 1985c; USEPA, 1985d; USEPA, 1986a; USEPA, 1986b; USEPA, 1986c; USEPA, 1986d; Birge et al., 1989; and Eagleson et al., 1990).

1.9 The use of any test species or test conditions other than those described in the methods summary tables in this manual shall be subject to application and approval of alternate test procedures under 40 CFR 136.4 and 40 CFR 136.5.

1.10 These methods are restricted to use by, or under the supervision of, analysts experienced in the use or conduct of aquatic toxicity tests and the interpretation of data from aquatic toxicity testing. Each analyst must demonstrate the ability to generate acceptable test results with these methods using the procedures described in this methods manual.

1.11 This manual was prepared in the established EMSL-Cincinnati format (USEPA, 1983).

SECTION 2

SHORT-TERM METHODS FOR ESTIMATING CHRONIC TOXICITY

2.1 INTRODUCTION

2.1.1 The objective of aquatic toxicity tests with effluents or pure compounds is to estimate the "safe" or "no effect" concentration of these substances, which is defined as the concentration which will permit normal propagation of fish and other aquatic life in the receiving waters. The endpoints that have been considered in tests to determine the adverse effects of toxicants include death and survival, decreased reproduction and growth, locomotor activity, gill ventilation rate, heart rate, blood chemistry, histopathology, enzyme activity, olfactory function, and terata. Since it is not feasible to detect and/or measure all of these (and other possible) effects of toxic substances on a routine basis, observations in toxicity tests generally have been limited to only a few effects, such as mortality, growth, and reproduction.

2.1.2 Acute lethality is an obvious and easily observed effect which accounts for its wide use in the early period of evaluation of the toxicity of pure compounds and complex effluents. The results of these tests were usually expressed as the concentration lethal to 50% of the test organisms (LC50) over relatively short exposure periods (one-to-four days).

2.1.3 As exposure periods of acute tests were lengthened, the LC50 and lethal threshold concentration were observed to decline for many compounds. By lengthening the tests to include one or more complete life cycles and observing the more subtle effects of the toxicants, such as a reduction in growth and reproduction, more accurate, direct, estimates of the threshold or safe concentration of the toxicant could be obtained. However, laboratory life-cycle tests may not accurately estimate the "safe" concentration of toxicants because they are conducted with a limited number of species under highly controlled, steady-state conditions, and the results do not include the effects of the stresses to which the organisms would ordinarily be exposed in the natural environment.

2.1.4 An early published account of a full life-cycle, fish toxicity test was that of Mount and Stephan (1967). In this study, fathead minnows, *Pimephales promelas*, were exposed to a graded series of pesticide concentrations throughout their life cycle, and the effects of the toxicant on survival, growth, and reproduction were measured and evaluated. This work was soon followed by full life-cycle tests using other toxicants and fish species.

2.1.5 McKim (1977) evaluated the data from 56 full life-cycle tests, 32 of which used the fathead minnow, *Pimephales promelas*, and concluded that the embryo-larval and early juvenile life-stages were the most sensitive stages. He proposed the use of partial life-cycle toxicity tests with the early life-stages (ELS) of fish to establish water quality criteria.

2.1.6 Macek and Sleight (1977) found that exposure of critical life-stages of fish to toxicants provides estimates of chronically safe concentrations remarkably similar to those derived from full life-cycle toxicity tests. They reported that "for a great majority of toxicants, the concentration which will not be acutely toxic to the most sensitive life stages is the chronically safe concentration for fish, and that the most sensitive life stages are the embryos and fry". Critical life-stage exposure was considered to be exposure of the embryos during most, preferably all, of the embryogenic (incubation) period, and exposure of the fry for 30 days post-hatch for warm water fish with embryogenic periods ranging from one-to-fourteen days, and for 60 days post-hatch for fish with longer embryogenic periods. They concluded that in the majority of cases, the maximum acceptable toxicant concentration (MATC) could be estimated from the results of exposure of the embryos during incubation, and the larvae for 30 days post-hatch.

2.1.7 Because of the high cost of full life-cycle fish toxicity tests and the emerging consensus that the ELS test data usually would be adequate for estimating chronically safe concentrations, there was a rapid shift by aquatic toxicologists to 30 - 90-day ELS toxicity tests for estimating chronically safe concentrations in the late 1970s. In

1980, USEPA adopted the policy that ELS test data could be used in establishing water quality criteria if data from full life-cycle tests were not available (USEPA, 1980a).

2.1.8 Published reports of the results of ELS tests indicate that the relative sensitivity of growth and survival as endpoints may be species dependent, toxicant dependent, or both. Ward and Parrish (1980) examined the literature on ELS tests that used embryos and juveniles of the sheepshead minnow, *Cyprinodon variegatus*, and found that growth was not a statistically sensitive indicator of toxicity in 16 of 18 tests. They suggested that the ELS tests be shortened to 14 days posthatch and that growth be eliminated as an indicator of toxic effects.

2.1.9 In a review of the literature on 173 fish full life-cycle and ELS tests performed to determine the chronically safe concentrations of a wide variety of toxicants, such as metals, pesticides, organics, inorganics, detergents, and complex effluents, Woltering (1984) found that at the lowest effect concentration, significant reductions were observed in fry survival in 57%, fry growth in 36%, and egg hatchability in 19% of the tests. He also found that fry survival and growth were very often equally sensitive, and concluded that the growth response could be deleted from routine application of the ELS tests. The net result would be a significant reduction in the duration and cost of screening tests with no appreciable impact on estimating MATCs for chemical hazard assessments. Benoit et al. (1982), however, found larval growth to be the most significant measure of effect, and survival to be equally or less sensitive than growth in early life-stage tests with four organic chemicals.

2.1.10 Efforts to further reduce the length of partial life-cycle toxicity tests for fish without compromising their predictive value have resulted in the development of an eight-day, embryo-larval survival and teratogenicity test for fish and other aquatic vertebrates (USEPA, 1981; Birge et al., 1985), and a seven-day larval survival and growth test (Norberg and Mount, 1985).

2.1.11 The similarity of estimates of chronically safe concentrations of toxicants derived from short-term, embryo-larval survival and teratogenicity tests to those derived from full life-cycle tests has been demonstrated by Birge et al. (1981), Birge and Cassidy (1983), and Birge et al. (1985).

2.1.12 Use of a seven-day, fathead minnow, *Pimephales promelas*, larval survival and growth test was first proposed by Norberg and Mount at the 1983 annual meeting of the Society for Environmental Toxicology and Chemistry (Norberg and Mount, 1983). This test was subsequently used by Mount and associates in field demonstrations at Lima, OH (USEPA, 1984), and at many other locations. Growth was frequently found to be more sensitive than survival in determining the effects of complex effluents.

2.1.13 Norberg and Mount (1985) performed three single toxicant fathead minnow larval growth tests with zinc, copper, and DURSBAN®, using dilution water from Lake Superior. The results were comparable to, and had confidence intervals that overlapped with, chronic values reported in the literature for both ELS and full life-cycle tests.

2.1.14 Mount and Norberg (1984) developed a seven-day cladoceran partial life-cycle test and experimented with a number of diets for use in culturing and testing the daphnid, *Ceriodaphnia reticulata* (Norberg and Mount, 1985). As different laboratories began to use this cladoceran test, it was discovered that apparently more than one species was involved in the tests conducted by the same laboratory. Berner (1986) studied the problem and determined that perhaps as many as three variant forms were involved and it was decided to recommend the use of the more common *Ceriodaphnia dubia* rather than the originally reported *Ceriodaphnia reticulata*. The method was adopted for use in the first edition of the freshwater short-term chronic methods (USEPA, 1985e).

2.1.15 The green alga, *Selenastrum capricornutum*, bottle test was developed, after extensive design, evaluation, and application, for the National Eutrophication Research Program (USEPA, 1971). The test was later modified for use in the assessment of receiving waters and the effects of wastes originating from industrial, municipal, and agricultural point and non-point sources (USEPA, 1978a).

2.1.16 The use of short-term toxicity tests including subchronic and chronic tests in the NPDES Program is especially attractive because they provide a more direct estimate of the safe concentrations of effluents in receiving waters than was provided by acute toxicity tests, at an only slightly increased level of effort, compared to the fish full life-cycle chronic and 28-day ELS tests and the 21-day daphnid, *Daphnia magna*, life-cycle test.

2.2 TYPES OF TESTS

2.2.1 The selection of the test type will depend on the NPDES permit requirements, the objectives of the test, the available resources, the requirements of the test organisms, and effluent characteristics such as fluctuations in effluent toxicity.

2.2.2 Effluent chronic toxicity is generally measured using a multi-concentration, or definitive test, consisting of a control and a minimum of five effluent concentrations. The tests are designed to provide dose-response information, expressed as the percent effluent concentration that affects the hatchability, gross morphological abnormalities, survival, growth, and/or reproduction within the prescribed period of time (four to seven days). The results of the tests are expressed in terms of the highest concentration that has no statistically significant observed effect on those responses when compared to the controls or the estimated concentration that causes a specified percent reduction in responses versus the controls.

2.2.3 Use of pass/fail tests consisting of a single effluent concentration (e.g., the receiving water concentration or RWC) and a control **is not recommended**. If the NPDES permit has a whole effluent toxicity limit for acute toxicity at the RWC, it is prudent to use that permit limit as the midpoint of a series of five effluent concentrations. This will ensure that there is sufficient information on the dose-response relationship. For example, the effluent concentrations utilized in a test may be: (1) 100% effluent, (2) (RWC + 100)/2, (3) RWC, (4) RWC/2, and (5) RWC/4. More specifically, if the RWC = 50%, appropriate effluent concentrations may be 100%, 75%, 50%, 25%, and 12.5%.

2.2.4 Receiving (ambient) water toxicity tests commonly employ two treatments, a control and the undiluted receiving water, but may also consist of a series of receiving water dilutions.

2.2.5 A negative result from a chronic toxicity test does not preclude the presence of toxicity. Also, because of the potential temporal variability in the toxicity of effluents, a negative test result with a particular sample does not preclude the possibility that samples collected at some other time might exhibit chronic toxicity.

2.2.6 The frequency with which chronic toxicity tests are conducted under a given NPDES permit is determined by the regulatory agency on the basis of factors such as the variability and degree of toxicity of the waste, production schedules, and process changes.

2.2.7 Tests recommended for use in this methods manual may be static non-renewal or static renewal. Individual methods specify which static type of test is to be conducted.

2.3 STATIC TESTS

2.3.1 Static non-renewal tests - The test organisms are exposed to the same test solution for the duration of the test.

2.3.2 Static-renewal tests - The test organisms are exposed to a fresh solution of the same concentration of sample every 24 h or other prescribed interval, either by transferring the test organisms from one test chamber to another, or by replacing all or a portion of solution in the test chambers.

2.4 **ADVANTAGES AND DISADVANTAGES OF TOXICITY TEST TYPES**

2.4.1 STATIC NON-RENEWAL, SHORT-TERM TOXICITY TESTS:

Advantages:

1. Simple and inexpensive.
2. Very cost effective in determining compliance with permit conditions.
3. Limited resources (space, manpower, equipment) required; would permit staff to perform many more tests in the same amount of time.
4. Smaller volume of effluent required than for static renewal or flow-through tests.

Disadvantages:

1. Dissolved oxygen (DO) depletion may result from high chemical oxygen demand (COD), biological oxygen demand (BOD), or metabolic wastes.
2. Possible loss of toxicants through volatilization and/or adsorption to the exposure vessels.
3. Generally less sensitive than static renewal, because the toxic substances may degrade or be adsorbed, thereby reducing the apparent toxicity. Also, there is less chance of detecting slugs of toxic wastes, or other temporal variations in waste properties.

2.4.2 STATIC RENEWAL, SHORT-TERM TOXICITY TESTS:

Advantages:

1. Reduced possibility of DO depletion from high COD and/or BOD, or ill effects from metabolic wastes from organisms in the test solutions.
2. Reduced possibility of loss of toxicants through volatilization and/or adsorption to the exposure vessels.
3. Test organisms that rapidly deplete energy reserves are fed when the test solutions are renewed, and are maintained in a healthier state.

Disadvantages:

1. Require greater volume of effluent than non-renewal tests.
2. Generally less chance of temporal variations in waste properties.

SECTION 3

HEALTH AND SAFETY

3.1 GENERAL PRECAUTIONS

3.1.1 Each laboratory should develop and maintain an effective health and safety program, requiring an ongoing commitment by the laboratory management. This program should include (1) a safety officer with the responsibility and authority to develop and maintain a safety program, (2) the preparation of a formal, written, health and safety plan, which is provided to each of the laboratory staff, (3) an ongoing training program on laboratory safety, and (4) regularly scheduled, documented, safety inspections.

3.1.2 Collection and use of effluents in toxicity tests may involve significant risks to personal safety and health. Personnel collecting effluent samples and conducting toxicity tests should take all safety precautions necessary for the prevention of bodily injury and illness which might result from ingestion or invasion of infectious agents, inhalation or absorption of corrosive or toxic substances through skin contact, and asphyxiation due to lack of oxygen or presence of noxious gases.

3.1.3 Prior to sample collection and laboratory work, personnel will determine that all necessary safety equipment and materials have been obtained and are in good condition.

3.1.4 Guidelines for the handling and disposal of hazardous materials must be strictly followed.

3.2 SAFETY EQUIPMENT

3.2.1 PERSONAL SAFETY GEAR

3.2.1.1 Personnel should use safety equipment, as required, such as rubber aprons, laboratory coats, respirators, gloves, safety glasses, hard hats, and safety shoes. Plastic netting on glass beakers, flasks, and other glassware minimizes breakage and subsequent shattering of the glass.

3.2.2 LABORATORY SAFETY EQUIPMENT

3.2.2.1 Each laboratory (including mobile laboratories) should be provided with safety equipment such as first aid kits, fire extinguishers, fire blankets, emergency showers, chemical spill clean up kits, and eye fountains.

3.2.2.2 Mobile laboratories should be equipped with a telephone or other means to enable personnel to summon help in case of emergency.

3.3 GENERAL LABORATORY AND FIELD OPERATIONS

3.3.1 Work with effluents should be performed in compliance with accepted rules pertaining to the handling of hazardous materials (see safety manuals listed in Section 3, Health and Safety, Subsection 3.5). It is recommended that personnel collecting samples and performing toxicity tests not work alone.

3.3.2 Because the chemical composition of effluents is usually only poorly known, they should be considered as potential health hazards, and exposure to them should be minimized. Fume and canopy hoods over the toxicity test areas must be used whenever possible.

3.3.3 It is advisable to cleanse exposed parts of the body immediately after collecting effluent samples.

3.3.4 All containers are to be adequately labeled to indicate their contents.

3.3.5 Staff should be familiar with safety guidelines on Material Safety Data Sheets for reagents and other chemicals purchased from suppliers. Incompatible materials should not be stored together. Good housekeeping contributes to safety and reliable results.

3.3.6 Strong acids and volatile organic solvents employed in glassware cleaning must be used in a fume hood or under an exhaust canopy over the work area.

3.3.7 Electrical equipment or extension cords not bearing the approval of Underwriter Laboratories must not be used. Ground-fault interrupters must be installed in all "wet" laboratories where electrical equipment is used.

3.3.8 Mobile laboratories should be properly grounded to protect against electrical shock.

3.4 DISEASE PREVENTION

3.4.1 Personnel handling samples which are known or suspected to contain human wastes should be immunized against tetanus, typhoid fever, polio, and hepatitis B.

3.5 SAFETY MANUALS

3.5.1 For further guidance on safe practices when collecting effluent samples and conducting toxicity tests, check with the permittee and consult general safety manuals, including USEPA (1986e) and Walters and Jameson (1984).

3.6 WASTE DISPOSAL

3.6.1 Wastes generated during toxicity testing must be properly handled and disposed of in an appropriate manner. Each testing facility will have its own waste disposal requirements based on local, state, and Federal rules and regulations. It is extremely important that these rules and regulations be known, understood, and complied with by all persons responsible for, or otherwise involved in performing the toxicity testing activities. Local fire officials should be notified of any potentially hazardous conditions.

SECTION 4

QUALITY ASSURANCE

4.1 INTRODUCTION

4.1.1 Development and maintenance of a toxicity test laboratory quality assurance (QA) program (USEPA, 1991a) requires an ongoing commitment by laboratory management. Each toxicity test laboratory should (1) appoint a quality assurance officer with the responsibility and authority to develop and maintain a QA program; (2) prepare a quality assurance plan with stated data quality objectives (DQOs); (3) prepare a written description of laboratory standard operating procedures (SOPs) for culturing, toxicity testing, instrument calibration, sample chain-of-custody procedures, laboratory sample tracking system, glassware cleaning, etc.; and (4) provide an adequate, qualified technical staff for culturing and testing the organisms, and suitable space and equipment to assure reliable data.

4.1.2 QA practices for toxicity testing laboratories must address all activities that affect the quality of the final effluent toxicity test data, such as: (1) effluent sampling and handling; (2) the source and condition of the test organisms; (3) condition of equipment; (4) test conditions; (5) instrument calibration; (6) replication; (7) use of reference toxicants; (8) record keeping; and (9) data evaluation.

4.1.3 Quality control practices, on the other hand, consist of the more focused, routine, day-to-day activities carried out within the scope of the overall QA program. For more detailed discussion of quality assurance and general guidance on good laboratory practices and laboratory evaluation related to toxicity testing, see FDA, (1978); USEPA, (1979d), USEPA (1980b), USEPA (1980c), and USEPA (1991c); DeWoskin (1984); and Taylor (1987).

4.1.4 Guidance for the evaluation of laboratories performing toxicity tests and laboratory evaluation criteria may be found in USEPA (1991c).

4.2 FACILITIES, EQUIPMENT, AND TEST CHAMBERS

4.2.1 Separate test organism culturing and toxicity testing areas should be provided to avoid possible loss of cultures due to cross-contamination. Ventilation systems should be designed and operated to prevent recirculation or leakage of air from chemical analysis laboratories or sample storage and preparation areas into organism culturing or testing areas, and from testing and sample preparation areas into culture rooms.

4.2.2 Laboratory and toxicity test temperature control equipment must be adequate to maintain recommended test water temperatures. Recommended materials must be used in the fabrication of the test equipment which comes in contact with the effluent (see Section 5, Facilities, Equipment and Supplies; and specific toxicity test method).

4.3 TEST ORGANISMS

4.3.1 The test organisms used in the procedures described in this manual are the fathead minnow, *Pimephales promelas*, the daphnid, *Ceriodaphnia dubia*, and the green alga, *Selenastrum capricornutum*. The fish and invertebrates should appear healthy, behave normally, feed well, and have low mortality in the cultures, during holding, and in test controls. Test organisms should be positively identified to species (see Section 6, Test Organisms).

4.4 LABORATORY WATER USED FOR CULTURING AND TEST DILUTION WATER

4.4.1 The quality of water used for test organism culturing and for dilution water used in toxicity tests is extremely important. Water for these two uses should come from the same source. The dilution water used in effluent toxicity tests will depend in part on the objectives of the study and logistical constraints, as discussed in detail in Section 7, Dilution Water. For tests performed to meet NPDES objectives, synthetic, moderately hard water should be used.

The dilution water used for internal quality assurance tests with organisms, food, and reference toxicants should be the water routinely used with success in the laboratory. Types of water are discussed in Section 5, Facilities, Equipment and Supplies. Water used for culturing and test dilution should be analyzed for toxic metals and organics at least annually or whenever difficulty is encountered in meeting minimum acceptability criteria for control survival and reproduction or growth. The concentration of the metals Al, As, Cr, Co, Cu, Fe, Pb, Ni, and Zn, expressed as total metal, should not exceed 1 mg/L each, and Cd, Hg, and Ag, expressed as total metal, should not exceed 100 ng/L each. Total organochlorine pesticides plus PCBs should be less than 50 ng/L (APHA, 1992). Pesticide concentrations should not exceed USEPA's Ambient Water Quality chronic criteria values where available.

4.5 EFFLUENT AND RECEIVING WATER SAMPLING AND HANDLING

4.5.1 Sample holding times and temperatures of effluent samples collected for on-site and off-site testing must conform to conditions described in Section 8, Effluent and Receiving Water Sampling, Sample Handling, and Sample Preparation for Toxicity Tests.

4.6 TEST CONDITIONS

4.6.1 Water temperature should be maintained within the limits specified for each test. The temperature of test solutions must be measured by placing the thermometer or probe directly into the test solutions, or by placing the thermometer in equivalent volumes of water in surrogate vessels positioned at appropriate locations among the test vessels. Temperature should be recorded continuously in at least one test vessel for the duration of each test. Test solution temperatures should be maintained within the limits specified for each test. DO concentration and pH should be checked at the beginning of each test and daily throughout the test period.

4.7 QUALITY OF TEST ORGANISMS

4.7.1 The health of test organisms is primarily assessed by the performance (survival, growth, and/or reproduction) of organisms in control treatments of individual tests. The health and sensitivity of test organisms is also assessed by reference toxicant testing. In addition to documenting the sensitivity and health of test organisms, reference toxicant testing is used to initially demonstrate acceptable laboratory performance (Subsection 4.15) and to document ongoing laboratory performance (Subsection 4.16).

4.7.2 Regardless of the source of test organisms (in-house cultures or purchased from external suppliers), the testing laboratory must perform at least one acceptable reference toxicant test per month for each toxicity test method conducted in that month (Subsection 4.16). If a test method is conducted only monthly, or less frequently, a reference toxicant test must be performed concurrently with each effluent toxicity test.

4.7.3 When acute or short-term chronic toxicity tests are performed with effluents or receiving waters using test organisms obtained from outside the test laboratory, concurrent toxicity tests of the same type must be performed with a reference toxicant, unless the test organism supplier provides control chart data from at least the last five monthly short-term chronic toxicity tests using the same reference toxicant and control conditions (see Section 6, Test Organisms).

4.7.4 The supplier should certify the species identification of the test organisms, and provide the taxonomic reference (citation and page) or name(s) of the taxonomic expert(s) consulted.

4.7.5 If routine reference toxicant tests fail to meet test acceptability criteria, then the reference toxicant test must be immediately repeated.

4.8 FOOD QUALITY

4.8.1 The nutritional quality of the food used in culturing and testing fish and invertebrates is an important factor in the quality of the toxicity test data. This is especially true for the unsaturated fatty acid content of brine shrimp nauplii, *Artemia*. Problems with the nutritional suitability of the food will be reflected in the survival, growth, and reproduction of the test organisms in cultures and toxicity tests. *Artemia* cysts, and other foods must be obtained as described in Section 5, Facilities, Equipment, and Supplies.

4.8.2 Problems with the nutritional suitability of food will be reflected in the survival, growth, and reproduction of the test organisms in cultures and toxicity tests. If a batch of food is suspected to be defective, the performance of organisms fed with the new food can be compared with the performance of organisms fed with a food of known quality in side-by-side tests. If the food is used for culturing, its suitability should be determined using a short-term chronic test which will determine the affect of food quality on growth or reproduction of each of the relevant test species in culture, using four replicates with each food source. Where applicable, foods used only in chronic toxicity tests can be compared with a food of known quality in side-by-side, multi-concentration chronic tests, using the reference toxicant regularly employed in the laboratory QA program.

4.8.3 New batches of food used in culturing and testing should be analyzed for toxic organics and metals or whenever difficulty is encountered in meeting minimum acceptability criteria for control survival and reproduction or growth. If the concentration of total organochlorine pesticides exceeds 0.15 mg/g wet weight, or the concentration of total organochlorine pesticides plus PCBs exceeds 0.30 µg/g wet weight, or toxic metals (Al, As, Cr, Cd, Cu, Pb, Ni, Zn, expressed as total metal) exceed 20 µg/g wet weight, the food should not be used (for analytical methods see AOAC, 1990 and USDA, 1989). For foods (e.g., such as YCT) which are used to culture and test organisms, the quality of the food should meet the requirements for the laboratory water used for culturing and test dilution water as described in Section 4.4 above.

4.9 ACCEPTABILITY OF SHORT-TERM CHRONIC TOXICITY TESTS

4.9.1 For the tests to be acceptable, control survival in fathead minnow, *Pimephales promelas*, and the daphnid, *Ceriodaphnia dubia*, tests must be 80% or greater. At the end of the test, the average dry weight of surviving seven-day-old fathead minnows in control chambers must equal or exceed 0.25 mg. In *Ceriodaphnia dubia* controls, 60% or more of the surviving females must have produced their third brood in 7 ± 1 days, and the number of young per surviving female must be 15 or greater. In algal toxicity tests, the mean cell density in the controls after 96 h must equal or exceed 1×10^6 cells/mL and not vary more than 20% among replicates. If these criteria are not met, the test must be repeated.

4.9.2 An individual test may be conditionally acceptable if temperature, DO, and other specified conditions fall outside specifications, depending on the degree of the departure and the objectives of the tests (see test condition summaries). The acceptability of the test would depend on the experience and professional judgment of the laboratory investigator and the reviewing staff of the regulatory authority. Any deviation from test specifications must be noted when reporting data from the test.

4.10 ANALYTICAL METHODS

4.10.1 Routine chemical and physical analyses for culture and dilution water, food, and test solutions must include established quality assurance practices outlined in USEPA methods manuals (USEPA, 1979a and USEPA, 1979b).

4.10.2 Reagent containers should be dated and catalogued when received from the supplier, and the shelf life should not be exceeded. Also, working solutions should be dated when prepared, and the recommended shelf life should be observed.

4.11 CALIBRATION AND STANDARDIZATION

4.11.1 Instruments used for routine measurements of chemical and physical parameters such as pH, DO, temperature, and conductivity, must be calibrated and standardized according to instrument manufacturer's procedures as indicated in the general section on quality assurance (see USEPA Methods 150.1, 360.1, 170.1, and 120.1 in USEPA, 1979b). Calibration data are recorded in a permanent log book.

4.11.2 Wet chemical methods used to measure hardness, alkalinity and total residual chlorine must be standardized prior to use each day according to the procedures for those specific USEPA methods (see USEPA Methods 130.2 and 310.1 in USEPA, 1979b).

4.12 REPLICATION AND TEST SENSITIVITY

4.12.1 The sensitivity of the tests will depend in part on the number of replicates per concentration, the significance level selected, and the type of statistical analysis. If the variability remains constant, the sensitivity of the test will increase as the number of replicates is increased. The minimum recommended number of replicates varies with the objectives of the test and the statistical method used for analysis of the data.

4.13 VARIABILITY IN TOXICITY TEST RESULTS

4.13.1 Factors which can affect test success and precision include (1) the experience and skill of the laboratory analyst; (2) test organism age, condition, and sensitivity; (3) dilution water quality; (4) temperature control; and (5) the quality and quantity of food provided. The results will depend upon the species used and the strain or source of the test organisms, and test conditions, such as temperature, DO, food, and water quality. The repeatability or precision of toxicity tests is also a function of the number of test organisms used at each toxicant concentration. Jensen (1972) discussed the relationship between sample size (number of fish) and the standard error of the test, and considered 20 fish per concentration as optimum for Probit Analysis.

4.14 TEST PRECISION

4.14.1 The ability of the laboratory personnel to obtain consistent, precise results must be demonstrated with reference toxicants before they attempt to measure effluent toxicity. The single-laboratory precision of each type of test to be used in a laboratory should be determined by performing at least five tests with a reference toxicant.

4.14.2 Test precision can be estimated by using the same strain of organisms under the same test conditions and employing a known toxicant, such as a reference toxicant.

4.14.3 Interlaboratory precision data from a 1991 study of chronic toxicity tests with two species using the reference toxicants potassium chloride and copper sulfate are shown in Table 1. Table 2 shows interlaboratory precision data from a study of three chronic toxicity test methods using effluent, receiving water, and reference toxicant sample types (USEPA, 2001a; USEPA, 2001b). The effluent sample was a municipal wastewater spiked with KCl, the receiving waster sample was a river water spiked with KCl, and the reference toxicant sample consisted of moderately-hard synthetic freshwater spiked with KCl. Additional precision data for each of the tests described in this manual are presented in the sections describing the individual test methods.

TABLE 1. NATIONAL INTERLABORATORY STUDY OF CHRONIC TOXICITY TEST PRECISION, 1991: SUMMARY OF RESPONSES USING A REFERENCE TOXICANT[1]

Organism	Endpoint	No. Labs	% Effluent[2]	SD	CV(%)
Pimephales promelas	Survival, NOEC	146	NA	NA	NA
	Growth, IC25	124	4.67	1.87	40.0
	Growth, IC50	117	6.36	2.04	32.1
	Growth, NOEC	142	NA	NA	NA
Ceriodaphnia dubia	Survival, NOEC	162	NA	NA	NA
	Reproduction, IC25	155	2.69	1.96	72.9
	Reproduction, IC50	150	3.99	2.35	58.9
	Reproduction, NOEC	156	NA	NA	NA

[1] From a national study of interlaboratory precision of toxicity test data performed in 1991 by the Environmental Monitoring Systems Laboratory- Cincinnati, U.S. Environmental Protection Agency, Cincinnati, OH 45268. Participants included Federal, state, and private laboratories engaged in NPDES permit compliance monitoring.

[2] Expressed as % effluent; in reality it was a reference toxicant (KCl) but was not known by the persons conducting the tests.

TABLE 2. NATIONAL INTERLABORATORY STUDY OF CHRONIC TOXICITY TEST PRECISION, 2000: PRECISION OF RESPONSES USING EFFLUENT, RECEIVING WATER, AND REFERENCE TOXICANT SAMPLE TYPES[1].

Organism	Endpoint	Number of Tests[2]	CV (%)[3]
Pimephales promelas	Growth, IC25	73	20.9
Ceriodaphnia dubia	Reproduction, IC25	34	35.0
Selenastrum capricornutum (with EDTA)	Growth, IC25	21	34.3
	Growth, IC50	22	32.2
Selenastrum capricornutum (without EDTA)	Growth, IC25	21	58.5
	Growth, IC50	22	58.5

1 From EPA's WET Interlaboratory Variability Study (USEPA, 2001a; USEPA, 2001b).

2 Represents the number of valid tests (i.e., those that met test acceptability criteria) that were used in the analysis of precision. Invalid tests were not used.

3 CVs based on total interlaboratory variability (including both within-laboratory and between-laboratory components of variability) and averaged across sample types. IC25s or IC50s were pooled for all laboratories to calculate the CV for each sample type. The resulting CVs were then averaged across sample types.

4.14.4 Additional information on toxicity test precision is provided in the Technical Support Document for Water Quality-based Control (see pp. 2-4, and 11-15 in USEPA, 1991a).

4.14.5 In cases where the test data are used in Probit Analysis or other point estimation techniques (see Section 9, Chronic Toxicity Test Endpoints and Data Analysis), precision can be described by the mean, standard deviation, and relative standard deviation (percent coefficient of variation, or CV) of the calculated endpoints from the replicated tests. In cases where the test data are used in the Linear Interpolation Method, precision can be estimated by empirical confidence intervals derived by using the ICPIN Method (see Section 9, Chronic Toxicity Test Endpoints and Data Analysis). However, in cases where the results are reported in terms of the No-Observed-Effect Concentration (NOEC) and Lowest-Observed-Effect Concentration (LOEC) (see Section 9, Chronic Toxicity Test Endpoints and Data Analysis) precision can only be described by listing the NOEC-LOEC interval for each test. It is not possible to express precision in terms of a commonly used statistic. However, when all tests of the same toxicant yield the same NOEC-LOEC interval, maximum precision has been attained. The "true" no effect concentration could fall anywhere within the interval, NOEC ± (NOEC minus LOEC).

4.14.6 It should be noted here that the dilution factor selected for a test determines the width of the NOEC-LOEC interval and the inherent maximum precision of the test. As the absolute value of the dilution factor decreases, the width of the NOEC-LOEC interval increases, and the inherent maximum precision of the test decreases. When a dilution factor of 0.3 is used, the NOEC could be considered to have a relative variability as high as ± 300%. With a dilution factor of 0.5, the NOEC could be considered to have a relative variability of ± 100%. As a result of the variability of different dilution factors, **USEPA recommends the use of the dilution factor of 0.5 or greater**. Other factors which can affect test precision include: test organism age, condition, and sensitivity; temperature control; and feeding.

4.15 DEMONSTRATING ACCEPTABLE LABORATORY PERFORMANCE

4.15.1 It is a laboratory's responsibility to demonstrate its ability to obtain consistent, precise results with reference toxicants before it performs toxicity tests with effluents for permit compliance purposes. To meet this requirement, the intralaboratory precision, expressed as percent coefficient of variation (CV%), of each type of test to be used in the laboratory should be determined by performing five or more tests with different batches of test organisms, using the same reference toxicant, at the same concentrations, with the same test conditions (i.e., the same test duration, type of dilution water, age of test organisms, feeding, etc.), and the same data analysis methods. A reference toxicant concentration series (0.5 or higher) should be selected that will consistently provide partial mortalities at two or more concentrations.

4.16 DOCUMENTING ONGOING LABORATORY PERFORMANCE

4.16.1 Satisfactory laboratory performance is demonstrated by performing at least one acceptable test per month with a reference toxicant for each toxicity test method conducted in the laboratory during that month. For a given test method, successive tests must be performed with the same reference toxicant, at the same concentrations, in the same dilution water, using the same data analysis methods. Precision may vary with the test species, reference toxicant, and type of test. Each laboratory's reference toxicity data will reflect conditions unique to that facility, including dilution water, culturing, and other variables; however, each laboratory's reference toxicity results should reflect good repeatability.

4.16.2 A control chart should be prepared for each combination of reference toxicant, test species, test conditions, and endpoints. Toxicity endpoints from five or six tests are adequate for establishing the control charts. Successive toxicity endpoints (NOECs, IC25s, LC50s, etc.) should be plotted and examined to determine if the results (X_1) are within prescribed limits (Figure 1). The chart should plot logarithm of concentration on the vertical axis against the date of the test or test number on the horizontal axis. The types of control charts illustrated (see USEPA, 1979a) are used to evaluate the cumulative trend of results from a series of samples, thus reference toxicant test results should not be used as a *de facto* criterion for rejection of individual effluent or receiving water tests. For endpoints that are point estimates (LC50s and IC25s), the cumulative mean ($\bar{X}$) and upper and lower control limits ($\pm$ 2S) are re-calculated with each successive test result. Endpoints from hypothesis tests (NOEC, NOAEC) from each test are plotted directly on the control chart. The control limits would consist of one concentration interval above and below the concentration representing the central tendency. After two years of data collection, or a minimum of 20 data points, the control chart should be maintained using only the 20 most recent data points.

4.16.3 Laboratories should compare the calculated CV (i.e., standard deviation / mean) of the IC25 for the 20 most recent data points to the distribution of laboratory CVs reported nationally for reference toxicant testing (Table 3-2 in USEPA, 2000b). If the calculated CV exceeds the 75^{th} percentile of CVs reported nationally, the laboratory should use the 75^{th} and 90^{th} percentiles to calculate warning and control limits, respectively, and the laboratory should investigate options for reducing variability. Note: Because NOECs can only be a fixed number of discrete values, the mean, standard deviation, and CV cannot be interpreted and applied in the same way that these descriptive statistics are interpreted and applied for continuous variables such as the IC25 or LC50.

4.16.4 The outliers, which are values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity, are readily identified. In the case of endpoints that are point estimates (LC50s and IC25s), at the $P_{0.05}$ probability level, one in 20 tests would be expected to fall outside of the control limits by chance alone. If more than one out of 20 reference toxicant tests fall outside the control limits, the laboratory should investigate sources of variability, take corrective actions to reduce identified sources of variability, and perform an additional reference toxicant test during the same month. Control limits for the NOECs will also be exceeded occasionally, regardless of how well a laboratory performs. In those instances when the laboratory can document the cause for the outlier (e.g., operator error, culture health or test system failure), the outlier should be excluded from the future calculations of the control limits. If two or more consecutive tests do not fall within the control limits, the results must be explained and the reference toxicant test must be immediately repeated. Actions taken to correct the problem must be reported.

4.16.5 If the toxicity value from a given test with a reference toxicant falls well outside the expected range for the other test organisms when using the standard dilution water and other test conditions, the laboratory should investigate sources of variability, take corrective actions to reduce identified sources of variability, and perform an additional reference toxicant test during the same month. Performance should improve with experience, and the control limits for endpoints that are point estimates should gradually narrow. However, control limits of $\pm$ 2S will be exceeded 5% of the time by chance alone, regardless of how well a laboratory performs. Highly proficient laboratories which develop very narrow control limits may be unfairly penalized if a test result which falls just outside the control limits is rejected *de facto*. For this reason, the width of the control limits should be considered in determining whether or not a reference toxicant test result falls "well" outside the expected range. The width of the control limits may be evaluated by comparing the calculated CV (i.e., standard deviation / mean) of the IC25 for the 20 most recent data points to the distribution of laboratory CVs reported nationally for reference toxicant testing (Table 3-2 in USEPA, 2000b). In determining whether or not a reference toxicant test result falls "well" outside the expected range, the result also may be compared with upper and lower bounds for $\pm$3S, as any result outside these control limits would be expected to occur by chance only 1 out of 100 tests (Environment Canada, 1990). When a result from a reference toxicant test is outside the 99% confidence intervals, the laboratory must conduct an immediate investigation to assess the possible causes for the outlier.

4.16.6 Reference toxicant test results should not be used as a *de facto* criterion for rejection of individual effluent or receiving water tests. Reference toxicant testing is used for evaluating the health and sensitivity of organisms over time and for documenting initial and ongoing laboratory performance. While reference toxicant test results should not be used as a *de facto* criterion for test rejection, effluent and receiving water test results should be reviewed and interpreted in the light of reference toxicant test results. The reviewer should consider the degree to which the reference toxicant test result fell outside of control chart limits, the width of the limits, the direction of the deviation (toward increased test organism sensitivity or toward decreased test organism sensitivity), the test conditions of both the effluent test and the reference toxicant test, and the objective of the test.

4.17 REFERENCE TOXICANTS

4.17.1 Reference toxicants such as sodium chloride (NaCl), potassium chloride (KCl), cadmium chloride ($CdCl_2$), copper sulfate ($CuSO_4$), sodium dodecyl sulfate (SDS), and potassium dichromate ($K_2Cr_2O_7$), are suitable for use in the NPDES Program and other Agency programs requiring aquatic toxicity tests. EMSL-Cincinnati hopes to release USEPA-certified solutions of cadmium and copper for use as reference toxicants through cooperative research and development agreements with commercial suppliers, and will continue to develop additional reference toxicants for future release. Standard reference materials can be obtained from commercial supply houses, or can be prepared inhouse using reagent grade chemicals. The regulatory agency should be consulted before reference toxicant(s) are selected and used.

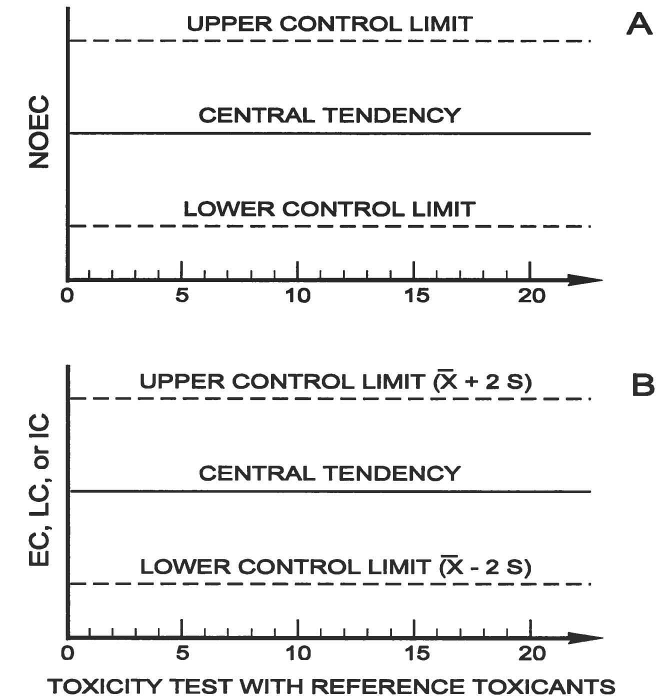


Figure 1. Control charts. (A) hypothesis testing results; (B) point estimates (LC, EC, or IC).

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - \frac{(\sum_{i=1}^{n} X_i)^2}{n}}{n-1}}$$

Where: X_i = Successive toxicity values from toxicity tests.

n = Number of tests.

$\bar{X}$ = Mean toxicity value.

S = Standard deviation.

4.18 **RECORD KEEPING**

4.18.1 Proper record keeping is important. A complete file should be maintained for each individual toxicity test or group of tests on closely related samples. This file should contain a record of the sample chain-of-custody; a copy of the sample log sheet; the original bench sheets for the test organism responses during the toxicity test(s); chemical analysis data on the sample(s); detailed records of the test organisms used in the test(s), such as species, source, age, date of receipt, and other pertinent information relating to their history and health; information on the calibration of equipment and instruments; test conditions employed; and results of reference toxicant tests. Laboratory data should be recorded on a real-time basis to prevent the loss of information or inadvertent introduction of errors into the record. Original data sheets should be signed and dated by the laboratory personnel performing the tests.

4.18.2 The regulatory authority should retain records pertaining to discharge permits. Permittees are required to retain records pertaining to permit applications and compliance for a minimum of 3 years [40 CFR 122.41(j)(2)].

SECTION 5

FACILITIES, EQUIPMENT, AND SUPPLIES

5.1 GENERAL REQUIREMENTS

5.1.1 Effluent toxicity tests may be performed in a fixed or mobile laboratory. Facilities must include equipment for rearing and/or holding organisms. Culturing facilities for test organisms may be desirable in fixed laboratories which perform large numbers of tests. Temperature control can be achieved using circulating water baths, heat exchangers, or environmental chambers. Water used for rearing, holding, acclimating, and testing organisms may be ground water, receiving water, dechlorinated tap water, or reconstituted synthetic water. Dechlorination can be accomplished by carbon filtration, or the use of sodium thiosulfate. Use of 3.6 mg (anhydrous) sodium thiosulfate/L will reduce l.0 mg chlorine/L. After dechlorination, total residual chlorine should be non-detectable. Air used for aeration must be free of oil and toxic vapors. Oil-free air pumps should be used where possible. Particulates can be removed from the air using BALSTON® Grade BX or equivalent filters, and oil and other organic vapors can be removed using activated carbon filters (BALSTON®, C-1 filter, or equivalent).

5.1.2 The facilities must be well ventilated and free from fumes. Laboratory ventilation systems should be checked to ensure that return air from chemistry laboratories and/or sample holding areas is not circulated to test organism culture rooms or toxicity test rooms, or that air from toxicity test rooms does not contaminate culture areas. Sample preparation, culturing, and toxicity test areas should be separated to avoid cross contamination of cultures or toxicity test solutions with toxic fumes. Air pressure differentials between such rooms should not result in a net flow of potentially contaminated air to sensitive areas through open or loosely- fitting doors. Organisms should be shielded from external disturbances.

5.1.3 Materials used for exposure chambers, tubing, etc., that come in contact with the effluent and dilution water should be carefully chosen. Tempered glass and perfluorocarbon plastics (TEFLON®) should be used whenever possible to minimize sorption and leaching of toxic substances. These materials may be reused following decontamination. Containers made of plastics, such as polyethylene, polypropylene, polyvinyl chloride, TYGON®, etc., may be used as test chambers or to ship, store and transfer effluents and receiving waters, but they should not be reused unless absolutely necessary, because they could carry over adsorbed toxicants from one test to another, if reused. However, these containers may be repeatedly reused for storing uncontaminated waters, such as deionized or laboratory-prepared dilution waters and receiving waters. Glass or disposable polystyrene containers can be used for test chambers. The use of large ($\geq$ 20 L) glass carboys is discouraged for safety reasons.

5.1.4 New plastic products of a type not previously used should be tested for toxicity before initial use by exposing the test organisms in the test system where the material is used. Equipment (pumps, valves, etc.) which cannot be discarded after each use because of cost, must be decontaminated according to the cleaning procedures listed below (see Section 5, Facilities, Equipment and Supplies, Subsection 5.3.2). Fiberglass and stainless steel, in addition to the previously mentioned materials, can be used for holding, acclimating, and dilution water storage tanks, and in the water delivery system, but once contaminated with pollutants the fiberglass should not be reused. All material should be flushed or rinsed thoroughly with the test media before using in the test.

5.1.5 Copper, galvanized material, rubber, brass, and lead must not come in contact with culturing, holding, acclimation, or dilution water, or with effluent samples and test solutions. Some materials, such as several types of neoprene rubber (commonly used for stoppers), may be toxic and should be tested before use.

5.1.6 Silicone adhesive used to construct glass test chambers absorbs some organochlorine and organophosphorus pesticides, which are difficult to remove. Therefore, as little of the adhesive as possible should be in contact with water. Extra beads of adhesive inside the containers should be removed.

5.2 TEST CHAMBERS

5.2.1 Test chamber size and shape are varied according to size of the test organism. Requirements are specified in each toxicity test method.

5.3 CLEANING TEST CHAMBERS AND LABORATORY APPARATUS

5.3.1 New plasticware used for sample collection or organism exposure vessels does not require thorough cleaning before use. It is sufficient to rinse new sample containers once with dilution water before use. New glassware must be soaked overnight in 10% acid (see below) and rinsed well in deionized water and dilution water.

5.3.2 All non-disposable sample containers, test vessels, tanks, and other equipment that have come in contact with effluent must be washed after use to remove contaminants as described below.

1. Soak 15 min in tap water and scrub with detergent, or clean in an automatic dishwasher.
2. Rinse twice with tap water.
3. Carefully rinse once with fresh, dilute (10%, V:V) hydrochloric or nitric acid to remove scale, metals and bases. To prepare a 10% solution of acid, add 10 mL of concentrated acid to 90 mL of deionized water.
4. Rinse twice with deionized water.
5. Rinse once with full-strength, pesticide-grade acetone to remove organic compounds (use a fume hood or canopy).
6. Rinse three times with deionized water.

5.3.3 Special requirements for cleaning glassware used in the green alga, *Selenastrum capricornutum*, toxicity tests (Method 1003.0, Section 14). Prepare all graduated cylinders, test flasks, bottles, volumetric flasks, centrifuge tubes and vials used in algal assays as follows:

1. Wash with non-phosphate detergent solution, preferably heated to ≥ 50°C. Brush the inside of flasks with a stiff-bristle brush to loosen any attached material. The use of a commercial laboratory glassware washer or heavy-duty kitchen dishwasher (under-counter type) is highly recommended.
2. Rinse with tap water.
3. Test flasks should be thoroughly rinsed with acetone and a 10% solution (by volume) of reagent grade hydrochloric acid (HCl). It may be advantageous to soak the flasks in 10% HCl for several days. Fill vials and centrifuge tubes with the 10% HCl solution and allow to stand a few minutes; fill all larger containers to about one-tenth capacity with HCl solution and swirl so that the entire surface is bathed.
4. Rinse twice with MILLIPORE® MILLI-Q® OR QPAK™$_2$, or equivalent, water.
5. New test flasks, and all flasks which through use may become contaminated with toxic organic substances, must be rinsed with pesticide-grade acetone or heat-treated before use. To thermally degrade organics, place glassware in a high temperature oven at 400°C for 30 min. After cooling, go to 7. If acetone is used, go to 6.
6. Rinse thoroughly with MILLIPORE® MILLI-Q® or QPAK™$_2$, or equivalent water, and dry in an 105°C oven. All glassware should be autoclaved before use and between uses.
7. Cover the mouth of each chamber with aluminum foil or other closure, as appropriate, before storing.

5.3.4 The use of sterile, disposable pipets will eliminate the need for pipet washing and minimize the possibility of contaminating the cultures with toxic substances.

5.3.5 All test chambers and equipment must be thoroughly rinsed with the dilution water immediately prior to use in each test.

5.4 **APPARATUS AND EQUIPMENT FOR CULTURING AND TOXICITY TESTS**

5.4.1 Apparatus and equipment requirements for culturing and testing are specified in each toxicity test method. Also, see USEPA, 2002a.

5.4.2 WATER PURIFICATION SYSTEM

5.4.2.1 A good quality, laboratory grade deionized water, providing a resistance of 18 megaohm-cm, must be available in the laboratory and in sufficient quantity for laboratory needs. Deionized water may be obtained from MILLIPORE® Milli-Q®, MILLIPORE® QPAK™$_2$ or equivalent system. If large quantities of high quality deionized water are needed, it may be advisable to supply the laboratory grade deionizer with preconditioned water from a Culligan®, Continental®, or equivalent mixed-bed water treatment system.

5.5 **REAGENTS AND CONSUMABLE MATERIALS**

5.5.1 SOURCES OF FOOD FOR CULTURE AND TOXICITY TESTS

1. Brine shrimp, *Artemia* sp., cysts -- Many commercial sources of brine shrimp cysts are available.
2. Frozen adult brine shrimp, *Artemia* -- Available from most pet supply shops or other commercial sources.
3. Flake fish food -- TETRAMIN® and BIORIL® are available from most pet shops.
4. Trout chow -- Available from commercial sources.
5. Cereal leaves, CEROPHYLL® or equivalent -- Available from commercial sources.
6. Yeast -- Packaged dry yeast, such as Fleischmann's, or equivalent, can be purchased at the local grocery store or commercial sources.
7. Alfalfa Rabbit Pellets -- Available from feed stores as Purina rabbit chow.
8. Algae - Available from commercial sources.

5.5.1.1 All food should be tested for nutritional suitability and chemically analyzed for organochlorine pesticides, PCBs, and toxic metals (see Section 4, Quality Assurance).

5.5.2 Reagents and consumable materials are specified in each toxicity test method section. Also, see Section 4, Quality Assurance.

5.6 **TEST ORGANISMS**

5.6.1 Test organisms should be obtained from inhouse cultures or from commercial suppliers (see specific test method; Section 4, Quality Assurance; and Section 6, Test Organisms).

5.7 **SUPPLIES**

5.7.1 See test methods (see Sections 11-14) for specific supplies.

Exhibit C

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FEB 22 1994

OFFICE OF WATER

EPA-823-B-94-001

MEMORANDUM

SUBJECT: Use of the Water-Effect Ratio in Water Quality Standards

FROM: Tudor T. Davies, Director
Office of Science and Technology

TO: Water Management Division Directors, Regions I - X
State Water Quality Standards Program Directors

PURPOSE

There are two purposes for this memorandum.

The first is to transmit the Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals. EPA committed to developing this guidance to support implementation of federal standards for those States included in the National Toxics Rule.

The second is to provide policy guidance on whether a State's application of a water-effect ratio is a site-specific criterion adjustment subject to EPA review and approval/disapproval.

BACKGROUND

In the early 1980's, members of the regulated community expressed concern that EPA's laboratory-derived water quality criteria might not accurately reflect site-specific conditions because of the effects of water chemistry and the ability of species to adapt over time. In response to these concerns, EPA created three procedures to derive site-specific criteria. These procedures were published in the Water Quality Standards Handbook, 1983.

Site-specific criteria are allowed by regulation and are subject to EPA review and approval. The Federal water quality standards regulation at section 131.11(b)(1) provides States with the opportunity to adopt water quality criteria that are "...modified to reflect site-specific conditions." Under section 131.5(a)(2), EPA reviews standards to determine "whether a State has adopted criteria to protect the designated water uses."

On December 22, 1992, EPA promulgated the National Toxics Rule which established Federal water quality standards for 14 States which had not met the requirements of Clean Water Act Section 303(c)(2)(B). As part of that rule, EPA gave the States discretion to adjust the aquatic life criteria for metals to reflect site-specific conditions through use of a water-effect ratio. A water-effect ratio is a means to account for a difference between the toxicity of the metal in laboratory dilution water and its toxicity in the water at the site.

In promulgating the National Toxics Rule, EPA committed to issuing updated guidance on the derivation of water-effect ratios. The guidance reflects new information since the previous guidance and is more comprehensive in order to provide greater clarity and increased understanding. This new guidance should help standardize procedures for deriving water-effect ratios and make results more comparable and defensible.

Recently, an issue arose concerning the most appropriate form of metals upon which to base water quality standards. On October 1, 1993, EPA issued guidance on this issue which indicated that measuring the dissolved form of metal is the recommended approach. This new policy however, is prospective and does not affect the criteria in the National Toxics Rule. Dissolved metals criteria are not generally numerically equal to total recoverable criteria and the October 1, 1993 guidance contains recommendations for correction factors for fresh water criteria. The determination of site-specific criteria is applicable to criteria expressed as either total recoverable metal or as dissolved metal.

DISCUSSION

Existing guidance and practice are that EPA will approve site- specific criteria developed using appropriate procedures. That policy continues for the options set forth in the interim guidance transmitted today, regardless of whether the resulting criterion is equal to or more or less stringent than the EPA national 304(a) guidance. This interim guidance supersedes all guidance concerning water-effect ratios previously issued by the Agency.

Each of the three options for deriving a final water-effect ratio presented in this interim guidance meets the scientific and technical acceptability test for deriving site-specific criteria.

Option 3 is the simplest, least restrictive and generally the least expensive approach for situations where simulated downstream water appropriately represents a "site." It is a fully acceptable approach for deriving the water-effect ratio although it will generally provide a lower water-effect ratio than the other 2 options. The other 2 options may be more costly and time consuming if more than 3 sample periods and water-effect ratio measurements are made, but are more accurate, and may yield a larger, but more scientifically defensible site specific criterion.

Site-specific criteria, properly determined, will fully protect existing uses. The waterbody or segment thereof to which the site-specific criteria apply must be clearly defined. A site can be defined by the State and can be any size, small or large, including a watershed or basin. However, the site-specific criteria must protect the site as a whole. It is likely to be more cost-effective to derive any site-specific criteria for as large an area as possible or appropriate. It is emphasized that site-specific criteria are ambient water quality criteria applicable to a site. They are not intended to be direct modifications to National Pollutant Discharge Elimination System (NPDES) permit limits. In most cases the "site" will be synonymous with a State's "segment" in its water quality standards. By defining sites on a larger scale, multiple dischargers can collaborate on water-effect ratio testing and attain appropriate site-specific criteria at a reduced cost.

More attention has been given to water-effect ratios recently because of the numerous discussions and meetings on the entire question of metals policy and because WERs were specifically applied in the National Toxics Rule. In comments on the proposed National Toxics Rule, the public questioned whether the EPA promulgation should be based solely on the total recoverable form of a metal. For the reasons set forth in the final preamble, EPA chose to promulgate the criteria based on the total recoverable form with a provision for the application of a water-effect ratio. In addition, this approach was chosen because of the unique difficulties of attempting to authorize site-specific criteria modifications for nationally promulgated criteria.

EPA now recommends the use of dissolved metals for States revising their water quality standards. Dissolved criteria may also be modified by a site-specific adjustment.

While the regulatory application of the water-effect ratio applied only to the 10 jurisdictions included in the final National Toxics Rule for aquatic life metals criteria, we understood that other States would be interested in applying WERs to their adopted water quality standards. The guidance upon which to base the judgment of the acceptability of the water-effect ratio applied by the State is contained in the attached Interim Guidance on The Determination and Use of Water-Effect Ratios for Metals. It should be noted that this guidance also provides additional information on the recalculation procedure for site-specific criteria modifications.

Status of the Water-effect Ratio (WER) in non-National Toxics Rule States

A central question concerning WERs is whether their use by a State results in a site-specific criterion subject to EPA review and approval under Section 303(c) of the Clean Water Act?

Derivation of a water-effect ratio by a State is a site-specific criterion adjustment subject to EPA review and approval/disapproval under Section 303(c). There are two options by which this review can be accomplished.

Option 1: A State may derive and submit each individual water-effect ratio determination to EPA for review and approval. This would be accomplished through the normal review and revision process used by a State.

Option 2: A State can amend its water quality standards to provide a formal procedure which includes derivation of water-effect ratios, appropriate definition of sites, and enforceable monitoring provisions to assure that designated uses are protected. Both this procedure and the resulting criteria would be subject to full public participation requirements. Public review of a site-specific criterion could be accomplished in conjunction with the public review required for permit issuance. EPA would review and approve/disapprove this protocol as a revised standard once. For public information, we recommend that once a year the State publish a list of site-specific criteria.

An exception to this policy applies to the waters of the jurisdictions included in the National Toxics Rule. The EPA review is not required for the jurisdictions included in the National Toxics Rule where EPA established the procedure for the State for application to the criteria promulgated. The National Toxics Rule was a formal rulemaking process with notice and comment by which EPA pre-authorized the use of a correctly applied water-effect ratio. That same process has not yet taken place in States not included in the National Toxics Rule.

However, the National Toxics Rule does not affect State authority to establish scientifically defensible procedures to determine Federally authorized WERs, to certify those WERs in NPDES permit proceedings, or to deny their application based on the State's risk management analysis.

As described in Section 131.36(b)(iii) of the water quality standards regulation (the official regulatory reference to the National Toxics Rule), the water-effect ratio is a site-specific calculation. As indicated on page 60866 of the preamble to the National Toxics Rule, the rule was constructed as a rebuttable presumption. The water-effect ratio is assigned a value of 1.0 until a different water-effect ratio is derived from suitable tests representative of conditions in the affected waterbody. It is the responsibility of the State to determine whether to rebut the assumed value of 1.0 in the National Toxics Rule and apply another value of the water-effect ratio in order to establish a site-specific criterion. The site-specific criterion is then used to develop appropriate NPDES permit limits. The rule thus provides a State with the flexibility to derive an appropriate site-specific criterion for specific waterbodies.

As a point of emphasis, although a water-effect ratio affects permit limits for individual dischargers, it is the State in all cases that determines if derivation of a site-specific criterion based on the water-effect ratio is allowed and it is the State that ensures that the calculations and data analysis are done completely and correctly.

CONCLUSION

This interim guidance explains and clarifies the use of site-specific criteria. It is issued as interim guidance because it will be included as part of the process underway for review and possible revision of the national aquatic life criteria development methodology guidelines. As part of that review, this interim guidance is subject to amendment based on comments, especially those from the users of the guidance. At the end of the guidelines revision process the guidance will be issued as "final."

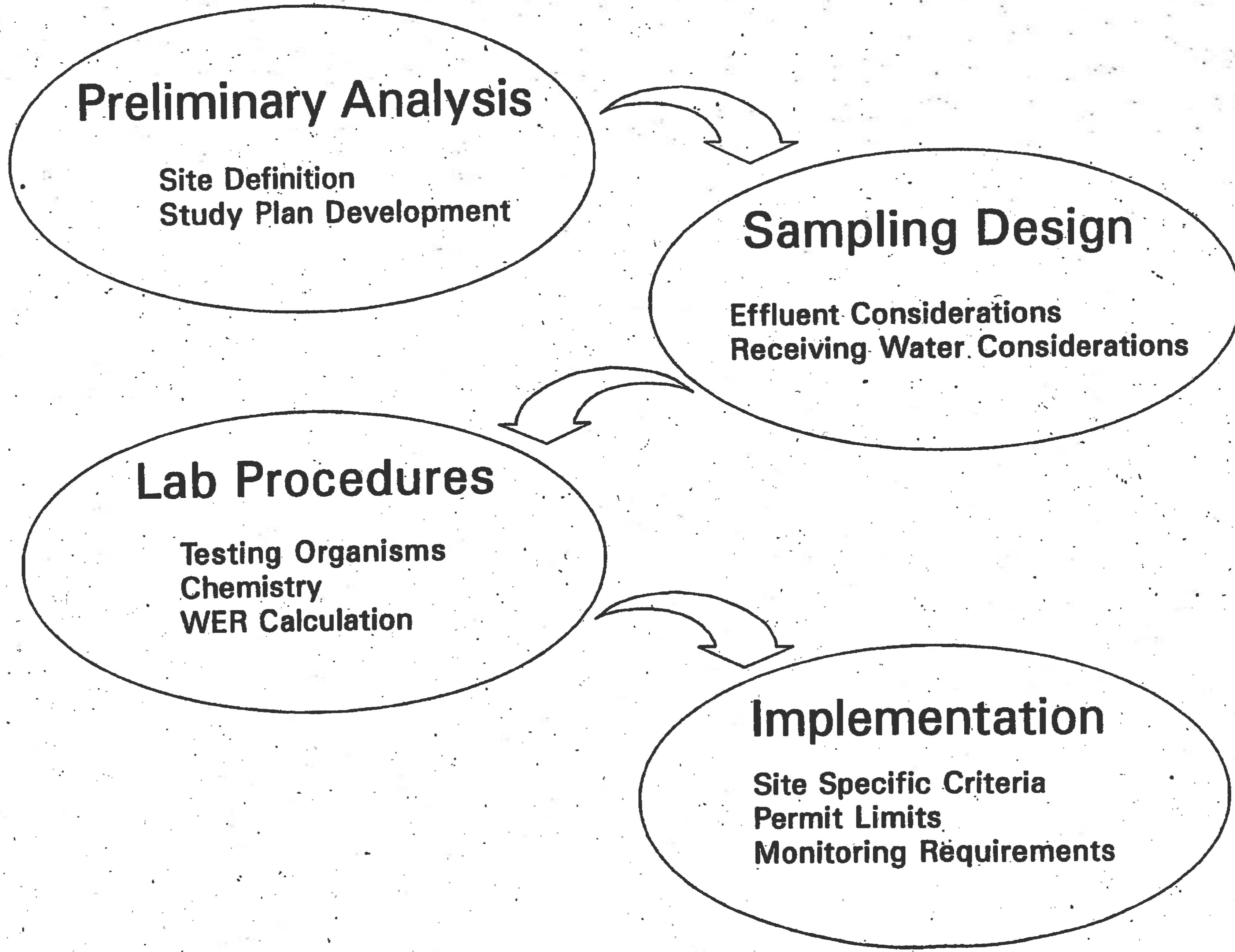
EPA is interested in and encourages the submittal of high quality datasets that can be used to provide insights into the use of these guidelines and procedures. Such data and technical comments should be submitted to Charles E. Stephan at EPA's Environmental Research Laboratory at Duluth, MN. A complete address, telephone number and fax number for Mr. Stephan are included in the guidance itself. Other questions or comments should be directed to the Standards and Applied Science Division (mail code 4305, telephone 202-260-1315).

There is attached to this memorandum a simplified flow diagram and an implementation procedure. These are intended to aid a user by placing the water-effect ratio procedure in the context of proceeding from at site-specific criterion to a permit limit. Following these attachments is the guidance itself.

Attachments

cc: Robert Perciasepe, OW
Martha G. Prothro, OW
William Diamond, SASD
Margaret Stasikowski, HECD
Mike Cook, OWEC
Cynthia Dougherty, OWEC
Lee Schroer, OGC
Susan Lepow, OGC
Courtney Riordan, ORD
ORD (Duluth and Narragansett Laboratories)
ESD Directors, Regions I - VIII, X
ESD Branch, Region IX
Water Quality Standards Coordinators, Regions I - X

WER Implementation



WATER-EFFECT RATIO IMPLEMENTATION

PRELIMINARY ANALYSIS & PLAN FORMULATION

- Site definition
  - How many discharges must be accounted for? Tributaries? See page 17.
  - What is the waterbody type? (i.e., stream, tidal river, bay, etc.). See page 44 and Appendix A.
  - How can these considerations best be combined to define the relevant geographic "site"? See Appendix A @ page 82.

- Plan Development for Regulatory Agency Review
  - Is WER method 1 or 2 appropriate? (e.g., Is design flow a meaningful concept or are other considerations paramount?). See page 6.
  - Define the effluent & receiving water sample locations
  - Describe the temporal sample collection protocols proposed. See page 48.
  - Can simulated site water procedure be done, or is downstream sampling required? See Appendix A.
  - Describe the testing protocols - test species, test type, test length, etc. See page 45, 50; Appendix I.
  - Describe the chemical testing proposed. See Appendix C.
  - Describe other details of study - flow measurement, QA/QC, number of sampling periods proposed, to whom the results are expected to apply, schedule, etc.

SAMPLING DESIGN FOR STREAMS

- Discuss the quantification of the design streamflow (e.g., 7Q10) - USGS gage directly, by extrapolation from USGS gage, or ?

- Effluents
  - measure flows to determine average for sampling day
  - collect 24 hour composite using "clean" equipment and appropriate procedures; avoid the use of the plant's daily composite sample as a shortcut.

- Streams
  - measure flow (use current meter or read from gage if available) to determine dilution with effluent; and to check if within acceptable range for use of the data (i.e., design flow to 10 times the design flow).
  - collect 24 hour composite of upstream water.

LABORATORY PROCEDURES (NOTE: These are described in detail in interim guidance).

- Select appropriate primary & secondary tests
- Determine appropriate cmcWER and/or cccWER
- Perform chemistry using clean procedures, with methods that have adequate sensitivity to measure low concentrations, and use appropriate QA/QC
- Calculate final water-effect ratio (FWER) for site. See page 36.

IMPLEMENTATION

- Assign FWERs and the site specific criteria for each metal to each discharger (if more than one).
- perform a waste load allocation and total maximum daily load (if appropriate) so that each discharger is provided a permit limit.
- establish monitoring condition for periodic evaluation of instream biology (recommended)
- establish a permit condition for periodic testing of WER to verify site-specific criterion (NTR recommendation)

United States
Environmental Protection
Agency

Office of Water
Office of Science & Technology
(Mail Code 4305)

February 1994
EPA-823-B-94-001

EPA

Interim Guidance on Determination and Use of Water-Effect Ratios for Metals

Interim Guidance on

Determination and Use of

Water-Effect Ratios for Metals

February 1994

U.S. Environmental Protection Agency

Office of Water
Office of Science and Technology
Washington, D.C.

Office of Research and Development
Environmental Research Laboratories
Duluth, Minnesota
Narragansett, Rhode Island

NOTICES

This document has been reviewed by the Environmental Research Laboratories, Duluth, MN and Narragansett, RI (Office of Research and Development) and the Office of Science and Technology (Office of Water), U.S. Environmental Protection Agency, and approved for publication.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This document provides interim guidance concerning the experimental determination of water-effect ratios (WERs) for metals; some aspects of the use of WERs are also addressed. It is issued in support of EPA regulations and policy initiatives involving the application of water quality criteria and standards for metals. This document is agency guidance only. It does not establish or affect legal rights or obligations. It does not establish a binding norm or prohibit alternatives not included in the document. It is not finally determinative of the issues addressed. Agency decisions in any particular case will be made by applying the law and regulations on the basis of specific facts when regulations are promulgated or permits are issued.

This document is expected to be revised periodically to reflect advances in this rapidly evolving area. Comments, especially those accompanied by supporting data, are welcomed and should be sent to: Charles E. Stephan, U.S. EPA, 6201 Congdon Boulevard, Duluth MN 55804 (TEL: 218-720-5510; FAX: 218-720-5539).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FEB 22 1994

OFFICE OF WATER

OFFICE OF SCIENCE AND TECHNOLOGY POSITION STATEMENT

Section 131.11(b)(ii) of the water quality standards regulation (40 CFR Part 131) provides the regulatory mechanism for a State to develop site-specific criteria for use in water quality standards. Adopting site-specific criteria in water quality standards is a State option--not a requirement. The Environmental Protection Agency (EPA) in 1983 provided guidance on scientifically acceptable methods by which site-specific criteria could be developed.

The interim guidance provided in this document supersedes all guidance concerning water-effect ratios and the Indicator Species Procedure given in Chapter 4 of the Water Quality Standards Handbook issued by EPA in 1983 and in Guidelines for Deriving Numerical Aquatic Site-Specific Water Quality Criteria by Modifying National Criteria, 1984. Appendix B also supersedes the guidance in these earlier documents for the Recalculation Procedure for performing site-specific criteria modifications.

This interim guidance fulfills a commitment made in the final rule to establish numeric criteria for priority toxic pollutants (57 FR 60848, December 22, 1992, also known as the "National Toxics Rule"). This guidance also is applicable to pollutants other than metals with appropriate modifications, principally to chemical analyses.

Except for the jurisdictions subject to the aquatic life criteria in the national toxics rule, water-effect ratios are site-specific criteria subject to review and approval by the appropriate EPA Regional Administrator. Site-specific criteria are new or revised criteria subject to the normal EPA review requirements established in Clean Water Act § 303(c). For the States in the National Toxics Rule, EPA has established that site-specific water-effect ratios may be applied to the criteria promulgated in the rule to establish site-specific criteria. The water-effect ratio portion of these criteria would still be subject to State review before the development of total maximum daily loads, waste load allocations or translation into NPDES permit limits. EPA would only review these water-effect ratios during its oversight review of these State programs or review of State-issued permits.

Each of the three options for deriving a final water-effect ratio presented on page 36 of this interim guidance meets the scientific and technical acceptability test for deriving site-specific criteria specified in the water quality standards regulation (40 CFR 131.11(a)). Option 3 is the simplest, least restrictive and generally the least expensive approach for situations where simulated downstream water appropriately represents a "site." Option 3 requires experimental determination of three water-effect ratios with the primary test species that are determined during any season (as long as the downstream flow is between 2 and 10 times design flow conditions.) The final WER is generally (but not always) the lowest experimentally determined WER. Deriving a final water-effect ratio using option 3 with the use of simulated downstream water for a situation where this simulation appropriately represents a "site", is a fully acceptable approach for deriving a water-effect ratio for use in determining a site-specific criterion, although it will generally provide a lower water-effect ratio than the other 2 options.

As indicated in the introduction to this guidance, the determination of a water-effect ratio may require substantial resources. A discharger should consider cost-effective, preliminary measures described in this guidance (e.g., use of "clean" sampling and chemical analytical techniques or in non-NTR States, a recalculated criterion) to determine if an indicator species site-specific criterion is really needed. It may be that an appropropriate site-specific criterion is actually being attained. In many instances, use of these other measures may eliminate the need for deriving final water-effect ratios. The methods described in this interim guidance should be sufficient to develop site-specific criteria that resolve concerns of dischargers when there appears to be no instream toxicity from a metal but, where (a) a discharge appears to exceed existing or proposed water quality-based permit limits, or (b) an instream concentration appears to exceed an existing or proposed water quality criterion.

This guidance describes 2 different methods for determining water-effect ratios. Method 1 has 3 options each of which may only require 3 sampling periods. However options 1 and 2 may be expanded and require a much greater effort. While this position statement has discussed the simplest, least expensive option for method 1 (the single discharge to a stream) to illustrate that site specific criteria are feasible even when only small dischargers are affected, water-effect ratios may be calculated using any of the other options described in the guidance if the State/discharger believe that there is reason to expect that a more accurate site-specific criterion will result from the increased cost and complexity inherent in conducting the additional tests and analyzing the results. Situations where this could be the case include, for example, where seasonal effects in receiving water quality or in discharge quality need to be assessed.

In addition, EPA will consider other scientifically defensible approaches in developing final water-effect ratios as authorized in 40 CFR 131.11. However, EPA strongly recommends that before a State/discharger implements any approach other than one described in this interim guidance, discussions be held with appropriate EPA regional offices and Office of Research and Development's scientists before actual testing begins. These discussions would be to ensure that time and resources are not wasted on scientifically and technically unacceptable approaches. It remains EPA's responsibility to make final decisions on the scientific and technical validity of alternative approaches to developing site-specific water quality criteria.

EPA is fully cognizant of the continuing debate between what constitutes guidance and what is a regulatory requirement. Developing site-specific criteria is a State regulatory option. Using the methodology correctly as described in this guidance assures the State that EPA will accept the result. Other approaches are possible and logically should be discussed with EPA prior to implementation.

The Office of Science and Technology believes that this interim guidance advances the science of determining site-specific criteria and provides policy guidance that States and EPA can use in this complex area. It reflects the scientific advances in the past 10 years and the experience gained from dealing with these issues in real world situations. This guidance will help improve implementation of water quality standards and be the basis for future progress.

Tudor T. Davies, Director
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Office of Water

CONTENTS

APPENDICES

FIGURES

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

A variety of physical and chemical characteristics of both the water and the metal can influence the toxicity of a metal to aquatic organisms in a surface water. When a site-specific aquatic life criterion is derived for a metal, an adjustment procedure based on the toxicological determination of a water-effect ratio (WER) may be used to account for a difference between the toxicity of the metal in laboratory dilution water and its toxicity in the water at the site. If there is a difference in toxicity and it is not taken into account, the aquatic life criterion for the body of water will be more or less protective than intended by EPA's Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. After a WER is determined for a site, a site-specific aquatic life criterion can be calculated by multiplying an appropriate national, state, or recalculated criterion by the WER. Most WERs are expected to be equal to or greater than 1.0, but some might be less than 1.0. Because most aquatic life criteria consist of two numbers, i.e., a Criterion Maximum Concentration (CMC) and a Criterion Continuous Concentration (CCC), either a cmcWER or a cccWER or both might be needed for a site. The cmcWER and the cccWER cannot be assumed to be equal, but it is not always necessary to determine both.

In order to determine a WER, side-by-side toxicity tests are performed to measure the toxicity of the metal in two dilution waters. One of the waters has to be a water that would be acceptable for use in laboratory toxicity tests conducted for the derivation of national water quality criteria for aquatic life. In most situations, the second dilution water will be a simulated downstream water that is prepared by mixing upstream water and effluent in an appropriate ratio; in other situations, the second dilution water will be a sample of the actual site water to which the site-specific criterion is to apply. The WER is calculated by dividing the endpoint obtained in the site water by the endpoint obtained in the laboratory dilution water. A WER should be determined using a toxicity test whose endpoint is close to, but not lower than, the CMC and/or CCC that is to be adjusted.

A total recoverable WER can be determined if the metal in both of the side-by-side toxicity tests is analyzed using the total recoverable measurement, and a dissolved WER can be determined if the metal is analyzed in both tests using the dissolved measurement. Thus four WERs can be determined:

- Total recoverable cmcWER.
- Total recoverable cccWER.
- Dissolved cmcWER.
- Dissolved cccWER.

A total recoverable WER is used to calculate a total recoverable site-specific criterion from a total recoverable national, state, or recalculated aquatic life criterion, whereas a dissolved WER is used to calculate a dissolved site-specific criterion from a dissolved criterion. WERs are determined individually for each metal at each site; WERs cannot be extrapolated from one metal to another, one effluent to another, or one site water to another.

Because determining a WER requires substantial resources, the desirability of obtaining a WER should be carefully evaluated:

1. Determine whether use of "clean techniques" for collecting, handling, storing, preparing, and analyzing samples will eliminate the reason for considering determination of a WER, because existing data concerning concentrations of metals in effluents and surface waters might be erroneously high.
2. Evaluate the potential for reducing the discharge of the metal.
3. Investigate possible constraints on the permit limits, such as antibacksliding and antidegradation requirements and human health and wildlife criteria.
4. Consider use of the Recalculation Procedure.
5. Evaluate the cost-effectiveness of determining a WER.

If the determination of a WER is desirable, a detailed workplan for should be submitted to the appropriate regulatory authority (and possibly to the Water Management Division of the EPA Regional Office) for comment. After the workplan is completed, the initial phase should be implemented, the data should be evaluated, and the workplan should be revised if appropriate.

Two methods are used to determine WERs. Method 1, which is used to determine cccWERs that apply near plumes and to determine all cmcWERs, uses data concerning three or more distinctly separate sampling events. It is best if the sampling events occur during both low-flow and higher-flow periods. When sampling does not occur during both low and higher flows, the site-specific criterion is derived in a more conservative manner due to greater uncertainty. For each sampling event, a WER is determined using a selected toxicity test; for at least one of the sampling events, a confirmatory WER is determined using a different test.

Method 2, which is used to determine a cccWER for a large body of water outside the vicinities of plumes, requires substantial site-specific planning and more resources than Method 1. WERs are determined using samples of actual site water obtained at various times, locations, and depths to identify the range of WERs in the body of water. The WERs are used to determine how many site-specific CCCs should be derived for the body of water and what the one or more CCCs should be.

The guidance contained herein replaces previous agency guidance concerning (a) the determination of WERs for use in the derivation of site-specific aquatic life criteria for metals and (b) the Recalculation Procedure. This guidance is designed to apply to metals, but the principles apply to most pollutants.

Exhibit D

Ambient Water Quality Criteria for Nickel

Acute Aquatic Toxicity Criterion: 46 µg/l at H of 50; A = +0.5173 (I F or E)

Chronic Aquatic Toxicity Criterion: 2.8 µg/l at H of 50; A = -2.286 (IF)
1.4 µg/L at H of 50; A = -2.985 (IIF)
3.7 µg/L at H of 50; A = -1.997 (IIE)

Wildlife and Domestic Animal Protection Criterion: not derived

Human Threshold Criterion: not derived

Human Nonthreshold Criterion: not derived

Comments: (General Use) The criteria derived here replace a single number water quality standard in 3 IAC 302.208g)

The acute criterion was derived for a hardness of 50 by the Subpart F Tier I procedure (35 Ill. Adm. Code 302.615)(n=33; t=4) and also could be calculated by Subpart E Tier I procedure (35 Ill. Adm. Code 302.555). Since the value of the criterion depends on the value of the hardness in the relevant water body, it is necessary to derive a regression equation, the intercept of which is +0.5173. The slope, 0.846, has been retaine from a previous USEPA document (EPA 86).

The chronic criterion was calculated by Subpart F Tier I procedure [35 Ill. Adm. Code 302.627a) and b)](n=8; t=4) using data for Brachydanio, a nonresident species as a surrogate to fulfill one of the requirements for distribution of taxa. Alternatively, the criterion was calculated according to Subpart F Tier II procedure (35 Ill. Adm. Code 302.627c) using the ACR for Chironomus from the 5 available ACRs. Another alternative is to use the Subpart E Tier II procedure [35 Ill. Adm. Code 302.565(a)(2) and (3)] using the FACR which is the geometric mean of 5 available ACRs. The slope, 0.846, has been retained from a previous USEPA document (EPA 86).

The derivation process as outlined in the attached document has been reviewed by the following Agenc staff members:

Clark Olson DWPC/Planning
Robert Mosher DWPC/Planning

Water Quality Criteria Derivation Fact Sheet - Individual Substances

1. Chemical Name: nickel (generic), 7440-02-0; nickel sulfate, $NiSO_4$, 7786-81-4; nickel chloride, $NiCl_2$, 7718-54-9; nickel nitrate 14216-75-2, no AQ record; nickelous nitrate 13138-45-9

1a. Molecular weight
2. CAS Number: 7440-02-0; nickel chloride 7718-54-9
3. Solubility: Reference No.:
4. KOC value: N/A Reference No.:
5. Environmental Fate: ; Reference No.:

6. Does the literature review indicate that this substance is significantly bioaccumulative? ___ Yes X No.

If yes, provide BCF value, if available:

Reference No.: See 35 Ill. Adm. Code 302.660-666.

7. Does the literature review indicate that the toxicity of this substance is dependent on any water quality characteristic?
X Yes ___ No

If yes, list these characteristics. hardness

Reference No.: See 35 Ill. Adm. Code 302.618 and 302.677(c)(1) and (4).

8. Freshwater Acute and Chronic Toxicity References. List computerized databases and printed literature compilations that were searched for references. Compile a list of all references obtained that provide empirical toxicity values for this substance. Also include any references pertaining to Items 3 through 7 above. Assign each reference a number and attach to this form.

AQUIRE: 7440-02-0, 10-04-99
JWPCF literature review issue 1982-1991
IRIS:
USEPA Ambient Water Quality Criterion document: EPA 440/5-004, 9-86
ATSDR Toxicity Profile:
USEPA Health and Environmental Effects document:
Mayer and Ellersieck:
Canadian Guidelines:
Suspect Chemicals Sourcebook:
RTECS:
ASTER:
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9. Acute Toxicity. List all individual data points for each species, whether it is believed to be an Illinois species
List invertebrates first, then vertebrates and vascular plants. Calculate SMAVs and GMAVs for the acceptable d

Species hard	cmpd	LC50 or Indicated Toxicity Value (µg/l)	Hcorr	SMAV	GMAV	Reference
Invertebrates						
Nais sp						
50	-	14,100	14,100*	14,100	14,100	EPA86
Tubifex tubifex						
245	Cl	96,380	25,140*	25,140	25,140	17
Dugesia tigrina						
-	-	16,800				31
130	Cl	32,000	6454*	~10,000	10,000	6
Lumbriculus variegatus						
45.5	-	12160 (10d)	13,170*			26
130	Cl	32,000	6454*			6
310	Cl	100,000 pH6	-			30
310	Cl	75,000 pH7	16,160*	11,120	11,120	30
310	Cl	26,000 pH8	-			30
Brachionus calyciflorus						
84.77	-	4000	2559*	2559	2559	32
Caenorhabditis elegans						
-	Cl	185,000 (2d)				34
-	Cl	3,000 (3d)				34
5(?)	Cl	1000 (4d)	7015*	7015	7015	34
?	Cl	3,722,000 (l) -				33
Physa gyrina						
26	-	298	518 *			GLI
26	-	239	415.4*	463.9	463.9	25
Amnicola sp						
50	-	11,400	11,400*			EPA86
50	-	14,300	14,300*	12,770	12,770	EPA86
Helisoma trivolvis						
130	Cl	3200	645.4*	645.4	645.4	6
Lymnaea luteola						
195	Cl	1430	452.3*	452.3	452.3	14
Anodonta imbecilis						
44	S	190	211.7*			10
90	S	252	153.2*	180.1	180.1	10
Viviparus bengalensis						
180	Cl	39,830	13,470*	13,470	13,470	7

Species hard	cmpd	LC50 or Indicated Toxicity Value (µg/l)	Hcorr	SMAV	GMAV	Reference

Daphnia magna					
-	-	<317	-		EPA86
45	-	510	554*		EPA86
51	-	915	898*		EPA86
51	-	1800	1770*		EPA86
100	-	2360	1313*		EPA86
104	-	1920	1033*		EPA86
206	-	4970	1500*		EPA86
240	Cl	7590	2013*		15
240	Cl	7300	1936*		12
130	Cl	3200	645.4*		6
250	S	4080	1045*	1168	9
-	-	2800(5o)	-		2
-	-	180(10o)	-		2
-	-	2000(20o)	-		2
-	-	2000(30o)	-		2
D. pulicaria					
48	-	2182	2259*		EPA86
48	-	1813	1877*		EPA86
44	-	1836	2046*		EPA86
47	-	1901	2003*		EPA86
~45?	-	697	762.0*		19
~45?	-	1140	1246*		19
~45?	-	1034	1130*		19
~45?	-	3014	3295*		19
~45?	-	2325	2542*		19
~45?	-	3414	3732*		19
~45?	-	3757	4107*		19

	~45?	-	2171	2373*			19
	~45?	-	2042	2232*			19
	~45?	-	2717	2970*			19
	~45?	-	3156	3450*			19
	~45?	-	3607	3943*			19
	~45?	-	3316	3625*	2337	-	19
D. pulex							
	127	Cl	912.332	414.6*	414.6	1042	8
Ceriodaphnia dubia							
	310	Cl	>200 pH6				30
	310	Cl	140 pH7	30.16*	30.16	30.16	30
	310	Cl	13 pH8				30
Moina macrocopa							
	5	Cl	1500(2.2d)	10,520*	10,520	10,520	32

Species	hard	cmpd	LC50 or Indicated Toxicity Value (µg/l)	Hcorr	SMAV	GMAV	Reference
Gammarus sp							
	50	-	13,000	13,000*	13,000	-	EPA86
G. fasciatus							
	130	Cl	>100,000	>20,170*	>20,170	>16,190	6
Crangonyx pseudogracilis							
	50		66,100	66,100*	66,100	66,100	GLI
Hyalella azteca							
	45.5	-	780 (10d)	844.6*			26
	310	Cl	2000 pH6				30
	310	Cl	1900 pH7	409.3*	588.0	588.0	30
	310	Cl	890 pH8				30
Asellus intermedius							

	130	Cl	75,000	15,130*	15,130	-	6
A. aquaticus	50	S	119,000	119,000*	119,000	42,430	20
Ephemerella subvaria	42	-	4000	4636*	4636	4636	EPA86
Damselfly sp	50	-	21,200	21,200*	21,200	21,200	EPA86
Acroneuria lycorias	40	-	33,500	40,460*	40,460	40,460	EPA86
Caddisfly sp	50	-	30,200	30,200*	30,200	30,200	EPA86
Chironomus sp	-	-	10,200 (1d)	-			28
	50	-	8600 (4d)	8600*	8600	-	28
C. riparius	55	-	72,400	66,635*			GLI
	55	-	81,300	74,832*			GLI
	55	-	84,900	78,146*	73,040	-	GLI
	55	-	184,000	169,362			GLI
	55	-	150,000	138,066			GLI
	55	-	174,000	160,000			GLI
C. tentans	25	-	69,500	119,300*	119,300	42,160	16

Species	hard	cmpd	LC50 or Indicated Toxicity Value (µg/l)	Hcorr	SMAV	GMAV	Reference
Vertebrates							
Anguilla rostrata							
	53	-	13,000	12,370*			EPA86
	55	-	13,000	11,990*	12,180	12,180	EPA86
Carassius auratus							
	20	-	9820	21,320*			EPA86
	135	Cl	86,600	37,370*	28,230	28,230	4
Cyprinus carpio							
	53		10,600	10,090*			EPA86
	55		10,400	9594*			EPA86
	5	Cl	1540	10,800*			1
	5	Cl	1300	9119*			1
	5	Cl	1640	11,500*			1
	5	Cl	2300	16,130*	11,000	11,000	1
Pimephales promelas							
	20	-	5180	11,250*			EPA86
	20	-	4580	9943*			EPA86
	360	-	42,400	7981*			EPA86
	360	-	44,500	8376*			EPA86
	210	-	27,000	8019*			EPA86
	210	-	32,200	9563*			EPA86
	210	-	28,000	8316*			EPA86
	210	-	25,000	7425*			EPA86
	45	-	5209	5695 *			EPA86

Species	hard	cmpd	LC50 or Indicated Value (µg/l)	Toxicity Hcorr	SMAV	GMAV	Reference
	44	-	5163	5753*			EPA86
	130	Cl	40,000	8071*			6
	310	Cl	>4000 pH6	-			30
	310	Cl	3400 pH7	732.5*			30
	310	Cl	31,000 pH8	-			30
	80	S	11,700	7812*	6691	6691	21
Fundulus diaphanus							
	53	-	46,200	43,980*			EPA86
	55	-	46,100	42,530*	43,250	43,250	EPA86
Morone americana							
	53	-	13,600	12,950*			EPA86
	55	-	13,700	12,640*	12,790	-	EPA86
M. saxatilis							
	53	-	6200	5902 *			EPA86
	55	-	6300	5812*			EPA86
	40	-	3900	4710*			EPA86
	285	-	33,000	7569*	5914	8697	EPA86

Species	hard	cmpd	LC50 or Indicated Value (µg/l)	Toxicity Hcorr	SMAV	GMAV	Reference
Ambloplites rupestris							
	26	-	2480	4312*	4312	4312	EPA86
Lepomis gibbosus							
	53	-	8100	7710*			EPA86
	55	-	8000	7380*	7544	-	EPA86
L. macrochirus							
	20	-	5180	11,250*			EPA86
	20	-	5360	11,640*			EPA86

360	-	39,600	7454*		
EPA86					
49	-	21,200	21,570*	12,040	9530
EPA86					
Bufo melanostictus					
185	S	19,860	6552*	6552	6552
13					

Plants no acute data

data marked with a * were used in the derivation

10. Unused Data. List these studies below along with the reason for rejection.

Species	Data Point (ug/l)	Reference Number	Reason for Rejection
Caenorhabditis elegans	3,722,000	33	outlier
Daphnia magna	<317	EPA86	no hardness
" "	several	2	no hardness
Chironomus riparius	169,362	GLI	less sensitive life stage
" "	138,000	GLI	less sensitive life stage
" "	160,000	GLI	less sensitive life stage

Other unused data are from non-native species and nonstandard tests

11. Rank the remaining GMAVs in the above list starting with the least sensitive one.

Genus	GMAV µg/L
33.) *Crangonyx*	66,100
32.) *Fundulus*	43,250
31.) *Asellus*	42,430
30.) *Chironomus*	42,160
29.) *Acroneuria*	40,460
28.) Caddisfly sp	30,200
27.) *Carassius*	28,230
26.) *Tubifex*	25,140
25.) Damselfly sp	21,200
24.) *Gammarus* sp	16,190
23.) *Nais* sp	14,100
22.) *Viviparus*	13,470
21.) *Amnicola*	12,770
20.) *Anguilla*	12,180
19.) *Lumbriculus*	11,120
18.) *Cyprinus*	11,000
17.) *Moina*	10,520
16.) *Dugesia*	~10,000?
15.) *Lepomis*	9,530
14.) *Morone*	8,697
13.) *Caenorhabditis*	7,015
12.) *Pimephales*	6,691
11.) *Bufo*	6,552
10.) *Ephemerella*	4,636
9.) *Ambloplites*	4,312
8.) *Brachionus*	2,559
7.) *Daphnia*	1,042
6.) *Helisoma*	645.4
5.) *Hyalella*	588.0
4.) *Physa*	463.9
3.) *Lymnaea*	452.3
2.) *Anodonta*	180.1
1.) *Ceriodaphnia*	30.16

12. Data requirements of Section 302.612(a).

__X__ met ____ not met (see Item 13 below)

Family	Species Tested
Fish	*Lepomis macrochirus*
Fish	*Pimephales promelas*
Daphnid	*Daphnia magna*
Benthic Macroinvertebrate	*Lymnaea luteola*
Vascular Plant or Fish	*Morone saxatilis*

13. If the requirements of 302.612(a) are not fulfilled as indicated above (Item 12), then a criterion under 35 Ill. Adm. Code 302.612(c) may be calculated, provided acceptable data for a representative of the family Daphnidae and either fathead minnow or bluegill exists. The most sensitive species from this entire data set (Item #11) is used to calculate the criterion by dividing the EC50 or LC50 by 10. Indicate species used, appropriate reference and AATC calculated. N/A

14. Additional Data. Data sets meeting all requirements of #12 above must be reviewed to see if the following taxa are also represented.

Family	Species Tested
Other Macroinvertebrate	*Hyalella azteca*
Different Phylum	*Dugesia tigrina*
Different Insect Order	*Acroneuria lycorias*

15. Indicate the value of "T" to be used: 4 (35 Ill. Adm. Code 302.615(f).

16. Indicate the value of "N" to be used: 33 (12-19-2000)

17. Calculate an FAV by applying the formula found at 35 Ill. Adm. Code 302.615(g). Divide the FAV by two to obtain the AATC.

(GU) criterion by Subpart F (and E)

FAV = 91.84323

AATC = 46 ug/L at hardness of 50

AATC = exp[A + BlnH] (µg/L) where (µg/L)

A = +0.5173 and

B = 0.8460

d AATC obtained at Item 17 above leave a commercially, recreationally or ecologically important species unprotected so far as can be demonstrated in the existing database? (35 Ill. Adm. Code 302.615(h))

_____ yes __X__ no

If yes, list the species and its LC50 or EC50 divided by two. This will then be the AATC. List all pertinent references and rationale for this decision.

N/A

19. Chronic Toxicity. List species in descending order of tolerance by MATC.

Species Test	cmpd	Hard	MATC (µg/l)	Corr	Reference
Invertebrates					
Daphnia magna					
LC	Cl	51	14.77	14.52	EPA86
LC	Cl	105	123.1	65.71	EPA86
LC	Cl	205	356.6	108.1	EPA86
-	-	63.5-66.5	<50	40.05	23
-	-	63.5-66.5	50-100(gm70.71)	56.71	23
-	Cl	62.2-76	<40	30.46	22
-	Cl	109	20-40 (gm28.28)	14.63	18
-	-	61-67	<40	32.46	24
POP EC10 =LOEC?(surv;length)			320	89.69	5
			SMCV <40.66		
Ceriodaphnia dubia					
-	Cl	42	3.8-7.5(gm5.339)	6.188	18
-	Cl	117	7.5-15(gm10.61)	5.169	18
			SMCV 5.656		
Moina macrocopa					
-	S	~5?	70.71	496.0	35
Clistornia magnifica					
LC	Cl	54	128.4	120.3	EPA86
Chironomus riparius					
30d	-?	-?	1100		27
Hydra littoralis					
-	Cl	70	<100	<75.22	29
Vertebrates					
Brachydanio rerio					
	S	100	45	25.03	3

Species	Test	cmpd	Hard	MATC (µg/l)	Corr	Reference
Pimephales promelas						
	LC	Cl	210	526.7	156.4	EPA86
	ELS	S	44-45	217.3	239.8	EPA86
				SMCV	gm 193.7	

20. Reject unacceptable data and assign rank as in Item 11 above.

Genus	GMCV µg/L
8.) *Chironomus*	1100
7.) *Moina*	496.0
6.) *Pimephales*	193.7
5.) *Clistornia*	120.3
4.) *Hydra*	<75.22
3.) *Daphnia*	<40.66
2.) *(Brachydanio*	25.03)
1.) *Ceriodaphnia*	5.656

21. Required Data. To derive chronic criteria according to 35 Ill. Adm. Code 302.627(b), the following minimium requirements must be met.

_X (?)_ met ____ not met (see Item 22 below)

Family	Species Tested
Fish	*Pimephales promelas*
Fish	*Brachydanio*?
Daphnid	*Daphnia magna*
Benthic Macroinvertebrate	*Chironomus riparius*
Alga or Plant	several

22. Additional Data. Data sets meeting all requirements of #12 above must be reviewed to see if the following taxa are also represented.

Family	Species Tested
Other Macroinvertebrate	*Moina macrocopa*
Different Phylum	*Hydra littoralis*
Different Insect Order	*Clistornia magnifica*

23. Indicate the result of the equation for calculating a CATC from 35 Ill. Adm. Code 302.627(b) below.

(GU) criterion by Subpart F (and E)

FCV = 2.785215 using *Brachydanio* (n = 8; t = 4)
CATC at 50 = 2.8 μg/L

CATC (ug/L) = exp[A + Bln(H)] (μg/L) where
A = -2.286 and
B = 0.846

24. If MATCs from the above are not available, a CATC may be calculated from acute-chronic ratios (ACRs) according to 35 Ill. Adm. Code 302.627(c). Indicate the species used, reference numbers and the calculated CATC below. If sufficient data are not available proceed to Item 23 below.

	Acute μg/L(ref)	Chronic μg/L(ref)	ACR
Daphnia magna			
	1800 (EPA86)	14.77 (EPA86)	122.4
	1920 (EPA86)	123.1 (EPA86)	15.60
	4970 (EPA86)	356.6 (EPA86)	13.94
	1182 (SMAV)	56.7 (23)	20.84
	1182 (SMAV)	14.63 (18)	80.79
		SMACR gm	33.91
Pimephales promelas			
	27,930	526.7	55.03 (EPA86)
	5186	217.3	23.87 (EPA86)
		SMACR gm	36.24
Ceriodaphnia dubia			
	30.16 (27)	5.656 (18)	5.332
Moina macrocopa			
	10,520 (32)	496.0 (35)	21.21
Chironomus riparis			
	73,040 (GLI)	1100 (27)	66.40
		FACR gm of all SMACRs	24.72

(GU) criterion by Subpart F:

The highest ACR is for Chironomus (66.40)

CATC = FAV / ACR = 91.84323 / 66.40 = 1.383 or 1.4 μg/L at hardness of 50

CATC = exp[A + Bln(H)] (μg/L) where
A = -2.985 and
B = 0.846

(GU) criterion by Subpart E: FACR is the geometric mean of 5 SMACRs at 24.72;
CATC = FAV / FACR = 91.84323 / 24.72 = 3.715 or 3.7 μg/L at hardness of 50

CATC = exp[A + Bln(H)] (μg/L) where
A = -1.997 and
B = 0.846

25. A default acute-chronic ratio of 25 is used where insufficient chronic data exists (35 Ill. Adm. Code 302.627(d)). To obtain the CATC divide the FAV obtained at Item 17 by 25. Express the result below. N/A

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED SITE SPECIFIC	)	
RULE FOR SANITARY DISTRICT	)	R14-24
OF DECATUR FROM 35 ILL. ADM.	)	(Site Specific Rule – Water)
CODE SECTION 302.208(e).	)	

PRE-FILED TESTIMONY OF PAUL BLOOM, Ph.D.
IN SUPPORT OF PROPOSED SITE SPECIFIC RULE

The Petitioner, SANITARY DISTRICT OF DECATUR ("District"), by and through its attorneys, HEPLERBROOM, LLC, and pursuant to 35 Ill. Adm. Code § 102.424 submits the following Pre-Filed Testimony of Paul Bloom, Ph.D. in Support of Proposed Site Specific Rule for presentation at the May 16, 2018 hearing scheduled in the above-referenced matter.

TESTIMONY OF PAUL BLOOM, Ph.D.

I. INTRODUCTION

My name is Paul Bloom and I am Vice President, Process & Chemical Research at Archer Daniels Midland Company ("ADM"). I received a B.S. in Chemistry from Illinois State University and a Ph.D. in Organic Chemistry with Research Excellence from Iowa State University. My resume is attached as Exhibit A.

My testimony today addresses and supports those portions of the District's Amended Petition for Site Specific Rule filed on November 30, 2017 ("Amended Petition") that concern ADM's Decatur Complex; how the District's National Pollutant Discharge Elimination System ("NPDES") permit nickel effluent limit impacts ADM; ADM's identification and evaluation of methods and technologies to control and reduce nickel in the Decatur Complex's wastewater; the technical feasibility and economic reasonableness of such methods and technologies; and the steps that ADM has undertaken to control and reduce nickel at the Decatur Complex.

R14-24
EXH. 6
5-16-18
TJF

The bases of my knowledge for this testimony come from my current position, and additional background review of information associated with this project.

II. ADM'S DECATUR COMPLEX

ADM's Decatur Complex is located at 4666 Faries Parkway, Decatur, Illinois. The Decatur Complex consists of multiple, separate processing plants which discharge their wastewater to the on-site wastewater treatment plant ("WWTP"). These processing plants consist of the Corn Plant (Wet Corn Mill, Alcohol Plant, and Sorbitol Plant), BioProducts Plant, Cogeneration Plant, East Soybean Processing Plant, West Plant (West Soybean Processing Plant, Vitamin E Plant, and Corn Germ Processing Plant), Glycols Plant, and the Polyols Plant (permanently shut down in 2015). Each of these plants produce multiple products, using both batch and continuous processes, and create unique process water streams which generally are reused multiple times prior to being discharged as wastewater to the WWTP. The WWTP treats approximately 11 MGD through an anaerobic treatment system followed by aerobic treatment prior to discharge to the District. ADM's Decatur Complex contributes a large portion of the flow to the District's Main Plant, located at 501 Dipper Lane, Decatur, Illinois.

III. HOW THE DISTRICT'S NPDES PERMIT NICKEL EFFLUENT LIMIT IMPACTS ADM

In August 2007, the District notified ADM of the nickel effluent limit included in the District's 2007 NPDES permit. Based on sampling conducted by the District, ADM was identified as a significant contributor of nickel. In January 2008, the District met with ADM and shared the proposed limit calculated from the sampling data, with which ADM would be required to comply by July 2009. It was not until that time that ADM first recognized the implications that this limit could have on its operations.

ADM has tested its raw materials and process water streams from each plant to determine the sources of nickel in ADM wastewater and has identified those streams that contain the highest concentration of nickel. Three primary sources of nickel have been identified:

1. Nickel contained in incoming soybeans (approximately 4.1 mg/kg soybeans) and corn (approximately 0.53 mg/kg corn);
2. Nickel solubilized from nickel catalysts used in hydrogenation; and
3. Nickel solubilized from metallurgy during processing at the Polyols Plant.

The contribution and total quantity of nickel to the WWTP from each of the ADM plants is summarized in Table 1, attached as Exhibit 20 to the District's Amended Petition. The data in Table 1 was derived from August to November 2010 weekly samplings.

ADM spent several years investigating the sources of nickel in its wastewaters and potential treatment strategies to reduce its nickel discharges. As the incoming nickel in soybeans (approximately 4.1 mg/kg soybeans) and corn (approximately 0.53 mg/kg corn) cannot be controlled, ADM initially focused on the potential to control major sources of nickel streams discharging to its WWTP. To that end, it has performed four comprehensive nickel material balances of its Decatur Complex and traced the majority of nickel entering the WWTP to the East Soybean Plant, Corn Plant and Polyols Plant.

IV. ADM'S IDENTIFICATION AND EVALUATION OF METHODS AND TECHNOLOGIES TO CONTROL AND REDUCE NICKEL IN THE DECATUR COMPLEX'S WASTEWATER AND THE TECHNICAL FEASIBILITY AND ECONOMIC REASONABLENESS OF SUCH METHODS AND TECHNOLOGIES

On January 7, 2010, the Board granted the District's Petition for Variance that authorized the continued discharges of nickel from the District's Main Plaint into the Sangamon River. Pursuant to the variance, the District required ADM, through an authorization to discharge issued by the District under its pretreatment ordinance, to complete a thorough technology review that is detailed in the Amended Petition at pages 9-10 and 54-58. ADM investigated each of those alternatives , but no alternative was identified that could consistently meet the required nickel limit and also be both technically feasible and economically reasonable. ADM continued to review new technologies entering the market but did not identify any technically feasible and economically reasonable options.

ADM's investment to identify and implement viable solutions to meet the nickel standard has been approximately $1.02 million in employee costs and $0.45 million in equipment rental and pilot trial costs from 2009 to December 2011. ADM also invested approximately $1.5 million in employee costs for additional technology reviews, monitoring, and optimization of the equipment installed over the last six years. In addition, ADM has spent $450,000 to install a resin capture system at the Decatur Sorbitol plant. It also spent an additional $2.7 million to install a system to allow removal of the soy molasses stream and roughly $750,000 to install a high pH precipitation and filtration process at the Polyols Plant. In 2013, ADM spent $450,000 to install facilities to manage removal of excess sludge from the wastewater treatment plant. ADM has also significantly improved housekeeping in the West Plant to minimize nickel catalyst from entering the wastewater system. At this point, all identified options have been explored and, in combination with the shutdown of the Polyols Plant, all technically feasible and economically reasonable solutions were pursued.

When considering the cost of compliance for ADM alone, the site specific rule is clearly necessary because there is no technically feasible and economically reasonable treatment available that will allow ADM to meet the nickel limitation imposed by the District's NPDES permit. Since no such technologies exist, ADM anticipates that, if the existing rules were to apply, ADM would be prevented from running at its full operating capacity or legally permitted levels. ADM may also have to curtail its soy processing operations at the Decatur Complex and evaluate possible shutdown at this location. When we first evaluated this impact, such a move was anticipated to result in a loss of approximately 150 jobs. In addition to the possible shutdown, the existing rules would put the Decatur complex at a substantial disadvantage for new commercialization opportunities compared with other ADM locations.

Even if some of the untested and experimental stage technologies that ADM evaluated were commercially available and scalable, ADM estimates from 2009 indicated that it would have to spend about $32.5 million in the first year to install a mix of technologies and chemicals, which may only remove between 3-7 lbs of nickel per day in a stream that averages 11 MGD. On a per pound nickel basis, that rate equates to a mitigation cost between $7,500 and $18,000 per pound of nickel removed. Moreover, the technology and chemical mix would likely generate about 15-20 tons per day of landfill waste.

V. STEPS THAT ADM HAS UNDERTAKEN TO CONTROL AND REDUCE NICKEL AT THE DECATUR COMPLEX

As a result of its evaluation of the individual nickel-containing wastewater streams, ADM has taken, or is taking, several steps to reduce the nickel that reaches the WWTP from each of its processing facilities. These steps include:

1. Spent and spilled catalyst from the West Soybean Processing Plant is collected and managed to keep it out of the wastewater system.
2. Particulate catalyst from the Corn Plant Sorbitol production is captured by filters and physically recovered for recycling or disposal as solid waste. ADM installed an ion exchange resin system at the Sorbitol Plant to

capture soluble nickel from wastewater. Used resin is managed in accordance with applicable regulations.

3. The East Soybean Processing Plant has installed a system that removes the soy molasses stream (containing approximately 2.4 lb/day, approximately 35% of the soluble nickel from the Decatur Complex) from the WWTP.

4. The Polyols Plant previously accounted for approximately 11% of the soluble nickel from the Decatur Complex. The Polyols Plant determined that this nickel could be precipitated by pH adjustment. ADM installed a precipitation and filtration treatment system which reduced the nickel from this process. This plant was permanently shut down in the fourth quarter of 2015.

5. During 2015, elevated nickel in the effluent occurred as a result of solids carry-over from the high-salt slow rate anaerobic digestion reactors. ADM has developed and implemented a sludge management plan to address the maintenance and removal of sludge from the anaerobic wastewater system. This plan includes removal and dewatering of solids from the system, short-term management of the solids in newly constructed storage basins, and land application of the sludge under Water Pollution Control Permit No. 2015-SC-60414 issued by Illinois EPA on December 29, 2015. During 2016, ADM removed approximately 10.08 and 11.44 million dry pounds of sludge from the system during 2016 and 2017, respectively.

ADM intends to continue to employ these process changes to reduce the nickel content in wastewater to ADM's WWTP, independent of flow in the Sangamon River.

ADM has continued to monitor total and soluble nickel in the effluent to the District's Main Plant, and since the fall of 2010, there has been a gradual decline in nickel from about 0.120 mg/L to about 0.060 mg/L. *See* Figure 1, attached as Exhibit 21 to the Amended Petition.

The above-described work that ADM has undertaken to reduce nickel within the individual wastewater streams has resulted in considerable reductions of nickel loads to the Decatur Complex WWTP. Also, as discussed above, ADM investigated a number of technologies to determine their associated potential to control nickel at the Decatur Complex WWTP. Nevertheless, ADM's efforts have not disclosed a means for it to consistently meet the proposed nickel limit that the District determined would apply to ADM based upon the District's current NPDES permit.

For additional information regarding ADM's nickel mitigation efforts, please see the District's December 21, 2011 Interim Report, attached as Exhibit 15 to the Amended Petition, as well as the District's June 25, 2012 Interim Report, attached as Exhibit 16 to the Amended Petition, the District's December 19, 2012 Interim Report, attached as Exhibit 17 to the Amended Petition, the District's June 27, 2013 Interim Report, attached as Exhibit 18 to the Amended Petition, and the District's December 20, 2013 Interim Report, attached as Exhibit 19 to the Amended Petition; see also Tables 3 and 4 attached as Exhibits 42 and 43 to the Amended Petition, which discuss all of the technologies ADM evaluated under the variance granted by the Board on January 7, 2010.

The steps already taken by ADM at a great cost have significantly reduced soluble nickel output by the Decatur Complex WWTP and will allow the District to maintain nickel levels at or below the proposed limit in the Amended Petition. Requiring further reductions in nickel from ADM will be both economically cost prohibitive and technically uncertain in effectiveness and substantially disadvantage Decatur for new commercialization opportunities.

VI. CONCLUSION

The information discussed today supports the promulgation of the proposed site specific rule. Thank you for the opportunity to testify. I will be happy to answer any questions.

* * *

The SANITARY DISTRICT OF DECATUR reserves the right to supplement this pre-filed testimony.

SANITARY DISTRICT OF DECATUR,

Dated: April 25, 2018

By: /s/ Katherine D. Hodge
One of Its Attorneys

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Exhibit A

Paul D. Bloom, Ph.D.
1001 N. Brush College Rd, Decatur, IL 62521; Phone: 217-451-2158

Professional Experience:

11/13- present Vice President, Process and Chemical Research, Archer Daniels Midland Company

1/2013-11/2013 General Manager–Evolution Chemicals™ & Director, Technology Commercialization – Corn Division, Archer Daniels Midland Company

2010-2012 Business Director–Industrial Chemicals, Archer Daniels Midland Company

2007-2010 Director– Chemical Technology Strategy, Archer Daniels Midland Company

2004-2007 Manager – New Industrial Chemicals/Industrial Products R&D, ADM

2001-2004 Senior Research Scientist/Coatings Group Leader, ADM

1997-2001 Graduate Student, Iowa State University, Ames, IA

1996-1997 Chemist, The Valspar Corporation, Wheeling, IL

Education:

Certificate of Completion, Executive Education Program, Harvard Business School, Boston, MA - 2012
Ph.D. Organic Chemistry (with Research Excellence), Iowa State University, Ames, IA – 2001
B.S. Chemistry, Cum Laude, Illinois State University, Normal, IL - 1996

Board Appointments & Leadership:

- 2014-present Vice Chairman, Board of Directors, iBio – Illinois Biotechnology Industry Organization
- 2013-present Steering team member, ADM-DuPont FDME Joint Development R&D and Pilot Program
- 2012-2013 Board of Directors, BioBlend Renewable Resources, LLC
- 2011-2012 Board of Directors, Economic Development Corporation of Decatur and Macon County
- 2008 Federal Committee Appointment - Renewable Energy Committee, National Agricultural Research, Education, Extension and Economics (NAREEE) Advisory Board, United States Department of Agriculture (mandated by 2008 Farm Bill).
- 2008-2013 Steering Committee Member, ADM-PolyOne Joint Development Agreement for bioplasticizers development and commercialization.
- 2009-2011 Renewable Energy Advisory Board, University of Wisconsin - Platteville
- 2008-2011 Adjunct Professor/Ph.D. Candidate Advisor, Department of Chemistry, Univ. of Memphis.
- 2007-2011 Executive Technical Committee Member and Industrial Board Chair. Center for Environmentally Beneficial Catalysis, NSF Engineering Research Center, headquartered at The University of Kansas, with core partners at The University of Iowa, Washington University in St. Louis, and Prairie View A&M University
- Current and previous ADM Committees: Leader –ADM STEM Education Programs, Community Engagement, Compliance and Ethics, Job Mapping Task Force

Awards:

- Raw Material Supplier of the Year, Mary Kay Inc., 2012.
- Wall Street Journal Technology and Innovation Award, Runner-Up, Materials and Other Base Technologies, 2012.
- R&D 100 Award, Propylene Glycol from Renewable Sources, ADM team co-developer with Pacific Northwest National Laboratory, 2010.

- Honored Alumnus, Department of Chemistry/LAS, Illinois State University, Homecoming 2009.
- U.S. EPA Presidential Green Chemistry Award – Designing Safer Chemicals, 2005
- U.S. EPA Pollution Prevention (P2) Award, 2005
- Ames National Laboratory Inventor Award, Ames Lab, Ames, IA, 2006, 2003, 2000
- Iowa State University Research Excellence Award, Iowa State University, 2001
- Dow Chemical Research Scholarship, Iowa State University, 2000, 1999
- Nelson Chemistry Scholarship, Iowa State University, 1997
- Robert Duty Service Award, Dept. of Chemistry, Illinois State University, 1996
- The Valspar Corporation Scholarship, Illinois State University, 1995
- American Chemical Society POLYED Undergraduate Research Award, 1995

Patents:

1. Bloom, P.D.; Sanborn, A. Reduction of HMF ethers with metal catalyst, U.S. Patent No. 9,422,258 2016.
2. Bloom, P.D.; Sanborn, A. Reduction of HMF ethers with metal catalyst, U.S. Patent No. 9,416,119 2016.
3. Bloom, P.D.; Sanborn, A. Reduction of HMF ethers with metal catalyst, U.S. Patent No. 8,709,286 2014.
4. Binder, T.; Bloom, P.D.; Doane, P.; Ma, C. Process for fractionation of lignocellulosic biomass. U.S. Patent No. 8,637,282. 2014.
5. Baseeth, S.; Bloom, P.D.; Sebree, B.; Smith, D. Microemulsions for bioremediation. U.S. Patent No. 8,377,329 2013.
6. Bloom, P.D. Lubricant additives. U.S. Patent No. 8,198,224, 2012.
7. Bloom, P.D. Lubricant additives. U.S. Patent No. 8,198,223, 2012.
8. Bloom, P.D. Hydrogenolysis of glycerol and products produced therefrom. U.S. Patent No. 8,153,847, 2012.
9. Baseeth, S.; Bloom, P.D.; Sebree, B.; Smith, D. Methods of remediation of water. U.S. Patent No. 8,057,675, 2011.
10. Bloom, P.D. Lubricant additives. U.S. Patent No. 7,994,107, 2011.
11. Bloom, P.D. Hydrogenated and partially hydrogenated heat-bodied oils and uses thereof. U.S. Patent No. 7,951,862, 2011.
12. Bloom, P.D. Hydrogenolysis of glycerol and products produced therefrom. U.S. Patent No. 7,928,148, 2011.
13. Bloom, P.D.; Tabuena-Salyers, T.R. Waterborne film-forming compositions containing reactive surfactants and/or humectants. U.S. Patent No. 7,906,571, 2011.
14. Bloom, P.D.; Fuge, P.K.; Poppe, G.B.; Tabuena-Salyers, T.R. Stabilized ester compositions and their use in film-forming compositions. U.S. Patent No. 7,875,664, 2011.
15. Bloom, P.D. Hydrogenated and partially hydrogenated heat-bodied oils and uses thereof. U.S. Patent No. 7,842,746, 2010.
16. Baseeth, S.; Bloom, P.D.; Sebree, B.; Smith, D. Compositions and uses thereof in bioremediation. U.S. Patent No. 7,785,468, 2010.
17. Binder, T.P.; Bloom, P.D. Vegetable based dioxanone derivatives, synthesis and uses thereof. U.S. Patent No. 7,754,823, 2010.
18. Bloom, Paul D.; Tabuena-Salyers, Teodora R. Thickening systems and aqueous-coating compositions, and methods of making and using the same. U.S. Patent No. 7,629,399, 2009.
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51. Nilles, D. "Combating the Glycerin Glut." *Biodiesel Magazine*, September 2006.
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53. Ritter, S. "Green success." *Chemical & Engineering News,* 83(26), June 27, 2005
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Selected Presentations:

1. *Chemurgy: Progress in Renewable Chemicals,* Invited Speaker, IHS 31st World Petrochemical Petrochemical Conference, Houston, TX. March 15, 2016.
2. *Chemurgy: A Continuing Journey.* Keynote Session Speaker, Clariant: Defining the Future VII, San Francisco, CA. August 25, 2015.
3. *Revitalizing Chemurgy,* Keynote Speaker, iBio Ag-Bio Industrial Summit, Illinois State University, Normal, IL. August 9, 2012
4. *Revitalizing Chemurgy: ADM Chemicals Initiatives.* Invited Speaker, ADM Women's Initiative Network Meeting, Decatur, IL. June 9, 2010
5. *Opportunities for Renewable Chemicals: Impact and Needs.* Plenary Lecture, POLY/PMSE Awards Dinner, National American Chemical Society Meeting, March 24, 2010, San Francisco, CA.
6. Honored Alumnus Lecture, Department of Chemistry/LAS, Illinois State University Homecoming, 2009
7. *New Industrial Chemicals and Fuels from Agricultural Resources.* Invited Speaker, Division of Petroleum Chemistry, 236th ACS National Meeting, Philadelphia, PA, United States, August 20, 2008
8. *Building the Biorefinery:Chemicals and Fuels from Agricultural Resources.* Invited Speaker, The Fifth Annual World Congress on Industrial Biotechnology & Bioprocessing, Chicago, Illinois, April 27-30, 2008
9. *Second Generation Biofuels and Biochemicals: An Industry Perspective*. Invited Speaker, American Institute of Chemical Engineers Meeting, Salt Lake City, Utah, November 7, 2007
10. *Designing a Sustainable Future: Fuels and Industrial Products Derived from Agricultural Feedstocks.* Invited Speaker, The Council for Chemical Research Presents its 28th Annual Meeting, New Orleans, LA, April 15-17, 2007
11. *Designing a Sustainable Future: BioProducts: Opportunities and Challenges*. Invited speaker and expert panelist for the National Agricultural Research, Extension, Education and Economics Board Meeting. Washingon D.C., October 25, 2006
12. *Designing a Sustainable Future: Fuels and New Industrial Products Derived from Vegetable Oils*. Invited speaker for Biomass '06: Power, Fuels, and Chemicals Workshop, Energy & Environmental Research Center in Grand Forks, North Dakota, July 18–19, 2006
13. *Biomass: Growing American Energy Independence.* Invited speaker on Biodiesel, U.S. Senate Briefing sponsored by the American Chemical Society Science & the Congress Project and the Senate Science and Technology Caucus. Russell Senate Office Building, Washington D.C., June 21, 2006
14. *Designing a Sustainable Future: New Industrial Products Derived from Vegetable Oils.* Invited speaker for 37th Great Lakes Regional Meeting of the American Chemical Society, Milwaukee, WI, May 31-June 2, 2006.
15. Invited Speaker, Growing the Bioeconomy Conference at Iowa State University, August 30th, 2005.

16. *Archer RC: Nonvolatile, Reactive Coalescent for the Reduction of VOC in Latex Paints.* Awards Address, 2nd International Conference on Green and Sustainable Chemistry, June 21st, 2005 http://www.epa.gov/gcc/dsca05.html
17. *Fatty acid esters: nonvolatile, reactive coalescents for latex paints.* Industrial Applications of Renewable Resources, A Conference on Sustainable Technologies, American Oil Chemists' Society, Chicago, IL., October 11-14, 2004
18. *Industrial chemicals from renewable resources.* Department of Chemistry, University of North Carolina, Chapel Hill. June 18th, 2004
19. *Synthesis and characterization of vegetable based lubricants.* Session 6F - Nonferrous I, Society of Tribologists and Lubrication Engineers 59th Annual Meeting, 2004
20. Session co-chair and *Synthesis and characterization of vegetable-based waxes.* Industrial Oil Products, 94th AOCS Annual Meeting & Expo, Kansas City, MO, 2003
21. *Synthesis of environmentally friendly lubricants from vegetable oils.* Society of Tribologists and Lubrication Engineers 58th Annual Meeting, 2003
22. *Nonvolatile Coalescents for Latex Paints.* Wisconsin Paint and Coatings Association Meeting, April 10, 2003
23. *Biobased Lubricant Research at ADM – Focus On Properties of the New Better Bean Initiative Varieties Under Study.* United Soybean Board Soy Lubricants Advisory Panel, Chicago, IL 2002

Affiliations:
American Chemical Society, American Oil Chemists' Society, Society of Tribologists and Lubrication Engineers, Society of Plastics Engineers

R14-24
Hearing Questions for Witnesses: Sanitary District of Decatur

Timothy Kluge:

The District's NPDES permit included a provision for conducting a "translator study" to gather data to recalculate the nickel effluent limit. Based on the report of that study, IEPA revised the hardness used to calculate the permit limit, changing the limit from 0.011 mg/L to 0.015 mg/L. Kluge Test. at 2-3.

1) Would you direct us to the translator study in the record?

2) Could you explain what a "translator" is and how it was applied to calculate a new permit limit?

3) Do you know what value was used for the translator? Exhibit 46 includes a translator value of 0.966. Is this the same?

4) Could you also explain the hardness value IEPA used to derive the 0.011 mg/L and 0.015 mg/L nickel effluent limits? Were those nickel effluent limits for total or dissolved nickel?

5) Would you be able to show the calculation used to determine these permit limits?

Allison Cardwell

Your prefiled testimony stated that using a sensitive species such as *Ceriodaphnia dubia* for toxicity testing "provides protection for many other aquatic species." Cardwell Test. at 3.

6) Does that means that, by protecting for the one of the most sensitive species that lives in the Sangamon River, the other less sensitive species would also be protected?

You explained that the test organisms were acclimated for over a year to the high hardness, high pH. Cardwell Test. at 2.

7) Does that involve breeding multiple generations in an increasingly high-hardness, high-pH environment?

8) Did you have to acclimate the organisms to different levels of dissolved organic carbon (DOC) as well?

9) What typically comprises natural organic matter (NOM) and the DOC component?

10) Is the Sangamon River's pH, hardness, or DOC concentration unusual in Illinois? If so, what is it about this portion of the Sangamon River that makes it unusual? Is it because of a geologic formation or runoff from the watershed?

R14-24
Ex4.7
5-16-18
TJT

You explained that nickel was spiked into the waters to determine an effect concentration (EC_{20}) where 20% of the organisms exhibited reduced survival and reproduction. Cardwell Test. at 3.

11) Would you explain why you chose 20% versus 10% or 30%, for example.

Robert Santore

Your testimony states that "[t]he Sangamon River chemistry is hard water with considerable amounts of organic matter." Santore Test. at 4.

12) Can you explain a reason or reasons for this state of the Sangamon River?

13) Do you think it could ever change? If so, how? Is such a change in the foreseeable future?

14) Does your experience indicate that the Sangamon River's DOC, NOM, and hardness is atypical of most other rivers in Illinois?

15) Are site-specific water quality standards reviewed during IEPA's triennial review process? If not, what would prompt a review?

Your testimony indicates that input data to the Biotic Ligand Model (BLM) were taken from two downstream sampling locations: Rock Springs B and Lincoln Homestead. Santore Test. at 5, Exh. 28 at 8-9.

16) Are both of these locations within the reach of the proposed site-specific standard?

USEPA's recommended criterion continuous concentration (CCC) for dissolved nickel is 0.052 mg/L at 100 mg/L hardness, and 0.154 mg/L at 359 mg/L hardness based on a calculation. Santore Test. at 7. Similarly, you calculated chronic water quality standards for Iowa and Indiana at 359 mg/L hardness of 0.154 mg/L and 0.465 mg/L, respectively. *Id.* You explain that "[a]ll of these chronic standards would still be converted to a total nickel basis using the appropriate translator to determine permit limits. For these calculations, please see Exhibit 46. . ." Santore Test. at 7-8.

17) Exhibit 46 contains the results of the calculations. Would you please show the calculations that were made in Exhibit 46, including the formulas and parameter values?

Although the USEPA CCC specifically states that it is for dissolved nickel, the values of 0.154 mg/L for Iowa and 0.465 mg/L for Indiana appear to be for the total concentration.

USEPA's National Recommended Aquatic Life Criteria Table also includes values for nickel in Appendix A: Conversion Factors for Dissolved Metals and Appendix B: Parameters for Calculating Freshwater Dissolved Metals Criteria that are Hardness-Dependent.

The Indiana rule states that "[t]he AAC and CAC columns of this table contain total recoverable metals criteria (numeric and hardness-based). The criterion for the dissolved metal is calculated by multiplying the appropriate conversion factor by the AAC of CAC." The CAC conversion factor for nickel is 0.997. 327 Indiana Adm. Code 2-1-6 Table 6-2. (http://www.in.gov/legislative/iac/T03270/A00020.PDF)

The Iowa rule states that "all values as micrograms per liter as total recoverable unless noted otherwise" 567 Iowa Adm. Code 61.3(3) Table 1. This section of the Iowa standards does not appear to list a conversion factor multiplier or translator for dissolved metals. (https://www.legis.iowa.gov/docs/ACO/chapter/567.61.pdf)

18) Would you comment on whether Exhibit 46 could be revised to more clearly reflect total and dissolved concentrations?

You point out that, while the proposed site-specific standard is above the current Illinois water quality standard, it is well below the USEPA recommended water quality criterion as well as other Indiana and Iowa state water quality standards. Santore Test. at 5, 7.

19) Could you state when the current Illinois nickel chronic water quality standard for general use waters was adopted and under which rulemaking?

20) Could you explain why this standard is so much lower than the criterion recommended by USEPA and standards set by the other states mentioned?

Your testimony states that, "[b]ased on the Illinois EPA-determined critical hardness value of 359 mg/L and nickel translator value of 0.966, the proposed site specific rule would result in an anticipated National Pollutant Discharge Elimination System (NPDES) permit limit of 38.20 ug/L (0.0382 mg/L) total nickel for the District." Santore Test. at 5.

21) Would you explain how the nickel translator value of 0.966 was determined? A translator study is mentioned being completed as part of the requirements of the NPDES permit. Is this the origin of the nickel translator value of 0.966?

22) How does this translator value of 0.966 fit into the equation for determining the WER that is applied to the general use nickel water quality standard?

23) Please provide the equation and show mathematically how the anticipated NPDES permit limit of 0.03820 mg/L is calculated?

24) Please explain how the difference between dissolved and total nickel is accounted for in the calculation of 0.0382 mg/L?

25) Please explain why the permit limit would be in total instead of dissolved nickel since the proposed site-specific water quality standard is for dissolved nickel?

26) Please explain whether the anticipated NPDES Permit Limit of 0.0382 mg/L would be equal to the water quality standard? Is this a Water Quality Based Effluent Limit?

27) Does the calculation of 0.0382 mg/L take into account eligibility for and availability of a mixing zone?

28) Has IEPA concurred with the anticipated NPDES Permit limit or commented on how the Agency would determine a NPDES Permit limit based on the proposed site-specific water quality standard?

Appendix 1 of Revised Exhibit 28 (OSU Ni Toxicity Test Reports) explains "the determination of effect concentrations to reduce survival or reproduction by 10%, 20% and 50% relative to control performance ($LC_{10}/LC_{20}/LC_{50}$ and $EC_{10}/EC_{20}/EC_{50}$)." Exh. 28, App. 1 at 2-5.

Exhibit 28 explains that this data is used to calculate the WER as the Ni Effect in Site water/Ni Effect in Reference water, where the Ni effects were calculated using the DOC equation derived from the ANCOVA analysis (Exh. 28 App. 2). Exh. 28 at 8.

The resulting equation was then used with downstream monitoring data to determine an overall equation that relates Ni toxicity to measured DOC concentrations. This equation, applied to average DOC concentrations in the Sangamon results in a WER of 2.50." Rev. Exh. 28 at 12.

29) Would you please state the DOC equation that was eventually derived and explain how was it applied to the calculation of the WER?

Revised Exhibit 28 explains that an average DOC concentration of 8.33 mg/L (Rev. Exh. 28 at 10, Table 1) in Sangamon River results in an average Ni EC20 of 16.662 ug/L. An average DOC concentration of 0.5 mg/L in the reference site results in an average Ni EC20 of 6.663 ug/L. "Substituting these Ni EC20 values in the WER equation yield a WER value of 16.662/6.663 = 2.50." Rev. Exh. 28 at 9-10.

30) Would you please point to where the values of 6.663 ug/L and 16.662 ug/L appear in the exhibits?

Exhibit 45 contains communication among the Sanitary District of Decatur, IEPA, and USEPA. The correspondence begins with comments from IEPA and USEPA (in black), followed by responses from the Sanitary District of Decatur on February 8, 2018 (in blue), USEPA on February 26, 2018 (in "JA" comments), and ends with Decatur's Robert Santore on March 8 and 21, 2018 (in "RCS" and "R" comments).

31) Has USEPA seen the reply comments from Mr. Santore dated March 8 and 21, 2018? If so, have they provided comment in response?

32) Has either USEPA or IEPA provided comment on Decatur's revised proposal with a WER of 2.50?

Paul Bloom, Ph.D.

Your prefiled testimony states that one of the primary sources of nickel is that contained in incoming soybeans and corn. Bloom Test. at 3.

33) Can you estimate the percentage of nickel in the waste stream accounted for by the incoming soybeans and corn?

34) Is nickel in the soil and taken up by the crops or is it in fertilizer or pesticides used on the crops?

35) Is the nickel issue specific to Illinois because of the soil types or other reasons?

Your testimony indicates that other sources are nickel catalysts used in hydrogenation and metallurgy during processing at the Polyols Plant. Bloom Test. at 3.

36) As part of its evaluation, did ADM also evaluate ways to reduce or substitute nickel as a raw material in the catalyst or the metallurgy?

You referred to the technologies evaluated by ADM, which summarized the findings in Exhibit 42. Bloom Test. at 4; Am. Pet at 9-10, 54-58. The only nickel capture methods that were identified as both technically feasible and economically reasonable were: "Evaporation and sale of Soy Molasses" and "pH>11". Exh. 42. Both were listed as being in some stage of pilot testing. The Amended Petition notes that the high pH precipitation (pH>11) was installed at the Polyols Plant, but the plant is now permanently shut down. Exh. 42, Bloom Test. at 6, Am. Pet. at 57. The amended petition states that ADM spent "$2.7 million to install a system to allow removal of the soy molasses stream" and $450,000 to install facilities to manage removal of excess sludge from the wastewater treatment plant. In addition, ADM improved housekeeping to prevent nickel catalyst from entering the wastewater system. Am. Pet. at 57, Bloom Test. at 4.

The amended petition states, "The steps already taken by ADM at a great cost have significantly reduced soluble nickel output…" Am. Pet. at 58.

37) Your prefiled testimony stated that the removal of the soy molasses stream accounts for 35% removal of the soluble nickel, and that the shutdown of the Polyols Plant accounts for 11% reduction. Bloom Test. at 6. Together, would you say those two steps alone have reduced the nickel output by 46%?

38) In addition, you pointed out that the excess sludge removal has enabled ADM to remove more than 10 million dry pounds per year in 2016 and 2017. Bloom Test. at 6. You also noted improved housekeeping has resulted in reductions as well. Bloom Test. at 5. Can you estimate what additional percentage sludge removal and housekeeping efforts have contributed to the reduction in nickel output?

39) With the gradual decline in nickel in the effluent to the District's Main Plant from about 0.120 mg/L to about 0.060 mg/L since 2010 (Bloom Test. at 7), would you estimate the reductions identified above at about 50% compared to how the facility was operating in 2007 when the nickel issue was brought to the forefront in the 2007 NPDES Permit?

40) The Amended Petition states that Table 4 of Exhibit 43 contains additional details about some of the technologies identified in Table 3 of Exh. 42. Table 4 is "Technical Challenges on Scale Up for Nickel Remediation Chemistries". The first column is blacked out. Should it list the nickel remediation chemistries for each row? If not, would you please explain to which chemistries each row in Table 4 is referring?

Robert Colombo, PhD

You testified that Eastern Illinois University studies of macroinvertebrates and fish communities have found no significant differences between the reaches upstream and downstream of the Decatur discharge. However, EIU did find that abundance and EPT richness, among other parameters, were higher while the macroinvertebrate index of biotic integrity (MBI) was lower downstream. Colombo Test. at 3-4. You also noted that the fish species diversity in the Sangamon River study areas is comparable to other Midwestern streams.

41) Did you evaluate or notice any differences in the study area compared to other Midwestern streams related to the high hardness levels or dissolved organic carbon concentrations? For example, do certain types of fish prefer the high hardness, high DOC aquatic environments?

Proposed Rule Language at Section 303.410

42) Please clarify whether the sample collection protocols to demonstrate attainment of chronic standards specified in Section 302.208(b) still apply to proposed site specific chronic nickel water quality standard.

43). Please comment on the following changes to the proposed site specific rule language:

Section 303.410 Chronic Nickel Water Quality Standard for Segment of the Sangamon River

The general use chronic water quality standard for dissolved nickel contained in Section 302.208(e) shall not apply to the segment of the Sangamon River, which receives discharges from the Sanitary District of Decatur's Main Sewage Treatment Plant~~STP~~, from that facility's Outfall 001 located at 39° 49' 56" North Latitude, 89° 0' 7" West Longitude, to the point of the confluence of the Sangamon River with the South Fork of the Sangamon River near Riverton. Instead, ~~nickel levels in such~~ waters in this segment of the Sangamon River must ~~shall~~ meet a chronic water quality standard for dissolved nickel as follows:

Chronic Dissolved Nickel Standard = exp[A+Bln(H)] x 0.997* x WER, where A = -2.286, B = 0.846, ln(H) = natural logarithm of Hardness, * = conversion factor multiplier for dissolved metals, and WER = 2.50