Peer Review of the Draft Transbasin Effects Analysis Technical Report Northwest Area Water Supply Project, North Dakota

November 2012

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TABLE OF CONTENTS

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1.0 INTRODUCTION

1.1 Background

For more than two decades, the Bureau of Reclamation (Reclamation), in partnership with the State of North Dakota, has completed numerous environmental and engineering studies relative to the planning and construction of the Northwest Area Water Supply Project (Project). For two of the alternatives currently being evaluated in the Supplemental Environmental Impact Statement, the proposed water source for this bulk water supply system is Lake Sakakawea, a U.S. Army Corps of Engineers reservoir impounded by Garrison Dam on the Missouri River. Water from Lake Sakakawea would be pumped 45 miles north to the City of Minot which would serve as the distribution point for city residents as well as distributing water to other communities and rural water systems throughout the service area.

Lake Sakakawea is located within the Missouri River drainage. The majority of the communities and rural water systems to be served by the Project are located within the Hudson Bay drainage. Potential impacts associated with this interbasin transfer of water have been a key issue evaluated during the planning and development of the Project.

The State of North Dakota initiated Project planning efforts in 1986 after passage of the Garrison Diversion Unit Reformulation Act in 1986 that authorized use of federal appropriations for planning and construction of municipal, rural and industrial (MR&I) water supply projects throughout North Dakota. Over the next several years, community and rural water system needs were identified and alternatives to meet those needs were evaluated. Various studies concluded that the existing ground water sources within the service area are of poor quality, and the Souris River is a marginal source from both a quality and quantity standpoint. The Project is intended to resolve these problems.

During planning of the Project, environmental issues associated with the construction, operation and maintenance of the Project were evaluated as required by the National Environmental Policy Act (NEPA). Based on the Final Environmental Assessment (EA), Reclamation signed a Finding of No Significant Impact (FONSI) in September 2001 and proceeded with the proposed Project. In January 2001, the Secretary of the Interior (Secretary) signed a determination that the Project would meet the requirements of the Boundary Waters Treaty of 1909 by providing adequate treatment of Project water transported from the Missouri River into the Hudson Bay drainage.

Project construction began in 2002; however, that same year the Province of Manitoba, Canada filed a lawsuit against the Department of the Interior (DOI) challenging the FONSI, and requested an injunction prohibiting authorization or expenditure of federal funds on the Project and a stop in construction activities. In 2005, the Court ordered Reclamation to revisit the FONSI upon completion of further environmental analyses, which consider potential impacts associated with not fully treating the Missouri River water at its source and potential impacts that could occur due to pipeline leaks and possible failure of water treatment systems. However, the Court has allowed construction to continue on project features that will not prejudice future decisions on water treatment. Construction was allowed to continue under existing contracts and the 45 miles of main water transmission pipeline between Lake Sakakawea and the City of Minot was completed in 2008.

In 2006, Reclamation initiated preparation of an environmental impact statement (EIS) to address issues identified in the Court Order and evaluate water treatment alternatives that would further reduce the risk of transferring invasive aquatic species from the Missouri River drainage to the Hudson Bay drainage through the operation and maintenance of the Project. The scope of the EIS focused on evaluating environmental impacts associated with the proposed biota water treatment alternatives in the event of an interruption in the treatment process for each alternative. To further reduce the risk of a Project-related biological invasion from the Missouri River drainage to the Hudson Bay drainage, Reclamation evaluated a range of biota water treatment technologies. The final EIS was released to the public in 2009, and a Record of Decision (ROD) was signed by Reclamation's Great Plains Regional Director in 2010.

In 2009, additional lawsuits were filed by the Province of Manitoba and the State of Missouri alleging that the EIS was insufficient. The Court subsequently ordered Reclamation to take a "hard look" at (1) cumulative impacts of water withdrawal on the water levels of Lake Sakakawea and the Missouri River, and (2) the consequences of biota transfer into the Hudson Bay basin including Canada. These items are being addressed in a supplemental EIS and in a draft *Transbasin Effects Analysis Technical Report* (Report), which evaluates the risks and consequences of transferring non-native aquatic biota to the Hudson Bay basin both through Project-related and non-Project pathways.

1.2 Scope of Peer Review

Reclamation requested a peer review of the draft Transbasin Effects Analysis Technical Report. The scope of this peer review included convening a panel of ecological risk assessment and fish disease/parasite experts to review the draft Report, determining whether the Report is based on the best available scientific information and determining whether the results and conclusions presented in the Report are supported by the best available scientific information, given the uncertainties in that science. The panel was requested to:

1. Review the draft Report and previous risk analyses conducted for the Project.
2. Review relevant scientific literature and other information associated with ecological risk and consequence analysis for aquatic invasive species with an emphasis on waterborne parasites and pathogens.
3. Determine whether any relevant scientific information that might influence the results and conclusions of the draft Report was not considered.
4. Determine whether the results and conclusions presented in the draft Report are supported by the best available scientific information, given the uncertainties in that science.
5. Prepare written comments including conclusions on whether the Report is based on the best available science and whether results and conclusions presented in the Report are supported by that science given the uncertainties, as well as any citations of relevant scientific literature that was not considered in the draft Report.
6. Consider, and incorporate as appropriate, comments provided by Reclamation.

2.0 PEER REVIEW PROCESS

Atkins, North America, hereafter referred to as Atkins, was retained by Reclamation to facilitate the peer review process. The terms of the contract include the following:

- Convene (interview, solicit and retain) a panel of three experts on fish pathogens and parasites, ecological risk and consequence analysis and surface water treatment and disinfection for waterborne parasites and pathogens.
- Coordinate the panel's review of the draft Report and previous risk analyses conducted for the Project.
- Coordinate the panel's review of relevant scientific literature and other information associated with ecological risk and consequence analysis for aquatic invasive species with an emphasis on waterborne parasites and pathogens.
- In coordination with the panel, determine whether any relevant scientific information that might influence the results and conclusions of the draft Report was not considered.
- In coordination with the panel, determine whether the results and conclusions presented in the draft Report are supported by the best available scientific information, given the uncertainties in that science.
- Provide a draft report within 30 calendar days of the award of the contract. The draft report should include the panel's conclusions whether the Report is based on the best available science and whether the results and conclusions presented in the Report are supported by that science given the uncertainties; individual and collective comments of respective panel members; and appropriate citations.
- Consider and incorporate, as appropriate, comments provided by Reclamation.
- Provide a final report within 60 calendar days of award of the contract.

Rebecca Burns and Tom St. Clair facilitated the peer review on behalf of Atkins.

2.1 Selection of Reviewers

As part of its proposal, Atkins was required to submit the names and resumes of three well-qualified, independent reviewers whose expertise includes the following:

1. Fish pathogens and parasites
2. Ecological risk and consequence analysis
3. Surface water treatment and disinfection for waterborne parasites and pathogens

Atkins was instructed not to consider individuals from the cooperating agencies, which reviewed the report, as members of the review panel. The cooperating agencies include the Environmental Protection Agency, the Corps, the U.S. Fish and Wildlife Service (USFWS or Service), the State of North Dakota, Garrison Diversion Conservancy District and the City of Minot. In addition, individuals from the United States Geological Survey and Mr. Walt Haerer from Decision Support Inc. were not to be considered for the review panel because they authored previous risk analyses for this Project.

In addition, Atkins was instructed to ensure reviewers had no financial or other conflicts of interest with the outcome or implications of the Report.

Atkins confirmed three potential reviewers who met the criteria listed above and were willing and available to participate in the review. Their names and resumes were submitted as part of the proposal and were confirmed by Reclamation with acceptance of the proposal. The final panel composition was:

- **Fish Pathogens and Parasites:** Dr. Paul R. Bowser, Cornell University
- **Ecological Risk and Consequence Analysis:** Dr. Nicholas A. Friedenberg, Applied Biomathematics
- **Surface Water Treatment and Disinfection:** Dr. Jörg E. Drewes, Colorado School of Mines

The qualifications of each reviewer are included in Appendix A.

2.2 Document Review and Report Development

Upon selection, the panel was provided with the draft Report, a link to a secure file-sharing site with copies of previous risk analyses and other relevant scientific literature provided by Reclamation and instructions for conducting the review. Atkins held a brief teleconference with the panel on October 12, 2012 to describe the review process and schedule and ensure that the panel did not release any information regarding this peer review or respond to any outside inquiries for information.

Reviewers conducted their independent desk reviews of the draft Report between October 8, 2012 and October 29, 2012. The compiled individual reviews are included in this document as Appendix B. On October 31, 2012 a teleconference was held with the panel to discuss their individual comments and develop any collective comments. In the Results section of this peer review report, Atkins summarizes the reviewers' individual and collective comments relative to whether the Report is based on the best available science and whether results and conclusions presented in the Report are supported by that science given the uncertainties associated with the design and operation of the Project. A draft of this report was submitted to Reclamation on November 2, 2012 for review and comment. On November 21, 2012 Reclamation staff notified Atkins that they had no specific technical comments or questions, but had two editorial changes to the Introduction to make it consistent with other information being prepared as part of the NEPA process. Those changes were incorporated and the peer review report was finalized.

3.0 RESULTS

Overall, the reviewers found the draft Transbasin Effects Analysis Report to be based on the best available science and its results and conclusions to be supported by that science, given the uncertainties. Each reviewer noted some, relatively minor, exceptions or areas that could be enhanced with additional and/or updated information; those points are summarized by discipline in the sections below. Two reviewers (Friedenberg and Drewes) independently raised related concerns about the impact of variability on the efficacy of water treatment methods, which is tied to turbidity. They pointed out the potential for failure of treatment system components, particularly if they are correlated or dependent, which is not adequately discussed in the Report.

Collectively, the panel agreed that the draft Transbasin Effects Analysis Technical Report could be improved by the inclusion of a quantitative microbial risk analysis. The qualitative analysis presented is intended to cope with the large uncertainties inherent in the biological and engineering systems within the scope of the study and to avoid the need for empirical studies. However, additional analysis in a quantitative framework is needed to make the Report's conclusions specific. Such an analysis should address the variability of disinfection efficiency, rates of human error in the operation of treatment and safety systems, and the extent to which the events required for aquatic invasive species (AIS) transfer may be correlated or dependent. The Report should also suggest a response plan for mitigating these consequences.

3.1 Fish Pathogens and Parasites

Dr. Bowser concluded that the draft Report was prepared utilizing the most current science-based information on infectious diseases of fish, with a few exceptions, and its results and conclusions are supported by that science given the uncertainties. His comments primarily concern information provided on Viral Hemorrhagic Septicemia Virus (VHSV) because of the fact that its recent emergence is a significant concern and the draft Report contains some misleading statements. Specifically, he noted far more than the 28 species of fish listed on the U.S. Department of Agriculture’s (USDA) Animal and Plant Health Inspection Service (APHIS) VHSV Federal Order are susceptible to this virus. Additionally, he provided references for updated information on VHSV genetics (Thompson et al. 2011, Cornwell et al. 2012) as the information cited in the draft Report is dated and possibly incorrect. In Table 2 of the draft Report, he identified two fish species (Common Carp and Fathead Minnow) which should be the added because they have been evaluated for their susceptibility to VHSV (Cornwell et al. in press-a, Al-Hussinee et al. 2010, Cornwell et al. in press-b). Perhaps most notably, he clarified there is no evidence documenting strain variation of VHSV in the Great Lakes Basin as is stated on page 88 of the draft Report. While research is underway no results are currently available; he suggested that the ISU (2007) report was misinterpreted in this instance. He also provided a general reference on VHSV (Bowser 2009) for further information, which is included as Appendix C.

Dr. Bowser identified several sentences within the Report related to bacterial and viral diseases and aquaculture that are vague, incorrect or confusing, and suggested either revision or deletion.

3.2 Ecological Risk and Consequence Analysis

Dr. Friedenberg offered several areas where the draft Report could be improved relative to its ecological risk and consequence analysis. Firstly, he commented that the Report should have taken a quantitative rather than a qualitative approach to risk analysis. He recommended the Report include the quantitative results of risk analyses previously conducted on the probability of introducing foreign biota to the Hudson Bay Basin (e.g., Reclamation and Decision Support 2000).

Dr. Friedenberg observed the draft Report does not directly consider variability and uncertainty in the efficacy of the proposed water treatment methods. He specifically noted the likelihood of environmental variation in turbidity (which is linked to treatment efficacy) at the point of chlorination, despite earlier steps to reduce turbidity. He added that this “Failure or chronic variance in the efficacy of the discrete systems discussed in the report should be considered in a framework that includes correlation or dependency among systems.” He further noted the Report overlooks the possibility system components (e.g., warning systems, control valves) could be correlated or dependent. For example, high turbidity resulting from a flood could reduce treatment efficacy and stress the delivery system. He provided two references on this topic for consideration (Ferson et al. 2004, Ferson and Burgman 1995).

He also recommended a sensitivity analysis be conducted to demonstrate the risk of biota transfer as a function of concentration and susceptibility to treatment for general classes of biota of concern. He noted the risk of biota transfer relative to non-project pathways may not be informative given uncertainty about the identity of future AIS, thus the Report should include and discuss absolute risks.

Finally, Dr. Friedenberg commented on uncertainty regarding the capacity of populations for compensatory growth (density dependence), noting that this is the area of population-level effects with the greatest lack of knowledge. He offered two publications on this topic for consideration (Ginzburg et al. 1990, Rose et al. 2002) and included several other specific comments in his review, which are relatively minor.

3.3 Surface Water Treatment and Disinfection

Dr. Drewes concluded that the results and conclusions presented in the draft Report relative to surface water treatment and disinfection are supported by the best available scientific information, and commented that the draft Report considers all relevant scientific information. His comments focused on additional recommendations to ensure proper operation of the proposed treatment alternatives, as well as a clarification on terminology used by the Report.

Dr. Drewes agreed with the Report’s conclusion that the likelihood of a complete failure of the Biota water treatment plant (WTP) is very low. However, he noted the possibility that certain treatment plant components could fail, in particular any or all of the proposed disinfection processes, and human error could cause accidental discharge of non-disinfected water. He provided a hypothetical example wherein the by-pass valve that routes raw water to the disinfection process is accidentally opened as high turbidity (greater than 10 nephelometric turbidity units [NTU]) raw water is being received. Under this scenario the disinfection efficiency for both chlorine and especially ultraviolet (UV) irradiation could fail, resulting in discharge of non-disinfected water into the transfer pipeline. He pointed out that detailed information on proposed procedures to mitigate failures such as this is not described in the draft Report or in supplemental information (e.g., USGS 2005, 2007; Reclamation 2008). As a result, he strongly recommended that, following a Hazard Analysis and Critical Control Point (HACCP) assessment, detailed response plans be developed for the final treatment plan design of the Biota WTP.

Additionally, Dr. Drewes clarified that the correct terms are “Chlorination/UV Irradiation” and “Enhanced Chlorination/UV Irradiation” and noted specific locations where corrections should be made.

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5.0 APPENDICES

Appendix A: Reviewer Curricula Vitae
Appendix B: Individual Reviewer Comments
Appendix C: Fish Diseases: Viral Hemorrhagic Septicemia (VHS)

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APPENDIX A: REVIEWER CURRICULA VITAE

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Paul R. Bowser
Department of Microbiology and Immunology
College of Veterinary Medicine
Cornell University, Ithaca, New York 14853-6401
Phone: 607-253-4029
Fax: 607-253-3384
e-mail: prb4@cornell.edu

EDUCATION

Degree	Institution	Year
B.S.	Cornell University	1970
M.S.	Iowa State University	1972
Ph.D.	Auburn University	1978

POSITIONS

1995-present: Professor of Aquatic Animal Medicine, College of Veterinary Medicine, Cornell University.
1985-1995: Associate Professor of Aquatic Animal Medicine, CVM, Cornell Univ.
1983-1985: Assoc. Professor of Aquatic Animal Med., CVM, Mississippi State Univ.
1980-1983: Assist. Professor of Aquatic Animal Med., CVM, Mississippi State Univ.
1978-1980: Assist. Professor/Assist. Pathologist, Agricultural Experiment Station, Univ. of California at Davis, Aquaculture Program, Bodega Marine Lab.
1972-1975: United States Naval Officer, Lieutenant at release from active duty:

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Fish Health Section/American Fisheries Society (President 2002-2003)
World Aquaculture Society
European Association of Fish Pathologists
Wildlife Disease Association
International Association for Aquatic Animal Medicine

HONORS

Sigma Xi, Phi Kappa Phi, Gamma Sigma Delta

Dean's Pegasus Award for Research, College of Veterinary Medicine, Mississippi State University, 1981

Fisheries Scientist, American Fisheries Society Board of Certification, 1980.Re-certified - 2003. 2009

Fish Pathologist, Fish Health Section Board of Certification, American Fisheries Society, Re-certified - 1988, 1993, 1998, 2003, 2007

SUNY Chancellor's Award for Excellence in Faculty Service – 2007.

S. F. Snieszko Distinguished Service Award, Fish Health Section, American Fisheries Society, June, 2009.

Sea Grant College Program Research to Application Award, National Sea Grant College Program, NOAA/Sea Grant, Silver Springs, MD, October, 2010.

SELECTED PUBLICATIONS (from a total of 201)

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Professor Dr.-Ing. JÖRG E. DREWES

Colorado School of Mines, Civil and Environmental Engineering Department, Golden, CO 80401, USA

Phone: +1 303 273-3401 E-mail: jdrewes@mines.edu

EDUCATION

Doctorate in Environmental Engineering (Ph.D.), Technical University of Berlin, Germany 1997

Dipl. Ing. Environmental Engineering (M.S.), Technical University of Berlin, Germany 1992

EXPERIENCE

8/2011-present: **Director of Research.** NSF Engineering Research Center on Reinventing America's Urban Water Infrastructure. Stanford University, Colorado School of Mines, University of California-Berkeley, and New Mexico State University.

8/2010-present: **Visiting Professor.** Water Desalination and Reuse Center (WDRC), King Abdullah University of Science and Technology, Thuwal, Saudi-Arabia.

7/2007-present: **Adjunct Professor**, UNSW Water Research Centre, The University of New South Wales, Sydney, Australia.

3/2010-present: **Professor**, Environmental Science and Engineering Division, Colorado School of Mines, Golden CO. Research and teaching in water supply engineering with an emphasis on advanced water treatment and fate of organic compounds in engineered and natural systems.

4/2007-7/2010: **Director**, Advanced Water Technology Center (AQWATEC). Environmental Science and Engineering Division, Colorado School of Mines, Golden CO.

4/2006-3/2010: **Associate Professor**, Environmental Science and Engineering Division, Colorado School of Mines, Golden CO.

8/2001-4/2006: **Assistant Professor**, Environmental Science and Engineering Division, Colorado School of Mines, Golden CO.

9/1999-7/2001: **Associate Director**, National Center for Sustainable Water Supply (NCSWS), Arizona State University, Tempe, AZ. Coordination of multi-agency and multi-university research and research on character and fate of organics in natural and engineered systems leading to indirect potable reuse.

8/1997-8/1999: **Visiting Professor**, Arizona State University, Tempe, AZ. Research on advanced characterization techniques for organic carbon in groundwater recharge systems.

7/1992-7/1997: **Research Associate,** Technical University of Berlin, Germany, Research on advanced wastewater treatment using powdered activated carbon and ozonation prior to groundwater recharge. Teaching design of water treatment processes, water chemistry, and environmental analytical chemistry.

RESEARCH INTEREST

Water and wastewater treatment engineering; desalination; treatment of co-produced water; potable and non-potable water reuse (soil-aquifer treatment, advanced oxidation and microfiltration/reverse osmosis); natural treatment systems (riverbank filtration, aquifer recharge and recovery); process performance assessments in indirect potable reuse; state-of-the-art characterization of natural and effluent organic matter; fate and transport of emerging contaminants (endocrine disrupting compounds, pharmaceutical residues, household chemicals) in natural and engineered systems.

AWARDS AND HONORS

Panel Member, National Research Council (NRC) on Water Reuse 2008-2010; Member, Research Advisory Council WateReuse Foundation (WRF); Chair, Science Advisory Committee on Compounds of Emerging Concern in Recycled Water, California State Water Resources Control Board; American Water Works Association Rocky Mountain Section Outstanding Research Award, 2007; Dr. Nevis Cook Graduate Teaching Award, Colorado School of Mines, 2003. Quentin Mees Research Award for outstanding water-related environmental research in the State of Arizona, 1999. Research Scholarship administered by the Deutsche Forschungsgemeinschaft (DFG), 1997 – 1999. Willy-Hager Award for outstanding research in the field of water and wastewater treatment, Germany, 1997.

PROFESSIONAL AFFILIATIONS AND SERVICE

Member, Editorial Boards *Journal of Environmental Science and Health; Environmental Engineering Research.* Member, American Water Works Association (AWWA); Water Environment Federation (WEF); International Water Association (IWA); American Membrane Technology Association (AMTA); North American Membrane Society (NAMS); Association of Environmental Engineering & Science Professors (AEESP), Member, Project Advisory Committee, Water Research Foundation, Environmental Protection Agency, Water Environment Research Foundation (WERF), and WateReuse Foundation (WRF). Member, WEF Water Reuse Committee. Member, Rocky Mountain Section AWWA/WEA Water Reuse Committee. Member, Blue Ribbon Panel, City of Aurora, Colorado. Member, Reference Panel, Western Corridor Project, Queensland, Australia. Peer review for scientific journals *(Env. Sci. & Techn., J. Env. Sci. and Health, Chemosphere, Water Research, J. Membrane Science, J. Env. Eng., et al.*).

CURRENT AND COMPLETED RESEARCH PROJECTS (exceeding $13.5M, selected projects listed)

Co-PI – “Reinventing America’s Urban Water Infrastructure Engineering Research Center”. 2011-2016. PI D. Luthy (Stanford), Co-PIs D. Sedlak (Berkeley), N. Khandan (NMSU). National Science Foundation.

Co-PI – “Trace Organic Compounds Removal during Wastewater Treatment – Categorizing Wastewater Treatment Processes by their Efficacy in Reduction of a Suite of Indicator TOrC”.

2009-2011. PI A. Salveson (Carollo), Co-PIs Drs. Snyder (SNWA), Dickenson (CSM), Rauch-Williams (Carollo). Water Environment Research Foundation (WERF) CEC4R08.

PI – "An Integrated Framework for Management and Treatment of Produced Water". 2008-2010. Co-PIs Drs. Cath and Xu (CSM), J. Graydon (Kennedy/Jenks), and J. Veil and S. Synder (Argonne Ant. Lab.) U.S. Dept. of Energy.

Co-PI – "Maximizing Recovery of Recycled Water for Groundwater Recharge". 2009-2010. PI. C. Yu (PSOMAS). Co-PI C. Bellona (CSM). WateReuse Foundation WRF-08-010.
Co-PI – "Water Reuse 2030". PI K. Linden (CU-Boulder), Co-PI S. Khan (UNSW, Australia). 2009-2010. WateReuse Foundation WRF-06-017.

PI - "Predictive Models to Aid in the Design of Membrane Systems for Organic Micropollutants Removal". 2008-2010. Co-PIs Dr. Chris Bellona and Mark Eberhart (CSM) and Dr. Shankar Chellam (University of Houston). WateReuse Foundation WRF-06-009.

PI – "Field Evaluation of a Sequencing batch/Membrane Bioreactor Hybrid System for Decentralized Wastewater Treatment". 2008-2011. Co-PI T. Cath (CSM). Aqua-Aerobics Systems, Inc.

Co-PI - "Comparison of Chemical Composition of Reclaimed and Conventional Waters"". 2007-2008. PI Dr. Shane Snyder (SNWA), Co-PIs Dr. Eric Dickenson (CSM) and Brett Vanderford (SNWA). WateReuse Foundation WRF-06-006.

PI - "Development of Surrogates to Determine the Efficacy of Groundwater Recharge Systems for the Removal of Trace Organic Chemicals". 2006-2009. Co-PIs Dr. Eric Dickenson (CSM) and Dr. Shane Snyder (SNWA). WateReuse Foundation WRF-05-004.

Co-PI - "Critical Assessment of Implementing Desalination Technology". 2007-2008. PI Dr. Pei Xu, Co-PIs Drs. Tzahi Cath and Andrea Schaefer (University of Edinburgh. Awwa Research Foundation.

PI – "Aquifer Recharge and Recovery City of Aurora". CH2MHill/City of Aurora. 2/05-12/07.

PI – "Evaluation of River Bank Filtration Systems to Optimize Removal of Bulk Organic Matter, Emerging Organic Micropollutants and Nutrients". Awwa Research Foundation #3180. 1/06/12/07 (Co-PI Ken Thompson, CH2MHill**).**

PUBLICATIONS (Selection)

Papers in peer-reviewed journals

Drewes, J. E. & Jekel, M. (1996), Simulation of Groundwater Recharge With Advanced Treated *Wastewater*, *Water Science & Technology* 33, 10-11, 409-418.

Drewes, J. E. & Jekel, M. (1998), Behavior of DOC and AOX using advanced treated wastewater for groundwater recharge. *Water Research* 32, 10, 3125-3133.

Drewes, J.E. & Fox, P. (1999), Fate of natural organic matter (NOM) during groundwater recharge using reclaimed water. *Water Science & Technology* 40, 9, 241-248.

Drewes, J.E. & Fox, P. (2000), Effect of drinking water sources on reclaimed water quality in water reuse systems. *Water Environment Research* 72, 3, 353-362.

Drewes, J. E., Fox, P. & Nellor, M. (2000), *Efficiency and Sustainability of Soil-Aquifer Treatment for Indirect Potable Reuse of Reclaimed Water*. I. Chorus et al. (eds.), Water, Sanitation & Health. IWA Publishing, London, 227-232.

Drewes, J. E. & Shore, L. S. (2001). Concerns about pharmaceuticals in water reuse, groundwater recharge, and animal waste. In: Ch. Daughton and T. L. Jones-Lepp (Eds.) American Chemical Society Symposium Series 791 "Pharmaceuticals and personal care products in the environment" No. 791, Washington, D.C., 206-228.

Drewes, J.E., Fox, P. & Jekel, M. (2001), Occurrence of iodinated X-ray contrast media in domestic effluents and their fate during indirect potable reuse. *Journal of Environmental Science and Health*, Part A **36A**. 1633-1645.

Drewes, J. E. & Shore, L. S. (2001), Concerns about pharmaceuticals in water reuse, groundwater recharge, and animal waste. In: Ch. Daughton and T. L. Jones-Lepp (Eds.) American Chemical Society Symposium Series 791 "Pharmaceuticals and personal care products in the environment" No. 791, Washington, D.C., 206-228.

Drewes, J. E. & Fox, P. (2001), Source Water Impact Model (SWIM) – A new planning tool for indirect potable water reuse systems. *Water Science & Technology* **43** (10), 267-275.

Drewes, J. E. & Croue, J.-P. (2002), New approaches for structural characterization of organic matter in drinking water and wastewater effluents. *Water Science & Technology – Water Supply* **2**, 2, 1-10.

Drewes, J. E. & Summers, R. S. (2002). Removal of NOM during bank filtration: Current knowledge and research needs. In: C. Ray, Melin, G. and Linsky, R. (eds.), Riverbank filtration: Improving source water quality. Kluwer Academic Publishers, Dordrecht, The Netherlands. 303-310.

Drewes, J. E., Heberer, T., Rauch, T. & Reddersen, K. (2003), Fate of pharmaceuticals during groundwater recharge. *J. Ground Water Monitoring and Remediation* **23**, 3, 64-72..

Drewes, J. E., Reinhard, M., & Fox, P. (2003), Comparing microfiltration-reverse osmosis and soil-aquifer treatment for indirect potable reuse of water. *Water Research* **37**, 3612-3621.

Kimura, K., Amy, G., Drewes, J. E., & Watanabe, Y. (2003). Adsorption of hydrophobic compounds onto NF/RO membranes – an artifact leading to overestimation of rejection. *J. Membrane Science* **221**, 89-101.

Mansell, J. and Drewes, J. E. (2004). Fate of steroidal hormones during soil-aquifer treatment (SAT). *J. Ground Water Monitoring and Remediation*. 24, 2, 94-101.

Bellona, C., Drewes, J. E., Xu, P. & Amy, G. (2004). Factors affecting the rejection of organic solutes during NF/RO treatment – A literature review. *Water Research* **38**, 2795-2809.

Mansell, J., Drewes, J. E., & Rauch, T., (2004). Removal mechanisms of endocrine disrupting compounds (steroids) during soil-aquifer treatment. *Water Science & Technology* **50**, 2, 229-237.

Rauch, T. & Drewes, J.E. (2004). Assessing the removal potential of soil-aquifer treatment systems for bulk organic matter. *Water Science & Technology* **50**, 2, 245-253.

Drewes, J. E. (2004). Fate and transport of organic constituents during ground water recharge using water of impaired quality. Risk Assessment of Waste Water Re-use on Groundwater Quality. J. Steenvoorden and T. Endreny (eds.). Wastewater Re-use and Groundwater Quality. International Association of Hydrological Sciences (IAHS) Publ. 285. 85-91.Oxfordshire, UK.

Bellona, C. & Drewes, J. E. (2005). The role of physico-chemical properties of membranes and solutes for rejection of organic acids by nanofiltration membranes. *Journal of Membrane Science* **249**, 227-234.

Xu, P., Drewes, J. E., Bellona, C., Amy, G., Kim, T., Adam, M. & Heberer, T. (2005). Rejection of emerging organic micropollutants in nanofiltration/reverse osmosis membrane applications. *Water Environment Research* **77**, 1, 40-48.

Drewes, J. E., Hemming, J., Ladenburger, S., Schauer, J. & Sonzogni, W. (2005). An assessment of endocrine disrupting activity changes in water reclamation systems through the use of bioassays and chemical measurements. *Water Environment Research* **77**, 1, 12-23.

Rauch, T. & Drewes, J. E. (2005). Quantifying biological organic carbon removal in groundwater recharge systems. *J. Environmental Engineering,* June, 909-923.

Kim, T.-U., Amy, G. & Drewes, J. E. (2005). Rejection of trace organic compounds by high-pressure membranes. *Water Science & Technology* **51**, 6-7, 335-344.

Drewes, J. E., Bellona, C., Oedekoven, M., Xu, P., Kim, T.-U., & Amy, G. (2005). Rejection of wastewater-derived micropollutants in high-pressure membrane applications leading to indirect potable reuse. *Environmental Progress* **24**, 4, 400-409.

Rauch-Williams, T. & Drewes, J. E. (2006). Using soil biomass as an indicator for the biological removal of effluent-derived organic carbon during soil infiltration. *Water Research* **40**, 961-968.

Drewes, J. E., Quanrud, D., Amy, G. & Westerhoff, P. (2006). Character of Organic Matter in Soil-Aquifer Treatment Systems. *J. Environmental Engineering* 11, 1447-1458.

Xu, P., Drewes, J. E., Kim, T. Bellona, C. & Amy, G. (2006). Effect of membrane fouling on transport of emerging organic contaminants in NF/RO membrane applications. *J. Membrane Science* 279, 165-175.

Xu, P. and Drewes, J. E. (2006). Viability of nanofiltration and ultra-low pressure reverse osmosis membranes for multi-beneficial use of methane produced water. *Sep. Pur. Techn.* 52, 67-76.

Amy, G. and Drewes, J. E. (2006). Soil-aquifer treatment (SAT) as a natural and sustainable wastewater reclamation/reuse technology: Fate of wastewater effluent organic matter (EfOM) and trace organic compounds. *Environmental Monitoring and Assessment* (in press).

Drewes, J. E., Hoppe, C., & Jennings, T. (2006). Fate and transport of N-nitrosamines under conditions simulating full-scale groundwater recharge operations. *Water Environment Research* 78, 13, 2466-2473.

Sethi, S., Walker, S, Drewes, J. E., & Xu, P. (2006). Existing and emerging concentrate minimization and disposal practices for membrane systems. *Florida Water Resources Journal*, June, 38-48.

Bellona, C. and Drewes, J. E. (2007). Viability of a low pressure nanofilter in treating recycled water for water reuse applications – A pilot-scale study. *Water Research* 41, 3948-3958.

Kim, T-U., Drewes, J.E., Summers, R.S., and Amy, G. (2007). Solute transport model for trace organic neutral and charged compounds through nanofiltration and reverse osmosis. *Water Research*, 41, 3977-3988.

Sethi, S., Xu, P. and Drewes, J.E. (2007). When less is more. *Civil Engineering* 77, 9, 72-75.

Xu, P., Drewes, J.E. and Heil, D. (2007). Beneficial use of co-produced water through membrane treatment: Technical-economic assessment. *Desalination* Vol 225/1-3 pp 139-155.

Benko, K. and Drewes, J.E. (2008). Co-produced water in the Western United States: Geographical distribution, occurrence, and composition. *Environmental Engineering Science* 25, 2, 239-246.

Trenholm, B., Vanderford, B.J., Drewes, J.E., & Snyder, S.A. (2008). Determination of household chemicals using gas chromatography and liquid chromatography with tandem mass spectroscopy. *J. Chromatography A.* 1190: 253-262.

Bellona C., Oelker, G., Luna, J., Filteau, G., Amy, G. & Drewes, J.E. (2008). Comparing nanofiltration and reverse osmosis for drinking water augmentation. *J. American Water Works Association* 100:9, 102-116.

Lowe, K., Van Cuyk, S., Siegrist, R. & Drewes, J. E. (2008). Field Evaluation of the Performance of Engineered Onsite Wastewater Treatment Units. *J. Hydrologic Engineering*, 13:8, 735-743.

Xu, P., Drewes, J.E., Heil, D., and Wang, G. (2008). Treatment of brackish produced water using carbon aerogel-based capacitive deionization technology. Water Research 42:10-11, 2605-2617.

Simon, A., Nghiem, L.D., Le-Clech, P., Khan, S., McDonald, J. and Drewes, J.E. (2009). Effects of membrane degradation on the removal of pharmaceutically active compounds (PhACs) by NF/RO filtration processes. *J. Membrane Science* 340: 16-25.

Drewes, J.E. (2009). Ground Water Replenishment with Recycled Water—Water Quality Improvements during Managed Aquifer Recharge. *Ground Water* 47:4, 502-505.

Dickenson, E.R.V., Drewes, J.E., Sedlak, D.L., Wert, E., and Snyder, S.A. (2009). Applying Surrogates and Indicators to Assess Removal Efficiency of Trace Organic Chemicals during Chemical Oxidation of Wastewater. *Environmental Science and Technology* **43**, 6242-6247.

Rauch-Williams, T., Hoppe-Jones, C., and Drewes, J.E. (2010). The Role of Organic Matter in the Removal of Emerging Trace Organic Contaminants during Managed Aquifer Recharge. *Water Research* 44, 449-460.

Xu, P., Bellona, C., and Drewes, J.E. (2010). Fouling of Nanofiltration and Reverse Osmosis Membranes during Municipal Wastewater Reclamation: Membrane Autopsy Results from Pilot-scale Investigations. *J. Membrane Science* **353**, 111-121.

Conn, K., Lowe, K., Drewes, J.E., Hoppe-Jones, C., and Tucholke, M.B. (2010). Occurrence of Pharmaceuticals and Consumer Product Chemicals in Raw Wastewater and Septic Tank Effluent from Single-Family Houses. *Environmental Engineering Science* **27**:4, 347-356.

Bellona, C., Marts, M., and Drewes, J.E. (2010). The Effect of Organic Membrane Fouling on the Properties and Rejection Characteristics of Two NF Membranes. *Separation and Purification Technology* **74**, 44-54.

Dickenson, E.R.V. and Drewes, J.E. (2010). Quantitative structure property relationships for the adsorption of pharmaceuticals onto activated carbon. *Water Science and Technology* **62** *(in press).*

Bellona, C.L., Würtele, A., Xu, P., and Drewes, J.E. (2010). Evaluation of a bench-scale membrane fouling protocol to determine fouling propensities of membranes during full-scale water reuse applications. *Water Science and Technology* **62**:5, 1198-1204.

Drewes, J.E., Khan, S.J., McDonald, J.A., Trang, T.T.T., and Storey, M.V. (2010). Chemical monitoring strategy for the assessment of advanced water treatment plant performance. *Water Science and Technology* **62** (in press).

Hoppe-Jones, C., Oldham, G., and Drewes, J.E. (2010). Attenuation of Total Organic Carbon and Unregulated Trace Organic Chemicals in U.S. Riverbank Filtration Systems. *Water Research* **44**, 4643-4659.

Le-Minh, N., Khan, S.J., Drewes, J.E., and Stuetz, R. (2010). Fate of antibiotics during municipal water recycling treatment processes. Review. Water Research **44**, 4295-4323.

Cath, T.Y., Hancock, N.T., Lundin, C.D., Hoppe-Jones, C., Drewes, J.E. (2010). A Multi Barrier Hybrid Osmotic Dilution Process for Simultaneous Desalination and Purification of Impaired Water. *J. Membrane Science* **362,** 417-426.

Dickenson, E., Drewes, J.E., Snyder, S.A., and Sedlak, D.L. (2011). Indicator Compounds: An Approach for Using Monitoring Data to Quantify the Occurrence and Fate of Wastewater-Derived Contaminants in Surface Waters. *Water Research* **45**, 1199-1212.

Laws, B., Dickenson, E., Johnson, T., Snyder, S., Drewes, J.E. (2011). Attenuation of Contaminants of Emerging Concern during Surface Spreading Aquifer Recharge. *Sci. Total Environment* 409, 1087-1094.

Stevens-Garmon, J., Drewes, J.E., *Khan*, S., McDonald, J., Dickenson, E. (in press). Sorption of Emerging Trace Organic Compounds onto Wastewater Sludge Solids. *Water Research* 45, 3417-3426.

Dahm, K., Guerra, K., Xu, P., Drewes, J.E. (2011). A Composite Geochemical Database for Coalbed Methane Produced Water Quality in the Rocky Mountain Region. *Environmental Science and Technology* 45, 7655-7663.

Bellona, C., Budgell, K., Ball, D., Drewes, J., and Chellam, S. (2011). Models to predict organic contaminant removal by RO and NF Membranes. IWA Journal, 3(2), 40-44.

Missimer, T., Drewes, J.E., Maliva, R., Amy, G. (2011). Aquifer Recharge and Recovery: Groundwater Recharge Systems for Treatment, Storage, and Water Reclamation. *Ground Water* 49(6), 771-772.

Bellona, C., Heil, D., Yu, C., Fu, P., and Drewes, J. E. (*in press*). The pros and cons of using nanofiltration in lieu of reverse osmosis for indirect potable reuse applications. Submitted to *Separation and Purification Technology*.

Peer-Reviewed Books and Book Contributions

Drewes, J. E. & Jekel, M. (1996). Reuse of Advanced Treated Sewage Effluent for Groundwater Recharge. Nordic Hydrological Programme. Report No. 38. 161-167.

Drewes, J. E., Bornhardt, C. & Jekel, M. (1996). Untersuchungen zur Nutzung von Klarwässern für eine Versickerung auf Rieselfeldböden. Schriftenreihe im Fachbereich Umwelt und Gesellschaft. Landschaftsentwicklung und Umweltforschung, Technische Universität Berlin, Berlin. Nr. 101. 93-100.

Drewes, J. E. (1996). Wende zu einer nachhaltigen Wassernutzung. K.H. Hübler, U. Weiland (Eds.). Nachhaltige Entwicklung. Eine Herausforderung für die Forschung? Verlag für Wissenschaft und Forschung. Berlin. 153-166.

Drewes, J. E. (1997). Behavior of organic compounds in domestic effluents used for groundwater recharge. Fortschritt-BerichteVDI-Verlag No 174, Umwelttechnik, Düsseldorf (in German).

Drewes, J. E., Fox, P. & Ziegler, D. (1998). Impact of drinking water sources on refractory DOC in water reuse systems. Peters et al. (eds.), Artificial Recharge of Groundwater. Balkema, Rotterdam, 461-463.

Drewes. J. E. (1998). Anforderungen an eine nachhaltige Wassernutzung in Berlin-Brandenburg. Forschungs- und Sitzungsberichte. Nachhaltige Raumentwicklung. Szenarien und Perspektiven für Berlin-Brandenburg. Band 205. Akademie fuer Raumforschung und Landesplanung. Hannover. 199-217.

Drewes, J. E., Fox, P. & Nellor, M. (2000), Efficiency and Sustainability of Soil-Aquifer Treatment for Indirect Potable Reuse of Reclaimed Water. I. Chorus et al. (eds.), Water, Sanitation & Health. IWA Publishing, London, 227-232.

Drewes, J. E. & Shore, L. S. (2001). Concerns about pharmaceuticals in water reuse, groundwater recharge, and animal waste. In: Ch. Daughton and T. L. Jones-Lepp (Eds.) American Chemical Society Symposium Series 791 "Pharmaceuticals and personal care products in the environment" No. 791, Washington, D.C., 206-228.

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Drewes, J. E., Barett, M., Appleyard, S., Chilton, J. & Fastner, J. (in press). Chemicals: Health Relevance, Transport and Attenuation. In: WHO Ground Water Monograph. World Health Organization (WHO), Geneva.

Drewes, J. E. (2004). Fate and transport of organic constituents during ground water recharge using water of impaired quality. Risk Assessment of Waste Water Re-use on Groundwater Quality. J. Steenvoorden and T. Endreny (eds.). Wastewater Re-use and Groundwater Quality. International Association of Hydrological Sciences (IAHS) Publ. 285. 85-91. Oxfordshire, UK.

Drewes, J. E. (2005). Wastewater Reclamation and Reuse Research. J.H. Lehr (ed) The Encyclopedia of Water. Wiley Water.

Drewes, J. E., Gower, A., Mitchell, R. & Zabel, T. (2007). Chemicals: Health Relevance, Transport and Attenuation. In: WHO Surface Water Monograph. World Health Organization (WHO), Geneva.

Xu, P., Drewes, J. E., Oedekoven, M., Bellona, C., Amy, G. (2007). Rejection of non-ionic organic micropollutants by nanofiltration membranes: Effect of membrane fouling. AWWA Best Membrane Papers Book. Kerry Howe (ed.). American Water Works Association (AWWA), Denver, Colorado.

Drewes, J.E. (2007). Removal of Pharmaceutical Residues during Wastewater Treatment. Eds. M. Petrovic and D. Barcelo. Analysis, Fate and Removal of Pharmaceuticals in the Water Cycle. Vol. 50. Wilson & Wilson's. Elsevier, Amsterdam. 427-447.

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Drewes, J.E. and Khan, S. (2010). Water Reuse for Drinking Water Augmentation. J. Edzwald (ed.) Water Quality and Treatment, 6th Edition. American Water Works Association. Denver, Colorado.

Xu, P., Cath, T., Wang, G., Drewes, J.E. and Ruetten, J. (2010). Consider the Pros and Cons of Desalination. In Sustainability of Water Resources and Supplies. *Editor Frederick Bloetscher. Publisher American Water Works Association (AWWA).*

Bellona, C. and Drewes, J.E. (2010). Comparing the Phenomenological and Hydrodynamic Modeling Approaches for Describing the Rejection of Emerging Nonionic Organic

Contaminants by a Nanofiltration Membrane. ACS Symposium Series, vol. 1048. Pharmaceuticals and Personal Care Products and Organohalogens. Chapter 20, pp 397–420. DOI: 10.1021/bk-2010-1048.ch020, Washington, D.C.

Applied Biomathematics
100 North Country Rd.
Setauket, NY 11733 USA

phone 631-751-4350
fax 631-751-3534
nick@ramas.com

Nicholas A. Friedenberg
curriculum vitae

EDUCATION

Ph.D., Dartmouth College, NH, 2002.
B.A., Carleton College, MN, 1996.

PROFESSIONAL HISTORY

Senior Scientist at Applied Biomathematics, Setauket, NY. Ecological and evolutionary risk analysis, software development – 2007 to present.

Postdoctoral research at Dartmouth College on the dynamics of southern pine beetle – 2005 to 2007.

Freelance statistical consultant and writer. Established archidictus.org – 2003 to 2005.

Postdoctoral research at the University of Florida on the coevolution of dispersal rate with specialization and its influence on niche conservatism – 2003.

RECENT PROJECTS

2012: Modeling the risk of golden eagle decline in response to wind energy development
The contribution of wind energy development to Indian bat extinction risk

2011: Modeling pest adaptation to transgenic crops (ongoing)
Impacts of invasive Asian carp on native paddlefish population viability (ongoing)
Ecological risks of renewable energy

2010: Evaluation of the USFWS golden eagle model used in determining the take of golden eagles permitted by the Hopi tribe.

2009: Population viability of endangered sturgeon in U.S. rivers (ongoing)

2008: Forest pest risk analysis in dynamic landscapes

2007: Effect of entrainment at cooling water intake structures on fish populations in the Ohio River

PUBLICATIONS AND REPORTS (*covered by NY Times, †noted by Faculty of 1000)

Friedenberg, N.A., J. Palmer, E. Aalto, D. Dixon. Impingement effects on three Ohio River fish species. *In prep.*, Transactions of the American Fisheries Society.

Friedenberg, N.A., J. Hoover, K. Boysen, J. Killgore. Water diversion and the viability of pallid sturgeon in the lower Mississippi River. *In prep.*, Transactions of the American Fisheries Society.

Friedenberg, N.A., J. Hoover, K. Boysen, J. Killgore. Abundance of pallid sturgeon in the middle and lower Mississippi River. *In prep.*, Journal of Applied Ichthyology.

Monzón, J. and **N.A. Friedenberg**. Linking golden eagle population stage structure to the risk of decline. *In prep.*, PLoS One.

Laybourn, A., J. Borrelli, J. Hoover, **N.A. Friedenberg**. Potential impacts of invasive Asian carp on the risk of paddlefish population decline. *In prep.*, Biological Invasions.

Thomas, M., **N.A. Friedenberg**, Klimley, P. *In review*., Stranding of green sturgeon in the Yolo Bypass of the Sacramento River: observations and potential population impacts. North American Journal of Fisheries Management.

Friedenberg, N.A. and K. Shoemaker. 2011. Wildlife risks of wind and solar energy. EPRI Report 1022183.

Dennehy, J.J., **N.A. Friedenberg**, R. McBride, R.D. Holt, P.E. Turner. 2010. Experimental evidence that source genetic variation drives pathogen emergence. Proceedings of the Royal Society of London, Series B, 277: 3113-3121.

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Friedenberg, N.A., J.A. Powell, M.P. Ayres. 2007. Synchrony's double edge: transient dynamics and the Allee effect in stage structured populations. Ecology Letters 10: 564-573.

*****Dennehy, J.J., **N.A. Friedenberg**, Y. Yang, P.E. Turner. 2007. Viral extinction via ecological traps. Ecology Letters 10: 230-340.

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Friedenberg, N.A. 2003. Determinism in a transient assemblage: the roles of dispersal and local competition. American Naturalist 162(5):586-596.

Friedenberg, N.A. 2003. Experimental evolution of dispersal in spatiotemporally variable microcosms. Ecology Letters 6:937.

Hampton, S.E., and **N.A. Friedenberg**. 2002. Nocturnal increases in the use of near-surface water by pond animals. Hydrobiologia 477:171-179.

REVIEWER FOR

American Naturalist, Ecological Applications, Ecology Letters, Journal of Animal Ecology, Functional Ecology, Biology Letters, Nature Reviews Microbiology

PROFESSIONAL MEMBERSHIPS

American Society of Naturalists
Entomological Society of America
American Fisheries Society
American Society for Limnology and Oceanography
New York Academy of Sciences

COMPUTATIONAL TOOLS

RAMAS software library, Matlab, Java, Delphi, R, ArcGIS, GeoTools API

APPENDIX B: INDIVIDUAL REVIEWER COMMENTS

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29 October 2012

Email: Burns, Rebecca E [Rebecca.Burns@atkinsglobal.com]

To: Rebecca Burns
Atkins North America, Inc.
1616 East Millbrook Road, Suite 310
Raleigh, NC, 27609

Fm: Paul R. Bowser, PhD, Sub-Consultant
785 Hayts Road
Ithaca, New York 14850

Re: Peer Review of the Transbasin Effects Document

I have reviewed the document “Transbasin Effects Analysis Technical Report “ (dated 5 October 2012) and am forwarding two documents. The first document contains my comments as a Sub-Consultant/ Peer Reviewer. This document contains those comments I consider most important in my review of the report. The second document, with the heading Minor Comments, contains a number of minor comments in addition to the comments contained in my review. The minor comments consist of such items as corrections of spellings, minor typographic errors and other minor/stylistic issues. I believe incorporating these minor corrections will enhance the credibility of the report.

Should you have any questions regarding my comments, please do not hesitate to contact me.

29 October 2012

Email: Burns, Rebecca E [Rebecca.Burns@atkinsglobal.com]

To: Rebecca Burns
Atkins North America, Inc.
1616 East Millbrook Road, Suite 310
Raleigh, NC, 27609

Fm: Paul R. Bowser, PhD, Sub-Consultant
785 Hayts Road
Ithaca, New York 14850

Re: Peer Review of the Transbasin Effects Document

Review of the "Transbasin Effects Analysis Technical Report " (dated 5 October 2012) Submitted by:

The below comments relate to my review of the "Transbasin Effects Analysis Technical Report " (dated 5 October 2012). My review was focused on issues associated with infectious diseases of fish that were included in the document. My overall conclusion from the Report was, with the exception of those items noted below, that it was prepared utilizing the most current science-based information and results and conclusions presented in the Report are supported by that science given the uncertainties.

Those items for which the authors of the report should consider revisions include:

Page 14: lines 671-672: There are currently 28 species of fish listed on the USDA APHIS VHSV Federal Order. There are far more species of fish that are susceptible to infection with this pathogen. I would suggest:

"Viral hemorrhagic septicemia virus (VHSV) is a serious viral pathogen that can infect a wide variety of freshwater and marine fish species. There are currently 28 species of freshwater fish found in the Great Lakes Basin that are regulated by the VHSV Federal Order (USDA 2009)."

Page 14: lines 678-679: This is old, and possibly incorrect information. I would suggest:

“While there are 4 major genotypes of VHSV on a worldwide basis, there is currently one genotype of VHSV (VHSV Genotype IVb) found in the Great Lakes Basin. However, recent studies have found isolates of VHSV with slight genetic variations (Thompson et al. 2011, Cornwell et al. 2012).”

Refs:

Thompson T.M., W.N. Batts, M. Faisal, P. Bowser, J.W. Casey, K. Phillips, K.A. Garver, J. Winton, G. Kurath. 2011. Emergence of viral haemorrhagic septicaemia virus in the North American Great Lakes Region is associated with low viral genetic diversity. Diseases of Aquatic Organisms. 96:29-43.

Cornwell, Emily R., Geofrey E. Eckerlin, Tarin M. Thompson, William N. Batts, Rodman G. Getchell, Geoffrey H. Groocock, Gael Kurath, James R. Winton, Rufina N. Casey, James W. Casey, Mark B. Bain and Paul R. Bowser. 2012. Predictive factors and viral genetic diversity for viral hemorrhagic septicemia virus infection in Lake Ontario and the St. Lawrence River. Journal of Great Lakes Research. 38:278-288.

A general reference on VHSV for inclusion would be (forwarded with this report as a separate attachment):

Bowser, P.R. 2009. Fish Diseases: Viral Hemorrhagic Septicemia (VHS). Northeast Regional Aquaculture Center, USDA. University of Maryland, College Park, MD. NRAC Publication No. 201-2009. 7 pp.

Page 15: Line 691: The virus was actually detected in a sample that was collected in 2003, but the isolate was not identified as VHSV until 2005. Suggest this wording:

“VHSV was first detected in the Great Lakes Basin in a sample that was collected in 2003. While it is not know when the virus entered the Great Lakes ecosystem, it is likely it was present for several years before that initial isolation.”

Page 16: Line 725: After “A1-7).” Insert: “There appears to be a correlation between clinical BKD and locations were soft water conditions are common.”

Page 17: Lines 783-785: Delete this sentence.
It is vague/incorrect, does not make any sense and contributes nothing to the document.

Page 45: Lines 1801-1804: I don’t see where this sentence contributes to the discussion. Also, rainbow trout and pink salmon are native to some parts of North America. I would delete this sentence and move lines 1804-1806 up to be part of the previous paragraph.

Page 52: in the column labeled “Susceptible to AIS Evaluated:

For Common Carp: add VHSV

Ref: Cornwell, E.R., S.L. LaBuda, G.H. Groocock, R.G. Getchell and P.R. Bowser. Experimental infection of koi *Cyprinus carpio koi* with viral hemorrhagic septicemia virus type IVb. Journal of Aquatic Animal Health. In Press.

For Fathead Minnow: add VHSV

Refs: Al-Hussinee, L., Huber, P., Russell, S., Lepage, V., Reid, A., Young, K.M., Nagy, E., Stevenson, R.M., Lumsden, J.S., 2010. Viral haemorrhagic septicaemia virus IVb experimental infection of rainbow trout, *Oncorhynchus mykiss* (Walbaum), and fathead minnow, *Pimphales promelas* (Rafinesque). J. Fish Dis. 33, 347–360.

Cornwell, E.R., C.A. Bellmund, G.H. Groocock, P.T. Wong, K.L. Hambury, R.G. Getchell, P.R. Bowser. Fin and gill biopsies are effective non-lethal detection methods for viral hemorrhagic septicemia virus type IVb. Journal of Veterinary Diagnostic Investigation. In press.

For this entry in the table, I would just list ***Flavobacterium columnare***

Page 79: Lines 2810-2811: delete this sentence. I think it indicates the mortality for a single event. The sentence implies that 1,500 carp died in 2002 due to VHSV, but the location (in one event, in one state, in the US, in the world?) is not given. I don't see that this sentence adds anything to the document.

Page 79: Lines 2814-2815: This is a poorly written and confusing sentence. I would substitute the following:
"When fish kills occur during the spring, large amount of virus are released into the water as the dead fish decompose."

Page 88: Lines3171-3172: Delete this sentence.
There is **no evidence** currently available that documents strain variation of VHSV in the Great Lakes Basin. I know research is underway in various laboratories (we are performing some), but no results are available yet and no information was available in 2007, the date of the reference. This must have been a mis-interpretation of the reference.

29 October 2012

Email: Burns, Rebecca E [Rebecca.Burns@atkinsglobal.com]

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Re: MINOR COMMENTS: Peer Review of the Transbasin Effects Document

Page ES-2: I would recommend, for the sake of consistency for the viruses, to provide the virus family for those pathogens listed:

Family Birnaviradae
Family Rhabdoviridae
Family Rhabdoviridae
Family Herpesviridae
Family Rhabdoviridae
Family Orthomyxoviridae

(as it stands now, some of the information listed in “Latin Name” contains species, subfamily and family)

Bacteria: Columnaris disease: the bacterium is ***Flavobacterium columnare***

Page 9: Same comments as above for Page ES-2.

Page 14: lines 671-672: There are currently 28 species of fish listed on the USDA APHIS VHSV Federal Order. There are far more species of fish that are susceptible to infection with this pathogen. I would suggest:

“Viral hemorrhagic septicemia virus (VHSV)is a serious viral pathogen that can infect a wide variety of freshwater and marine fish species. There are currently 28 species of freshwater fish found in the Great Lakes Basin that are regulated by the VHSV Federal Order (USDA 2009).”

Page 14: lines 678-679: This is old, and possibly incorrect information. I would suggest:

“While there are 4 major genotypes of VHSV on a worldwide basis, there is currently one genotype of VHSV (VHSV Genotype IVb) found in the Great Lakes Basin. However, recent studies have found isolated of VHSV with slight genetic variations (Thompson et al. 2011, Cornwell et al. 2012).”

Refs:

Thompson T.M., W.N. Batts, M. Faisal, P. Bowser, J.W. Casey, K. Phillips, K.A. Garver, J. Winton, G. Kurath. 2011. Emergence of viral haemorrhagic septicaemia virus in the North American Great Lakes Region is associated with low viral genetic diversity. Diseases of Aquatic Organisms. 96:29-43.

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Page 15: Line 691: The virus was actually detected in a sample that was collected in 2003, but the isolate was not identified as VHSV until 2005. Suggest this wording:

"VHSV was first detected in the Great Lakes Basin in a sample that was collected in 2003. While it is not know when the virus entered the Great Lakes ecosystem, it is likely it was present for several years before that initial isolation."

Page 16: Line 725: After "A1-7)." Insert: "There appears to be a correlation between clinical BKD and locations were soft water conditions are common."

Page 16: Lines 731, 732 and 759 (3 lines): ***Flavobacterium columnare***

Page 17: Lines 783-785: Delete this sentence.
It is vague/incorrect, does not make any sense and contributes nothing to the document.

Page 17: Line 797: Hemorrhagic spots……..

Page 31: Lines 1370: delete the second mention of potassium permanganate.

Page 45: Lines 1801-1804: I don't see where this sentence contributes to the discussion. Also, rainbow trout and pink salmon are native to some parts of North America. I would delete this sentence and move lines 1804-1806 up to be part of the previous paragraph.

Page 48: Line 1921: delete "in" at the end of the sentence

Page 52: in the column labeled "Susceptible to AIS Evaluated":

For Common Carp: add VHSV

Ref: Cornwell, E.R., S.L. LaBuda, G.H. Groocock, R.G. Getchell and P.R. Bowser. 2012. Experimental infection of koi *Cyprinus carpio koi* with viral hemorrhagic septicemia virus type IVb. Journal of Aquatic Animal Health. In Press.

For Fathead Minnow: add VHSV

Refs: Al-Hussinee, L., Huber, P., Russell, S., Lepage, V., Reid, A., Young, K.M., Nagy, E., Stevenson, R.M., Lumsden, J.S., 2010. Viral haemorrhagic septicaemia virus IVb experimental infection of rainbow trout, *Oncorhynchus mykiss* (Walbaum), and fathead minnow, *Pimphales promelas* (Rafinesque). J. Fish Dis. 33, 347–360.

Cornwell, E.R., C.A. Bellmund, G.H. Groocock, P.T. Wong, K.L. Hambury, R.G. Getchell, P.R. Bowser. Fin and gill biopsies are effective non-lethal detection methods for viral hemorrhagic septicemia virus type IVb. Journal of Veterinary Diagnostic Investigation. In press.

Page 58: Columnaris: ***Flavobacterium columnare***

The history of names is: ***Flavobacterium columnare***
Flavobacterium columnaris
Flexibacter columnaris
Cytophaga columnaris
Myxobacter columnaris
Chondrococcus columnaris

(Note: I did my M.S. Thesis on this bacterium when it was *Chondrococcus columnaris*.)

For this entry in the table, I would just list ***Flavobacterium columnare***

Page 72: Line2543: ***Renibacterium salmoninarum***

Page 73: Line 2555 ***Flavobacterium columnare***

Page 79: Lines2810-2811: delete this sentence. I think it indicates the mortality for a single event. The sentence implies that 1,500 carp died in 2002 due to VHSV, but the location (in one event, in one state, in the US, in the world?) is not given. I don't see that this sentence adds anything to the document.

Page 79: Lines 2814-2815: This is a poorly written and confusing sentence. I would substitute the following:
"When fish kills occur during the spring, large amount of virus are released into the water as the dead fish decompose."

Page 82: Line 2916: at the end of the line: "Lake St. Clair"

Page 88: Lines3171-3172: Delete this sentence.

There is **no evidence** currently available that documents strain variation of VHSV in the Great Lakes Basin. I know research is underway in various laboratories (we are performing some), but no results are available yet and no information was available in 2007, the date of the reference. This must have been a mis-interpretation of the reference.

Page 110: 8^{th} entry in the table: ***Flavobacterium columnare***

Review of Transbasin Effects Analysis Technical Report

Nicholas A. Friedenberg
Applied Biomathematics, Setauket, NY

Report summary:
The Transbasin Effects Analysis Technical Report (referred to henceforth as the report) discusses the agents and mechanisms of biological risk associated with the transfer of water between the upper Missouri River Basin and the Hudson Bay Basin. The report extends the methods and findings of previous government studies to an expanded set of biota and additionally draws on a range of sources from the scientific literature.

General Comments:
1) While this report addresses a much larger set of specific biota than the USGS (2007) biota transfer risk analysis, it reaches the same basic conclusion
The report does not make effective use of the quantitative risk analyses that have been conducted on the project relating to the probability of introducing foreign biota to the Hudson Bay Basin. Where quantitative estimates of the risk of biota transfer have been made for *Giardia*, viruses, and whirling disease spores (e.g., NAWS Comparative Risk Analysis, 2000), those results are primarily reported here in qualitative terms such as “practically zero.” The report should include the quantitative results.

2) The report should have taken a quantitative rather than qualitative approach to risk analysis.

3) To the extent that the report relies upon the USGS (2007) NAWS Risk Analysis Report, it suffers from an apparent lack of direct consideration of variability and uncertainty in the efficacy of water treatment methods. The 2007 report gives some elaboration of sources of contamination or re-contamination in treated water (e.g., Marshall 1992; LeChevallier 1999) but seems to have stopped short of introducing those risks into estimates of treatment efficacy. Furthermore, the TetrES (2001) report includes comments that treatment efficacy is tied to turbidity. While treatment alternatives now include methods that help to reduce turbidity before chlorination, it is hard to imagine that some environmental variation in turbidity is not inherited by the treatment plant at the point of chlorination.

4) The report concludes that biota transfer is highly unlikely in part because it would depend on a cascade of events. However, such a cascade is itself only unlikely if its components are considered independent events. If the disaster at Fukushima taught us nothing, it is that the failure of multiple backup systems is not unlikely if all systems are stressed at the same time. In the case of the transbasin project, failure of treatment facility and warning systems or control

valves could be correlated or dependent. For instance, high turbidity associated with a flood event would reduce treatment efficacy and also stress the delivery system. Correlation and dependency of events are often overlooked, leading to widespread underestimates of risk. A good discussion on this topic can be found in: Scott Ferson, Roger B. Nelsen, Janos Hajagos, Daniel J. Berleant, Jianzhong Zhang, W. Troy Tucker, Lev R. Ginzburg, and William L. Oberkampf. 2004. *Dependence in probabilistic modeling, Dempster-Shafer theory, and probability bounds analysis*. Sandia National Laboratory, SAND2004-3072. 151 pp. Another reference, aimed more at biological assessments, can be found in: Ferson, S. and M. Burgman. 1995. Correlations, dependency bounds and extinction risks. Biological Conservation 73:101–105.

5) The bulk of the uncertainty elaborated in the report concerns consequences of AIS transport. To date there is no model that can predict the success of an invasion or its precise ecological effects. However, from a precautionary perspective, it is sufficient to assume that the consequences will be “bad” or “undesirable” and will lead to irreversible alteration of ecosystem services.

6) The fact that a set of focal biota present a low absolute risk or low risk relative to non-project pathways is not a general assessment of the risk of biota transfer. The history of notable species invasions is one of novel and unexpected species. This report would benefit from a sensitivity analysis demonstrating the risk of biota transfer as a function of biota concentration and susceptibility to treatment for general classes of biota of concern. Such an analysis would be an elegant and defensible companion to the extended list of specific biota currently included in the report.

Specific Comments:
L302-313. The summary of the TetrES Technical Report should include the assertion that the efficacy of chlorination was overestimated in the CRA.

L 2099. Population declines of threatened, endangered, and recovering species in the HBB should also be considered.

L 2168-2170. While there is indeed always uncertainty about whether reduced vital rates impose a risk of population decline, this is a mature field of applied ecology with well-defined methods. The greatest lack of knowledge regarding population-level effects often surrounds the capacity of the population for compensatory growth (also called density dependence). However, conservative methods for estimating risk to populations in the absence of information about density dependence are long-established (Ginzburg, Ferson, and Ackakaya. 1990. Reconstructability of density dependence and the conservative assessment of extinction risks. Conservation Biology 4(1): 63-70.

L 2451-2456. The transfer of biota is here (and throughout the report) described as a result of an episodic failure of treatment systems. However, it is more likely to be the result of variation in a constant, chronic failure to inactivate/physically exclude AIS. This is perhaps a semantic or rhetorical distinction, but an important one given the report's largely qualitative description of risk.

L 2745-2752. As mentioned above, the uncertainty regarding the impact of any adverse condition on a population largely hinges on that population's capacity for compensatory growth. The statements made and literature cited in this paragraph suggest that we cannot make even a precautionary assessment of risk due to uncertainty in how to scale individual impacts to the population level. Other authors have been more will to try. Again, Ginzburg et al. 1990 is a good reference for conservative assumptions and methods. Also see Rose et al. 2002. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2(4): 293-327 for a more specific discussion of fish population dynamics.

L 3151-3154. The idea that there is such thing as a "new niche" is somewhat controversial. The example given here, a change in the rank abundance of competitors, does not require that a new niche is created. It may be more defensible to say that a common effect of aquatic invasions, and disturbances of ecosystems in general, is to alter the relative abundance or rank dominance of species.

L 3744- 3750. As mentioned in my general comments, the conclusion that transfer of AIS is unlikely because it requires a cascade of events implies that such events are independent. Consideration of correlation or, more severely, dependence among the events required to transfer AIS would increase the assessment of risk.

Main Conclusions:
The Transbasin Effects Analysis Technical Report could be improved by the inclusion of a quantitative risk analysis. Such an analysis could avoid the pitfalls of using specific taxa and target classes of biota and their transfer risk via a broad sensitivity analysis. Failure or chronic variance in the efficacy of the discrete systems discussed in the report should be considered in a framework that includes possible correlation or dependency among systems. Risk relative to non-project pathways may not be informative given that the identity of future AIS is unknown. The report should therefore include and discuss absolute risks.

DREWES ENVIRONMENTAL, LLC
Professor Dr. Jörg E. Drewes

P.O. Box 548
Golden, CO 80402
Phone 303-884-9746
E-mail: jdrewes@mines.edu

October 27, 2012

ATKINS
Attn.: Rebecca Burns
1616 East Millbrook Rd.
Suite 310
Raleigh, NC 27609

Re: Peer review of Transbasin Effects Analysis Technical Report prepared by BOR

Dear Mrs. Burns,

Please find attached my review report as requested for BOR's Transbasin Effects Analysis Technical Report – Oct. 2012.

Please feel free to contact me, if you have any additional questions.

Sincerely,

Professor Jörg Drewes

General:
I reviewed the Technical Report and conclude that the results and conclusions presented in the draft Report are supported by best available scientific information. In particular, I focused my review as requested on water quality and treatment related issues as well as the risk assessment for transbasin water supply. I conclude that any relevant scientific information that affect the results and conclusions of the draft Report was considered. Nevertheless, I have a few recommendations both how to assure proper operation of proposed treatment alternatives and to improve the overall quality of the draft Report.

1. Water Treatment: A potential failure of the Biota WTP to protect against AIS represents a high risk with low probability. While the reviewer agrees with the authors of the draft Report that is unlikely that the Biota water treatment plant would experience a complete failure, it is possible that certain treatment plant components might fail, in particular any or all of the proposed disinfection processes, or human error (plant operators) results in accidental discharge of non-disinfected water. For example, one alternative proposes to utilize filtration steps only if the raw water turbidity exceeds 10 NTU. Therefore, the plant will be equipped with a by-pass to route raw water directly to the disinfection process. If this by-pass valve is accidently opened during times of receiving high turbidity (>10 NTU) raw water the disinfection efficiency both for chlorine and in particular for UV irradiation can fail resulting in discharge of non-disinfected water into the transfer pipeline. Detailed information regarding proposed procedures to mitigate any of these failures are not described in the draft Report or supplemental information (for example the "Northwest Area Water Supply Project Final Environmental Impact Statement" prepared by BOR in December 2008 or the "Risk Assessment Reports" prepared by USGS in 2005 and 2007). The draft Report only states that the Biota WTP "was designed with a robust set of engineering and operational considerations as well as sophisticated failure response systems including alarms, automatic shutdown procedural mechanisms, and motor-operated pipeline isolation valves". Thus, it is highly recommended that following a Hazard Analysis and Critical Control Point (HACCP) assessment detailed response plans are developed for the final treatment plant design of the Biota WTP. Since the Biota WTP technically doesn't have to meet SDWA standards, the operational safeguards and procedures should be comparable if not more stringent given that one incident could result in the release of water containing high amounts of AIS.
2. Technical Specifications: The draft Report uses the term "Chlorination/UV inactivation" and "Enhanced Chlorination/UV Inactivation" to describe a disinfection process, which is correctly described as "Chlorination/UV Irradiation" or "Enhanced Chlorination/UV Irradiation". The reviewer suggests to correct the term used on lines 91, 92, 2254, 2255, 2270, 2290, and 2299.

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APPENDIX C: FISH DISEASES: VIRAL HEMORRHAGIC SEPTICEMIA (VHS)

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NRAC Publication No. 201-2009

Northeastern Regional Aquaculture CENTER
University of Maryland, 2113 Animal Science Building
College Park, Maryland 20742-2317
Telephone: 301-405-6085, FAX: 301-314-9412
E-mail: nrac@umd.edu Web: http://www.nrac.umd.edu

Fish Diseases: Viral Hemorrhagic Septicemia (VHS)

Paul R. Bowser, Professor of Aquatic Animal Medicine
Aquatic Animal Health Program
Department of Microbiology and Immunology
College of Veterinary Medicine
Cornell University, Ithaca, New York 14853-6401

Viral Hemorrhagic Septicemia (VHS) has been described as one of the most devastating fish diseases on a worldwide basis. VHS is caused by the Viral Hemorrhagic Septicemia Virus (VHSV), a member of the virus family *Rhabdoviridae*. Rhabdoviruses are bullet-shaped viruses that contain a single-stranded RNA genome. This is the same family of viruses that contains a distant relative to VHSV, the Rabies Virus. However, it is extremely important to realize that VHSV is a pathogen of fish and poses no health risk to humans.

Historically, VHS has been known for many years as a devastating disease of freshwater-reared rainbow trout on the European continent. Disease events known as early as the 1930's were thought to have a viral cause (a viral etiology), but it was not until the early 1960's, when the techniques of fish cell culture became available, that the virus was cultured and proven to be the cause of Viral Hemorrhagic Septicemia. A major event in the history of VHS occurred in 1988 and 1989 when VHSV was isolated from apparently normal returning sea-run chinook and coho salmon in the Puget Sound area of Washington, in the Pacific Northwest of the United States. There was great concern surrounding the apparent movement of this disease from the European continent to the Pacific Northwest by some unknown mechanism. It was around this time that fish pathologists in Europe isolated VHSV from Atlantic cod. This was followed by the isolation of VHSV from Pacific cod and then from other marine fish species. Discovery of VHSV in marine fish made the fish health community think of VHSV as a pathogen of marine fish that somehow moved into the freshwater trout culture facilities of Europe. While it is not possible to prove the mechanism by which VHSV moved into the freshwater fish culture environment in Europe, one potential mechanism could have been the feeding of unpasteurized "rough fish", which were considered a by-catch of the marine harvest, to those rainbow trout reared in freshwater aquaculture.

The emergence of VHSV in the Great Lakes Basin of North America in 2005 marked another major milestone in the history of this virus and the disease it causes. Up to this time, VHSV was known to exist in various marine fish species in the Atlantic and Pacific Oceans. The confirmation of VHSV infections in several fish species in Lake St. Claire and Lake Ontario (Bay of Quinte) in the spring of 2005 marked the first time this pathogen was identified as a cause of mortality in freshwater fish in North America. As a pathogen that is listed by the OIE (World Organization for Animal Health) as reportable, the finding of VHSV in this new location has significant trade implications on a national and international level.

Because VHSV is an OIE reportable pathogen, the scientific community as well as fisheries managers and aquaculturists must be aware of some special regulatory requirements associated with this pathogen. If a USDA APHIS (United States Department of Agriculture Animal and Plant Health Inspection Service) accredited veterinarian or a laboratory official from an APHIS approved laboratory suspects that they have a diagnostic case in which VHSV will be found, they are legally obligated to report to their USDA APHIS Area Veterinarian-in-Charge. From that point, depending on the circumstances of the case (such as a new fish species being identified as a potential host), arrangements may be made to ship appropriate diagnostic materials to the USDA APHIS National Veterinary Services Laboratories, in Ames, Iowa, for confirmation of the finding.

As of the summer of 2007, appropriate diagnostic materials are understood to mean original fish tissues from the suspect animals. Requirements for veterinarians to report to state authorities will be based on legislation in the state where the veterinary has a license to practice. Reporting may also occur to the Competent Regulatory Authority in the state where the finding occurs as well as the State Veterinarian and the state natural resource agency, depending on whether the identification occurred in a wild or farmed fish and which state agency has authority within the state. Individuals with suspect cases of VHSV and who are not veterinarians, will typical report in a similar manner as a professional courtesy to USDA APHIS as well as other entitites and cooperate in efforts that will limit the adverse impact of important OIE notifiable pathogens, such as VSHV. Upon receipt of a VHSV report, APHIS and state authorities may take regulatory action to eradicate or prevent further spread of the virus. The action taken will depend on circumstances and may include anything from no action to quarantine and eradication of affected fish populations.

The Emergence of VHSV in the Great Lakes Basin

As noted above, VHSV in the Great Lakes Region was first identified in fish collected from the Bay of Quinte, Lake Ontario, Canada in the spring of 2005. The Bay of Quinte isolation of VHSV was the result of an investigation of a massive mortality event of freshwater drum *Aplodinotus grunniens* as well as other species. Subsequent investigation revealed that a virus isolated from diseased muskellunge *Esox masquinongy* collected from Lake St Claire, Michigan in 2003 was, in fact, VHSV. The Lake St. Claire isolate was obtained when muskellunge were being examined for the presence of the piscirickettsia organism and is the earliest isolate from the Great Lakes Region to be identified to date. Until 2005, there were four genotypes of VHSV. Genotypes I, II, and III were known to occur in Europe and Japan. Genotype IV was known to occur in the marine environment of North America, Japan and Korea. The Lake St. Claire isolate of VHSV was most closely related to Genotype IV, which had only been found in the marine environment. However, there was enough difference between the marine VHSV Genotype IV and the freshwater VHSV Genotype IV, that the marine isolates were classified as belonging to Genotype IVa, while the freshwater isolate from the Great Lakes was classified as belonging to Genotype IVb. It is most interesting that all of the subsequent isolates (approximately 30) from the Great Lakes Basin that have undergone genetic evaluation have been found to belong to Genotype IVb and all are virtually identical to the original Lake St. Claire isolate. The value of this information is that it suggests that the emergence of VHSV IVb in the Great Lakes Basin is a relatively new occurrence. This can be said because VHSV is an RNA virus and RNA viruses have a much greater tendency to undergo genetic changes than do DNA viruses. If VHSV IVb had been present in the Great Lakes Basin for a considerable period of time, one would expect to find more genetic diversity in the isolates than has been observed to date (Table 1).

Table 1. Currently known Genotypes and Distribution Viral Hemorrhagic Septicemia Virus (VHSV).

VHSV Genotype I	**Europe**
VHSV Genotype II	**Europe**
VHSV Genotype III	**Europe**
VHSV Genotype IVa	**North America, Japan, Korea**
VHSV Genotype IVb	**North America**

The spring and summer of 2006 were marked by a number of significant mortality events in a wide variety of fish species. Significant mortality events were documented in such species as freshwater drum, yellow perch, and smallmouth bass. Through disease investigations and surveillance efforts, by the end of 2006 VHSV IVb was found in the Great Lakes Basin in the St. Lawrence River, Lake Ontario, Lake St. Claire, and Lake Huron. The 2006 season also marked the first time that VHSV IVb was found in fish outside of the Great Lakes proper when the virus was isolated from walleye from Conesus Lake in New York State.

In 2007, VHSV IVb was found in Lake Michigan in the region of Green Bay, Wisconsin. Most disturbing was that the virus continued to be found in additional inland bodies of water when it was found in Skaneateles Lake, Little Salmon River, Cayuga-Seneca Canal, and a private pond in western New York State, the Lake Winnebago chain of lakes in Wisconsin and in Budd Lake, Michigan. The example of the private pond may stand as a particularly interesting lesson. The owners of the pond were hiking in the area and noted fish in "obvious distress" in a local stream. In a desire to do something they thought would be helpful, they "rescued the fish" and brought them home to be placed them in their private pond. Within approximately one month virtually all of the fish in the pond died and VHSV IVb was identified and confirmed in diagnostic specimens.

The 2008 season was marked by two significant events in the spread of VHSV IVb. The virus was isolated from wild muskellunge collected for use as broodfish from Clear Fork Reservoir, Ohio. This marked the first time that VHSV IVb was found in fish from a location outside of the Great Lakes drainage basin. Clear Fork Reservoir lies in the Mississippi River drainage. A second significant event was the isolation of VHSV IVb in sea lampreys from northern Lake Huron by fish health specialists from the U.S. Fish and Wildlife Service. Fish for which the isolation of VHSV has been confirmed by USDA APHIS are considered regulated species with regard to the VHSV interim rule. With the diversity of regulated fish species (Table 2), the

Table 2. List of Species Regulated by the VHSV interim rule (list effective to 9 September 2008)

Family Centrarchidae	
Black Crappie	*Pomoxis nitromaculatus*
Bluegill	*Lepomis macrochirus*
Largemouth Bass	*Micropterus salmoides*
Pumpkinseed	*Lepomis gibbosus*
Rock Bass	*Ambloplites ruprestris*
Smallmouth Bass	*Micropterus dolomieu*
Family Cyprinidae	
Bluntnose Minnnow	*Pimephales notatus*
Emerald Shiner	*Notropis atherinoides*
Spottail Shiner	*Notropis hudsonius*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Silver Redhorse	*Moxostoma anisurum*
Family Ictaluridae	
Brown Bullhead	*Amieurus nebulosus*
Channel Catfish	*Ictalurus punctatus*
Family Esocidae	
Muskellunge	*Esox masquinongy*
Northern Pike	*Esox niger*
Family Percidae	
Walleye	*Sander vitreus*
Yellow Perch	*Perca flavescens*
Family Salmonidae	
Brown Trout	*Salmo trutta*
Chinook Salmon	*Oncorhynchus tshawytscha*
Lake Whitefish	Coregonus *clupeaformis*
Rainbow Trout	*Oncorhynchus mykiss*
Family Gadidae	
Burbot	*Lota lota*
Family Scianidae	
Freshwater Drum	*Aplodinotus grunniens*
Family Gobiidae	
Round Goby	*Neogobius melanostomus*
Family Clupeidae	
Gizzard Shad	*Dorosoma cepedianum*
Family Moronidae	
White Bass	*Morone chrysops*
White Perch	*Morone americana*
Family Percopsidae	
Trout-Perch	*Percopsis omiscomacys*

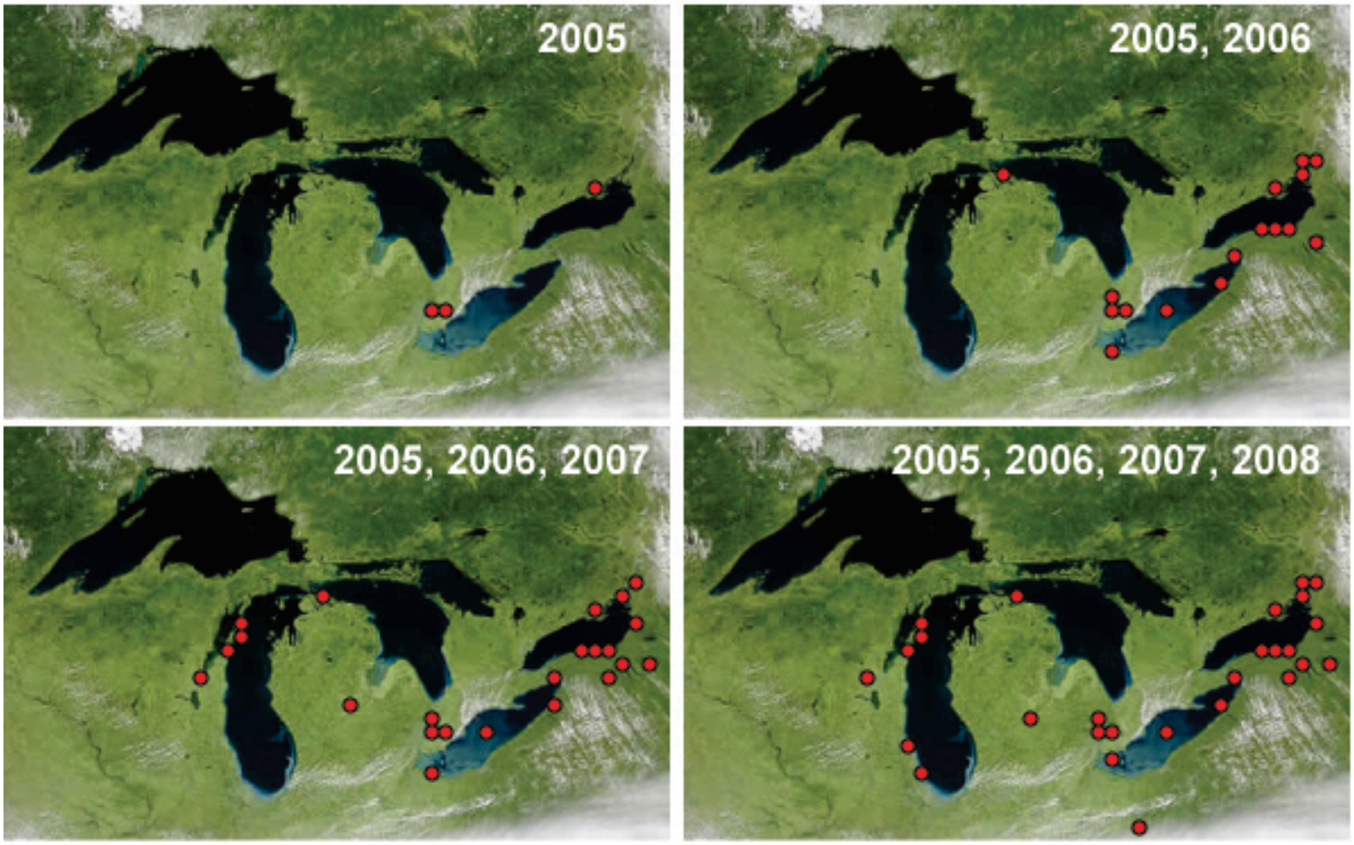

Figure 1. Map of the Great Lakes Region showing cumulative fish mortality events with confirmed isolations of VHSV IVb from 2005 through 2008. (basic map from http://www.coastwatch.msu.edu)

aquaculturist should exercise caution even when dealing with fish that are not on the regulated list. As of the end of the 2008 season, the "List of Fish Species Affected by the VHSV Federal Order" included 28 species from a variety of fish families.
(http://www.aphis.usda.gov/animal_health/animal_dis_spec/aquaculture/ downloads/vhs_regulated_spp.pdf).

The Disease: Viral Hemorrhagic Septicemia

The name of the disease, Viral Hemorrhagic Septicemia, describes the typical pathology one might observe. Among the various types of lesions caused are those involving hemorrhage. The virus can destroy the endothelial cells, the cells lining the interior of the blood vessels. The vessels are then unable to retain blood and hemorrhage occurs. While hemorrhage is a common lesion associated with VHS, hemorrhage can also occur as a result of fish diseases caused by a wide variety of other viral, bacterial, parasitic diseases and can be caused by water quality, toxic or even mechanical injuries. A further complication in the disease diagnostic picture is that not all fish species and not all fish in a group of the same species may show what are described as the most common or "typical signs" of VHSV. The bottom line is that visible signs of disease are used by the fish pathologist or veterinarian as supportive information in reaching a diagnosis, but a confirmed diagnosis can only be reached when supportive laboratory-based information is also available.

Diagnosis of VHS

A diagnosis of the presence of VHSV must be based on laboratory testing of appropriate samples from infected fish. In that VHSV is an OIE reportable pathogen, there are specific laboratory techniques that have been designated by the international community as acceptable for the diagnosis of VHSV. The accepted diagnostic techniques have undergone a rigorous evaluation prior to their acceptance as the methods of choice.

The current accepted method for the diagnosis of VHSV is a two-stage procedure. The first stage is a screening step where the virus is cultured in fish cell cultures grown in the laboratory. If the virus is present in

The current accepted method for the diagnosis of VHSV is a two-stage procedure. The first stage is a screening step where the virus is cultured in fish cell cultures grown in the laboratory. If the virus is present in the cultured fish cells, a visible change or destruction of the cells can be seen with a microscope. To determine the specific identity of the virus (i.e. is it VHSV or some other virus?) the second stage of the process involved using testing methods that are specific for VHSV. In this second stage, material from the infected cell culture is prepared and assayed by a Reverse Transcriptase – Polymerase Chain Reaction (RT-PCR) that is specific for VHSV. There are two documents that are generally accepted as providing the specific details of thses procedures. These documents are the OIE Aquatic Manual and the American Fisheries Society, Fish Health Section "Blue Book."

Diagnostic methods are continually being modified and improved upon as the biomedical sciences move forward. New and rapid tests that can detect the genetic material of VHSV directly from fish tissues are being developed. While such methods show great promise, they are not currently listed in either the OIE Aquatic Manual or the "Blue Book" and thus are not currently a method that can be used to provide a confirmed diagnosis of any genotype of VHSV for regulatory purposes.

VHSV – Preventing Further Spread

To date there have been no isolations of VHSV from fish reared in any aquaculture facility, government or private, in North America. All individuals who have a stake in fisheries and aquaculture in North America have a stake in maintaining the VHSV-free status of aquaculture on this continent. Preventing the movement of VHSV to locations where it is not currently found can only be accomplished by a multi-faceted effort. That effort must include an understanding of how the virus can be transmitted as well as how it might be transmitted.

While much has been stated in the popular press regarding how VHSV gained entrance into the Great Lakes Basin, there is no definitive proof that demonstrates the method by which that event occurred. The genetic similarities of the Great Lakes Basin and the marine VHSV suggest that the virus moved from the marine environment of the Atlantic coast into the Great Lakes, but this is speculation and not fact. If VHSV did move from the ocean to the Great Lakes and then move within the Great Lakes, some of the methods by which such a movement could have occurred include:

1. Natural movement of an infected fish up the St. Lawrence River.
2. Movement of an infected fish as a food item by a non-human animal (note: investigations have shown that the virus can withstand the acid nature of the gut of animals for approximately 120 minutes).
3. Movement of an infected fish through human intervention (e.g. movement of an infected adult fish for the purpose of "ad hoc stocking."
4. Movement of infected bait.
5. Movement of infected water by recreational boating (e.g. live well water).
6. Movement of the virus on equipment (e.g. fishing equipment, nets, boat hulls).
7. Movement of the virus in ballast water.

Concerns over the spread of VHSV in the United States resulted in Emergency Regulations being implemented in October, 2006 by USDA APHIS. These regulations required that listed live fish that were destined to be shipped interstate within the 8 states bordering the Great Lakes, or entering the United States from the provinces of Ontario or Quebec, Canada, must undergo a fish health inspection and found to be free of VHSV. In addition, certain states have implemented fish health regulations in addition to those of USDA APHIS. At the time of this writing, the Emergency Rule is still in effect, but it is logical to expect that it will some day be supplanted by a more detailed and permanent rule.

The emergence of VHSV in the Great Lakes Basin has heightened the awareness of the aquaculture community of the need for practicing effective biosecurity on their facility. Commercial aquaculturists who have not already done so, should investigate opportunities to receive formal training in biosecurity measures for aquaculture. An effective biosecurity program will include the establishment of the following procedures:

1. Training for all personnel on the aspects of the facility biosecurity program.
2. Maintenance of training records for all personnel.
3. Development of written Standard Operating Procedures (SOPs) for fish health and - biosecurity practices.
4. Limit the movement of new fish onto the - facility property.
5. Only allow the entrance of new fish, or,

preferably, only disinfected fish eggs into the facility after they have undergone a fish health inspection and were found to be free of VHSV and other important fish pathogens.

6. Evaluation of water used on the facility (use only well water or spring water–water that is devoid of other fish and fish pathogens).
7. Establishment of a professional relationship with a fish health program that can provide fish disease diagnostic expertise to the facility.
8. The maintenance of records for all disease events, corrective action(s) taken and success of those actions.
9. Evaluation of the various facility systems, the need for back-up electricity, water and back-up equipment.

Summary

The emergence of VHSV IVb in the Great Lakes Basin has had a significant impact on the wild fish populations of the Great Lakes Basin. Massive mortality events have occurred in some fish species. Because VHSV is one of the few fish pathogens to be listed as a reportable organism by the OIE, the impact of VHSV has also extended into commercial aquaculture in the form of regulations designed to limit the spread of VHSV beyond its current geographic distribution. To date VHSV has not been found in any commercial aquaculture facility in the Great Lakes States. In that VHSV is considered to be the most serious fish disease on a world wide basis, it goes without saying that it is critical that aquaculturist become familiar with and practice sound biosecurity on a day-to-day basis to prevent this devastating pathogen from entering their production facility. As a disease caused by a virus, VHS is not treatable. Currently the only practical means to avoid losses is to avoid the pathogen.

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General Web Sites of Interest

Aquatic Animal Health Program, College of Veterinary Medicine, Cornell University–VHSV Web Page. http://www.vet.cornell.edu/Public/FishDisease/AquaticProg/highlights/VHSV/VHSV%20NYS%20Public.htm

Focus on Fish Health–VHS web site.
http://www.focusonfishhealth.org/
USDA APHIS Newsroom. Viral Hemorrhagic Septicemia. (updated periodically).
http://www.aphis.usda.gov/newsroom/hot_issues/vhs/vhs.shtml

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