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August 2013 To present	Professor, Department of Agricultural and Resource Economics University of Maryland, College Park.
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October 2002 To Dec. 2006	Coordinator, Research Programme in Sustainability Indicators and Environmental Valuation, Fondazione Eni Enrico Mattei (FEEM), Venice.
January 2000 To June 2002	Assistant Professor, Department of Agricultural and Resource Economics University of Maryland, College Park.
August 1995 to December 1999	Assistant Professor, Department of Economics University of Colorado, Boulder.

October 1992 to August 1995 — Fellow, Quality of the Environment Division, Resources for the Future, Washington, D.C.

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Alberini, Anna, Christoph M. Rheinberger, Andrea Leiter, Charles A. McCormick, and Andrew Mizrahi (2010), "What is the Value of Hazardous Weather Forecasts? Evidence from a Survey of Backcountry Skiers," FEEM working paper 2010.085, Milan, Italy, June.

Alberini, Anna, and Milan Ščasný (2010), "Context and the VSL: Evidence from a Stated Preference Study in Italy and the Czech Republic," FEEM working paper 2010.066, Milan, Italy, April.

Cropper, Maureen L., Yi Jiang, Anna Alberini and Patrick Baur (2010), "Getting Cars Off the Road: The Cost-Effectiveness of an Episodic Pollution Control Program," NBER working paper w15904, Cambridge, MA, April.

Cropper, Maureen L., Yi Jiang, Anna Alberini and Patrick Baur (2010), "Getting Cars Off the Road: The Cost-Effectiveness of an Episodic Pollution Control Program," FEEM working paper 2010.046, Milan, Italy, April.

Tonin, Stefania, Anna Alberini, and Margherita Turvani (2009), "The Value of Reducing cancer Risks at Contaminated Sites: Are More Heavily Exposed People Willing to Pay More?" FEEM working paper 09.60, Milan, Italy, July.

Alberini, Anna, Stefania Tonin and Margherita Turvani (2009), "Rates of Time Preferences for Saving Lives in the Hazardous Waste Site Context," FEEM working paper 09.03, Milan, Italy, January.

Rosato, Paolo, Anna Alberini, Valentina Zanatta, and Margaretha Breil (2008), "Redeveloping Derelict and Underused Historic City Areas: Evidence from a Survey of Real Estate Developers," FEEM working paper 2008.60, Milan, Italy, July.

Guignet, Dennis and Anna Alberini (2008), Voluntary Cleanups and Redevelopment Potential: Lessons from Baltimore, Maryland," FEEM working paper 87.08, Milan, Italy, October.

Alberini, Anna and Alberto Longo (2007), "Valuing the Cultural Monuments of Armenia: Bayesian Updating of Prior Beliefs in Contingent Valuation," FEEM working paper 36.07, Milan, Italy, April.

Turvani, Margherita, Aline Chiabai, Anna Alberini and Stefania Tonin (2007), "Public Policies for Contaminated Site Cleanup: The Opinions of the Italian Public," FEEM working paper 11.2007, Milan, Italy, February.

Alberini, Anna, Alberto Longo and Patrizia Riganti (2006), "Using Surveys to Compare the Public's and Decisionmakers' Preferences for Urban Regeneration: The Venice Arsenale," FEEM working paper 137.07, Milan, Italy, November.

Hintermann, Beat, Anna Alberini, and Anil Markandya (2006), "Estimating the Value of Safety with Labor Market Data: Are the Results Trustworthy?" FEEM working paper 119.06, Milan, Italy, September.

Alberini, Anna, Stefania Tonin, Margherita Turvani, and Aline Chiabai (2006), "Paying for Permanence: Public Preferences for Contaminated Site Cleanup," FEEM working paper 113.06, Milan, Italy, September.

Bhattacharya, Soma, Anna Alberini and Maureen Cropper (2006), "The Value of Mortality Risk Reductions in Delhi, India," World Bank Policy Research Working paper 3995, Washington, DC, August.

Alberini, Anna and Aline Chiabai (2006), "Discount Rates in Risk v. Money and Money v. Money Tradeoffs," FEEM working paper 8.2006, Milan, Italy, January.

Alberini, Anna (2006), "Determinants and Effects on Property Values of Participation in Voluntary Cleanup Programs: The Case of Colorado," FEEM working paper 1.2006, Milan, January.

Valentina Zanatta, Paolo Rosato, Anna Alberini and Dimitrios Reppas (2005), "The Impact of Speed Limits on Recreational Boating in the Lagoon of Venice," FEEM working paper 135.05, Milan, November.

Alberini, Anna, Marcella Veronesi and Joseph Cooper (2005), "Detecting Starting Point Bias in Dichotomous-choice Contingent Valuation Surveys," FEEM working paper 119.2005, Milan, October.

Anna Alberini and Alberto Longo (2005), "The Value of Cultural Heritage Sites in Armenia: Evidence from a Travel Cost Method Study," FEEM working paper 112.2005, Milan, Italy, September.

Longo, Alberto and Anna Alberini (2005), "What Are The Effects of Contamination Risks on Commercial and Industrial Properties? Evidence from Baltimore, Maryland," FEEM working paper 111.2005, Milan, Italy, September.

Alberini, Anna, Aline Chiabai and Lucija Muehlenbachs (2005), "Using Expert Judgment to Assess Adaptive Capacity to Climate Change: Evidence From a Conjoint Choice Survey," FEEM Working paper 106.2005, Milan, September.

Alberini, Anna and Aline Chiabai (2005), "Urban Environmental Health and Sensitive Populations: How Much are the Italians Willing to Pay to Reduce their Risks?" FEEM working paper 105.2005, Milan, Italy, September.

Alberini, Anna, Erik Lichtenberg, Dominic Mancini and Gregmar Galinato (2005), "Was It Something I Ate? Implementation of the FDA Seafood HACCP Program," FEEM working paper 104.05, Milan, Italy, July.

Alberini, Anna, Erik Lichtenberg, Dominic Mancini and Gregmar Galinato (2005), "Was It Something I Ate? Implementation of the FDA Seafood HACCP Program," AREC Discussion paper 05-03, University of Maryland, College Park, July.

Alberini, Anna, Valentina Zanatta and Alberto Longo (2005), "Combining Actual and Contingent Behavior to Estimate the Value of Sports Fishing in the Lagoon of Venice," FEEM Working paper 44.05, Milan, March.

Alberini, Anna (2004), "Robustness of VSL Values from Contingent Valuation Surveys," FEEM Working Paper 135.04, Milan, October.

Alberini, Anna, Alistair Hunt, and Anil Markandya (2004), "Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-country Contingent Valuation Study," FEEM Working Paper 111.04, Milan, July.

Alberini, Anna, Maureen Cropper, Alan Krupnick and Nathalie Simon (2004), "Willingness to Pay for Risk Reduction: Does Latency Matter?" National Center for Environmental Economics Discussion paper 2004-01, Washington, DC, February. Available at http://yosemite.epa.gov/EE/epa/eed.nsf/WPNumberNew/2004-01?OpenDocument

Alberini, Anna, Paolo Rosato, Alberto Longo, Valentina Zanatta (2004), "Information and Willingness to Pay in a Contingent Valuation Study: The Value of S. Erasmo in the Lagoon of Venice," FEEM Working Paper 19.2004, Milan, February. Available at www.feem.it.

Alberini, Anna, Alberto Longo, Stefania Tonin, Francesco Trombetta and Margherita Turvani (2003), "The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers," FEEM Working Paper 7.2003, Milan, January. Available at www.feem.it.

Alberini, Anna, Alberto Longo, Stefania Tonin, Francesco Trombetta and Margherita Turvani (2002), "The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers," AREC Discussion Paper 02-21, University of Maryland, College Park, November.

Alberini, Anna, Patrizia Riganti and Alberto Longo (2002), "Can People Value the Aesthetic and Use Services of Urban Sites? Evidence from a Survey of Belfast Residents," Fondazione ENI Mattei Nota di Lavoro 70.2002, Milan, Italy.

Alberini, Anna and Alberto Longo (2002), "Non-Use and Use Values of S. Erasmo: Statistical Sampling and Models," CO.RI.LA. Working Paper, Venice, Italy, May.

Alberini, Anna, Maureen Cropper, Alan Krupnick, and Nathalie Simon (2002), "Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the United States and Canada," Resources for the Future Discussion Paper 02-19, Washington, DC, April.

Alberini, Anna, Alan Krupnick, Maureen Cropper, Nathalie Simon and Joseph Cook (2001), "The Willingness to Pay for Mortality Risk Reductions: A Comparison of the United States and Canada," FEEM Discussion Paper 92.01, Milan, Italy.

Krupnick, Alan, Anna Alberini, Maureen Cropper, Nathalie Simon, Bernie O'Brien, Ron Goeree, and Martin Heintzelman (2000), "Age, Health, and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Survey of Ontario Residents," RFF Discussion Paper QE00-37, Washington, DC, September.

Alberini, Anna and Shelby Frost (1999), "Forcing Firms to Think about the Future: Economic Incentives and the Fate of Hazardous Waste," University of Colorado Discussion Paper 99-26, Boulder, CO, November.

Alberini, Anna, Kevin Boyle and Michael Welsh (1999), "Analysis of Contingent Valuation Data with Multiple Bids and Response Options Allowing Respondents to Express Uncertainty," University of Colorado Discussion Paper 99-18, Boulder, CO, October.

Alberini, Anna and Julio R. Videras (1999), "The Appeal of Voluntary Environmental Programs: Which Firms Participate and Why?" University of Colorado Discussion Paper 99-15, Boulder, CO, October.

Alberini, Anna (1999), "The Effects of Regulation, and Substitution between Sources of Pollution: An Empirical Analysis of Florida's Storage Tanks," University of Colorado Discussion Paper 99-11, Boulder, CO, September.

Krupnick, Alan, Anna Alberini, Maureen Cropper, and Nathalie Simon with Kenshi Itaoka and Makoto Akai (1999), "Mortality Risk Valuations for Environmental Policy," Resources for the Future Discussion paper 99-47, Washington, DC, August.

Alberini, Anna and John Bartholomew (1999), "The Determinants of Hazardous Waste Disposal Choice: An Empirical Analysis of Halogenated Solvent Waste Shipments," University of Colorado Discussion paper 98-8, Boulder, CO, June.

Alberini, Anna and David Austin (1999), "Accidents Waiting to Happen: Liability Policy and Toxic Pollution Releases," University of Colorado Discussion paper 99-4, Boulder, February.

Harrington, Winston, Alan Krupnick and Anna Alberini (1998), "Overcoming Public Aversion to Congestion Pricing," Resources for the Future Discussion paper QE98-27, Washington, DC, April.

Alberini, Anna, Winston Harrington and Virginia McConnell (1998), "Fleet Turnover and Old Car Scrap Policies," Resources for the Future Discussion paper 98-23, Washington, DC, March.

Krupnick, Alan, Anna Alberini, Robert Belli, Maureen Cropper and Nathalie Simon (1997), "Mortality Risk Valuation and Stated Preference Methods: An Exploratory Study," November.

Alberini, Anna and David Austin (1997), "Strict Liability as a Deterrent in Toxic Waste Management: Empirical Evidence from Accident and Spill Data," University of Colorado Discussion Paper 97-26, Boulder, CO, November.

Alberini, Anna and David Austin (1997), "Off and On the Liability Bandwagon: Explaining State Adoptions of Strict Liability in Hazardous Waste Programs," University of Colorado Discussion Paper 97-12, Boulder, CO, October.

Cropper, Maureen, Nathalie Simon, Anna Alberini, Seema Arora and P.K. Sharma (1997), "The Health Benefits of Air Pollution Control in Delhi," World Bank Working Paper, Washington, DC.

Metge, Colleen and Anna Alberini (1997), "Determinants of Willingness to Pay for Community-Based Pharmacist Services," University of Colorado Discussion paper 97-5, Boulder, CO, April.

Krupnick, Alan, Winston Harrington and Anna Alberini (1996), "Public Support for Pollution Fee Policies for Motor Vehicles: Survey Results," Resources for the Future Discussion paper QE97-13, Washington, DC, December.

Alberini, Anna, Winston Harrington and Virginia McConnell (1996), "Fleet Turnover and Old Car Scrap Policies," University of Colorado Discussion paper 96-31, Boulder, CO, November.

Alberini, Anna and Alan Krupnick (1996), "Air Quality and Episodes of Illness in Taiwan: Evidence from Survey Data," University of Colorado Discussion paper 96-30, Boulder, CO, October.

Harrington, Winston, Virginia McConnell and Anna Alberini (1996), "Economic Incentives Under Uncertainty: The Case of Emissions Fees," RFF Discussion Paper QE96-32, Washington, DC, August.

Alberini, Anna, Gunnar Eskeland, Alan Krupnick and Gordon McGranahan (1995), "Determinants of Diarrheal Disease in Jakarta", Resources for the Future Discussion Paper, 95-23, Washington, DC, May.

Alberini, Anna, Maureen Cropper, Tsu-Tan Fu, Alan Krupnick, Jin-Tan Liu, Daigee Shaw and Winston Harrington (1994), "Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan," RFF Discussion Paper QE95-01, Washington, DC, October.

Alberini, Anna, Barbara Kanninen and Richard T. Carson (1994), "Random-Effect Models of Willingness to Pay Using Discrete Response CV Survey Data," RFF Discussion Paper QE94-34, Washington, D.C., June.

Alberini, Anna, David Edelstein, Winston Harrington and Virginia McConnell (1994), "Reducing Emissions from Old Cars: The Economics of the Delaware Vehicle Retirement Program," RFF Discussion Paper QE94-27, Washington, DC, April.

Alberini, Anna (1994), "Efficiency v. Bias of Willingness-to-Pay estimates: Bivariate and Interval Data", Resources for the Future, Discussion Paper, 94-16.

Alberini, Anna and Richard T. Carson (1993), "Choice of Thresholds for Efficient Binary Discrete Choice Estimation," Resources for the Future Discussion Paper QE-14, Washington, DC, May.

Alberini, Anna, Winston Harrington, and Virginia McConnell (1994), "Estimating an Emissions Supply Function from Accelerated Vehicle Retirement Program", Resources for the Future Discussion Paper 94-09, Washington, DC.

Alberini, Anna, Winston Harrington and Virginia McConnell (1993), "Determinants of Participation in Acceleration Vehicle Retirement Program, Resources for the Future, Discussion Paper, 93-18, Washington, DC.

Alberini, Anna (1993), "Optimal Designs for Discrete Choice Contingent Valuation Surveys: Single-bound, Double-bound and Bivariate Models", Resources for the Future, Discussion Paper QE93-15, Washington, DC.

Papers under Review at Refereed Journals

Newburn, David, and Anna Alberini (2015), "Household Response to Environmental Incentives for Rain Garden Adoption," submitted to *Water Resources Research*.

Anna Alberini, Markus Bareit, and Massimo Filippini (2015), "Does the Swiss Car Market Reward Fuel Efficient Cars? Evidence from Hedonic Pricing Regressions, a Regression Discontinuity Design, and Matching," revised and resubmitted to *The Energy Journal.*

Draft Papers

Alberini, Anna and Charles Towe (2014), "Information v. Energy Efficiency Incentives: Evidence from Residential Electricity Consumption in Maryland," University of Maryland, College Park, June.

Alberini, Anna and Andrea Bigano (2014), "How Effective Are Energy-Efficiency Incentive Programs? Evidence from Italian Homeowners," paper submitted to the 2014 WCERE Congress, Istanbul, University of Maryland, College Park, January.

Alberini, Anna, Jim Frehs, and Jay Storfer (2013), "What are the Mortality and Morbidity Benefits of Extreme Heat Response Systems? Evidence from Canada," paper submitted to the 2013 EAERE annual meeting, Toulouse, University of Maryland, College Park, January.

Alberini, Anna, Will Gans, and Daniel Lopez-Velez (2010), "Residential Consumption of Gas and Electricity in the US: What are the Effects of Prices and Energy-Efficiency Investments?" University of Maryland, College Park, October, available at http://www.cepe.ethz.ch/education/lunchseminar/Alberini_paper.pdf.

Veronesi, Marcella and Anna Alberini (2010), "Extreme Weather Events: Do Families "Keep An Eye" On Children And The Elderly? University of Maryland, College Park, January.

Alberini, Anna, Erin Mastrangelo and Hugh Pitcher (2009), "Climate Change and Human Health: Assessing the Effectiveness of Adaptation to Heat Waves," paper submitted to and accepted at the EAERE Annual meeting, Amsterdam, June 2009, University of Maryland, College Park: January.

Talks and Professional Papers Presented

(i) Invited Talks

"The Benefits of Avoiding Cancer (or Dying from Cancer): Evidence from a Four-country Study," presented at the European Chemicals Agency, Helsinki, June 2015.

"Information v. Energy Efficiency Incentives: Evidence from Residential Electricity Consumption in Maryland," presented at the 6th Atlantic Workshop on Energy and Environmental Economics: Frontiers in the Economics of Energy Efficiency, Atoxa, Spain, June 2014, KU Leuven, Department of Business, Brussels, December 2014, and Centre for Energy Policy and Economics, ETH-Zurich, March 2014.

"Free Riding, Upsizing, and Energy Efficiency Incentives in Maryland Homes," presented at the University College London Energy Institute, London, March 2014.

"CO_2 Emissions, Fuel Efficiency, and Car Markets," keynote speech at the 2nd annual meeting of the Italian Association of Environmental and Resource Economists, Milan, February 2014.

"Does the Swiss Car Market Reward Fuel Efficient Cars? Evidence from Hedonics, Matching and a Regression Discontinuity Design," presented at the Centre for International Environmental Studies, Graduate Institute, Geneva, October 2013; the Economics Department, School of Management, Queen's University, Belfast, December 2013; and the Economics Department, American University, Washington, DC, February 2014.

"Energy Efficiency Incentives: Do They Work for Heating and Cooling Equipment? Evidence from Maryland Homeowners," presented at the Centre for Energy Policy and Economics, ETH Zürich, May 2013.

"Estimating a Rain Garden Supply Function: Evidence from Maryland Households," presented at the US Environmental Protection Agency, Washington, DC, November 2012, and EEBEE seminar at Queen's University, Belfast, January 2013.

"Energy Efficiency Incentives: Do They Work? Evidence from Maryland Homeowners," presented at the Economics Department, Queen's University Belfast, Northern Ireland, March 2012, at the Department of Economics, University of Basel, Switzerland, September 2012, and as a keynote speech at the 1st CMCC-FEEM Convention, Venice, Italy, October 2012.

"Does the Cause of Death Matter? The Effect of Dread, Controllability, Exposure and Latency on the VSL," presented at ABT, Bethesda, Maryland, November 2011.

"Repeated Questioning in Choice Experiments: Are We Improving Statistical Efficiency or Getting Respondents Confused?" presented at the International Workshop on Recent Trends in Non-market Valuation, International Center for Climate Governance, FEEM, Venice, November 2011.

"Smart Meter Devices and the Effect of Feedback on Residential Electricity Consumption: Evidence from a Natural Experiment in Northern Ireland," presented at Queen's University Belfast, June 2011, at the Centre for Energy Policy and Economics, ETH Zurich, October 2011, and at the Inter Development Bank, Washington, D.C., November 2012..

"Energy Efficiency in the Home: What Are the Preferences of Swiss Households," presented at the ISW Energy Economics Workshop, Queen's University, Belfast, January 2011.

"Residential Consumption of Gas and Electricity in the US: What are the Effects of Prices and Energy-Efficiency Investments?" presented at the Centre for Energy Policy and Economics, ETH Zurich, October 2010, paper available at http://www.cepe.ethz.ch/education/lunchseminar/Alberini_paper.pdf.

"The VSL for Children and Adults: Evidence from Conjoint Choice Experiments in Italy and the Czech Republic," presented the Center for Risk Communication Research, University of Maryland, College Park, February 2009, at the OECD VERHI-Children Workshop, Prague, September 2009, and the National Center for Environmental Economics, US Environmental Protection Agency, October 2009.

"Climate Change and Human Health: Assessing the Effectiveness of Adaptation to Heat Waves," presented at the Economics Department, Università della Svizzera Italiana, Lugano, Switzerland, and ETH Zürich, Switzerland, October 2008.

"Paying for Permanence: Public Preferences for Contaminated Site Cleanup," presented at the US Environmental Protection Agency, National Center for Environmental Economics, June 2006; FEEM, Venice, May 2006; Harvard Center for Risk Analysis, Harvard School of Public Health, February 2007; Queen's University, Belfast, Northern Ireland, May 2007; and CEPE-ETH, Zurich, June 2007.

"Important Parameters: What Do the Users Think?," presented at the workshop 'Probabilistic Integrated Assessment Modeling: A Workshop on Uncertainty and Learning in IAMs of Climate Change," US Environmental Protection Agency, Washington, DC, May 2006.

"Willingness to Pay to Protect Cultural Heritage: Three Case Studies," presented at the Joint Workshop of ICP Materials Task Force and NEBEI of the UNECE Convention on Long-Range Transboundary Air Pollution, CULT-STRAT and Clean Air For Europe Program on Economic Impacts of Air Pollution on Cultural Heritage, Catania, Sicily, April 2006.

"Adaptive Capacity and the Human Health Effects of Climate Change: Evidence from a Survey of Experts," presented at the Joint Global Change Research Institute, College Park, April 2006, and ESSIC, University of Maryland, College Park, February 2006.

"Urban Environmental Health and Sensitive Populations: How Much are the Italians Willing to Pay to Reduce their Risks?" presented at Riunione Plenaria FEEM, Desenzano sul Garda, October 2005.

"Climate Change and Adaptation Strategies for Human Health: Project Results," presented at the workshop "Global Environmental Change: Risks to Human Health?" DG-Research, European Commission, Brussels, June 2005.

"Valuing Risks to Life and Health: The State of the Art," Keynote Lecture, annual meeting of the Swiss Society of Economics and Statistics, ETH, Zurich, March 2005.

"Willingness to Pay for Mortality Risk Reductions: The Effects of Age, Health Status, and Latency," presented at the Department of Economics, Rice University, October 2004, and at the Department of the Environment, University of York, October 2004.

"Three-Country Application of Alberini/Krupnick Survey Instrument: Methodology and Results," presented at the U.K. Department of Environment, Food and Rural Affairs, London, UK, June 2004.

"Willingness to Pay for Risk Reductions: The Effects of Age, Health Status, and Latency," Presented at North Carolina State University and Research Triangle Institute, Durham, April 2004.

"Robustness of VSL Estimates from Contingent Valuation Surveys," presented at the National Center for Environmental Economics, US Environmental Protection Agency, February 2004.

"Valuing the Health Effects of Climate Change," presented at the Workshop on Economic Valuation of Health Effects due to Transport, Swedish National Institute of Public Health, Stockholm, Sweden, June 2003.

"Willingness to Pay for Future Risk: How Much Does Latency Matter?" presented at the DIEM Health Valuation Workshop in Bergen, Norway, June 2003, and at UC Santa Barbara, October 2003.

"Valuing the Health Effects of Climate Change," presented at the cCASHh Workshop on Vector-Borne Diseases and Climate Change, Prague, Czech Republic, June 2003

"The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Survey of Developers," presented at the School of Architecture, Queen's University Belfast, Belfast, Northern Ireland, October 2002, and to the Fondazione ENI Enrico Mattei, Venice, Italy, October 2002.

"Willingness to Pay for Future Risk: How Much does Latency Matter?" presented at the Economics Department, University of Central Florida, Orlando, September 2002.

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"The Effects of Age and Health Status on the Willingness to Pay for Mortality Risk Reductions," Presented to the Department of Resource Economics and Policy, University of Maine, Orono, October 2001, to the Department of Economics, University of Oregon, Eugene, January 2002, and to the Department of Agricultural and Resource Economics, Oregon State University, Corvallis, February 2002.

"Age, Health and the Willingness to Pay for Mortality Risk Reduction" Resources for the Future seminar, Washington, DC, February 2001.

"The Willingness to Pay for Mortality Risk Reductions: A Survey of US Residents," Presented to the CORILA Conference on Economic Valuation of Environmental Goods, Venice, Italy, 2001.

"Willingness to Pay for Mortality Risk Reductions: The Robustness of Values from Contingent Valuation Studies," Presented at the Workshop "Economic Valuation of Mortality Risk Reduction: Assessing the State of the Art for Policy Applications," organized by the US EPA National Center for Environmental Economics and the US EPA National Center for Environmental Research, Silver Spring, MD, November 2001.

"What Are Older People Willing to Pay to Reduce Their Risk of Dying?" presented at the Harvard School of Public Health, February 2000

"Willingness to Pay for Noxious Weeds Control Programs: The Importance of Respondent Information and Uncertainty," presented at ERS-USDA, January 1999.

"Environmental Policy Based on Liability: An Empirical Analysis of Spill and Accident Data," presented to the Department of Agricultural and Resource Economics, University of Maryland, College Park, January 1999.

"Air Quality and Episodes of Acute Respiratory Illness in Taiwan Cities: Evidence from Survey Data," presented at the School of Environmental Science and Management, University of California, Santa Barbara, February 1998.

"Estimating The Health Effects of Air Pollution in Taiwan: Evidence from Survey Data," presented at the Department of Resource Economics and Policy, University of Maine, Orono, July 1996.

"Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan," presented at the Department of Policy Research, the World Bank, Washington, D.C., October, 1994, at Resources for the Future, Washington, D.C., December, 1994; at the Department of Economics, University of Colorado, Boulder, January, 1995; and at the Department of Agricultural Economics, University of California, Berkeley, February 1995.

"Determinants of Diarrheal Illness in Jakarta," presented at the Public Economics Division, The World Bank, Washington, D.C. (June 1995) and at Resources for the Future (June, 1995).

"Determinants of an Emissions Supply Function from Accelerated Vehicle Retirement Programs," Resources for the Future Seminar Series, Washington, D.C. (November 1993) and presented at North Carolina State University, Raleigh, (April, 1994), University of Maryland, College Park (April, 1994) and University of California, Los Angeles (November, 1994).

"Methods and Problems with Contingent Valuation Surveys: An Overview" presented at the Final Session of the 1992 Autumn Workshop in Environmental Economics, Venice, Italy, September 1992.

. "Issues in Discrete Choice Estimation for Public and Environmental Goods," presented at G.R.E.T.A., Venice, Italy, May 1992.

"Efficient Discrete Choice Estimation for Public Goods" presented at Indiana University, Bloomingtom, IN, February 1992.

"The Informational Content of Discrete Choice Responses," presented at Cal State Hayward, January 1992; University of Texas, Austin, January 1992; Concordia University and Universite' du Quebec a Montreal, January 1992; SUNY Buffalo, February 1992; Resources for the Future, Washington, D.C., February 1992; College of William and Mary, Williamsburg, VA, February 1992.

(ii) Contributed Talks

"The Benefits of Avoiding Cancer (or Dying from Cancer): Evidence from a Four-country Study," presented at the 21st annual meeting of the European Association of Environmental and Resource Economists, Helsinki, June 2015.

"Free Riding, Upsizing, and Energy Efficiency Incentives in Maryland Homes," presented at the 5th World Congress of Environmental and Resource Economists, Istanbul, July 2014.

"Does the Swiss Car Market Reward Fuel Efficient Cars? Evidence from Hedonics, Matching and a Regression Discontinuity Design," presented at the 2nd annual CMCC and FEEM Convention, Venice, Italy, October 2013.

"What are the Mortality and Morbidity Benefits of Extreme Heat Response Systems? Evidence from Canada," presented at the 20th annual meeting of the European Association of Environmental and Resource Economists, Toulouse, June 2013.

"Energy Efficiency Incentives: Do They Work for Heating and Cooling Equipment? Evidence from Maryland Homeowners," presented at the 2nd Northeast Workshop on Energy Policy and Environmental Economics, Cornell University, Ithaca, NY, May 2013, and at the 6th annual Empirical Methods in Energy Economics Workshop, Ottawa, Canada, July 2013..

"Energy Efficiency Incentives: Do They Work? Evidence from Maryland Homeowners," presented at the Empirical Methods in Energy Economics annual meeting in Berlin, Germany, June 2012.

"Energy Efficiency Investments in Swiss Homes: The Effect of Uncertainty and Expectations about Energy Prices," presented at the Empirical Methods in Energy Economics annual meeting in Dallas, TX, July 2011.

"Mortality Risk Reductions or Life Expectancy Gains? A Three Country Comparison of Approaches to Mortality Benefits Estimation," presented at the 18th annual EAERE conference, Rome, June 2011.

"Labels and Perceptions in Mortality Risk Reduction Valuations," presented at the 4th World Congress of Environmental and Resource Economists, Montreal, June 2010.

"The Benefits of Contaminated Site Cleanup Revisited: The Case of Naples and Caserta, Italy," presented at the 4th World Congress of Environmental and Resource Economists, Montreal, June 2010.

"The VSL for Children and Adults: Evidence from Conjoint Choice Experiments in Milan, Italy," presented at the annual EAERE meeting, Amsterdam, June 2009.

"Mama's Boy, Daddy's Girl? The Effect of Parent, Age, and Gender on Child VSL," presented at the annual EAERE meeting, Amsterdam, June 2009.

"Climate Change and Human Health: Assessing the Effectiveness of Adaptation to Heat Waves," presented at the AERE Summer Workshop, Berkeley, CA, June 2008, and at the EAERE Annual meeting, Amsterdam, June 2009.

"Rates of Time Preference for Saving Lives in the Hazardous Waste Site Context," presented at the EAERE annual meeting, Thessaloniki, Greece, June 2007.

"Was It Something I Ate? Implementation of the FDA Seafood HACCP Program," presented at the 3rd World Congress of Environmental and Resource Economists, Kyoto, July 2006.

"Paying for Permanence: Public Preference for Contaminated Site Cleanup," presented at the 3rd World Congress of Environmental and Resource Economists, Kyoto, July 2006, and the ASSA meetings, Chicago, January 2007.

"Discount Rates in Risk v. Money and Money v. Money Tradeoffs," presented at the 3rd World Congress of Environmental and Resource Economists, Kyoto, July 2006.

"The Value of Mortality Risk Reductions in Delhi, India," presented at the 3rd World Congress of Environmental and Resource Economists, Kyoto, July 2006.

"Attracting Private Investment to Contaminated Properties: The Value of Public Interventions," presented at the annual APPAM meeting, Washington, DC, November 2005, and at the Southern Economic Association annual meeting, Washington, DC, November 2005.

"Using Surveys to Compare the Public's and Decisionmakers' Preferences for Urban Regeneration: The Case of the Venice Arsenale," presented at the Conference "Tourism and Sustainable Development," Chia, Sardinia, September 2005.

"The Value of a Statistical Life in the Czech Republic: Evidence from a Contingent Valuation Study," presented at the 2005 EAERE annual meeting, Bremen, June 2005.

"Adaptive Capacity And The Human Health Effects of Climate Change: Evidence from a Conjoint Choice Survey of Experts," presented at the 2005 EAERE annual meeting, Bremen, June 2005.

"Model Misspecification and Endogenous On-site Sampling in the Travel Cost Method," presented at the 2005 EAERE annual meeting, Bremen, June 2005.

"The Value of Recreational Sports Fishing in the Lagoon of Venice: Evidence from Actual and Hypothetical Fishing Trips," presented at the annual EAERE Meeting, Budapest, June 2004.

"Policies for Cleanup and Reuse of Contaminated Sites: Evidence from a Survey of US Real Estate Developers," presented at the annual EAERE Meeting, Budapest, June 2004.

"Willingness to Pay for Reducing Mortality Risks: Evidence from a Three-country Contingent Valuation Survey," presented at the annual EAERE Meeting, Budapest, June 2004.

"Robustness of VSL Values from Contingent Valuation Surveys," presented at the annual EAERE Meeting, Budapest, June 2004.

"Information and Contingent Valuation: Willingness to Pay for S. Erasmo in the Venice Lagoon," presented at the SØM Conference on Environment, Information, and Consumer

Behavior, Copenhagen, April 2003, and at the EAERE Annual Meeting, Bilbao, June 2003.

"The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Survey of Developers," presented at the First IUAV Conference on Brownfields as Opportunities for Sustainable Development, Venice, Italy, February 2003.

"Determinants of Participation in Voluntary Cleanup Programs: The Case of Colorado," presented at the First IUAV Conference on Brownfields as Opportunities for Sustainable Development, Venice, Italy, January 2003, and at EAERE Annual Meeting, Bilbao, June 2003.

"The Effect of Contamination and Cleanup on Commercial and Industrial Properties: The Case of Maryland," presented at the First IUAV Conference on Brownfields as Opportunities for Sustainable Development, Venice, Italy, January 2003.

"Liability for Environmental Cleanup: Is Less More? Evidence from Voluntary Cleanup Programs," presented at the Second World Congress of Environmental and Resource Economists, Monterey, CA, June 2002.

"The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers in Europe and the US," presented at the Second World Congress of Environmental and Resource Economists, Monterey, CA, June 2002.

"Willingness to Pay for Future Risk: How Much does Latency Matter?" presented at the Second World Congress of Environmental and Resource Economists, Monterey, CA, June 2002.

"The Willingness to Pay for Mortality Risk Reductions in the United States and Canada," presented to the Summer Workshop on Public Economics and the Environment, National Bureau of Economic Research, Cambridge, MA, July 2001

"Time and Spatial Patterns in Assessing Hazardous Waste Sites: What Do They Tells Us About Agency Behavior?" presented at the session "Regulation and Asymmetric Information I," annual meeting of the European Association of Environmental and Resource Economists, Southampton, England, June 2001.

"Yea-Sayers, Nay-sayers, Or Just Plain Confused? Mixtures of Populations in Contingent Valuation Survey Responses," presented at the session "Contingent Values," Annual meeting of the European Association of Environmental and Resource Economists, Southampton, England, June 2001.

"Using Contingent Valuation to Value a Noxious Weeds Program: The Effects of Including a 'Not Sure' Response Category", presented at the AERE session "Data Collection and Modeling in Non-Market Valuation," AAEA annual meeting, Tampa, Florida, August 2000.

"Accidents Waiting to Happen: Liability Policy and Toxic Pollution Release," presented at the session "Compensation for Environmental Damage," AAEA annual meeting, Tampa, Florida, August 2000.

"The Effects of Regulation and Substitution between Sources of Pollution: An Empirical Analysis of Florida's Storage Tanks," presented at the annual meeting of the European Association of Environmental and Resource Economists, Crete, Greece, June 2000.

"Analysis of Contingent Valuation Data with Multiple Bids and Response Options Allowing Respondents to Express Uncertainty", presented at the annual meeting of the European Association of Environmental and Resource Economists, Crete, Greece, June 2000.

"Environmental Policy Based on Liability: An Empirical Analysis of Spill and Accident Data," presented to the 74th Annual Western Economic Association Conference, San Diego, July 1999, and to the session "Economic Incentives and Hazardous Waste Management" at the Eastern Economics Association annual meeting, Crystal City, VA, March 2000.

"The Effects of Waste-end Taxes and Liability Laws on Interstate Shipments of Hazardous Waste Materials" (co-authored with Shelby D. Frost), presented to the 74th Annual Western Economic Association Conference, San Diego, July 1999, to the CU Environmental and Resource Economics Workshop, July 1999, and to the session entitled "Economic Incentives and Hazardous Waste Management" at the Eastern Economics Association annual meeting, Crystal City, VA, March 2000.

"Environmental Policy Based on Polluter Financial Responsibility: The Case of Underground Storage Tanks," presented to the CU Environmental and Resource Economics Workshop, Boulder, CO, July 1999, and at the session entitled "Economic Incentives and Hazardous Waste Management" at the Eastern Economics Association annual meeting, Crystal City, VA, March 2000.

"What Are Older People Willing to Pay to Reduce Their Risk of Dying?" presented at the AERE session entitled "Valuation of Mortality Risk Reductions" at the ASSA Meetings, Boston, MA, January 2000.

. "Strict Liability as a Deterrent in Toxic Waste Management: Empirical Evidence from Accident and Spill Data," presented at the 1998 World Congress of Environmental and Resource Economists, Venice, Italy, June 1998.

"The Determinants of Hazardous Waste Disposal Choice: An Empirical Analysis of Halogenated Solvent Waste Shipments," presented at the 1998 World Congress of Environmental and Resource Economists, Venice, Italy, June 1998.

"The Determinants of Hazardous Waste Disposal Choice: An Empirical Analysis of Halogenated Solvent Waste Shipments," presented at the annual meeting of the American Economic Association, Chicago, January 1998.

"Mortality Risk Valuation and Stated Preference Methods: An Exploratory Study," presented at the annual meeting of the Southern Economics Association, Atlanta, GA, November 1997.

"The Health Benefits of Air Pollution Control in Delhi," presented at the annual meeting of the *American Agricultural Economics Association*, Toronto, July 1997.

"Air Pollution and Acute Respiratory Illness: Evidence from Taiwan and Los Angeles," presented at the annual meeting of the *American Agricultural Economics Association*, Toronto, July 1997.

"Do Non-Users Have More Preference Uncertainty than Users?," presented at the W-133 annual meeting, Portland, Oregon, March 1997.

"Using Multiple-Bounded Questions to Incorporate Preference Uncertainty in Non-market Valuation," presented at the W-133 annual meeting, Portland, Oregon, March 1997.

"The Role of Strict, Joint and Several Liability in Toxic Waste Management: Empirical Evidence from Accident and Spill Data," presented at the session on "Risk and Regulation," American Economic Association annual meeting, New Orleans, January 1997.

"Determinants of Reclamation and Disposal of Halogenated Solvents," presented at the Front Range Environmental and Natural Resource Economics Seminar, September 1996.

"Fleet Turnover and Old Car Scrap Policies," presented at the American Economic Association Annual Meeting, San Francisco, January 1996, and at the W-133 Annual Meeting, Jekyll Island, March 1996.

"Combining Epidemiologic Evidence and Contingent Valuation to Estimate the Benefits of Improved Air Quality: The Case of Taiwan," presented at the Dept. of Agricultural and Resource Economics, Colorado State University, Fort Collins, November 1995.

"Open-ended and Dichotomous-choice Contingent Valuation," presented at the Annual Meeting of the Western Economics Association, San Diego, July 1995.

"Sensitivity of Multiple-bound Referendum Contingent Valuation Estimates to the Specification of the Underlying Utility," presented at the Annual W-133 Meeting in Monterey, CA, March 1995.

"Cross-validation Techniques in Contingent Valuation Data Analysis," presented at the Annual W-133 Meeting in Monterey, CA, March 1995.

"Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan," presented at the American Economic Association Annual Meeting in Washington, D.C., January 1995.

"Efficiency Gains from Joint Estimation: When Does a Second Equation Improve Estimation of the First?" presented at the American Agricultural Economics Association Annual Meeting in San Diego, August, 1994.

"Air Quality and the Value of Health in Taiwan," presented at the Eastern Economic Association Annual Meeting in Boston, March, 1994.

"Efficiency v. Bias of Willingness-to-pay Estimates: Bivariate and Interval Data Models" presented at the W-133 Annual Meeting in Tucson, February, 1994

"Determinants of Participation in Accelerated Vehicle Retirement Programs," presented at the Eastern Economics Association Meetings, Washington, D.C., March 1993.

(iii) Posters

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Alberini, Anna, Andrea Bigano and Marco Boeri (2012), "Free-riding Opportunities: Energy Efficiency Incentives and Italian Homeowners," poster presented at the 2012 Empirical Methods in Energy Economics meeting, Berlin, June.

Alberini, Anna and Po Yin Wong (2012), "Are Energy Efficiency Renovations Capitalized into Housing Prices? Evidence from the American Housing Survey," poster presented at the 2012 Empirical Methods in Energy Economics meeting, Berlin, June.

Alberini, Anna and Aline Chiabai (2005), "WTP for Reduction in the Risk of Dying in Heat Waves: Sensitivity to Scope, Age and Health Status," poster presented at the 2005 EAERE annual meeting, Bremen, June.

Alberini, Anna, Marcella Veronesi and Joseph C. Cooper (2005), "Detecting Starting-point Bias in Dichotomous-choice Contingent Valuation Surveys," poster presented at the 2005 EAERE annual meeting, Bremen, June.

Conference Proceedings

Alberini, Anna, Milan Scasny, Marketa Braun Kohlova, and Jan Melichar (2005), "The Value of Statistical Life in the Czech Republic: Evidence from Contingent Valuation Study," in Milan Scasny and Jan Melichar (eds.), *Rozvoj ceske spolecnosti v Evropske Unii - V. (Development of Czech Society in the European Union - V). Part V - Environment: Non-market Valuation Methods in Environmental Area*. Proceedings from the Conference, Charles University, Prague, 21-23 October 2004, Matfyzpress. ISBN: 80-86732-35-5.

Alberini, Anna (2001), "Willingness to Pay for Mortality Risk Reductions: The Robustness of VSL Figures from Contingent Valuation Studies," Proceedings of the Workshop "Economic Valuation of Mortality Risk Reductions: Assessing the State of the Art for Policy Applications," Silver Spring, MD, December, available at http://yosemite.epa.gov/ee/epa/eermfile.nsf/vwAN/EE-0464-01.pdf/$File/EE-0464-01.pdf.

Alberini, Anna and Patricia Champ (1998), "An Approach for Dealing with Uncertain Responses to a Contingent Valuation Question," in *W-133, Benefit and Cost Transfer in Natural Resource Planning, 10th Interim Report*, Knoxville, TN: University of Tennessee.

Alberini, Anna, Kevin Boyle and Michael Welsh (1997), "Using Multiple-Bounded Questions to Incorporate Preference Uncertainty in Non-market Valuation," in *W-133, Benefit and Cost Transfer in Natural Resource Planning, 9th Interim Report*, Reno: University of Nevada, Reno.

Alberini, Anna and Joseph Cooper (1995), "Sensitivity of Multiple-Bound Referendum CV Estimates to the Specification of the Underlying Utility," in *W-133, Benefit and Cost Transfer in Natural Resource Planning, 8th Interim Report*, Davis: University of California, Davis.

Contracts and Grants

European Commission-DG Environment FP-7 grant, Public Health Impacts in Urban Environments of Greenhouse Gas Emissions Reduction Strategies (PURGE), with Fondazione Eni Enrico Mattei (FEEM), FEEM share €214,812.50. Workpackage leader.

Cooperative Agreement with the Economic Research Service, US Department of Agriculture, "The Adoption of GE Corn: Farm Level Effects," August 2011-September 2012, $16,000.

Research Contract from the Government of Canada (Policy Research Initiative/Horizons Canada and Health Canada), "Valuing the Mortality and Morbidity Effects of Heat Waves," 2009-August 2012, $32,000.

Research Contract from the US Environmental Protection Agency via the Joint Global Change Research Institute, "Assessing the Effectiveness of Heat/Health Watch Systems," December 2007-December 2011, $98,125.

Research Contract from the US Environmental Protection Agency via Industrial Economics, "Estimating the Social Benefits of Cleanup Activities by EPA's Underground Storage Tanks: Two Approaches," January 2008-June 2009, AREC's share $73,606.

Research Grant from the European Commission, Research Directorate-General, "A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis (EXIOPOL)," in partnership with 37 research institution in and outside of Europe, 2007-2010, total funding €5,000,000 (to be shared among all institutions). [*]

[*] At Fondazione Eni Enrico Mattei (FEEM), Milan and Venice.

Research Grant from the European Commission, Research Directorate-General, "Valuation of Environment-related Health Impacts: Accounting for Differences Across Age, Latency and Risk Categories with a Particular Focus on Children," in partnership with OECD, University of East Anglia, and Charles University, 2004, total funding €1,000,000.*

Research Grant from CORILA (Consorzio Ricerche Lagunari, based in Venice, Italy, and affiliated with the Universities of Venice and Padua), "Valutazione Economica degli Interventi di Salvaguardia e Protezione Ambientale nella Laguna di Venezia" (Economic Valuation of Programs for Environmental Protection in the Lagoon of Venice), 2001, total funding €195,000.**

Grant from the National Center for Smart Growth, University of Maryland, "Cleanup and Reuse of Contaminated Sites: A Case Study of Maryland's Voluntary Cleanup Program," 2002, total funding $19,968, contract period September 2002-June 2003.

Research Contract with the Fondazione ENI Mattei, Italy, "Public Preferences and Urban Regeneration: Land Use Changes and Aesthetics at the Venice Arsenale," 2002, total funding €74,670, contract period May 2002-June 2004.

Grant from US Environmental Protection Agency, Star Competition, "Urban Regeneration through Environmental Remediation: Valuing Market-based Incentives for Brownfields Development," 2002, total funding $277,388, contract period 01/02/02-09/30/03. (University of Maryland share: $85,000)

Cooperative Agreement with the US Environmental Protection Agency, "Willingness to Pay for Mortality Risk Reductions: A Re-examination of the Literature," 2001, total funding $97,864, award period from 10/01/2001 to 12/31/2003.

Research Contract with CORILA (Consorzio Ricerche Lagunari, based in Venice, Italy, and affiliated with the Universities of Venice and Padua), "Valutazione Economica degli Interventi di Salvaguardia e Protezione Ambientale nella Laguna di Venezia" (Economic Valuation of Programs for Environmental Protection in the Lagoon of Venice), 2001, funding $12,500.

Grant from the Joint Institute for Food Safety and Applied Nutrition (JIFSAN), "Monitoring and Compliance Under the Seafood HACCP," 2001, total funding $30,000. (As the Principal Investigator. Other Investigators: Erik Lichtenberg and Dominic Mancini.)

Research Contract with the European Commission, "An Analysis of the Preventive Effect of Environmental Liability," 2001, total funding $50,000. (As the Principal Investigator. Co-principal investigator: David Austin.)

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* At Fondazione Eni Enrico Mattei (FEEM), Milan and Venice.

** At the Department of Economics of the University of Venice

Grant from the University of Maryland's Experiment Station, "Liability for Environmental Cleanup: Is Less More? An Application to Maryland's and Colorado's Voluntary Cleanup Programs," 2001, total funding $16,450.

Cooperative Agreement with the US Department of Agriculture entitled "Modeling Respondent Confidence in the Grassland Birds Survey," 1999, $20,000.

Grant from NSF/EPA, 1998-99, to support further research on willingness to pay for mortality risk reductions using the contingent valuation approach, $273,000. (Principal Investigator: Alan Krupnick; other investigators: Maureen Cropper, Bob Belli and Nathalie Simon.)

Research Contract with the Regional Air Quality Council, Denver, $11,000, to examine the cost of alternative strategies for improving visibility in the metro Denver area.

Cooperative Agreement with the US Forest Service entitled "Valuing Biodiversity: The Issue of Invasive Species," $25,000.

Grant from NSF/EPA, 1995-96, to support research on the valuation of mortality risk reductions using the contingent valuation approach. (Principal investigator: Alan Krupnick; other investigator: Maureen Cropper.)

Grant from the Office of Exploratory Research of E.P.A., 1995-1996, to support research on ownership and use of older vehicles. (Other investigator: Virginia McConnell).

Grant from the Office of Exploratory Research of E.P.A., 1993-1995, to support research on the health effects of air pollution (using epidemiological data) and the value of reduced morbidity (using contingent valuation survey data). (Other investigators: Alan Krupnick and Maureen Cropper).

Grant from Fondazione E.N.I. Mattei, Milan, Italy, 1993, to support research on the design of contingent valuation surveys.

Honors and Awards

Best research paper, first semester 2013, awarded to Will Gans, Anna Alberini, and Alberto Longo (2013), "Smart Meter Devices and The Effect of Feedback on Residential Electricity Consumption: Evidence from a Natural Experiment in Northern Ireland," *Energy Economics*, Volume 36, March 2013, Pages 729-743 and FEEM WP 2011.036, at the 2nd Climate Change and Sustainable Development Economics FEEM-CMCC Convention, Venice, 21-23 October 2013

Editorships, Editorial Boards, and Reviewing Activities for Journals

(i) Editorial Activities

Editorial Board Member, *Review of Environmental Economics and Policy*, January 2006 to present.

Member of the Scientific Advisory Board, *Environmental and Resource Economics,* June 2004 to present.

Co-Editor, *Journal of Environmental Economics and Management,* January 2001-June 2004.

Associate Editor, *Journal of Environmental Economics and Management,* January 2000-December 2000.

Member of the editorial board, *Journal of Environmental Management,* January 1999-August 2001.

Member of the editorial council, *Journal of Environmental Economics and Management*, January 1998-December 1999.

(ii) Refereeing Activities

Reviewer for *Energy Economics*, *The Energy Journal*, *Energy Policy, Journal of Risk and Uncertainty*, *Health Economics*, *Applied Economics*, *Journal of Regulatory Economics*, *Global Environmental Change*, *Regional Science and Urban Economics*, *The Energy Journal*, *Journal of Environmental Economics and Management, Land Economics, American Journal of Agricultural Economics, The Journal of Agricultural and Resource Economics, The Review of Economics and Statistics, The Journal of Human Resources, The Journal of Industrial Economics, Journal of Environmental Behavior and Organization, The Journal of Developing Areas, Water Resources Research, Journal of Development Economics, Forest Science, Environmental and Resource Economics.*

Teaching and Advising

Courses Taught

University of Maryland:

AREC 623 (Applied Econometrics I) (Fall Semesters 2000-2012)

AREC 624 (Applied Econometrics II) (Spring Semesters 2000-2013)

AREC 382 (Computer Applications) (Spring Semesters 2004-2013)

University of Colorado:

ECON7828 (Ph.D.-level Econometrics) (Fall Semesters 1997, 1998, and 1999)

ECON4818 (Undergraduate-level Econometrics) (Fall Semesters 1996, 1997, 1998)

ECON6818 (MA-level Econometrics) (Spring Semester 1997)

ECON4535 (Undergraduate-level Environmental Economics) (Spring Semester 1998)

ECON8535 (Ph.D.-level, Environmental Economics Seminar) (Spring Semesters 1998 and 1999)

ECON6535 (MA-level, Environmental Economics) (Spring Semesters 1996 and 1997)

Special Courses Taught

Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zurich), Department of Management, Technology and Economics: Empirical Methods in Energy and Environmental Economics, 11-14 January 2010.

Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zurich), Department of Management, Technology and Economics: Empirical Methods in Energy and Environmental Economics, 7-8 October 2008 and 15-16 January 2009.

Vreij Universitaat Amsterdam, Institute for Environmental Studies (IVM), "Choice Modelling of Water Resources Benefits," 21-24 November 2007.

KVL Royal Veterinarian University, Copenhagen, October 2006, "Discrete Choice Models for Environmental Valuation," October 2006.

Advising: Research Direction

(i) Undergraduate Honors Thesis Advisor

At the University of Colorado: Heather Allerdice-Gerow (1996), Kyle Evashevsky (1997), Mark Kiolbasa (1998), Matthew Lannon (1999)

At the University of Maryland: Jason Wong (with high honors, 2013)

(ii) Master's Thesis Advisor

At the University of Colorado: David Mills (1996), Timothy Cipullo (1997), John Bartholomew (1997), Sean Kearns (1998), William Kugel (1999)

(iii) Master's Thesis Committee Member

At the University of Maryland: Manbar Khadka (AREC, 2009), Robyn Edwards (Landscape Architecture, 2015)

(iv) Ph.D. Dissertation Advisor

At the University of Colorado: Julio R. Videras (2002), Ignacio Correas and Shelby Frost (2002)

At the University of Maryland: Valerie Mueller (graduated 2005), Habiba Djebbari (co-chair; graduated 2004), Soma Bhattacharya (co-chair; graduated 2006), Marcella Veronesi (co-chair; graduated 2008); Shannon Wilson (co-chair; graduated 2009); Dennis Guignet (graduated 2011); Will Gans (graduated 2012); Trang Tran (graduated 2013); Qing Li, Seth Wechsler, Po Ying Wong (graduated 2015).

(v) Ph.D. Dissertation Committee Member

At the University of Colorado: Omar Bello (2000)

At the University of Maryland: Cindy Nickerson (AREC, 2000), Marc Fleming (AREC, 2003), Tim Thomas (AREC, 2003), Beomsoo Kim (Economics Department, 2006), Ye Zhang (Economics Department, 2007), Aparajita Goyal (Economics Department, 2008), Yi Jiang (Economics Department, 2008), Sarah Adelman (AREC, 2009), Yabei Zhang (AREC, 2009), Meltem Daysal (Economics Department, 2009), Liangsheng Meng (Economics Department, 2010), David Herberich (AREC, 2010), Diether Bauermann (Economics Department, 2010), Jing Zhang J. (Economics Department, 2011), Renting Xu (Civil Engineering, 2011), Alessandro Orfei (Economics Department, 2012), Geret DePiper (AREC, 2012), Elisabeth Newcomb (AREC, 2012), Adan Martinez Cruz (AREC, 2013), Takahiko Kiso (AREC, 2013), Kabir Malik (AREC, 2013), Sean Sylvia (AREC, 2014), Hei Sing ("Ron") Chan (Economics Department, 2014), Dana Andersen (AREC, 2014), Rowena Rowie Jean-Louise Kirby Straker (Communications, 2014), Pinar Gunes (AREC, 2014), Kanishka Kacker (AREC, 2014), Seth Wechsler (2014), Dan Werner (2014), Ian B. Page (2015), Magda Tsaneva Rumanova (2015), Anand Murugesan (2015).

(vi) External Examiner

At ETH Zürich: Celine Ramseier (D-MTEC, CEPE-ETH, Switzerland 2013), Marieke Francke (KU Leuven, Belgium).

Service

(i) Professional

Member of the Board of Directors, Association of Environmental and Resource Economists (AERE), January 2000-December 2002.

Chair of the AERE Contributed Papers Selection Committee, January 1999-December 2000.

Member of the AERE Contributed Papers Selection Committee, 1997-98.

(ii) for Agencies

European Environment Agency, member of the Network of Economists, April 2004 to present.

US EPA Science Advisory Board, Environmental Economics Advisory Council, December 2003 to December 2009 (two terms).

Panel Review member for the US Environmental Protection Agency (US EPA) Graduate Fellowships (Social Sciences), 1999, 2000, 2001.

Panel Review member for the National Science Foundation (NSF) Environmental Statistics funding competition, 1999.

Reviewer of research proposals for US EPA and National Science Foundation

(iii) Department

Chair, Placement Committee, academic years 2006-07, 2007-08, 2009-10, 2010-11, 2011-12, 2012-13.
Undergraduate Advisor, 2006-07, 2009-10, 2010-11.
Search committee, 2010-11.
Chair of the Search Committee, 2011-12 and 2012-13.
Seminar Committee, 2010-11, 2012-13.
Chair of the Seminar Committee, 2011-12.
Director of Graduate Studies, academic year 2004-05.
Member, Graduate Committee, 2002-2005.
Member, Scholarship Committee, 2001-2002.
Member, Graduate Placement Committee, 2001-2004.

Professional Memberships

American Economics Association, Association of Environmental and Resources Economists, and European Association of Environmental and Resource Economists, International Association for Energy Economics.

GRAHAM A. DAVIS

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Boulder, Colorado 80305, USA
Tel: (303) 273-3550
email: gdavis@mines.edu

Education

Degrees:

Ph.D., Mineral Economics, 1993
Pennsylvania State University, USA

MBA, 1988
University of Cape Town, South Africa

B.Sc. (with honors), **Metallurgical Engineering**, 1982
Queen's University at Kingston, Canada

Employment

Academic:

Professor, April 2006 –
Division of Economics and Business, Colorado School of Mines

Undergraduate Courses Taught	Graduate Courses Taught
Microeconomics	Microeconomics
International Economics	Resource Economics
Economic Development	Economic Development
Freshman Success	Asset Valuation (Real Options)
Mathematical Economics	Mathematical Economics
Economics Field Session	Mineral and Energy Policy Analysis
Investments	Social License in Exploration and Mining
Public Policy (Honors)	Research Methodology
	Advanced Project Analysis

Associate Professor, April 1999 - April 2006
Division of Economics and Business, Colorado School of Mines

Assistant Professor, August 1993 - April 1999
Department of Mineral Economics, Colorado School of Mines

Instructor, 1992 - 1993
Department of Mineral Economics, The Pennsylvania State University

Assistant Lecturer, 1988 - 1989
The Graduate School of Business, University of Cape Town

Employment (continued)

Industry:

Resource Economics Consultant and Expert Witness, 1993 - Present
United States Dept. of Energy, United States Dept. of Justice, RMB Resources, Yates and Leal LLP, Hall and Evans LLP, Corporate Tax Management, Monument Resources, National Research Council, Pincock, Allen and Holt, Frommer Lawrence & Haug LLP, Platts Research & Consulting, Stevens Littman Biddison Tharp & Weinberg LLC, Berg Hill Greenleaf & Ruscitti LLP, Royal Gold, Community Systems Associates, Birch Mountain Resources, Westchester Resources, Africore (Ghana), Patterson Belknap Webb & Tyler LLP, De Beers, De Beers Canada, Duke Corporate Education, Shutts & Bowen LLP, Reoforce Inc., Australian Centre for Geomechanics, United Nations Conference on Trade and Development, Hines Norman Hines PL, Foulston Siefkin LLP, Rio Tinto Coal Australia, Yetter, Warden & Coleman, LLP, Boulder Scientific, GLG, Newmont Mining USA, CRC Mining, Ernst & Young LLP, Summit Consulting LLC, Debevoise and Plimpton LLP, Pomerantz, Grossman, Hufford, Dahlstrom & Gross LLP, The Brattle Group, Dechert (Paris) LLP, White & Case LLP.

World Bank Group Staff Member, 2013 - 2014

Consulting Metallurgist, 1986
Deblin Mines (silver/lead/zinc), Swakopmund, Namibia

Mill Metallurgist, 1985 - 1986
Equity Silver Mines Ltd. (Placer Dome), British Columbia, Canada

Metallurgical Engineer, 1982 - 1985
Rössing Uranium Ltd. (RTZ), Swakopmund, Namibia

Research Grants

Earth Resources Institute Mini-Grant, 2015, $12,500

Inter-American Development Bank, 2013: $20,666

Denham Capital Management LP, 2011 - 2012: $129,956

Ernst and Young LLP, 2011: $2,580

Ernst and Young LLP, 2010: $8,000

United Nations Industrial Development Organization, 2010: $29,038.

World Trade Organization, 2009: $9,396.

CRC Mining, 2009: $9,331.

CRC Mining, 2008: $30,000.

Research Grants (continued)

RCF Management LLC, 2008: $1,367.

International Council on Mining and Metals: $15,000.

AMEC Americas, 2004 - 2006: $2,000 annually.

U.S. Dept. of Energy, Fossil Energy Division, 2002 - 2003: $30,000.

International Council on Mining and Metals, 2002: $10,400.

National Renewable Energy Laboratory, 2001: $4,976.

Rio Tinto, 1997: $10,000.

Rio Tinto, 1996: $10,000.

National Science Foundation/Environmental Protection Agency Partnership for Environmental Research (NSF 95-48), R824705-01-0, 1995 - 1997: $101,000.

Professional Awards, Appointments, and Distinctions

Honorary Professor, GĔRENS Escuela de Postgrado, Lima, Peru, 2016 -

William J. Coulter Chair in Mineral Economics, 2014 - 2016

Research Council, J.P. Morgan Center for Commodities, University of Colorado at Denver Business School, 2015 -

Associate Editor, Journal of Commodity Markets (Elsevier), 2015 -

Co-editor, Global Commodity Issues (Editor's Choice) eJournal, 2015 -

Mineral Economics Award, Society for Mining, Metallurgy and Exploration/American Institute of Mining, Metallurgical, and Petroleum Engineers, 2014.

Academic Advisor, The Brattle Group, 2013 -

Outstanding Instructor in Mineral and Energy Economics, Division of Economics and Business, Colorado School of Mines, 1995 - 1996, 1996 - 1997, 1997 - 1998, 2005 - 2006, 2007 - 2008, 2011 - 2012, 2012 - 2013, 2014 - 2015, 2015 - 2016.

Editorial Board, Resources Policy (Elsevier), 2007 -

Board of Trustees, Queen's University at Kingston (Canada), 2006 - 2012.

Board of Directors, Mineral Economics and Management Society, 2005 - 2007.

Professional Awards, Appointment, and Distinctions (continued)

Visiting Scholar, Centre Interuniversitaire de Recherches en Economique Quantitative (CIREQ), McGill University, 2004.

Member, National Research Council Standing Committee on Earth Resources, Board on Earth Sciences and Resources, 1999 - 2001.

Visiting Teaching Fellow, Department of Mineral Economics, Western Australia School of Mines, 1997.

Domingo Moreno Developmental Professorship in Mineral Economics, Colorado School of Mines, 1996 - 1997.

United Nations Conference on Trade and Development (UNCTAD) Secretary-General's Expert Group on Development Policies in Resource-based Economies, 1996.

Centennial Fellow, College of Earth and Mineral Sciences, Pennsylvania State University, 1996.

Visiting Scholar, Graduate School of Business, University of Cape Town, 1995.

Memberships

Member, American Economic Association (AEA)

Member, Association of Environmental and Resource Economists (AERE)

Registered Member, Society for Mining, Metallurgy, and Exploration (SME)

Fellow, Australasian Institute of Mining & Metallurgy (AusIMM)

Member, International Association for Energy Economics (IAEE)

Member, United States Association for Energy Economics (USAEE)

Member, Prospectors & Developers Association of Canada (PDAC)

Publications

Books:

Davis, G. A. South African Managed Trade Policy: The Wasting of a Mineral Endowment. Westport: Praeger (1994).

Publications (continued)

Chapters in Books:

(Refereed) Davis, G. A., "Replicating 'Sources of Slow Growth in African Economies'," in Methodological Challenges and New Approaches to Research in International Development, Laura Camfield, ed. London, Palgrave Macmillan (2014), 261-82.

Samis, M., and Davis, G. A., "Using Dynamic DCF and Real Options Methods to Value and Assess Flexible Mine Project Design," in Mineral Resources/Reserves and Valuation Standards, CIM Special Volume 56, Montreal: Canadian Institute of Mining, Metallurgy and Petroleum (2009), 632-50.

(Refereed) Davis, G. A., "Extractive Economies, Growth and the Poor," in Mining, Society, and a Sustainable World, Jeremy P. Richards, ed. Berlin: Springer-Verlag (2009), 37-60.

Davis, G. A., "Project Feasibility Evaluation: New Trends," in Sustainable Management of Mining Operations, edited by Jose A. Botin. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. (2009), 240-48.

(Refereed) Davis, G. A., and Samis, M. "Using Real Options to Value and Manage Exploration," in Wealth Creation in the Minerals Industry: Integrating Science, Business, and Education, edited by Michael D. Doggett and John R. Parry. Littleton, CO: Special Publication Number 12, Society of Economic Geologists (2006), 273-94.

Davis, G. A., and Tilton, J. E. "La Maldición de los Recursos Naturales," in Minería y Desarrollo, Foro en Economía de Minerales, Vol. III, edited by Gustavo Lagos. Santiago: Ediciones Universidad Católica de Chile (2005), 83-103.

Davis, G. A., and Moore, D. "Valuing Mineral Stocks and Depletion in Green National Income Accounts," in Natural Resource Accounting and Economic Development: Theory and Practice, edited by Charles Perrings and Jeffrey R. Vincent. Cheltenham: Edward Elgar (2003), 105-23. Reprinted from Environmental and Development Economics 5 (2000): 109-27.

Davis, G. A. "The Potential for Economic Recovery of Metals from the Sillamäe Site," in Turning a Problem into a Resource: Remediation and Waste Management at the Sillamäe Site, Estonia, edited by Cheryl K. Rofer and Tõnis Kaasik. Dordrecht: Kluwer Academic Publishers (2000), 195-206.

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“The Empty Economics in South Africa's Industrial Policy,” 68th Annual Western Economic Association International Conference, Lake Tahoe, Nevada, June 20-24, 1993.

“The South African Export Incentive Scheme: Boom or Bust for the Minerals Sector?”, First Annual Mineral Economics and Management Society Professional Program, Sterling, Virginia, March 19-21, 1992.

“The Declining Influence of Economic Growth on Metal Demand,” International Symposium on Productivity and Technology in the Metallurgical Industries, co-sponsored by The Minerals, Metals & Materials Society and Gesellschaft Deutscher Metallhütten-und Bergleute, Cologne, West Germany, September 17-22, 1989.

Executive Short Courses

“Using Dynamic DCF and Real Options to Design, Value and Manage Natural Resource Projects,” with Michael Samis. 8 hours or 24 hours of instruction, 2 Continuing Education units, offered through the Colorado School of Mines Office of Special Programs and Continuing Education.

“Using Monte Carlo Simulation to Design, Value and Manage Mineral and Energy Projects,” with Michael Samis. 8 hours or 24 hours of instruction, 2 Continuing Education units, offered through the Colorado School of Mines Office of Special Programs and Continuing Education.

Refereeing Services

Agricultural and Resource Economics Review, American Economic Review, American Journal of Agricultural Economics, Annals of Operations Research, Applied Economics, Applied Financial Economics, Applied Mathematical Modelling, The Australasian Institute of Mining and Metallurgy, Australian Journal of Management, Blackwell Publishing, Boston University, Canadian Institute of Mining and Metallurgy (CIM) Bulletin, Canadian Journal of Economics, China: An International Journal, Development & Society, Ecological Economics, Economic Development and Cultural Change, Economic Inquiry, Economics Bulletin, Energy - The International Journal, Energy Economics, Energy Journal, Energy Policy, Engineering Economist, Environment and Development Economics, Environmental and Resource Economics, European Journal of Development Research, European Journal of Finance, European Journal of Operational Research, Exploration and Mining Geology, Greener Management International, IEEE Transactions on Engineering Management, International Economic Review, International Journal of Industrial Organization, International Journal of Oil, Gas, and Coal Technology, International Journal of Risk Assessment and Management, International Review of Economics and Finance, Japan International Cooperation Agency Research Institute, Journal of Commodity Markets, Journal of Corporate Finance, Journal of Development Studies, Journal of Economics and Business, Journal of Economic Dynamics & Control, Journal of Energy and Development, Journal of Environmental Economics and Management, Journal of Industrial Ecology, Journal of International Development, Journal of Nonlinear Studies, Journal of Petroleum Science and Engineering, Journal of Political Economy, Management Science, Mining Engineering, MIT Press, Natural Resources Forum, Natural Resources Research, New Zealand Economic Papers, Operations Research, Oxford University Press, PennWell Publishing, Policy Sciences, Raw Materials Report, Resource & Energy Economics, Resources Policy, Review of International Economics, SEG Newsletter, Studies in Comparative International Development, United States Environmental Protection Agency, United States National Science Foundation, United States National Research Council, The World Bank, World Development.

LUCIJA ANNA MUEHLENBACHS

Department of Economics
University of Calgary
Phone: (403) 220-7264
Email: lmuehlen@ucalgary.ca
Website: https://sites.google.com/site/lucijamuehlenbachs/

Citizenships: US, Canada, Latvia

EDUCATION

Ph.D. Agricultural and Resource Economics, University of Maryland, 2004-2009
"Internalizing Production Externalities: A Structural Estimation of Real Options in the Upstream Oil And Gas Industry," Committee: John Rust (Co-Chair), Marc Nerlove (Co-Chair), Andreas Lange, Lars Olson, Steven Gabriel.
M.S. Agricultural and Resource Economics, University of Maryland, 2008
B.S. Physical Sciences and Japanese, University of Alberta, 2002, Dean's Honor Roll

PROFESSIONAL EXPERIENCE

University of Calgary, Department of Economics, Assistant Professor, January 2014-
Resources for the Future, Washington, D.C., Visiting Fellow, January 2014-
Swiss Federal Institute of Technology (ETH Zurich), Affiliate Researcher, July 2014-
Resources for the Future, Washington, D.C., Fellow, July 2010-January 2014
Tribune Media Services, Glens Falls, NY, Editor, 2002-2004

PUBLICATIONS

Muehlenbachs, L., Staubli, S., and M.A. Cohen, 2016, "The Effect of Inspector Group Size and Familiarity on Enforcement and Deterrence," *Journal of the Association of Environmental and Resource Economists.* 3(1): 159-204.

Muehlenbachs, L., E. Spiller, and C. Timmins, 2015, "The Housing Market Impacts of Shale Gas Development," *American Economic Review*, 105(12): 3633-59.

Shih, J., Saiers, J.E., Anisfeld, S.C., Chu, Z., Muehlenbachs, L. and Olmstead, S. 2015, "Characterization and analysis of liquid waste from Marcellus Shale gas development," *Environmental Science & Technology*, 49(16): 9557–9565.

Muehlenbachs, L. 2015 "A Dynamic Model of Cleanup: Estimating Sunk Costs in Oil and Gas Production," *International Economic Review*, 56(1): 155-185.

Mason, C., L. Muehlenbachs, and Olmstead, S. 2015 "The Economics of Shale Gas Development," *Annual Review of Resource Economics*, 7(1).

Graham, J., X. Tang, J. Irving, S. Sellers, J. Crisp, D. Horwitz, D. Carey, L. Muehlenbachs, A. Krupnick. 2015. "Increased Traffic Accident Rates Associated with Shale Gas Drilling in Pennsylvania," *Accident Analysis & Prevention,* 74: 203-209.

Olmstead, S., L. Muehlenbachs, J. Shih, J. Chu, and A. Krupnick. 2013. "Shale Gas Development Impacts on Surface Water Quality in Pennsylvania." *Proceedings of the National Academy of Sciences.* 110 (13):4962−4967.

Muehlenbachs, L. M.A., Cohen, and T. Gerarden. 2013. "The Impact of Water Depth on Safety and Environmental Performance in Offshore Oil and Gas Production." *Energy Policy,* 55: 699-705.

Alberini, A., A. Chiabai, and L. Muehlenbachs. 2006. "Using Expert Judgement to Assess Adaptive Capacity to Climate Change: Evidence from a Conjoint Choice Survey." *Global Environmental Change,* 16: 123–144.

WORKING PAPERS

Hausman, C. and L. Muehlenbachs. "Price Regulation and Environmental Externalities: Evidence from Methane Leaks." NBER Working Paper 22261.

Ho, J, A., Krupnick, L. Muehlenbachs, C. Munnings, and J. Shih, "Oil and Gas Well Plugging Costs and Liability," 2016

Linn, J., L. Muehlenbachs, and Y. Wang, "Do Low Natural Gas Prices Benefit Electricity Consumers or the Environment?"

Muehlenbachs, L., E. Newcomb-Sinha and N. Sinha, "Politics and the Strategic Release of News at the EPA," RFF Discussion Paper 11-45, October 2011.

WORK IN PROGRESS

Chu, J., Muehlenbachs, L., and S. Staubli, "The Effect of Hydraulic Fracturing Truck Traffic on Vehicle Crashes"

Muehlenbachs, L., E. Newcomb-Sinha and N. Sinha, "Hitting the violators where it hurts? Stock market reaction to USEPA press releases"

PERMANENT WORKING PAPER

Muehlenbachs, L., E. Spiller, and C. Timmins, "Shale Gas Development and Property Values: Differences across Drinking Water Sources," NBER Working Paper No. 18390, September 2012.

OTHER PUBLICATION

Muehlenbachs, L. and S. Olmstead, "Hydraulic Fracturing and Water Resources," 2014, *Choices*

RESEARCH GRANTS

Principal Investigator, "Rate of Return Regulation and Environmental Externalities: Evidence from Natural Gas," SSHRC Insight Development Grant, $30,870 (2016-2018). Collaborator: Catherine Hausman.

Co-Investigator, "Understanding the Impacts of Shale Gas and Oil Development on Local Communities," $308,088 (2015-2016), Smith Richardson Foundation, PI: Alan Krupnick.

Co-Investigator, "Subsurface impacts of hydraulic fracturing (including contamination, seismic sensitivity, and groundwater use and demand management)," Canadian Water Network, $120,000 (2014-2015). PI: Cathy Ryan. Co-Investigators: Daniel Alessi, David Eaton, Bernhard Mayer, Uli Mayer, John Molson, Beth Parker.

Principal Investigator, "Inspection Group Dynamics and Deterrence," National Science Foundation, SES-1251916, $77,994 (2013-2015). Co-PI: Mark Cohen.

Co-Investigator, "Regulating Risks from Shale Gas Development," Sloan Foundation, $1,171,667 (2011- 2012). PI: Alan Krupnick; Co-Investigators: Sheila Olmstead, Juha Siikamaki, Jhih-Shyang Shih.

Co-Principal Investigator, "Analysis of BOEMRE Enforcement and Compliance Data," National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, $50,000 (2010-2011). Co-PI: Mark A. Cohen.

HONORS AND AWARDS

Outstanding Reviewer, *Journal of Environmental Economics and Management*, 2015
Outstanding Reviewer, *Energy Policy*, 2015
Dr. and Mrs. Bill V. Lessley Dissertation Excellence Award, University of Maryland, 2010
Student Travel Award, European Economics Association Congress, Barcelona, 2009
Dennis J. O'Brien Best Student Paper Award, 32nd International Association for Energy Economics International Conference, 2009
National Capital Area Chapter, U.S. Association for Energy Economics Student Scholarship for the IAEE International Conference, 2009
Institute on Computational Economics Fellow, University of Chicago and Argonne National Laboratory, 2008
Distinguished Teaching Assistant Award, University of Maryland, 2007-2008
Canadian Economics Association Travel Grant, Vancouver, 2008
Jacob K. Goldhaber Travel Award, University of Maryland, 2007

PRESENTATIONS

2017 University of Tennessee (scheduled); ASSAs (Discussant).
2016 HEC Montreal (scheduled); Environmental Defense Fund; Carnegie Mellon University; Cornell University; ASSAs (Discussant).

2015 Arizona State University; University of Alberta; University of Michigan; Colorado School of Mines; University of British Columbia; ASSAs (discussant); University of Oklahoma's Energy Finance Research Conference (discussant).
2014 Duke University (Arctic Drilling Workshop); UC Berkeley (Guest Lecture); Georgia Institute of Technology; Environmental Protection Agency (National Center for Environmental Economics); International Industrial Organization Conference; World Congress of Environmental and Resource Economists; American Society of Civil Engineers Shale Conference (panelist).
2013 AERE Conference Sponsored Session; ETH Zurich; Triangle Resource and Environmental Economics Seminar (Duke University, North Carolina State University, and RTI); University of Calgary.
2012 MIT CEEPR workshop; APPAM Conference; CREE Study Group; Pembina Shale Gas Thought Leaders Forum; World Bank Sustainable Development Forum; 1st NE workshop on Energy Policy and Environmental Economics; Empirical Methods in Energy Economics.
2011 2nd Annual Energy Policy Symposium, Washington DC; University of Basel, Department of Economics; Resources for the Future.
2010 University of Aberdeen; Resources for the Future; University of Alaska-Anchorage; University of Alberta; University of Calgary; Bank of Canada; Congressional Budget Office; Stockholm Institute of Transition Economics, Stockholm School of Economics; International Association for Energy Economics Conference.
2009 European Economics Association Congress; Department of Civil and Environmental Engineering, University of Alberta; International Association for Energy Economics Conference; ETH Zurich.
2008 CREE Study Group; the Canadian Economics Association Annual Meeting.
2007 European Association of Environmental and Resource Economists Conference ; the Banff International Research Station Workshop on "Mathematics and the Environment: Energy Risk, Environmental Uncertainty and Public Decision Making."
2006 Earth System Science Interdisciplinary Center at the University of Maryland; the Global Change Research Institute at the University of Maryland.

RESEARCH IN THE MEDIA

Ph.D. Dissertation: *Alberta Views*

Politics and the Strategic Release of News at the EPA: *E&E News PM, The Hill, Oil and Gas Journal, Washington Post, USA today*

Shale Gas Development and Property Values: Differences across Drinking Water Sources: *Chicago Policy Review, EnergyWire, McClatchy Natural Gas Daily, Washington Post, WCPN-Cleveland Public Radio*

Shale Gas Development Impacts on Surface Water Quality in Pennsylvania: *Circle of Blue, Huffington Post, NGT News, IHS The Energy Daily, Wall Street Journal*

The Housing Market Impacts of Shale Gas Development: *Bloomberg, EnergyWire, Forbes, Reuters, SNL Financial, The Economist, BBC radio.*

Price Regulation and Environmental Externalities: Evidence from Methane Leaks: *the Conversation, NBER digest, SNL News, Michigan Public Radio.*

SERVICE

2014-present Co-organizer of University of Calgary's Empirical Microeconomics Workshop 2014, 2015, 2016

2015-present Vice President, Canadian Association of Energy Economics (CAEE) (the Canadian affiliate of the International Association for Energy Economics, IAEE)

2016 Scholarship Committee, Faculty of Graduate Studies, University of Calgary

2016-Present Board Member, Van Horne Institute

REVIEWING

Editorial council, *Journal of Environmental Economics and Management*, 2016-present

Agricultural and Resource Economics Review; Alfred P. Sloan Foundation Proposal; American Economic Journal: Economic Policy; American Economic Review; American Journal of Agricultural Economics; Canadian Journal of Economics; Conservation Letters; Czech Science Foundation; Economic Inquiry; Energy Economics; Energy Journal; Energy Policy; Environmental Management; Environmental and Resource Economics; Environmental Politics; Environmental Science & Technology; Journal of the Association of Environmental and Resource Economists, Journal of Environmental Economics and Management; Journal of Policy Analysis and Management; Journal of Public Economics; Journal of Regulatory Economics; Michigan Sea Grant Proposal; Resource and Energy Economics

Abstracts for *AAEA Annual Meeting 2014; AERE summer conference 2016; CEA 2016; CREE 2016; Calgary's Empirical Microeconomics Workshop 2014, 2015, 2016.*

SUPERVISORY COMMITTEES

Naima Farah (PhD, ongoing), Wojciech Fulmyk (PhD, ongoing), Blake Schaffer (PhD, ongoing), Yuan Wen (PhD, 2015); Grant Freudenthaler (MA, 2016); Alaz Munzur (PhD Candidacy Committee, 2016); Xiaoli Zheng (PhD Candidacy Committee, 2015), Younes Ahmadi (PhD Candidacy Committee, 2014).

LANGUAGES

English (Native); Spanish (Proficient); Japanese (Proficient); French (Proficient); Latvian (Proficient).

Hilary Sigman

Department of Economics
Rutgers University
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New Brunswick, NJ 08901–1248

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Email: hsigman@rutgers.edu
http://econweb.rutgers.edu/sigman

Current appointments:

Professor (2008-present), Department of Economics, Rutgers University, New Brunswick, NJ
Associate Professor (2001-08), Assistant Professor (1999-2001)

Nonresident Fellow, Resources for the Future, Washington, DC (2011-present)

Research Associate (2008-present), National Bureau of Economic Research, Cambridge, MA
Faculty Research Fellow (1994–2008)

Education:

1993 Massachusetts Institute of Technology, Ph.D. in Economics
Thesis: "Economic Instruments for Hazardous Waste Policy"
National Tax Association Award for Outstanding Doctoral Dissertation

1988 Cambridge University, M.Phil. in Economics

1987 University College of Wales, Aberystwyth, Study in Human and Physical Geography

1986 Yale College, B.A. *summa cum laude*
Honors in Economics and Studies in the Environment, Phi Beta Kappa

Visiting and previous positions:

Summer 2007 Visiting Scholar, Copenhagen Business School

Spring 2002 Visiting Associate Professor, Ford School of Public Policy, University of Michigan

1992–98 Assistant Professor, Department of Economics, UCLA

Fellowships:

Fall 1998 Visiting Fellowship, Hoover Institution, Stanford, CA

1996–1997 Gilbert F. White Fellowship, Resources for the Future, Washington, DC

Spring 1997 Faculty Research Fellowship, UCLA Center for American Politics and Public Policy

Fall 1996 UCLA Faculty Career Development Award

1990–1992 M.I.T. Center for Energy and Environmental Policy Research, Dissertation funding

1988–1990 Robert M. Solow Fellowship

1986–1988 Keasbey Memorial Scholarship (for two years' study in the U.K.)

Professional activities:

Board of Directors (2003–2005), Nominating Committee (2007), Publication of Enduring Quality Committee (2014-17) of the Association of Environmental and Resource Economists (AERE)

Environmental Economics Advisory Committee (1998–2004) and UST/RCRA Benefits, Costs, and Impacts Review Panel (2002) of the Science Advisory Board, U.S. Environmental Protection Agency (EPA)

Research grants and contracts:

2011–2012 World Bank, Knowledge for Change Program, "Damming the commons: An analysis of international cooperation and conflict over water" (Co-investigator)

2005–2009 U.S. EPA, National Center for Environmental Research, Science to Achieve Results (STAR) Research Grant, "Environmental liability, cleanup expenditures, and redevelopment of old industrial land," $149,237 (P.I.)

1999–2003 National Science Foundation, Research Grant
"International spillovers and water quality in rivers," $137,792 (P.I.)

1994–1997 U.S. EPA, Office of Exploratory Research, Research Grant
"Liability funding and Superfund clean-up strategies," $218,805 (P.I.)

1994–1995 U.C. Toxic Substances Research and Teaching Program, Research Grant
"Cross-media substitution in toxic chemical emissions," $19,200 (P.I.)

1993 Marine Policy Center, Woods Hole Oceanographic Institution,
Subcontract for Focal Study, "The cost of waste reduction"

Publications:

"Damming the Commons: An Empirical Analysis of International Cooperation and Conflict in Dam Location" (with Sheila M. Olmstead), *Journal of the Association of Environmental and Resource Economists* 2 (December 2015), 497–526.

"An Empirical Analysis of Cost Recovery in Superfund Cases: Implications for Brownfields and Joint and Several Liability" (with Howard F. Chang), *Journal of Empirical Legal Studies* 11 (September 2014), 477–504.

- Summarized in *NBER Digest,* December 2010

"Endogenous Decentralization in Federal Environmental Policies" (with Howard F. Chang and Leah G. Traub), *International Review of Law and Economics* 37 (March 2014), 39–50.

"Decentralization and Environmental Quality: An International Analysis of Water Pollution Levels and Variation," *Land Economics* 90 (February 2014), 114–30.

"Monitoring and Enforcement of Climate Policy" in Don Fullerton and Catherine Wolfram, eds. *The Design and Implementation of U.S. Climate Policy* (Chicago: University of Chicago Press, 2012), 213–25.

"Management of Hazardous Waste and Contaminated Land" (with Sarah Stafford), *Annual Review of Resource Economics* 3 (2011), 255–75.

"The Effect of Allowing Pollution Offsets with Imperfect Enforcement" (with Howard F. Chang), *American Economic Review (Papers and Proceedings)* 101 (May 2011), 268–72.

"Environmental Liability and Redevelopment of Old Industrial Land," *Journal of Law and Economics* 53 (May 2010), 289–306.

"Implications of Globalization and Trade for Water Quality in Transboundary Rivers" (with Howard F. Chang) in Claudia Ringler, Asit Biswas, and Sarah Cline, eds. *Global Change: Impacts on Water and Food Security* (New York: Springer, 2010), pp. 97–111.

Economics of Hazardous Waste and Contaminated Land. Cheltenham, UK: Edward Elgar, 2008 (edited volume in International Library of Critical Writings in Economics).

"Economics of Hazardous Waste," in Steven N. Durlauf and Lawrence E. Blume, eds. *The New Palgrave Dictionary of Economics, 2nd edition* (Basingstoke and New York: Palgrave Macmillan, 2008).

"A Cross-Country Comparison of Decentralization and Environmental Protection," in Greg Ingram and Yu-Hung Hong, eds. *Land Policies and Fiscal Decentralization* (Cambridge, MA: The Lincoln Institute for Land Policy, 2008), 195–215.

"The Effect of Joint and Several Liability under Superfund on Brownfields," (with Howard F. Chang), *International Review of Law and Economics* 27 (December 2007), 363–384.

"Legal Liability as Climate Change Policy," *University of Pennsylvania Law Review* 155 (June 2007), 1953–1959.

"The Incidence of Pollution Control Policies" (with Ian W.H. Parry, Margaret Walls, and Roberton C. Williams III) in Tom Tietenberg and Henk Folmer, eds. *International Yearbook of Environmental and Resource Economics 2006/2007* (Cheltenham, UK: Edward Elgar, 2006), 1–44.

"Transboundary Spillovers and Decentralization of Environmental Policies," *Journal of Environmental Economics and Management* 50 (June 2005), 82–101.

"Does Trade Promote Environmental Coordination? Pollution in International Rivers," *Contributions to Economic Analysis and Policy,* 3 (Issue 2, 2004), Article 2.

- reprinted in D. Fullerton, ed., *The Economics of Pollution Havens,* Cheltenham, UK: Edward Elgar, 2006.
- reprinted in K.W. Easter and N. Zeitouni, eds. *Economics of Water Quality,* Ashgate Publishing, 2007.

"Targeting Lead in Solid Waste," in Nils Axel Braathen, ed. *Addressing the Economics of Waste* (Paris: OECD, 2004), 161–180.

"Taxes on Hazardous Waste: The U.S. Experience," *Public Finance and Management* 3(1), 2003, 12–33.

"Letting the States Do the Dirty Work: State Responsibility for Federal Environmental Regulation," *National Tax Journal* 56 (March 2003), 107–122.

"International Spillovers and Water Quality in Rivers: Do Countries Free Ride?" *American Economic Review* 92 (September 2002), 1152–1159

- reprinted in J. Geoghegan and W. Gray, eds., *Spatial Aspects of Environmental Policy,* Ashgate Publishing, 2006

"The Pace of Progress at Superfund Sites: Policy Goals and Interest Group Influence," *Journal of Law and Economics*, 44 (April 2001), 315–44

- reprinted in Geoghegan and Gray (2006)

"Environmental Liability in Practice: Liability for Cleanup of Contaminated Sites under Superfund," in Anthony Heyes, ed. *The Law and Economics of the Environment*, (Cheltenham, U.K.: Edward Elgar, 2001), 136–149.

"Hazardous Waste and Toxic Substance Policies," in Paul R. Portney and Robert N. Stavins, eds. *Public Policies for Environmental Protection,* Second Edition (Washington, DC: Resources for the Future, 2000), 215–260.

"Incentives to Settle Under Joint and Several Liability: An Empirical Analysis of Superfund Litigation" (with Howard F. Chang), *Journal of Legal Studies* 29 (January 2000), 205–236.

"Reforming Hazardous Waste Policy," Hoover Institution Essays in Public Policy (Stanford, CA: Hoover Institution, 1999).

"Liability Funding and Superfund Clean-Up Remedies," *Journal of Environmental Economics and Management* 35 (May 1998), 205–224.

"Midnight Dumping: Public Policies and Illegal Disposal of Used Oil," *RAND Journal of Economics* 29 (Spring 1998), 157–178.

"The Cost of Reducing Municipal Solid Waste" (with Karen Palmer and Margaret Walls), *Journal of Environmental Economics and Management* 33 (June 1997), 128–150.

- reprinted in T. Kinnaman, *The Economics of Residential Solid Waste Management*, Ashgate Publishing, 2003
- reprinted in R.K. Turner, I. Bateman, and J. Powell, eds. *Waste Management and Planning,* Edward Elgar, 2001.

"Cross-Media Pollution: Responses to Restrictions on Chlorinated Solvent Releases," *Land Economics* 72 (August 1996), 298–312.

"The Effects of Hazardous Waste Taxes on Waste Generation and Disposal," *Journal of Environmental Economics and Management* 30 (March 1996), 199–217.

"A Comparison of Public Policies for Lead Recycling," *RAND Journal of Economics* 26 (Autumn 1995), 452–478.

Book reviews, proceedings, and other works:

"Comments on 'Distributional Aspects of a Comprehensive Climate Policy' " in Fullerton and Wolfram, eds. *The Design and Implementation of U.S. Climate Policy* (Chicago: University of Chicago Press, 2012), 34-6.

"Members' Responses to the Survey on the AERE Journal Proposal," *AERE Newsletter*, 2004.

"Review of *The Economics of Waste* by Richard C. Porter," *Journal of Economic Literature* 42 (March 2004), 229–31.

"Review of *The Greening of Industry: A Risk Management Perspective* by John Graham and Jennifer Hartwell," *Journal of Economic Literature,* 36 (June 1998), 996–998.

"Economic Instruments for Hazardous Waste Policy," *Proceedings of the National Tax Association*, vol. 86, 1994.

"An Empirical Assessment of State Hazardous Waste Taxes," *Proceedings of the National Tax Association*, vol. 86, 1994.

"State Hazardous Waste Fees: An Assessment," *New Partnerships: Economic Incentives in Environmental Management*, Pittsburgh: Air and Waste Management Association, 1994.

Working papers and work in progress:

"Droughts, Dams, and Economic Activity" (with Sheila M. Olmstead), work in progress.

Reviewing and related activities:

1997–2004	Editorial Council, *Journal of Environmental Economics and Management*
2003–	Editorial Council, *Public Finance Review*
2003	Co-organizer, NBER Summer Institute Environmental Economics and Policy Workshop

Reviewer for:
Journals: *American Economic Review, B.E. Press Journal of Applied Economics and Policy, Canadian Journal of Economics, Contemporary Economic Policy, Ecological Economics, Economic Inquiry, Economic Journal, Energy Journal, Environment and Development Economics, Environment and Planning A, Environmental and Resource Economics, Finnish Economic Papers, Frontiers in the Economics of China, International Tax and Public Finance, Journal of the Association of Environmental and Resource Economics, Journal of Economic Literature, Journal of Environment and Development, Journal of Environmental Economics and Management, Journal of Environmental Management, Journal of Industrial Economics, Journal of Law and Economics, Journal of Law, Economics and Organization, Journal of Policy Analysis and Management, Journal of Public Economics, Journal of Regulatory Economics, Land Economics, National Tax Journal, Policy Studies Review, Public Finance Quarterly, Quarterly Journal of Economics, RAND Journal of Economics*, *Regional Studies and Urban Economics, Resource and Energy Economics*, *Review of Economics and Statistics, Review of Economic Studies, Review of Environmental Economics and Policy, Review of Law and Economics, Science, Southern Economic Journal*
Granting Organizations: National Science Foundation, Social Science and Humanities Research Council of Canada, Czech Research Foundation, University of California Energy Institute
Conference Selection Committees: 2011-13, 2015 AERE Annual Meetings, 2011, 2012, 2015 EAERE Annual Meetings, 2006, 2010, 2014 World Congresses of the Environmental and Resource Economists, 1999 AERE-Harvard Workshop on Market Mechanisms
Other: National Research Council, U.S. Environmental Protection Agency, Edward Elgar, Addison-Wesley, National Tax Association Dissertation Awards

Presentations (since 2005):

Fordham University, Department of Economics, April 2014
American Economic Association Annual Meeting, Philadelphia, January 2014
Resources for the Future, Washington, DC, May 2012
University of California, Santa Barbara, Department of Economics, October 2011
Society for Environmental Law and Economics, Amsterdam, June 2011
American Economic Association Annual Meeting, Denver, January 2011
Association for Public Policy Analysis and Management Annual Meeting, Boston, Nov. 2010
World Congress of Environmental and Resource Economists IV, Montreal, June 2010
NBER Conference, "The Design of U.S. Climate Policy," Washington, DC, May 2010
Conference on Empirical Legal Studies, Los Angeles, November 2009
Latin American and Caribbean Law and Econ Association Annual Meeting, Barcelona, June 2009
Yale University, Environmental Economics Workshop, April 2009
Fordham University, Department of Economics, October 2008
Conference on Empirical Legal Studies, New York, November 2007
Copenhagen Business School, Denmark, August 2007
Lincoln Institute for Land Policy, Symposium on Fiscal Decentralization, June 2007
EPA Market Mechanisms and Incentives Workshop, Washington, DC, October 2006
World Congress of Environmental and Resource Economics III, Kyoto, Japan, July 2006
NBER Environmental Working Group Meeting, April 2006
National Brownfields Association Annual Meeting, Denver, November 2005
New Jersey Department of Environmental Protection, Trenton, June 2005
Yale Environmental Economics Workshop, May 2005
International Food Policy Research Institute Workshop, Costa Rica, April 2005
Harvard-MIT Joint Environmental Economics and Policy Workshop, March 2005

Recent teaching:

Environmental Economics (Economics 332; 65–85 undergraduate students)
Industrial Organization (Economics 341; 50–90 undergraduate students)
Applied Econometrics for Microeconomics (Economics 509, 5-13 Ph.D. students)
Public Economics (Economics 515; 5-10 Ph.D. students)

Recent university service:
Graduate Program Director, Department of Economics, 2015-18
Coordinator, Empirical Microeconomics Workshop, 2006-15
Executive Committee, Department of Economics, 2008-2010, 2013-14, 2015-18
Graduation Education Committee and Graduate Admissions Committee, 2009-2011, 2012-13
Executive Committee, Graduate School-New Brunswick, 2009-2012
Undergraduate Admission Committee, School of Arts and Sciences, 2012-2014
Undergraduate Honors Committee, School of Arts and Sciences, 2015-2016
Advisory Committee for Appointments and Promotions, School of Arts and Sciences, 2014-16

Board Member, Rutgers Energy Institute, 2009-present
Affiliated Faculty, Rutgers-NSF IGERT on Sustainable Fuel Solutions, 2009-2013

Reviewer Conflict of Interest Letters

Dear Anna Alberini,

Thank you for agreeing to participate in the peer review of the **EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula**.

Please review the following questions and sign the acknowledgement below. Return the signed letter to Suzanne France, either by email to sfrance@michaeldbaker.com or by fax to (919)287-2901.

- Do you know of any reason that you might be unable to provide impartial advice on the document submitted for review or any reason that your impartiality in the matter might be questioned? NO
- Have you had any current or previous involvement with the review document(s) under consideration including authorship, collaboration with the authors, or previous peer review functions? If so, please identify and describe that involvement. NO
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the document under consideration? If so, please identify those activities. NO
- Have you made any public statements (written or oral) on the issue that would indicate to an observer that you have taken a position on the issue? If so, please identify those statements. NO
- Are you a federal employee? (Contractors, grantees, and consultants to a federal agency are not considered federal employees in this matter) NO

Ms. France will be sending you a separate email regarding payment for your efforts on the review of this document.

I, ANNA ALBERINI, certify to the best of my knowledge and belief, that I am not aware of any information, facts, activities, or circumstances bearing on the existence of any potential or actual conflicts of interest (including but not limited to any activities or relationships that would affect, impair, or influence my ability to review applications impartially and objectively) regarding my responsibility to review applications in an impartial, fair, and objective manner in accordance with the stated evaluation criteria. If such a conflict of interest materializes during performance of my responsibilities, I will immediately notify and make a full disclosure to Daniel Fiorino, Project Manager, stop performance, and not continue performance unless and until the conflict of interest can be mitigated, resolved, or avoided.

ANNA ALBERINI	Anna Alberini	26 Sept 2016
Print name	Signature	Date

Dear Dr. Graham Davis,

Thank you for agreeing to participate in the peer review of the **EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula**.

Please review the following questions and sign the acknowledgement below. Return the signed letter to Suzanne France, either by email to sfrance@michaeldbaker.com or by fax to (919)287-2901.

- Do you know of any reason that you might be unable to provide impartial advice on the document submitted for review or any reason that your impartiality in the matter might be questioned?

  No.

- Have you had any current or previous involvement with the review document(s) under consideration including authorship, collaboration with the authors, or previous peer review functions? If so, please identify and describe that involvement.

  No.

- Have you served on previous advisory panels, committees, or subcommittees that have addressed the document under consideration? If so, please identify those activities.

  No.

- Have you made any public statements (written or oral) on the issue that would indicate to an observer that you have taken a position on the issue? If so, please identify those statements.

  No.

- Are you a federal employee? (Contractors, grantees, and consultants to a federal agency are not considered federal employees in this matter)

  No.

Ms. France will be sending you a separate email regarding payment for your efforts on the review of this document.

I, GRAHAM DAVIS, certify to the best of my knowledge and belief, that I am not aware of any information, facts, activities, or circumstances bearing on the existence of any potential or actual conflicts of interest (including but not limited to any activities or relationships that would affect, impair, or influence my ability to review applications impartially and objectively) regarding my responsibility to review applications in an impartial, fair, and objective manner in accordance with the stated evaluation criteria. If such a conflict of interest materializes during performance of my responsibilities, I will

immediately notify and make a full disclosure to Daniel Fiorino, Project Manager, stop performance, and not continue performance unless and until the conflict of interest can be mitigated, resolved, or avoided.

GRAHAM DAVIS		9/28/16
Print name	Signature	Date

Dear Lucija Muehlenbachs,

Thank you for agreeing to participate in the peer review of the **EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula**.

Please review the following questions and sign the acknowledgement below. Return the signed letter to Suzanne France, either by email to sfrance@michaeldbaker.com or by fax to (919)287-2901.

- Do you know of any reason that you might be unable to provide impartial advice on the document submitted for review or any reason that your impartiality in the matter might be questioned?
- Have you had any current or previous involvement with the review document(s) under consideration including authorship, collaboration with the authors, or previous peer review functions? If so, please identify and describe that involvement.
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the document under consideration? If so, please identify those activities.
- Have you made any public statements (written or oral) on the issue that would indicate to an observer that you have taken a position on the issue? If so, please identify those statements.
- Are you a federal employee? (Contractors, grantees, and consultants to a federal agency are not considered federal employees in this matter)

Ms. France will be sending you a separate email regarding payment for your efforts on the review of this document.

I, Lucija Muehlenbachs , certify to the best of my knowledge and belief, that I am not aware of any information, facts, activities, or circumstances bearing on the existence of any potential or actual conflicts of interest (including but not limited to any activities or relationships that would affect, impair, or influence my ability to review applications impartially and objectively) regarding my responsibility to review applications in an impartial, fair, and objective manner in accordance with the stated evaluation criteria. If such a conflict of interest materializes during performance of my responsibilities, I will immediately notify and make a full disclosure to Daniel Fiorino, Project Manager, stop performance, and not continue performance unless and until the conflict of interest can be mitigated, resolved, or avoided.

Lucija Muehlenbachs		29/9/2016
Print name	Signature	Date

Dear Hilary Sigman,

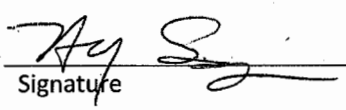
Thank you for agreeing to participate in the peer review of the **EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula**.

Please review the following questions and sign the acknowledgement below. Return the signed letter to Suzanne France, either by email to sfrance@michaeldbaker.com or by fax to (919)287-2901.

- Do you know of any reason that you might be unable to provide impartial advice on the document submitted for review or any reason that your impartiality in the matter might be questioned?
- Have you had any current or previous involvement with the review document(s) under consideration including authorship, collaboration with the authors, or previous peer review functions? If so, please identify and describe that involvement.
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the document under consideration? If so, please identify those activities.
- Have you made any public statements (written or oral) on the issue that would indicate to an observer that you have taken a position on the issue? If so, please identify those statements.
- Are you a federal employee? (Contractors, grantees, and consultants to a federal agency are not considered federal employees in this matter)

Ms. France will be sending you a separate email regarding payment for your efforts on the review of this document.

I, Hilary Sigman, certify to the best of my knowledge and belief, that I am not aware of any information, facts, activities, or circumstances bearing on the existence of any potential or actual conflicts of interest (including but not limited to any activities or relationships that would affect, impair, or influence my ability to review applications impartially and objectively) regarding my responsibility to review applications in an impartial, fair, and objective manner in accordance with the stated evaluation criteria. If such a conflict of interest materializes during performance of my responsibilities, I will immediately notify and make a full disclosure to Daniel Fiorino, Project Manager, stop performance, and not continue performance unless and until the conflict of interest can be mitigated, resolved, or avoided.

Hilary Sigman		9/26/16
Print name	Signature	Date

Review Requests and Charge Questions

Review Request for External Letter Peer Review of the EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula

I. Background

Section 108(b) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or the Act) requires the promulgation of requirements that classes of facilities establish and maintain evidence of financial responsibility consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances.

On July 28, 2009, the EPA published a Federal Register notice that identified classes of facilities within the hardrock mining industry for which the agency will first develop financial responsibility requirements and defined hardrock mining facilities as facilities which extract, beneficiate, or process metals (e.g., copper, gold, iron, lead, magnesium, molybdenum, silver, uranium, and zinc) and nonmetallic, non-fuel minerals (e.g., asbestos,, phosphate rock, and sulfur). The definition includes mineral processing (including primary smelting), but does not include coal mining. EPA also identified some classes of facilities that are not included in the identified classes even though they fell within the definition of "hardrock mining."

EPA's forthcoming proposed CERCLA section 108(b) financial responsibility rule for hard rock mining facilities is expected to establish a consistent nationwide process for owners and operators subject to the proposed rule to determine their potential financial responsibility amounts for their sites, to demonstrate evidence of financial responsibility, and to maintain the required amount of financial responsibility until the requirement for financial responsibility for the site is released by EPA.

EPA developed the Hard Rock Mining Financial Responsibility Formula (the Formula) to provide a practical and consistent approach to determine the amount of financial responsibility needed at each facility, based on those facilities' characteristics. EPA does not intend for the Formula to be used for other purposes, including for estimating response costs in the context of a CERCLA response action. EPA intends to continue to use existing procedures, guidance and the National Contingency Plan, 40 C.F.R. Part 300, in taking CERCLA responses. Nor does EPA intend for the Formula to be used for estimating costs in development of future regulatory impact analyses.

CERCLA section 107 defines the scope of liability under the Act to include health assessment costs, natural resource damages, and response costs. Therefore, EPA developed the Formula to estimate a level of financial responsibility for each of these components consistent with the degree and duration of risks associated with management of hazardous substances at the facility. A fourth component (state-specific adjustment factors) adjusts direct engineering costs to account for recoverable overhead and oversight costs, and makes adjustments for location-specific differences in the costs of engineering supplies and labor. The components thus consist of the following:

(1) Health assessment costs;
(2) Natural resource damages;

(3) Responses costs; and
(4) State-specific adjustment factors.

The components are then combined into a single Formula.

The draft report, *CERCLA 108(b): Financial Responsibility Formula for Hardrock Mining Facilities Background Document*, contains a detailed discussion of the development of the Formula.

In developing the formula EPA was constrained by the available data, and the need for a practical approach that could be applied across a heterogenous set of mining facilities and locations throughout the United States. Practicality is a necessity, and time constraints had to be considered when gathering data and developing the Formula.

II. Purpose

The purpose of this letter peer review is to gather responses to charge questions from individual experts on the Formula development methodology. EPA's report consists of approximately 130 pages of text intended to be accessible and clear, supplemented by approximately 700 pages of appendices of data, statistical regressions, and more.

III. Qualifications of Expert Peer Reviewers

The pool of potential well-qualified reviewers should have expertise in:

- Applied statistics and/or econometrics;
- Applied economics or policy analysis; and
- Preferably some knowledge of
    - Hard rock mining processes;
    - The general principles behind estimating environmental damages;
    - CERCLA actions and Superfund sites; and/or
    - Experience studying releases of hazardous substances and working with data on response and remediation costs and natural resource damages.

The reviewers shall have credentials equivalent to a Ph.D. and shall be judged by authorship on original publications and/or review in independent peer-reviewed journals. Reviewers may also be judged by other measures of expertise including professional accomplishments.

The contractor shall compile a list of roughly 8 to 12 potential reviewers. EPA will then review the list to confirm that the potential reviewers are adequately qualified. Upon receiving direction from the EPA-COR, the contractor shall then randomly select and contact potential reviewers. The contractor shall secure four experts to participate in the letter peer review. The four selected reviewers shall meet the following criteria:

- At least one of the four reviewers shall have demonstrated knowledge of hard rock mining or related processes.
- At least one reviewer must have experience with the CERCLA program and related data.
- At least two reviewers must be researchers with level 3 expertise or higher.

Level 1 reviewers will have engaged in relevant research as evidenced by at least one peer-reviewed journal publication in the subject of the review.

Level 2 reviewers will have engaged in relevant research as evidenced by at least three peer-reviewed journal publications in the subject of the review; or by at least one peer-reviewed journal publication in the subject of the review and by serving as the principal investigator for a research project comparable to the product being reviewed.

Level 3 reviewers will have engaged in relevant research and achieved standing in the field as evidenced by at least four peer-reviewed journal publications in the subject of the review; by serving as the principal investigator for at least one research project comparable to the product being reviewed; and by achieving recognition in the field as reflected by awards, and other honors received from scientific and professional organizations (e.g. an AERE or AAAS Fellow), distinguished or named professorships, journal editorships, or appointment to high-level review committees (such as the National Research Council or Science Advisory Board).

Examples of potential reviewers may include:

- Dr. Mary E. Barth; Graduate School of Business; Stanford University
- Dr. David Gerard; Department of Economics; Lawrence University
- Dr. Katherine Kiel; Department of Economics and Accounting; College of the Holy Cross
- Dr. David M. Konisky; School of Public and Environmental Affairs; Indiana University Bloomington
- Dr. Lucija Muehlenbachs; Department of Economics; University of Calgary
- Dr. Hilary Sigman; Department of Economics; Rutgers University
- Dr. Kris Wernstedt; School of Public and International Affairs; Virginia Tech

IV. Kickoff Conference Call

Upon securing four reviewers, the contractor shall coordinate a conference call between EPA and the reviewers. The objective of the conference call is to provide background information on the Formula and key objectives, as well as outline the charge questions and answer any initial questions the reviewers may have. The conference call will likely require Adobe Connect or similar capabilities.

V. Charge Questions

Based on your knowledge of econometrics, statistics, hard rock mining, contaminated sites, and Superfund cleanups, please assess the report and appendices in response to the following charge questions. Please keep in mind EPA's two objectives for the Formula:

- To provide a practical approach to determine the amount of financial assurance needed at each regulated facility
- To provide a consistent procedure that can be applied to all regulated hard rock mines and processing facilities across the United States.

V.1 Overarching Questions

1.) As mentioned above, EPA developed the Formula to estimate reasonable financial assurance amounts at the diverse range of mining facilities that are being potentially regulated under the 108b rule. Please provide an overall assessment of the underlying methodology that EPA used to develop the Formula, keeping in mind the immediate need for a feasible consistent nationwide approach, and provide recommendations for enhancing the methodology.

2.) Do you have any recommendations that might improve the soundness and transparency of the analytical and statistical methods used to develop the Formula? If so, please distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.

V.2 Specific Questions

3.) EPA collected data on specific response activities conducted at historical National Priorities List or Superfund alternative approach[1] hardrock mining sites. Please assess the appropriateness of these data for the subsequent analysis. Are you aware of additional nationwide datasets that may further supplement the data used by EPA to identify response activities that EPA may have to undertake during a CERCLA response at a hard rock mining facilities? If so, please discuss.

4.) Several steps were taken to "standardize" data on response costs (e.g., adjust for inflation and account for state level differences in input costs). Given the application of these data, please comment on these pre-analysis data steps. What improvements (if any) would you recommend? Please elaborate on the specifics of any recommendations, and distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.

5.) Using the aforementioned data on response activities, EPA linked specific site features to the release of hazardous substances and the resulting response costs. Are there additional site features that you recommend EPA consider and how might these additional features be key explanatory variables of response costs? Please distinguish between suggestions that are immediately feasible with available data versus those that might be more appropriate in the long term or with significant resources.

6.) Several tests were conducted to examine the robustness of the chosen statistical models (e.g., examining internal and external transfer error). In your professional opinion, do these robustness checks reasonably support the chosen statistical models? If applicable, please describe any additional robustness checks that EPA should consider in the development of the Formula which could feasibly be carried out with the available data.

[1] Information on EPA's Superfund alternative approach is available at the following EPA website: https://www.epa.gov/enforcement/superfund-alternative-approach

VI. Milestones, Schedule, and Deliverables

Milestone	**Schedule**
Provide list of 8-12 potential reviewers and provide an academic and professional biography and CVs, information concerning the reviewer's availability and willingness to provide review within the specified time frame if possible, and Statement of Conflict of Interest to the CO if possible	Two weeks (10 business days) after receipt of review request
Finalize peer reviewer selection	3 business days after CO verifies the list of potential reviewers conforms to the qualifications of reviewers provided to contractor and Statement of Conflict of Interest
Signed peer reviewer COI declarations	Within one weeks (5 business days) of CO's verification of potential reviewers
Contractor distributes the report and charge to reviewers	Within 3 business days after peer reviewers have signed COI, and all materials for review are provided by CO to contractor
Contractor coordinates and holds conference call with reviewers and EPA	Within 8 business days after peer reviewers have signed COI
Contractor receives and compiles reviewers comments	35 calendar days after documents distributed for peer review
Contractor provides reviewer comments and responses to charge questions	Within 5 calendar days after comments received from peer reviewers, no later than November 1, 2016

VII. Conflict of Interest

The contractor shall follow Conflict of Interest procedures for Task Orders in accordance with Contract Clause: Ordering Procedures, Organizational Conflict of Interest (EPAAR 1552.209-71), Notification of Interest Regarding Personnel (EPAAR 1552.209-73), and "Conflict of Interest Evaluation for Task Orders".

Conference Call Description and Presentation

CERCLA 108(b) Financial Responsibility Formula for Hardrock Mining
Conference Call
Monday October 3rd, 2016
1:00 – 3:00 p.m.

OLEM attendees:
Richard Benware
Alyssa Cultice
Mark Huff
Lee Hofmann
Joseph Krahe
Mike Pease
Laura Stanley
Taetaye Shimeles

NCEE attendees:
Dennis Guignet
Robin Jenkins
Carl Pasurka
Brett Snyder

MDB attendees:
Justin Crane
Daniel Fiorino
Suzanne France
Kathryn Kiel
Larry Reed

Peer Reviewers:
Anna Alberini (listened to a taping of the conference call at a later date)
Graham Davis
Lucija Muehlenbachs
Hilary Sigman

Purpose of the Conference Call
The purpose of the conference call was for NCEE and OLEM to give the background of CERCLA 108(b) and an overview of the Financial Responsibility formula to the Peer Reviewers. The phone call also went through each component of the review document in summary. At the end of the call the Peer Reviewers were given an opportunity to ask questions.

CERCLA 108(b) Financial Responsibility Formula for Hardrock Mining

10-03-2016 Hardrock Mining Peer Review Conference

Presentation Overview

- CERCLA 108(b) Background
- Formula Overview
- Response Component
  - Linking response categories to engineering cost estimates
  - Response component data collection
  - Response component regression analysis
  - Converting O&M costs into a net present value
  - State-specific adjustment factors
- Natural Resource Damages Component
- Health Assessment Component
- Financial Responsibility Formula
- Charges to Peer Reviewers
- Questions

Background: CERCLA Section 108(b) Financial Responsibility

- Section 108(b) of CERCLA directs EPA to develop requirements that classes of facilities establish and maintain evidence of financial responsibility consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances.
- A key purpose of this provision is to assure that owners and operators make financial arrangements to address risks from the hazardous substances at their sites.
  - EPA calculations show that, through FY2011, the Agency had spent approximately $4.6 billion to clean up hardrock mines and mineral processors.
- EPA also intends for the rule to create financial incentives for improved mining practices that reduce financial responsibility costs where existing and certain future practices ultimately may also help reduce risks and costs to the Superfund program.

Background: CERCLA Section 108(b) Financial Responsibility

- Section 108(b) also requires that EPA issue a *Federal Register* Notice identifying the classes of facilities for which it will first develop requirements.
- EPA issued that *"Priority Notice"* on July 28, 2009, and identified classes of facilities within the hardrock mining industry as those for which it would first develop requirements.
- https://www.epa.gov/superfund/superfund-financial-responsibility

Background: CERCLA Section 108(b) Financial Responsibility

- For purposes of the notice, EPA defined "hardrock mining" as the extraction, beneficiation, or processing of metals (e.g., copper, gold, iron, lead, magnesium, molybdenum, silver, uranium, and zinc) and nonmetallic, non-fuel minerals (e.g., asbestos, phosphate rock, and sulfur).
- EPA also identified some classes of facilities that are not included in the rulemaking even though they fell within the above definition of "hardrock mining." (See *Memorandum to The Record* entitled *"Mining Classes not Included in Identified Hardrock Mining Classes of Facilities"*, Dated June 29, 2009, EPA-HQ-SFUND-2009-0265-0033).

A Preliminary Clarification: What the Rule Does *Not Do*

- EPA's proposed Section 108(b) regulations will be stand-alone financial responsibility requirements. There are significant differences between these requirements and other existing requirements for hardrock mining facilities. In particular:
  - CERCLA is primarily a response program that does not establish a permitting regime and thus the proposed regulation would operate differently from other financial responsibility programs;
  - The proposed rule does not include technical requirements regulating the operation, closure, or reclamation of hardrock mining facilities;
  - For purposes of Section 108(b), EPA intends to develop only those requirements that are appropriate for the limited purpose of demonstrating evidence of financial responsibility under CERCLA; and,
  - The proposed rule does not provide financial responsibility to ensure closure or reclamation requirements made applicable to hardrock mining facilities through a permit.
- In addition:
  - By promulgating and implementing this regulation, EPA is *not* determining that a CERCLA response is required at a regulated facility.
  - CERCLA liability is unaffected by an owner or operator providing evidence of financial responsibility under EPA's Section 108(b) regulations.

Financial Responsibility Formula - Overview

- EPA intends to propose use of a national, site-based financial responsibility formula to determine the financial responsibility amount for a facility.
- The formula EPA is considering is comprised of the following three components:
  - Response component;
  - Natural resource damage component; and
  - Health assessment component.

Response Component

- **Section 2.1 – CERCLA Response Costs**
- EPA collected information on response costs from national priorities list (NPL) and non-NPL CERCLA hardrock mining facilities (HMFs):
  - Records of decision (RODs)
  - Settlements
  - Actual expenditures to date by EPA
  - Estimated expenditures for present and future work by potentially responsible parties
- EPA used this data to generate a best estimate of total response costs at 319 HMF sites

Response Component

- **Section 2.2 – Response Activities**
- EPA collected data on activities conducted at 438 operable units at 88 NPL or Superfund alternative sites.
- Using this data, EPA could link specific site features to releases or threatened releases of hazardous substances, and to remedies that incurred response costs.
- EPA found that 13 site features (e.g., tailings) served as the source of release that resulted in remedies within an initial list of 12 categories (e.g., water treatment).

Response Component

- **Section 2.3 – Linking Response Categories to Engineering Cost Estimates**
- EPA linked the majority of the initial list of remedy categories to similar tasks identified in the current engineering cost data from reclamation and closure plan detailed cost estimates.
- For example, EPA linked the remedy category of on-site disposal to current engineering cost estimate tasks such as backfill, earthwork, revegetation, stormwater diversion, and source controls (e.g., synthetic cover).

Response Component

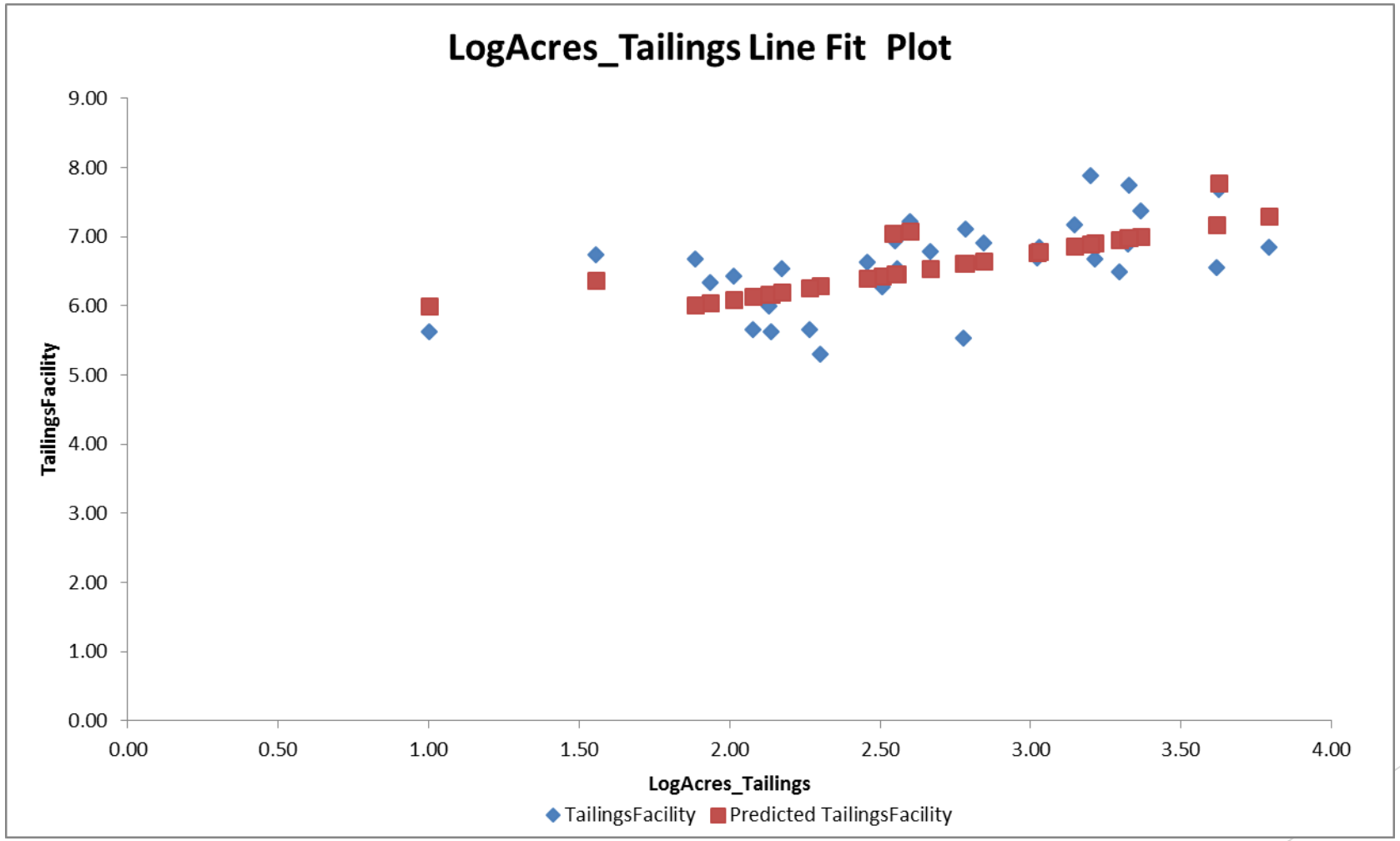
- **Section 3 – Response Component Data Collection**
- EPA obtained a sample of 63 facilities' reclamation and closure plan engineering cost estimates with data on
  - Capital and operations and maintenance costs,
  - Acreage of various site features (e.g., open pits), and
  - Water treatment flows
- These sites were supplemented with three historical sites for additional water treatment cost data.
- EPA subject-matter experts believed that other variables could explain the differences between higher and lower costs at sites based on their professional experience. Thus, EPA located and collected the following data from Environmental Impact Statements or other publicly available documents:
  - Water balance data (e.g., precipitation), and
  - Process method data (e.g., use of cyanide leaching)

Response Component

- **Section 4 – Response Component Regression Analysis**
- EPA conducted statistical analysis to establish a relationship between a limited number of facility's site-specific characteristics and the resulting reclamation and closure plan costs. This was used to generate a sub-formula that results in an expected financial responsibility amount for each response category, on a nation-wide basis.
- Bidirectional elimination stepwise regression - started with variables believed to be most significant and test the addition or deletion of individual variables.
- Results generally confirmed the significance of the variables EPA expected to be predictive

Tailings Facility Line Fit Plot

Log Capital Costs (Tailings Facility) vs. Log Acreage (LogAcres_Tailings)



Response Component

- **Section 4 – Response Component Regression Analysis (continued)**
- Two response categories either did not obtain a statistical fit with any variables, or did not have sufficient data to conduct regression analysis.
- Furthermore, EPA calculated overhead and oversight costs as a percent of direct engineering costs

OC Category	HMFs Reporting	Average % of Direct Engineering Costs
Mobilization/Demobilization	46	2.83%
Engineering Design and Redesign	45	4.76%
Contingency	59	11.82%
Contractor Profit and Overhead	48	12.95%
Contractor Liability Insurance	32	0.77%
Payment and Performance Bonds	34	2.65%
Subtotal (Overhead Costs)		***35.78%***
Agency Direct Costs	54	8.88%
Agency Indirect Costs	N/A	Region-Specific[1]

[1] EPA calculated 10 region-specific overhead and oversight cost percentages to be applied to the direct engineering costs estimated in the formula responses components.

Response Component

- **Section 4 – Response Component Regression Analysis (continued)**
- Annualized operations and maintenance costs from some regressions had to be converted into a net present value for the purposes of establishing a single financial responsibility amount.
- Specifically, EPA used the following based on the experience of Superfund:
  - a 10-year short-term operations and maintenance period;
  - a perpetual long-term operations and maintenance period; and
  - a discount rate of 2.63%.
- Additionally, to adjust for locality differences in prices of labor and materials, the response cost formula is multiplied by the most current state cost adjustment factors in U.S. Army Corps of Engineers, "Civil Works Construction Cost Index System" (2015).

Natural Resource Damages Component

- **Section 5**
- EPA collected information on natural resource damages from HMFs through:
  - CERCLA hardrock mining court settlements and judgments,
  - Records of voluntary natural resource damages payments, and
  - Israel, B.D. 2013. State-by-State Guide to NRD Programs in All 50 States. Arnold & Porter LLP.
- EPA found 24 sites with both natural resource damages and response costs.
- After excluding four statistical outliers, EPA divided the average natural resource damaged by the average response costs to generate a multiplier.

Health Assessment Component

- **Section 6**
- Agency for Toxic Substances and Disease Registry (ATSDR) provided EPA with average, minimum, and maximum costs for their site health assessments from a recent 18 month period.
- Most health assessments make use of EPA-collected data and require similar types of activities and reports. Thus, costs are expected to be relatively consistent across facilities.
- EPA assumed a fixed cost of $550,000 for all sites, representing the average provided by ATSDR.

Financial Responsibility Formula

- **Section 7**
- Since the formula is to be applied every three years, but will not receive updates every three years, it is adjusted for inflation using the GDP deflator.
- The use of source controls and water treatment are assumed as a conservative assumption.
- Since source controls are assumed, the volumes of water calculated for water treatment are reduced to represent the percolation expected through site features with source controls such as store-and-release or synthetic covers.
- EPA data from the field indicates that such covers result in, on average, percolation of 5% of annual precipitation.

Charges to Peer Reviewers

- Overall assessment of the appropriateness of the underlying methodology.
- Recommendations that might improve the soundness and transparency.
- Appropriateness of, or supplemental data to, response activities collected.
- Improvements to the standardization and other pre-analysis steps.
- Linkages to response categories and/or additional site features.
- Statistical models chosen and robustness analyses.

Questions?

Reviewer Comments

Reviewer 1 Comments

Review Request for External Letter Peer Review of the EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula

I. Charge Questions

V.1 Overarching Questions

1.) As mentioned above, EPA developed the Formula to estimate reasonable financial assurance amounts at the diverse range of mining facilities that are being potentially regulated under the 108b rule. Please provide an overall assessment of the underlying methodology that EPA used to develop the Formula, keeping in mind the immediate need for a feasible consistent nationwide approach, and provide recommendations for enhancing the methodology.

CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula details the tremendous work that went into the construction of the financial responsibility formula. The econometrics behind the formula make sense, and the EPA has found a parsimonious specification to assign financial assurance amounts across different facilities.

An enormous data collection effort was undertaken to obtain information. These fall into six data categories:

Actual Response Costs: A dataset on expenditures made on CERCLA hardrock mining facilities on the National Priorities List and non-National Priorities List. These are actual expenditures in the past, as well as estimated future expenditures. There are 319 facilities in this dataset.

Remedy Study Universe: A dataset of actions taken for specific components at 88 national-priority-list or Superfund-alternative hardrock mining sites. Gives a general description of the type of features and the types of remedies.

Currently Operating Facilities: From MSHA and USGS, the EPA collected data on characteristics of currently-operating hardrock mining facilities, including only facilities that would be eligible to the proposed rule (e.g., dropping coal mines and abandoned mines). From this dataset there are 354 facilities that are predicted to be affected by the proposed rule.

Engineering Cost Estimates: Of the 354 Currently Operating Facilities, EPA obtained predicted engineering costs for reclamation and closure plans for 63 facilities.

Natural Resource Damages: Use data from 64 hardrock mining sites from CERCLA court settlements and judgements and voluntary payments. Of these 24 of the hardrock mining facilities are also found in the Engineering Cost Estimate dataset.

Health Assessment Costs: Various different sources providing examples of health assessment costs as well as averages.

Here I outline how I understand these different datasets are being used:

The Actual Response Costs are used to obtain an estimate of response costs that can be used to compare costs found in future sections of the document. For example, the response costs are compared to the NRD in section 5. The Remedy Study Universe gives insights into the size of sites, hazardous compounds on sites, and most frequently used response action (e.g., off-site disposal, water treatment etc.). The EPA uses the sample of 354 of Currently Operating Facilities to show that the 63 facilities with Engineering Cost Estimates are representative of the larger sample. The 63 facilities with Engineering Cost Estimates comprise the data that are used to estimate the response-cost parameters in the financial responsibility formula. The response actions in the Remedy Study Universe are different from the response categories in the Engineering Cost Estimates data (for example, the Remedy Study Universe has off-site disposal, on-site disposal, sediment dredging, water treatment, building deconstruction and the Engineering Cost Estimates have open pit capital costs, tailings facility capital costs, interim O&M costs, with Table 2-2 providing a crosswalk). In the Engineering Cost Estimates data, costs are formed into 13 different action categories. Cost functions for these 13 actions are estimated separately (each running stepwise regressions to determine the important determinants of cost). The Natural Resource Damage dataset is used together with facilities that are also found in the Engineering Cost Estimates data to calculate the NRD multiplier.

The document goes through the reasoning for all steps EPA takes, for example, the reasoning to turn to the Engineering Cost Estimates, the reasoning to log-transform the data, and the reasoning to drop outliers in the calculating the NRD multiplier. My overall assessment is that the methodology used to develop the formula is reasonable, especially given the small sample of facilities EPA had to work with.

2.) *Do you have any recommendations that might improve the soundness and transparency of the analytical and statistical methods used to develop the Formula? If so, please distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.*

Much work was put into carefully thinking about how different pieces of the financial responsibility formula could be estimated. Throughout reading the document, concerns that I came up with were quickly allayed by further reading.

Recommendations to improve soundness:

Estimation of the Natural Resource Damages (NRD) multiplier:

EPA acknowledges that "natural resource damages and response costs are not independent of each other. Instead, response actions have regularly been shown to influence natural resource

damages." Nonetheless, this interdependency is not accounted for when calculating the NRD multiplier, because of the reasoning that "the total magnitude of potential liabilities (response costs and natural resource damages combined) will increase or decrease together." I can imagine how generally this might be true: for example, sites that cover more acres will have higher response costs and higher NRD. But I can also imagine that it is possible that they do not always increase together. Couldn't it be the case that a stitch in time saves nine, and if response costs are increased NRD fall by a lot? If there is this interdependency between response costs and NRD then this is problematic for the way the NRD multiplier is currently calculated. For example, say that in the sample of 24 HRMs there are two different types of facilities: some facilities spend a lot on response costs, lowering NRD, and resulting in a smaller multiplier, while other facilities spend little on response costs, raising NRD, and resulting in a larger multiplier. This means that the distribution of the types of facilities in the sample will change the multiplier.

Ideally you could calculate the NRD multiplier in absence of this tradeoff. One idea, which I would label as immediately feasible, is to treat these type-specific differences as error. Specifically, you could use coefficients in the financial responsibility formula to obtain a *predicted response cost* for each of the 24 HRMs (i.e., for each facility, use their characteristics and predict what their response cost would be). It is easier to obtain a predicted response cost than it is to obtain a predicted NRD, because you have already estimated the parameters that would be used in the prediction. For the NRD you would have to first estimate coefficients similar to the response cost coefficients and then predict each facility's predicted NRD would be. Then you could divide the predicted NRD by the predicted response cost to obtain the multiplier. The difference between the predicted costs and actual costs would just be error, and would not be included in the formula. If you have site features in the full NRD data, you could use data from outside of the 24 HRMs. If restricted to using only the 24 HRMs, dropping the outliers will also be important. Figure 5-1. "Response Costs and NRD at 24 HMFs" is stunning—it is really apparent that few facilities might really skew your estimates. However, this is not the sample you use. You drop the outliers, and are not using these data as they are presented. (As an aside, why not present Figure 5-1 for the sample you do use? It would not look as stark.)

Taking logs:

In the financial responsibility formula there are some variables that are logged but perhaps once this formula is implemented across more data, there might be instances when they take on a value of zero? For these variables that are logged, will it always be the case that they are greater than zero? (For example, will there always be at least one acre of open pit? Or at least one acre of waste rock?) If it is in the realm of possibility for a facility to have an observation of zero, then perhaps you should add 1 (or say if the variable is zero then set log(variable)=0). Some of the variables are log(variable+1) but why not all of them? If you do change this, then I suppose you should also re-estimate the parameters after transforming all your data to +1. Alternatively, you could use an inverse hyperbolic sine transform that does not require adding 1. This would be immediately feasible.

Recommendations to improve transparency:

Description of data:

This document entails a lot of work with a lot of different datasets, however, as far as I can tell, not all datasets described are used to obtain the final formula, which makes the methodology less transparent. (I wrote out in the first charge question how I understand the different datasets and how they are used in the formula--if I am wrong, then this points to the need for clarity and if I am right then much of the text may be extraneous). Documenting all work and datasets demonstrates that formula was very carefully developed, without leaving rocks unturned. However, not all pieces discussed are used for the final formula, which makes things less transparent to a reader. For example, much time is spent discussing the dataset on Actual Response Costs, yet as far as I can tell, these data are not being used for the final formula. It is impressive that you collected all these data, but other than calculating the average response costs for these sites, I don't understand their purpose. It might be that you could use these data more. For example, when looking at the formula, given the logs and powers of 10, it is hard to get an idea of how big the financial responsibility bond will eventually be. After listing the formula, it would be interesting to see what the amount required would be for the average facility. And then this could be compared to the average cost found in the Actual Response Cost dataset.

I have a similar comment for the discussion of the Remedy Study Universe dataset. It is not clear how these data are used to construct the formula. Without using the Remedy Study Universe data, would you have arrived at the same 13 action categories as you have? That is the 13 action categories used to create the financial responsibility formula? Could you have not just looked at the Engineering Cost Estimate data to realize these 13 action categories? It would help if the purpose of the Remedy Study Universe data was made more apparent. Similar to the comment above, could the typical costs seen in these data be compared to the final predictions from the financial responsibility formula?

Minor comments:

-Similar to the comment above on increasing transparency, I don't understand why you need to show Table 5-3. You are not using column three to determine your multiplier.

-I was confused by the discussion of the Standardized Reclamation Cost Estimator model. You predicted costs using acreage, then used that prediction to regress on acreage to get a coefficient on acres? "This dataset included costs as well as related inputs that drive these costs components. For example, acreage is an input of the Standardized Reclamation Cost Estimator model used to conduct several of the collected engineering cost estimates." Is the reason that this was only one part of the engineering costs? Otherwise, you could skip the estimation procedure by knowing how the Standardized Reclamation Cost Estimator model determines the cost of acres.

-The proposed formula uses the GDP deflator to account for changes in inflation. The GDP deflator does not include any imported goods or services. A detailed accounting of the goods and services used in the mining industry could be checked in order to ensure that imported goods and services are not, in fact, widely used or significant in enough to materially impact

the estimated costs, as in that case usage of the GDP deflator would not be sufficient to account for the actual inflationary pressures faced by the operators.

Very minor:

-Missing bracket in Equation ES-1 and Equation 7-5 around LogAcresProcessPondReservoir.

-Text moves from referring to "data" as singular to referring to data as plural. Change all to plural.

-When reading equation 5-1 not clear that cost terms are costs from the same facility.

Outside the scope of this charge:

Regarding implementation of the formula—will each facility's financial responsibility amount be recalculated every year? As time goes on, I imagine tailings would increase (which would mean collecting more money) but could also decrease (which would mean returning money).

"Data were not collected for mines less than five acres…because EPA is proposing to exclude such mines from the proposed rule" --- With this type of cut off, you might end up with mines bunching at 4.99 acres?

V.2 Specific Questions

3.) EPA collected data on specific response activities conducted at historical National Priorities List or Superfund alternative approach[1] hardrock mining sites. Please assess the appropriateness of these data for the subsequent analysis. Are you aware of additional nationwide datasets that may further supplement the data used by EPA to identify response activities that EPA may have to undertake during a CERCLA response at a hard rock mining facilities? If so, please discuss.

I did not think the data from historical NPL and Superfund-alternative-approach HRM sites are used in the subsequent analysis. (I thought it was the Engineering Cost Estimates that are used in the analysis.) One concern with using Actual Response Cost data from the NPL is that compared to data from currently operating facilities, the facilities on the NPL might be more costly than currently operating facilities to remediate (e.g. you have to be above a threshold in the hazard ranking system). So using NPL sites would result in an overestimate of costs.

On the other hand data, engineering cost estimates often raise concerns--these are only estimates and not actual costs. So perhaps more could be done to show that these are a good representation of actual costs. In the document there is much time spent demonstrating that the sample with Engineering Cost Estimates is similar to the sample of Currently Operating Facilities. Is there

[1] Information on EPA's Superfund alternative approach is available at the following EPA website: https://www.epa.gov/enforcement/superfund-alternative-approach

more that could be done to show that the Engineering Cost Estimates are similar to the response costs found in the Actual Response Costs?

Could you also use the Actual Response Costs dataset more? Do these data have variables listing the site characteristics such that they could be used in the final financial responsibility formula? I understand the current method of estimating the cost functions separately and then aggregating. However you could also regress aggregate costs on site characteristics (e.g., acres open pit). The reason listed to use the Engineering Cost Estimates rather than the Actual Response Costs data is that "response costs were in total dollars per site rather than in dollars per category of response activity." The reason should be that these data do not have information on specific characteristics. I don't see why you need dollars per category of response activity if you end up aggregating. You would need characteristics though, and perhaps that is why you moved to the Engineering Cost Estimates. If you have characteristics in the Actual Response Cost data, you could use this dataset and regress total dollars per site on site characteristics. This should let you back out estimates that are similar to your current estimates.

I am not aware of additional datasets.

4.) *Several steps were taken to "standardize" data on response costs (e.g., adjust for inflation and account for state level differences in input costs). Given the application of these data, please comment on these pre-analysis data steps. What improvements (if any) would you recommend? Please elaborate on the specifics of any recommendations, and distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.*

These standardization steps make sense.

5.) *Using the aforementioned data on response activities, EPA linked specific site features to the release of hazardous substances and the resulting response costs. Are there additional site features that you recommend EPA consider and how might these additional features be key explanatory variables of response costs? Please distinguish between suggestions that are immediately feasible with available data versus those that might be more appropriate in the long term or with significant resources.*

Not familiar enough to say.

6.) *Several tests were conducted to examine the robustness of the chosen statistical models (e.g., examining internal and external transfer error). In your professional opinion, do these robustness checks reasonably support the chosen statistical models? If applicable, please describe any additional robustness checks that EPA should consider in the development of the Formula which could feasibly be carried out with the available data.*

The regression results are robust to changes in the stepwise procedure. One concern is that potentially unrelated variables that happen to be correlated with costs may still be included in the regression. However it is reassuring that when looking at the final regressions this does not appear to be the case (e.g. costs of tailings includes acres tailings).

I think the second robustness test is very innovative—and is a great demonstration of how good the out-of-sample prediction is. It would be difficult to do another type of an out-of-sample prediction when samples are so small. My only comment is that it would be helpful to know how to interpret the magnitude of the external transfer (Table K-12). This is observed value minus predicted value: are the values "log response costs"? Is there a way to demonstrate this so it is easy to interpret, e.g., dollar terms or percent terms?

If you have data on site characteristics in the Actual Response Cost dataset, then you could also predict these costs using the financial responsibility formula.

Reviewer 2 Comments

Response to charge questions Hard Rocking Mining

V.1 Overarching Questions

1.) *As mentioned above, EPA developed the Formula to estimate reasonable financial assurance amounts at the diverse range of mining facilities that are being potentially regulated under the 108b rule. Please provide an overall assessment of the underlying methodology that EPA used to develop the Formula, keeping in mind the immediate need for a feasible consistent nationwide approach, and provide recommendations for enhancing the methodology.*

The EPA's overall methodology is sound and reasonable, given the information, resource, and time constraints. The categories of response costs, approach to their predictions, and handling of various adjustments in the formula all seem appropriate.

2.) *Do you have any recommendations that might improve the soundness and transparency of the analytical and statistical methods used to develop the Formula? If so, please distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.*

I have two recommendations for alternative methodologies:

A first and smaller methodological concern is the inclusion of an indicator variable for source control in several of the capital cost equations. Future need for source control cannot be observed, so the EPA assumes all sites will eventually need source control and uses values with this variable set to one in the Responsibility Formula. In practice, however, the CERCLA data show that source control is not always used, so this assumption overstates the true expected future response costs. One solution would be simply to exclude the variable from the estimated equations. Such estimates would yield more accurate predictions for the expect costs, if the distribution of facilities at which the states evaluate source control reflects the distribution of facilities at which source control is especially likely. However, if some factor other than the likelihood of needing source control determines where source course response costs are evaluated, then EPA's conservative assumption may be at least as valid as any alternative approach.

A second and longer term methodological recommendation is to take more advantage of the realized response cost information from CERCLA. The engineering cost estimates from state permit documents for active facilities currently serve as the basis for most of the quantitative analysis. Although these engineering cost projections allow the Responsibility Formula to vary with more site features, this disaggregation comes at significant cost. Using the realized response cost would have had several advantages:

1. Realized response costs would give a better sense of the expected costs in the real world, including contingencies (mistakes, bad luck) that the idealized conditions in the engineering models may miss.

2. By focusing on engineering cost estimates made by the states, much of EPA's analysis is effectively a reverse-engineering of the states' models and may thus import their oversights. For example, the weak estimated relationship between response costs and hydrologic characteristics of the site (distance to surface water, groundwater level, etc.) may reflect limited attention to these factors in the models.
3. Relying on CERCLA realized costs would allow a sounder approach to Natural Resource Damages (NRD). If the analysis sample were CERCLA sites, response costs and NRD could be summed to create a measure of the total social cost. This approach would capture the possible tradeoff between high response costs and high NRD and allow the predicted NRD to vary appropriately with facility characteristics. The current approach, treating NRD as a multiple of response costs, is not supported by the data in Table 5-4. But some such ad hoc assumption is necessary because NRD values cannot be matched to active facilities.
4. The CERCLA data would provide more observations and thus improve the reliability of the estimates. Some of the response cost categories have very small sample sizes with the current method.

It is difficult to judge whether the gains from EPA's disaggregated approach are worth these costs. For a partial assessment, an analysis could be run on the current data that would mimic the less disaggregated analysis that could be conducted on the realized costs data: sum the engineering costs over facility features to create a total facility response cost and run equations that use only the less detailed explanatory variables available for the CERCLA data (perhaps only total acreage, presence of some contaminants, and hydrologic variables). Then a comparison of these estimates with the current approach (disaggregate-estimate-reaggregate) would indicate how much the multi-step disaggregated approach actually improves the fit. In practice, the improvement may not be that great once all the categories are recombined (especially when some categories vary only with total acreage anyway). This comparison would still not determine whether the engineering estimates are good enough, but would give a sense of the benefits of disaggregation.

V.2 Specific Questions

3.) EPA collected data on specific response activities conducted at historical National Priorities List or Superfund alternative approach hardrock mining sites. Please assess the appropriateness of these data for the subsequent analysis. Are you aware of additional nationwide datasets that may further supplement the data used by EPA to identify response activities that EPA may have to undertake during a CERCLA response at a hard rock mining facilities? If so, please discuss.

Except for the concern discussed above about the reliance on engineering cost estimates, the data seem appropriate. I am not aware of any additional pertinent data sources.

4.) Several steps were taken to "standardize" data on response costs (e.g., adjust for inflation and account for state level differences in input costs). Given the application of these data, please comment on these pre-analysis data steps. What improvements (if any) would you recommend? Please elaborate on the specifics of any recommendations, and distinguish between suggestions

that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.

Overall, the EPA's choices seem sound. I have a few comments on specifics:

(a) The handing of O&M costs might be simplified. The current approach estimates annual O&M and then constructs present values of these estimates. An alternative would be to form the present values first and take the log of them as dependent variable in the equation. Smearing could then be done on these PVs. OLS provides the best linear predictor of the dependent variable (see Angrist and Pischke, *Mostly Harmless Econometrics*, 2009). Forming the present value first would harness this feature of OLS in predicting the object of interest (the PV), rather than its component parts. It would also make the Financial Responsibility Formula simpler to specify.

(b) The Responsibility Formula applies Overhead and Oversight costs (OOC) to NRD as well as the response costs. Although this may be appropriate for some components of NRD (e.g., Sediment dredging/disposal, c.f. p. 2-16), is it appropriate for most components of NRD?

(c) The Responsibility Formula could make clearer the intent to include only the cost for those site features with non-zero acreages.

5.) Using the aforementioned data on response activities, EPA linked specific site features to the release of hazardous substances and the resulting response costs. Are there additional site features that you recommend EPA consider and how might these additional features be key explanatory variables of response costs? Please distinguish between suggestions that are immediately feasible with available data versus those that might be more appropriate in the long term or with significant resources.

The choice of features seems appropriate. The inclusion of additional covariates does not seem to be a high priority for additional resources. Sample sizes are small, so the data may not provide enough information to estimate additional relationships precisely. Instead, if additional resources are available, I would recommend they go into expanding the sample or allowing greater use of the CERCLA cost data, as argued above.

6.) Several tests were conducted to examine the robustness of the chosen statistical models (e.g., examining internal and external transfer error). In your professional opinion, do these robustness checks reasonably support the chosen statistical models? If applicable, please describe any additional robustness checks that EPA should consider in the development of the Formula which could feasibly be carried out with the available data.

Generally, the statistical models seem well chosen given the constraints imposed by the small sample sizes. OLS is suited to predicting the response costs under broader circumstances than the requirements for the Gauss-Markov Theorem (which are anyway not entirely correctly specified on p. 4-3 and include

a typo in point 5), so if anything a stronger case could be made for the validity of the approach by focusing on conditions for the predictions themselves.

However, a more convincing case might be made for the choice of functional form for the response cost equations. Most of the analysis assumes a log-log relationship between the independent variables and the dependent variables. The EPA provides extensive analysis of the lognormality of the variables, but this analysis does not actually establish the form of the relationship between the variables (and is not really necessary in any other regard). Instead, the choice of functional form could be supported in several ways:

(a) The log-log functional form is plausible a priori because it allows the response costs to rise proportionately with acreage and other variables;
(b) The plots of the log-log relationships J1, J4, J6, and J8 make a compelling visual case that the relationships are linear after the log transformation and thus that the transformation is appropriate before OLS estimation.
(c) Explicit tests for the functional form would be appropriate. The Wooldridge text cited in the Background Document provides two straightforward tests, the Ramsey RESET test for general misspecification and a Davidson-MacKinnon test that could be implemented to test the choice of logs vs. levels for the explanatory variables.

Reviewer 3 Comments

Review Request for External Letter Peer Review of the EPA CERCLA 108(b) Hard Rock Mining and Mineral Processing Financial Responsibility Formula

Reviewer report/comments.

I will start this report by noting that I do not have any conflict of interest, and that I have done research in the area of hazardous waste sites, remediation, and the public's willingness to pay and preferences for hazardous waste site policies. I have also lived in Colorado, where I saw several of the mining sites covered in the EPA document (you drive by them on the way to and from the ski slopes), other major Superfund sites, and documentation and records about cleanup under various programs at the Colorado Department of Public Health and Environment. I used to be familiar with the bond system—at least for the type of mining (coal) covered by Department of the Interior's Office of Surface Mining (more on this below).

I read the EPA document report with curiosity and interest, and I am most impressed with the effort to extract data from and link so many different databases and sources of information. It must have taken a small army of research assistants and programmers to get this done.

Charge question 1

The general approach seems reasonable—estimate likely environmental remediation costs, given the size of the operation, proximity of natural resources such as ground- and surface water, and processes used. The approach dutifully takes into account constraints imposed by the statute, namely which categories of cost should be considered (NRD and health assessment cost) and which are not allowed.

Charge question 2

See my response to charge question 3

Charge question 3

* General comments: The work is generally described in detail (with the exceptions noted below), but because there are so many sources of data and so many different types of information that the EPA is trying to put together, I got lost several times, despite the fact that I was taking notes while reading the report, and in some places I just cannot follow the logic of the Agency.

Let me recap quickly what I learned and highlight where things are unclear.

1) They selected hard rock mining sites from the NPL list or from non-NPL CERCLA sites. This produces a total of 315 facilities, from which it is possible to get total cleanup costs for 185 sites. Total includes past and future, and is based on the records of decision (RODs), actual or anticipated expenditures, etc.
2) From NPL or Superfund alternative sites, it is possible to get activity-specific cost figures for a total of 488 operating units (OUs) at 88 sites. There are many specific activities, but these are aggregated into a total of 12 categories, such as water treatment, off-site

disposal, on-site disposal, etc.

3) EPA collected the cost of removals from non-NPL, non-listed sites where removals took place. This is for a total of 171 response actions at 82 sites.
4) Then, the EPA developed an inventory of facilities registered with the Mining Safety and Health Administration and the US Geological Survey, restricting attention to those were identified in the 2009 notice and excluding facilities smaller than 5 acres and closed and abandoned facilities. This results in a total of 354 facilities.
5) They collected data from state and federal sources about the (expected) reclamation and closure (R&C) costs from a subset of these 354 facilities (63 to be exact). The EPA believes this subset to be sufficiently representative of the universe of 354. It turns that only at 15 currently open facilities is there any information about water treatment and water treatment costs, so EPA supplemented this information with data coming from 3 CERCLA facilities with exact information about water treatment costs.
6) EPA and matched the R&C activities from 5) as closely as possible with those listed in 2) for mining sites on the NPL. In this way, the engineering estimates of the costs of the activities in the R&C plans may be imputed to the remediation activities in 2).
7) Finally, a variety of sources are used to find information about site conditions, hydrology, processes, etc.

Finally, data on specific activities are used to run regressions relating the costs to the facility size (in acres), and, when appropriate, to other site or process characteristics, such the hydrological conditions at the site or in-situ leaching.

And this is where my questions start:

- Which dataset was used to run the regressions? I thought it was the one in 2) the first time I read the report, 5) the second time, and I had literally no idea the third time around. Help!
- Is the purpose of 2) to understand what kind of remediation may become necessary at closed or abandoned facilities, and thus should be covered by the financial responsibility formula? What is done with the data coming from these sites and the related activities?
- What happens to the data documenting the cost of removals? Are they ever used again in this analysis, in their own right or to supplement other sources? If so, I couldn't find where.
- Were the total response costs used only as the denominator of NRD to total response costs?
- How do total response costs compare with activity-by-activity costs? Are they consistent, in that at one site total response costs exceed or are equal to the sum of activity-by-activity costs?

Also see my response to charge questions 5 and 6 for more discussion on certain decisions made by EPA in constructing data and variables.

* Additional sources of data:

DoI's Office of Surface Mining: http://www.osmre.gov/index.shtm (details about bonds, permits

and mining activities). They cover coal mines, which are not covered by the rule EPA examines in this document, but they too have a reclamation program for abandoned mines, which may be useful for getting reclamation cost estimates, and water and groundwater modeling tools.

BLM Hard Rock Mining http://www.blm.gov/nv/st/en/prog/minerals/mining.html

Charge question 4

I am fine with the procedures used by EPA

Charge question 5 and 6

* Econometric analysis

I am generally not a fan of stepwise selection, whether it's backward or forward or back-and-forth. I much prefer the analyst to make decisions in terms of what should go into a model and what the final specification should be. Fortunately, in this case the automatic procedure and I agree. Based on my research experience, I had expected acres to be the only significant predictor of most types of costs—and they are. I had expected acres and one or two hydrology variable to be predictors of water treatment costs, and they are.

The EPA used a log-log specification for most regressions, which is appropriate, and included in some early and final specifications dummies denoting whether a certain type of process is present. The EPA conducted a large number of tests to check that all continuous variables (whether they are dependent variables or regressors in the regressions) are lognormally distributed, but the appropriate procedure is to run the regressions after taking the appropriate log transformations, and check that the regression *residuals* are normally distributed.

Charge question 6) asks me to discuss whether the models are appropriate and whether the "external transfer value." I teach econometrics at the graduate and undergraduate level, and yet I have no idea what this term and the text from the EPA document reproduced below mean.

> "The second robustness check compared the external validity of the final model to two alternative specifications by analyzing the average external transfer value. This comparison of the average external transfer value allowed EPA to test the accuracy of the final model. The first alternative specification was an "average" model where a fixed, average cost was used but no additional variables were considered. The second alternative specification was an "all variable" model. This model included every initial and potential variable EPA considered. In every case, the final model had the lowest external transfer value, indicating that the final model out-performed the accuracy of the "average" and "all variable" versions when producing out of sample estimates."

First of all, any model with regressors (whether or not those regressors have any explanatory

power) will do better or no worse than a model with just the intercept, which effectively uses the average to predict the dependent variable. In that sense, the text above is stating the obvious. If the EPA is suggesting that they re-ran the regression using a subsample of observations, and reserved the remaining observations to check the quality of out-of-sample predictions, then they should say so clearly. They should also say whether they use the average forecast error squared (i.e., the variance of the forecast or prediction error) to judge the quality of the predictions. If this is what the EPA document is trying to say, there is insufficient documentation to understand whether this is just a general goodness-of-fit test, or if by strategically selecting the observations to leave out of the regression the EPA is testing the stability of the coefficients over geography, size, time when R&C plans were prepared, etc.

An easy way to check the robustness of the results and identify unduly influential (in the statistical sense) observations is to cross-validation: re-run the regression after dropping one observation (or a handful), look at the estimated coefficients, then put back into the sample the observations that were excluded but drop another observation (or another handful), etc. When you observe a relatively large change in coefficients, the procedure is pointing you to an influential observation (a potential outlier). This procedure (cross-validation or the jackknife) allows the analyst to obtain standard errors around the estimated coefficients in the presence of heteroscedasticity or suspected outliers, and is easy to implement.

* Data construction:

I fear that the R&C reclamation and closure plans might be kept artificially low by the companies in an effort to minimize potential future exposure to liability or bond payments. I took a quick look at the various R&C costs for selected mining facilities in Colorado (the two molybdenum mines) in one of the Appendices, and they indeed seem low, considering the size of operations.

* Variable construction:

Water treatment capital costs

Why are you considering only O&M water treatment costs? Isn't there a capital cost for setting up water treatment equipment, or is that already included in the other categories of table 3-7? If so, it might help to state so explicitly.

Sediment dredging. The EPA writes that

> 'Also excluded was "Sediment dredging/disposal." Although this element has appeared historically as a response category, EPA notes that it was already incorporated in the natural resource damages (NRD) component. For example, the final restoration plan for the Upper Arkansas River/California Gulch Superfund site (one of the data points used in developing the NRD multiplier) includes dredging of contaminated soils as a restoration alternative.1 Thus, EPA believes that since this cost is already represented in the NRD

multiplier, it is inappropriate to duplicate that cost in the response component of the formula.'

I do not understand this argument. It seems to me that the capital and operating costs of dredging sediments should be included in the costs associated with reclamation and post-closure remediation. They should not be placed in the Natural Resource Damage (NRD).

Here's my reasoning. Suppose that contaminated sediments are impairing water quality and biota at a body of water. The body of water is used by recreational anglers, birdwatchers, hikers and backpackers, and is of cultural and historical significance to a Native American tribe. There are no commercial fishing activities at this body of water. Suppose that dredging the sediments takes 10 years, and at the end of these 10 years the water quality and the biota are back at the pre-contamination level. Then the trustees of the natural resources (which may include state, federal and tribal agencies), can demand payment of the natural resource damages, which should include the welfare losses experienced by recreational anglers, birdwatchers and hikers, and existence values for each of the 10 years when the body of water continues to be impaired. Sediment dredging costs have nothing to do with these values and should be placed in a different category. It is incorrect to regard the cost of remedies as the damages to the natural resources (although, in the complete absence of information about the NRD, I would presume that the agencies believe that the NRD figures are at least as high as the cost of the remedies). I briefly looked at EPA's own language on NRD, and the reasoning I provide above seems consistent with what I read at https://www.epa.gov/superfund/natural-resource-damages-frequently-asked-questions#7.

Natural Resource Damages

The EPA document simply does not provide enough information about the NRD. My concerns and comments:

- The documents states at some point that the NRD sample may be unrepresentative in that it omits facilities with small NRD figures, but I wonder whether facilities where high and controversial NRD figures may likewise be missing from the sample. In practice, omitting very small and very large NRD may still produce acceptable and reliable result because these omissions are effectively working as a trimming/outlier elimination procedure, but we don't know this for sure. (I note that EPA did exclude some facilities with large NRD from its calculations, but the above discussion refers to cases that are missing from the sample in the first place.)
- There is absolutely no information about the types of damages that went into the calculation of the NRDs. Did they include recreational use of the natural resources? Are the damages captured through market and market data, including quality of the soil used in agriculture, lost or compromised commercial harvests, etc.? Did the nature of the pollutant and the contaminated environmental media play a role? Were there any existence values? If this information were available or could be collected, it would enable the EPA to estimate regressions relating the NRD with site and community characteristics and improve the calculation of expected post-closure NRDs.
- One would expect NRD and cost of remedial activities to be *positively* correlated with the seriousness of the environmental contamination, which may depend in turn on the acres,

proximity to ground and surface water at the facility, and processes used at the facility. Yet all we read in this EPA document is that

> 'Instead, response actions have regularly been shown to influence natural resource damages. This is particularly true in the case of sites receiving technical impracticability (TI) waivers. When a TI waiver is issued, previously projected response costs may be reduced. However, the remaining contamination may lead to additional natural resource damages.'

I would expect TI waiver to be the exception, rather than the rule, and it would be good for the Agency to compute, and report, the coefficient of correlation between response costs and NRD (with and without the TI waiver sites) and run some simple regressions to check the relationship between NRD amounts, site characteristics, and type of NRD claimed (e.g., recreational use, existence values, etc.)

- The Agency chose to use the ratio of NRD to total response costs in the final formula and came up with a figure of 13.4%. The problem is that this was computed as average NRD divided by average response costs, and this is not the same as 1) computing the ratio of NRD to total response costs at each individual facility, and 2) then taking the average. The two procedures may give very different results, and I would recommend using the latter.

  Also note that reassigning dredging sediment costs into total response costs rather than NRD may change all results, depending on how many facilities this affects and how large the figures are.

- The NRD sample comes from two sources of data—EPA CERCLA sources and Israel (2013). The two sources overlap for 8 sites, and Israel is based mostly on state programs (mini-superfund and others). Descriptive statistics should be reported for the combined sample as well as for each of the two subsamples separately.

Health Assessment costs

Please explain what an ATSDR health assessment entails. Do they get samples of blood from residents? Do they test the drinking water? Do they do an assessment at their desk based on the results of lab tests and published risk assessment and materials?

I went to their most relevant web page (http://www.atsdr.cdc.gov/about/program_overview.html) and it was last updated only back in 2013.

In the absence of more detailed information, I am fine with assigning a fixed amount to the health assessment cost component of the formula.

Reviewer 4 Comments

External Review of

CERCLA 108(b) FINANCIAL RESPONSIBILITY FORMULA FOR HARDROCK MINING FACILITIES

BACKGROUND DOCUMENT, September 19, 2016

Date of Review: 10/19/2016

This report provides an external review of the CERCLA 108(b) Financial Responsibility Formula for Hardrock Mining Facilities Background Document, September 19, 2016, Interagency Review Draft.

Reviewers were provided with the CERCLA document, a Background Document with Appendices, and a third document that provided a brief background for the draft and a series of specific charge questions. There were two overarching charge questions and four specific charge questions. I will begin with my response to the two overarching questions:

1.) **As mentioned above, EPA developed the Formula to estimate reasonable financial assurance amounts at the diverse range of mining facilities that are being potentially regulated under the 108b rule. Please provide an overall assessment of the underlying methodology that EPA used to develop the Formula, keeping in mind the immediate need for a feasible consistent nationwide approach, and provide recommendations for enhancing the methodology.**

Financial assurance was to include response costs, natural resources damages, and health assessment costs.

The question mentions estimating "reasonable financial assurance amounts," and part of the evaluation of methodology has to be guided by a definition of what is "reasonable." On our conference call we were informed that the goal was that the Formula would provide an estimate of financial assurance that would be up to 100% higher than or 50% lower than the realized costs in the event of government cleanup of a facility, meaning that the realized cost should be in a range between 50% below or 100% above the estimated assurance cost. I take this to be the standard for each of the three categories of costs, and not the total cost and nor for each component of the response costs, though this was not made clear on the call.

EPA developed the Formula in a stepwise manner, first estimating total response costs for a specific facility, and then estimating natural resource damages and health assessment costs for that facility. In the end the health assessment cost was taken to be the same for each facility, at $550,000 (in 2014 dollars), and the natural resource damage was taken to be 13.4% of the estimated fully overheaded response cost for the facility. Given the magnitudes of the response costs the health assessment cost is, for all but the smallest facilities, trivial. For example, from Table 3-7 the average response costs, inclusive of overhead and oversight but ignoring ongoing

annual operating and maintenance costs, is around $50 million.[1] The natural damages multiplier of 13.4% is by inspection a fraction of the overall costs. Hence, the weight of the financial assurance in the Formula is placed on the response costs. Appropriately, then, the majority of EPA's methodological design and effort focused on response costs.

EPA's first step was to attempt to estimate what types of response cost activities might take place at the HMFs regulated by 108(b). They collected data on historical CERCLA expenditures by all parties at 319 NPL and non-NPL cites, from which they estimate the current and future response costs at each of the facilities using one of three formulas presented in Section 2. Appendix B presents the results for each facility, while Table 2-1 presents summary statistics. The average response cost was $67 million (2014 dollars). The text notes that the response cost was higher for NPL facilities and much lower for non-NPL facilities.

It is not clear that the results of this first analysis are used anywhere else in the report or in coming up with the Formula or testing the Formula for external validity. One might think, for example, that the Formula should produce response costs in the order of $67 million for the average facility. I have no idea if it does. Moreover, I can find no evidence that the Formula differentiates response costs estimates according to whether or not any of the 354 HMFs that EPA estimates will be subject to the proposed rule, and to which the Formula applies, are more likely than not to be NPL facilities. Or, more precisely, there has been no effort to establish an adjustment to the Formula should a facility already be nominated to be a NPL facility at the time of application of the Formula. Since the difference in response costs between an NPL and non-NPL CERCLA facility is on average $110.7 million - $6.6 million = $104.1 million, this must be addressed.

EPA then evaluated the types of response activities at a cross-section of 88 NPL mining facilities, presumably with a view to understanding what response activities to include in the Formula. The data set included a well-diversified sample across size, cleanup status, metal or mineral, and cleanup facility leads. This step of the process was not well motivated given the ultimate method by which the Formula was developed. The ultimate method looked to engineering remediation plans at a set of active HMFs, and estimated costs based on these plans. The plans included efforts to control solids and liquids, contour land, seal portals, and so on. These *are* the response actions that are required. Was EPA worried that actual experience would reveal that mining companies are overlooking a response activity? Or were they looking for the broad categories of response activity that should be included in the Formula? The document needs clarity here.

In the end I have no idea what the relevance is of any of the data presented in Section 2.2. On page 2-15 EPA states "EPA's prior experience with CERCLA cleanups leads it to expect that similar types of remedies will continue to be selected for mining facilities in the future." There is no reason to make any presumptions here – the closure and reclamation plans and data collected in Section 3 indicate exactly what types of remedies are required at current HMFs. The engineering studies relied upon categorize the expense categories (tailings, leach dumps, pit, hazard removal, indirect costs, direct costs, etc., pp. 2-19 – 2-20). Perhaps the idea is that EPA was looking for justification for its methodology in Section 3, feeling it needed to prove that

[1] Of course, not every mine will have every response category, and so the estimate is simply to provide an order of magnitude of response costs estimated by the active facilities sampled by the EPA.

relying on company engineering plans was reasonable and that companies would not be leaving anything important out.

Despite the lack of methodological clarity, Section 2 does introduce some foundational assumptions. The first is that response control expenses are separable and additive across activities. This is a reasonable assumption, and is consistent with the way engineers think about the problem. The second is that costs would be categorized around the following unit operations: open pit, underground mine, waste rock, heap/dump leach, tailings facilities, process pond/reservoir, slag pile, solid hazardous waste disposal, drainage controls, water treatment, short term monitoring and treatment, long-term (perpetual) monitoring and treatment, and overhead and oversight costs. This list is reasonable and complete but for a credit for salvage and patented land sales at closure, which should be added as a responsibility offset if legally permissible.[2] At the Johnson Camp facility, for example, mine salvage costs are estimated to exceed all closure costs, in which case no financial assurance would be required.[3] Most mine reclamation cost models do not include salvage, but these can usually be found in the technical studies for each facility (cf. fn 3).

Section 3 devotes itself to estimating the response costs based on closure and remediation plans at 63 HMFs that are representative of HMFs likely to be impacted by the rule. Cost data more than 10 years old were not collected. EPA claims to have prioritized data collection such that the HMFs identified would be representative of the HMFs ultimately regulated. Tables 3-3 and 3-4 compare the full universe of 354 HMFs likely to be regulated with the 63 HMFs selected for data collection. In addition, three CERCLA facilities were used for water treatment cost data.

I am generally happy with the geographic representativeness of the sample. I am concerned that there is no cost data for all but one of the industrial minerals that will be regulated (phosphate, barite, potash, phosphate, boron, zirconium, antimony, bauxite, Brucite, lithium, titanium, vermiculite, chromite, fluorspar, and magnesium). This group makes up 15% of the Full Universe according to Table 3-4. Generally the extraction and processing of industrial minerals has very different environmental effects from the extraction and processing of metals. Likewise, rare earths and uranium are different due to radioactivity. I have trouble with the EPA's methodology not having separate formulas for industrial minerals, and for radioactive rare earths and uranium. Or, at a minimum, I would like to see some data analysis that looks at the performance of the Formula for these mineral categorizations to identify whether it systematically underestimates or overestimates costs for these groups. The latter task will involve additional data collection for industrial minerals response costs since there is only two industrial minerals producers, both mining phosphates, in the sample.

Section 3.3 outlines the data collection exercise. Here EPA used actual engineering plans and cost estimates as presented by the operating company. This is an excellent approach, as it includes incredible cost detail. The raw summary cost data for each activity is presented in

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[2] A question could be whether more or less aggregation would be advisable. For instance, waste rock and tailings contouring are similar, suggesting more aggregation. Or, open pit fencing is different from open pit berms, suggesting less aggregation. I believe that the categorizations are reasonable, providing enough fidelity and yet not being too detailed so as to be overwhelming in the estimation process that follows.

[3] Johnson Camp Mine Project Feasibility Study, Cochise County, Arizona, Technical Report Pursuant to National Instrument 43-101 of the Canadian Securities Administrators. Prepared For Nord Resources Corp. Prepared By Bikerman Engineering & Technology Associates, Inc., Old Lyme, Connecticut, September 2007, p. 186.

Appendix G. While the source documents are excellent, I have grave concerns about the integrity of the data as collected. In preparing for my review I randomly sampled four source documents from which the data in Appendix G was allegedly taken (Rosemont Reclamation and Closure Plan 2007, Phoenix Mine Reclamation Permit 0223 2011, Pinto Valley Operations Closure and Post-Closure Strategy 2013, and Cripple Creek & Victor Gold Mining Company Reclamation Cost Model to Support Mine Life Extension Project 2 (MLE2) DRMS Warranty Version 2014). Using those source documents I attempted to do some spot checking of the data in Appendix G. Of the sampling I did I could not replicate a single cost number in the Appendix, and in some cases could not replicate the acreages. I tested to see whether I could reproduce the cost data under the assumption that it the data as presented in Appendix G was pre-conditioned per Equations 3-1 and 3-2. I could not. This is highly troubling given the assurance that "Reviewers independently replicated the data entry process using the original source documents…" (p. 3-17).

Let me provide examples of my replication failures. At Pinto Valley, according to the source document, there are 3 tailings impoundments. The acreage of each, based on revegetation requirements, is 385, 363, and 965. Adding these gives 1,713 acres. Table G.4 lists Pinto Valley as having 1,586 acres of tailings. I cannot find that number anywhere in the Pinto Valley document. Table G.4 lists the costs of tailings reclamation at Pinto Valley as $74,854,056. This is greater than the total estimated closure cost of $66,964,028 million as reported in the source document. In the source document the tailings reclamation costs add up to some $28 million, not $75 million.

I am astounded that the independent reviewers did not find these errors. A simple inspection of the Pinto Valley data in Appendix G compared with the data from other facilities leads me to believe that its response costs are some 10 times what they should be. If I am mistaken and the data in Appendix G is correct then the methods by which EPA preconditioned the primary source data should be made clear.

I am also not confident that those collecting the primary data from the source documents correctly understood the information in the documents or mine reclamation in general. Consider the Rosemont reclamation plan. On page 46 of the source document we see that the Rosemont pit will be 135 acres and upon closure will require the construction of a safety berm and some soil amendments and seeding. On page 52 we see that these costs total $70,600 in direct costs and $19,600 in indirect costs. Because of Rosemont's location next to the highway and because of the local opposition to the project there will also be a massive perimeter berm, constructed out of waste rock, to shield the workings from public view. That berm, which is unusual and specific to this particular mining facility, will be 402 acres and will cost $1,673,000 in direct costs to regrade and seed, for a total cost of $2,138,000 including indirect costs. It is not part of the open pit. It is more like a waste rock dump that needs contouring and revegetation. Table G.1 lists the open pit acreage at Rosemont as 402, which is the acreage of the berm, not the correct number of 135, which is the acreage of the pit. It lists the response cost associated with these 402 acres of berm as $2,235,771. I do not know where this number comes from. The difference from $1,673,000 cannot be preconditioning, as if I use Equation 3-1 to bring these 2007 direct costs up to 2014 I get $1,673,000 x 9,806/7,966 = $2,059,432, which after adjusting for Equation 3-2 gives $2,059,432/0.96 = $2,145,242. In any event, the correct data point here should be an open pit size of 135 acres and a direct response cost of $70,600. If anything the 402 acre special berm should have been aggregated into the waste rock cost calculations.

Phoenix Historic heap leach treatment is also incorrectly interpreted. The heap leach is 472 acres and will undergo contouring, evapotranspiration covering (ET covering), and revegetation. The covering should be coded as source control. Page 14 of the source document lists costs for this of $3.6 million, which is approximately what is reported in Table G.3 but that table does not allocate some of this into source control. It should. Phoenix Historic also covers its tailings, and yet there is no demarcation for source control costs for Phoenix Historic in Table G.4. Table G.2 does correctly list source controls for waste dumps at Phoenix Historic. On page 26 of the source document we also see that the Phoenix Historic heap leach pad will be neutralized prior to coverage, at a cost of $8 million. Then there will be interim fluid management at the heap ($500,000) and at the wet tailings facility ($400,000), process fluid stabilization at the heap ($5 million) and the wet tailings facility ($11 million), and solution evaporation at the heap ($300,000) and the wet tailings facility ($8 million). These would all appear to be interim O&M expenditures. Table G.11 lists $9 million in Interim O&M for Phoenix Historic, which is not what these costs add up to.

Please note that I have not checked every data entry in Appendix G for the four facilities I sampled. I am relating here my experiences from some spot checks. These checks should be enough to show that the original data collection and entry process is not reliable and that the subsequent review and replication exercise that is noted in the report was ineffective.

Section 4 performs the regression analysis to estimate the specific relationship between direct response costs and mine facility attribute. I find the approach here reasonable subject to five substantive caveats. First, a visual inspection of the data in Appendix G along with the regression plots in Appendix J convinces me that the data includes influential points (sometimes incorrectly called outliers by economists). Influential points are data points with both leverage and outlier effect that have undue influence on the regression coefficient. I have not seen any tests for influence points in the report (e.g., DFBETAS, robust regression), yet I am sure that influence points are having an effect on the regression coefficient estimates. Note that once influence points are identified they should not necessarily be removed from the data. Rather, they are likely to be showing that the model is incomplete or that the data point contains an error. One area where the model is incomplete, for example, is in open pit backfilling. Two obvious influence points are the open pit response costs and Cresson and Phoenix. Both have leverage (the acres is high) and outlier effect (the response costs are huge). What is different about these two facilities? Both require backfilling of the pit. Such backfilling is unusual, and very expensive. A test for influence points would likely reveal that the Cresson and Phoenix are influential points, and then a further review of the primary source data would reveal that these two properties require backfilling. The model can then be adjusted to include a dummy for open pit backfilling. Once this is done the coefficient on $LogAcres_{OpenPit}$ will likely drop to 0.5 (see below). Cresson is also an outlier in the Heap Leach activity. An inspection of the source document shows why: like Phoenix, Cresson will rinse and detoxify its leach piles, an unusual requirement that adds substantial closure costs. Whoever collected the data did not move these costs into Interim O&M. The influence point test directs us back to the source document to figure out what is going on at Cresson, which is why this is such a useful exercise.

The main second concern that I have is that the confidence intervals in the bidirectional analysis for regression robustness are too generous. When one is “regression mining” one has no strong priors about what should or should not be in the regression. The chance of spurious results is

high. I suggest a 99% confidence interval here when looking to add or drop independent variables.

The third caveat is that there was no attempt to form priors about the regression coefficients. Let's take open pit reclamation. A review of the source documents will show that the main response activity for open pits is building fences or berms around the pit perimeter. If we assume that pits are circular their area will be πr^2, where *r* is radius. Their circumference, which is what matters for building fences and berms, is $2\pi r$, which is proportional to the square root of acreage.[4] Hence, I would expect a coefficient of 0.5 on $LogAcres_{OpenPit}$. The estimated coefficient is 1.08. Given my prior, and due to likely data errors and influence points, some of which I have identified above, I have no confidence in this number. The fact that it should be 0.50 gives me additional conviction about there being data errors.

EPA will note in looking at the source documents that engineers use constant average costs when calculating response costs. There are no economies of scale in the source data. That means that the coefficients on independent variables like Waste Piles, Leach Pads, and Tailings Dams, whose response costs are proportional to acreage, should have coefficient estimates of near 1.00 or slightly above to take into account the diseconomies of scale associated with increased cycle times as distances grow (the total engineering costs on the larger piles are likely to be higher due to increased numbers of cost units per acre). Where the estimated coefficients are not in line with these priors there should be added emphasis to investigate why not.

Along these lines, if the coefficient on area is approximately 1.00 the first term in each Waste Piles, Leach Pads, and Tailings Dam regression provides the average response cost per acre. Take heap reclamation. Since the coefficient is 1.01 the regression results can be interpreted to reveal that the average response cost is $2.29 \times 10^{4.57}$ = $44,651/acre. This is very high. Even without the source control adjustment the value is $2.29 \times 10^{3.87}$ = $16,976/acre. I would expect something in the range of $5,000/acre to $10,000/acre. The value is likely high due to the smearing adjustments to the regression estimates. The smearing factor is heavily affected by outlying data. For example, in Table J.5 there are two observations that are creating a high smear factor. If one of these is Cresson and the other is the erroneous data for Pinto Valley, which I presume it is, then correcting these for the data entry problems will lower the smear factor and bring the average cost in line with industry norms. If we reduce the smear factor to 1.00 the average cost prior to source controls becomes $10^{3.87}$ = $7,413, which is right where I would expect it to be. Each of the coefficient estimates needs to be thought about in this way.

EPA could also test the source control effects on per acre response cost against known cost estimates for source control. Albright (2015) says tailings covers range from $25,000/acre to $125,000/acre. In the example of heap reclamation that I presented in the previous paragraph the source control cost adds $30,000/acre if the smearing factor is included and $15,000/acre if it is not. Is this reasonable? EPA should check for the reasonableness of the source control parameter estimates in each of the reclamation tasks.

My fourth concern is the treatment of source controls in Section 7 of the report. My understanding is that some facilities' reclamation plans included cover for open pits, waste dumps, heaps, and tailings, and these are treated in the regression as additional costs indexed by

[4] Circumference = $2\pi r = 2\sqrt{\pi}\sqrt{\pi r^2} = \left(2\sqrt{\pi}\right)\sqrt{acres}$.

a 1,0 dummy.[5] The final expanded regression presented by EPA, in order to be conservative, assumes source controls will be needed in a financial assurance estimate and includes the added costs for these in the final Formula. Yet surely adding costs for source controls reduces other costs such as drainage, water treatment, and ongoing O&M. The only place I see any credit for source controls is in the impact of gross precipitation in the water treatment equation, where only 5% of the gross precipitation flow needs to be treated.[6] A better approach would have been to estimate the water treatment and O&M regressions with a 1,0 dummy when there was upstream source controls applied at a facility. I would think the coefficient on the dummy should then be negative, indicating that there are downstream payoffs to enhanced upstream environmental controls.

I am also concerned at the outright assumption in the financial assurance formula that financial assurance necessarily include source controls, as represented in the Table 7-1 regressions. Is this to say that there will be no discretion in the financial assurance formula as to whether source controls are necessary at a specific facility?

My final concern is that the model is not tested for the type of reasonable accuracy that I referred to in my initial comments. Are the actual source data cost estimates within a range that is 50% below to 100% above the Formula estimates? One needs to look at the performance of the whole regression here, and not just each component, as the errors across components for a given facility are likely to be serially correlated. For example, take the estimated response cost for Pinto Valley absent source controls (and excluding agency direct and indirect costs, the NRD multiplier, and the health assessment cost, and adjusting the coefficient on water treatment from 0.05 to 1.00 given the absence of source controls) and compare it with the $60 million grand total direct and indirect cost estimated in the source document. Is the Formula estimate within range? My own application of the Formula for my four sample properties indicates that reasonableness in accuracy as defined by -50% +100% is not achieved.[7]

For that exercise I spent the most care estimating the financial responsibility direct response costs for Rosemont. Adjusting the results to 2007 to make them comparable with the 2007 Rosemont reclamation source document I get $TotalFinancialResponsibility_{2007}$ of $99 million based on facility conditions at the termination of operations. The company estimates total response costs of $19 million at closure. If we add indirect costs the totals rise to $131 million and $24 million, respectively. Adding EPA oversight, NRD, and Health Assessment creates a

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[5] The coefficient for source controls on heaps was not statistically significant, which is problematic since we know that source controls add costs. This is probably because of errors in the data file and the way in which it categorizes costs. Many of the heaps in the 63 HMF sample will have cover but this has not been recognized in the data collection exercise. The source document for Pinto Valley, for example, has ET cover on its heaps (source document Table 1), and yet this was not noted in the data in Appendix G. More generally, the definition of source controls is not clear. Does earth cover and revegetation, which is undertaken at all facilities, count as source control?

[6] I presume that without source controls more gross precipitation would need to be treated. In my Rosemont Formula estimate I presumed 100% of precipitation would have to be treated given the absence of source controls.

[7] My application was approximate given that I did not know exactly how to apply the formula. What year in the operating life do I choose? Do I aggregate all waste dump piles into a single pile, or do I treat each as a separate formula element? Is $LogAcres_{Total}$ the total acreage of the whole facility, or the total of the individual facility elements; is $LogAcres_{Total} = \sum_{f=1}^{k} Acres_f$? What is the set that f indexes? Where do obtain gross precipitation data? What acreages do I use for the open pit – reclaimed acres or total acres of disturbed area?

final $TotalFinancialResponsibility_{200}$ of $163 million for Rosemont. Unless Tetra Tech, a well-known mining engineering consulting company, has grossly misestimated the environmental cleanup costs at Rosemont I would say this exercise shows that the Formula is not producing reasonable numbers for this facility.

Appendix K.3, while it was used for robustness purposes, is also an external validity test. The test supports my assertion that the Formula is well wide of the source data response costs. The numbers in the first column of the table can be manipulated to give the average regression error as $\%error = (10^{x} - 1)/10$, where x is the coefficient listed in the table. For example, if the average absolute value of 0.56 in the first row means that on average the error in the log estimate is either -0.56 or +0.56, then the average regression error on open pit costs is $\%error = (10^{0.56} - 1)/10 = 263\%$ when the log true cost is higher than the log estimated cost by 0.56. Put differently, the +0.56 value tells us that on average the true costs from the primary source data are 263% higher than the cost estimate by the Formula for an out-of-sample test. If we look at the other case, the average regression error is $\%error = (10^{-0.56} - 1)/10 = -72\%$ when the true cost is lower than the estimated cost. If the goal is Class 5 bounds of the true value being between -50% and +100% of the Formula estimate then the average error obviously has to be lower than these numbers (> -50% and < 100%).[8] As I noted before, errors are likely to be serially correlated across response activities (favorable geographic location that lowers diesel costs will affect each response cost's error in the same direction), and so based on the numbers in this table I hardly think that the Formula is giving total response estimates that are within +100%, -50% of the true numbers.

By the way, the technique used in K.3 can address influence points. Do the regression coefficients move around substantially when a data point is omitted? This is exactly what the DFBETAS test does.

I would also say, in a brief comment on incentives, that requiring $163 million in financial assurance for Rosemont, as opposed to the $18 million being planned by the company as of its 2007 technical study, would not have killed this mining project. Its economics at the time looked able to sustain the increased up-front capital expenditure. Nevertheless, in building up my Formula estimate of $163 million for Rosemont I found several areas that required data judgements that I can see companies and the EPA arguing over or even litigating over. For example, there is no definition of $LogAcres_{Total}$. Nor is there a clear definition of $LogAcres_{Tailings}$ when it is dry stacked and mixed with waste rock. Even where the technology is fairly clear a given project will have several estimates for facility acreage (e.g., open pit acreage can be measured as actual pit, pit plus buffer, total pit disturbance including roads and ramps, reclaimed pit, etc.). It will be advantageous for the firm to select the lowest possible number in order to minimize its financial assurance.

[8] I would note that Class 5 estimates have lows of -20% to -50%, and highs of +30% to +100%. EPA's selection of -50% to +100% are the worst cases for Class 5 estimates. While not asked to comment on it, I hardly think a Formula whose performance is -50% +100%, and that could result in a company posting financial assurance that is twice that required is satisfactory.

Section 5 moves on to the NRD estimate, and concludes that it should be 13.4% of the response cost. Given the relatively minor impact of NRD and health assessment on the financial responsibility I don't suggest EPA spend more time refining this. I would like EPA to further investigate and document the possibility that NRD is inversely proportional to response cost, or that it changes by commodity type. Radioactive minerals are an obvious example. There is likely, also, to be sample bias in the NRD data given that this is taken from CERCLA sites that clearly had something go wrong well before EPA got there. I realize, however, that the data sample is small, and when this is the case averages are about all we can use.

Likewise, I am fine with the analysis in Section 6. Any error in the HA costs will be swamped by the errors in the response costs.

Let me summarize. Given the time constraints and data constraints experienced by EPA I am of the opinion that the overall methodology is sound. I especially appreciate the scientific, data-driven approach. However, even with the goal of presenting only a Class 5 facility-specific assurance cost, the implementation of the data collection and analysis leaves much to be desired, and a careful consideration of my previous comments is needed. I would also observe that if it has not done so EPA could benefit from closely interacting with industry professionals. While I have not been privy to the generation of the Formula or report, the little bit of close data inspection that I have done gives me the impression that there is a stark lack of understanding of the workings of the industry that the EPA is tasked with regulating. There are also important state-level controls that are missing. SMARA requires California mining lands disturbed after 1976 to be backfilled. Even if backfilling is not part of the reclamation plans for the two California open pit mines in EPA's sample, a forward-looking Formula needs to take this into account with a California dummy in the open pit cost category. Florida has special wetland restoration costs for phosphate mines, but neither phosphate mine in the sample is from Florida and so this special characteristic would not be revealed in the data. Other states may have special requirements as well. New Mexico and Michigan do not allow mine designs that require perpetual water treatment, and to charge firms for ongoing O&M in these states is unwarranted. I cannot help but believe that reclamation in Alaska is an order of magnitude more difficult and expensive due to location and weather. These regional differences need to be accounted for and teased out of the data if possible.

And, as I noted above, I have little confidence that those who read the source documents in Appendix G and transferred the data from the source documents into the data file understood what they were reading. I would recommend that EPA redo this data collection exercise using mining industry interns or specialists who know how to read and interpret a mine reclamation and closure plan. Finally, I would suggest that the methodology not stop at the production of regression results, but that the results be interpreted and tested against industry benchmarks for reasonableness; the regression results need to be post processed. Sitting down with industry professionals and asking them about the results and special response cost situations is an important reasonableness check that has not apparently been done and that would have revealed the types of implementation flaws I have identified.

All of this is not to say that I don't think the proposed methodology can achieve EPA's goals. I am broadly in favor of the approach taken. It is just to say that the exercise is not yet over the finish line, and my hope is that my comments will help to move the exercise in that direction.

I have one question about use of the Formula that I will mention here. The methodology collected facility-level estimates of final closure response costs based on engineering plans and models used by the facility owner. Yet on our initial conference call the idea was that the facilities establish and maintain evidence of financial responsibility should bankruptcy, for example, occur at any moment and the facility be taken over for reclamation by the government. Can the Formula's estimates of final closure costs, determined by acreage of facility disturbance at closure *and facility conditions at closure*, reasonably represent likely financial responsibility at a facility *prior to closure*? This question has not been addressed or answered. I would think that this is yet another way in which the initial collection of NPL and non-NPL costs at CERCLA facilities can be compared against Formula estimates for these same facilities such that any shortcomings of the Formula for estimating costs prior to closure can be identified.

2.) Do you have any recommendations that might improve the soundness and transparency of the analytical and statistical methods used to develop the Formula? If so, please distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.

I have included several suggestions in my comments above, all of which I believe are manageable in the near term. I have suggested above that more data is needed on response costs for industrial minerals facilities, and that these facilities may need their own formula. I am hoping that this can be done prior to the release of the Formula.

I would add here comments related to transparency that are immediately feasible. First, I would suggest that all regression results be reported, not just those that were statistically significant. Waste disposal regressions, for example, were not reported. Second, the source documents for the data should be publically available. I had to ask EPA to supply me with the closure reports that I sampled since I could not find them in the public domain. Third, there needs to be complete data files supporting the preconditioning of the data and the regression results such that one can exactly replicate this work. This would alleviate perhaps the concerns I have about the source data in Appendix G: if it is preconditioned data I could see how it was done. I would also recast the Formula (expanded) for public viewing in simplified form, as "smear factor x leach response cost factor x $acres^{1.01}$" or "$2.29 \times 10^{4.29} \times acres^{1.01}$" or "$\$44{,}651 \times acres^{1.01}$" or something like that. There is no reason to present the formula in its original and unsimplified logged form.

All data in the written documentation should have footnotes indicating where the data can be found (listing source document and page number). See my concerns above regarding reproduction of the source data used in Appendix G.

To aid transparency on how the Formula will be used I would suggest that EPA, in addition to giving the final expanded Formula in Section 7, provide worked examples of how the Formula would be applied to selected facilities (ideally, there would be an example for a mining facility, a processing facility, and a smelting facility). That is, take the information in one of its Appendix G source documents and use that to calculate the total financial responsibility for a given year for that facility. I have attempted to do this exercise for Rosemont, but my efforts would have been aided by a worked example with advisory notes.

For the longer term, more data is needed on slag piles, in-situ leaching that is not uranium, and water flows that are not based on CERCLA facility data.

The next four questions presented in the Reviewer Guidance Document deal with specifics:

3.) **EPA collected data on specific response activities conducted at historical National Priorities List or Superfund alternative approach hardrock mining facilities. Please assess the appropriateness of these data for the subsequent analysis. Are EPA aware of additional nationwide datasets that may further supplement the data used by EPA to identify response activities that EPA may have to undertake during a CERCLA response at a hard rock mining facilities? If so, please discuss.**

As I noted above, I did not see that this historical NPL data was used in generating the Formula other than to identify and categorize response activities and to suggest order of magnitude response cost experiences. I would think that some marriage of this data with the Formula data would be useful, particularly in differentiating financial responsibility at facilities that are likely to become NPL facilities. It would also be useful to compare cost estimates for these NPL and non-NPL facilities generated using the Formula with the actual CERCLA spending. Cost estimates by engineers, the source of the data for the Formula, are often underestimated.[9] That may also be the case here, since we to date have no fully reclaimed mining facility in the US that was undertaken in situations other than CERCLA management. This exercise may suggest that in addition to the smearing factors an overall upward adjustment for cost bias is necessary (in addition to the overhead and oversight adjustment, which includes contingency).

I am not aware of additional nationwide data sources.

4.) **Several steps were taken to "standardize" data on response costs (e.g., adjust for inflation and account for state level differences in input costs). Given the application of these data, please comment on these pre-analysis data steps. What improvements (if any) would you recommend? Please elaborate on the specifics of any recommendations, and distinguish between suggestions that are immediately feasible versus those that might be more appropriate in the long term or with significant resources.**

As I mentioned above, a data file showing the pre-analysis should be provided to the public.

[9] There is a large literature on this. I suggest looking at some of Bent Flyvbjerg's work on cost overruns at large infrastructure projects. A recent survey by Ernst & Young found that 69% of mining megaprojects ran over budget by an average of 62%. Unfortunately, the raw data is not publically available and so an average overrun over all projects cannot be calculated. Nevertheless, this provides additional motivation to test the Formula's predictions against historical CERCLA spending to see if actual spends are substantially above the Formula's estimates.

The first step in standardization was to bring all engineering costs to 2014. The index used was the ENR construction cost index. The index is appropriate for mining cost changes over time. The second step was to account for differences in state-level labor and materials costs using a US Army Core of Engineers cost index. This is reasonable, since the engineering costs in the source documents would have attempted to take these local variations in costs into account. Finally, EPA standardized the costs by converting into annualized costs using amortization. EPA should report the rate it used in the amortization.

5.) **Using the aforementioned data on response activities, EPA linked specific facility features to the release of hazardous substances and the resulting response costs. Are there additional facility features that EPA recommend EPA consider and how might these additional features be key explanatory variables of response costs? Please distinguish between suggestions that are immediately feasible with available data versus those that might be more appropriate in the long term or with significant resources.**

Open pit backfilling and wetlands restoration are facility features that EPA should consider now as key explanatory variables. There is data in the file on backfilling. I don't know if there is data on wetlands remediation, but perhaps CERCLA data could be used for this. Radiation decontamination is something that would be associated with uranium and rare earths extraction, and should be investigated as an additional feature.

6.) **Several tests were conducted to examine the robustness of the chosen statistical models (e.g., examining internal and external transfer error). In your professional opinion, do these robustness checks reasonably support the chosen statistical models? If applicable, please describe any additional robustness checks that EPA should consider in the development of the Formula which could feasibly be carried out with the available data.**

No. On the specification robustness tests I suggested above that the confidence level be increased to 99% in the bidirectional elimination to avoid spurious regressors. I also recommended that the regressions be tested for sample robustness (the impact of influence points) using a multi-row deletion test like DFBETAS. Robust regression could also be used to be sure single points are not driving the regression results.

Other comments

I have two types of comments that are not covered in the questions above. The first relates to the effect of this Formula on firm activity, and the second are some minor points.

Based on the data provided in the study, the financial assurances required will be substantial in relation to other costs at the regulated facilities. I believe that firms will attempt to reduce exposure to these costs as in traditional microeconomic theory. They are not quite irreversible

capital costs, however, since they would be returned once the facility is reclaimed. It would be better to think of them as reversible capital costs, *rK*, where *r* is the opportunity cost of having the funds tied up. If interest equal to *r* is provided by EPA while the funds are in escrow, then there is in theory no opportunity cost to the financial assurance. Nevertheless, given capital market imperfections and the difficulty many mining firms have in raising capital during the development phase of the project, I believe they will be incentivized to create design changes to avoid the costs. Since the Formula is mainly based on area (acres), there will be efforts to reduce the acreage of open pits, heaps, tailings facilities, and so on. "Use land efficiently" will be the industry's new mantra. There will be incentives to prefer dry stack to wet tailings and locate in negative precipitation areas. There will be incentives to locate facilities in states where EPA oversight costs are lower. Some projects will not go forward given the additional up-front capital costs associated with the financial assurance. All of this would reduce risks and costs for the Superfund program.

That said, are any of these effects likely to be welfare-enhancing? I doubt it. I can't see that the externalities associated with mining are from privately selected acreage being greater than the social optimum. The incentive to dry stack tails and to locate facilities in arid areas may be beneficial from a water management and pollution point of view, but it can be damaging to water supply sources in arid areas.

Minor and editorial comments:

a) p. vi, "EPA considered how to develop an amount of financial responsibility that reflected an amount of funds that might be required in the event of a release from a regulated facility"? Why are the funds targeted to a specific release? We were told on the conference call that the funds reflect EPA responsibilities in the event of bankruptcy or project abandonment. The Formula estimates the total suite of response costs.
b) p. ix, "In addition to water-balance-related data, EPA collected data related to process methods for the four leaching processes identified at the 63 facilities in EPA's data set. These process method data included the use of floatation, cyanide, acid, and in-situ leaching processes." Flotation (note spelling) is not a leaching process. It is a chemical separation process.
c) The labels for short-term O&M monitoring, long-term O&M monitoring, and interim O&M are vague and confusing. Both the short term and interim O&M are taken over 10 years, for example, and so why the time differentiation?
d) The discount rate used to calculate present values of O&M costs is real (deflated). The deflator is the implicit GDP deflator. That means that the cost stream that is discounted must be in real terms, *with the adjustment from nominal to real being made using this same deflator*. The current approach, which is to project the 2014 engineering costs as constants and then discount those at 2.63%, is not correct. The 2014 engineering costs must first be projected as nominal costs using the escalation factor for these specific costs, then discounted at the same deflator used to estimate the real discount rate (the GDP price deflator). The result will not result in constant real engineering costs over time since their inflation rate is different from the deflator used to calculate the real interest rate. I suggest inflating the engineering costs at average historical rate in the ENR data, Table 3-6. Then discount these nominal costs

using the projected GDP deflator to get the real series. This is then the series that is discounted at 2.63%.

e) Likewise, the inflator for response costs on page 7-2 should not be the GDP deflator. It should reflect the inflation in response costs, which are likely to be higher than the GDP basket. I would again suggest the escalation rate from the historical ENR series as a starting point.

f) On page 5-2, and elsewhere in the report, use common notation. On page 7-2 D_{y^*} is used to denote the deflator, and then $Deflator_{y^*}$ is used further down. Are these the same thing? Why develop IF_y and then not use it in Equation 7-3?

g) Does the NRD data which comes from court settlements and judgements differ from that from voluntary payments. I suspect these are two different populations, and it is not correct to combine them without some analysis.

h) Given the skewness of the truncated data in Table 5-4, would a median or geometric mean be more appropriate? Using the median would produce a 3.8% multiplier, so the question is not rhetorical.

i) Equation ES-1 is the expanded formula for a facility "with a single facility feature of each type (*e.g.*, a single heap leach)" (p. xvi). Does this mean that if a facility has two heaps the acreage of each would be costed separately? I suggest for clarity that EPA present an expanded formula for a facility that has two waste dumps, for example.

j) Though EPA will not likely have time to do this, I think it would be very useful to apply the Formula to the 63 facilities in Appendix G and see whether the results match historical CERCLA response costs. I realize that the historical CERCLA response costs may have been directed at specific releases and not total facility restoration. But if EPA suspects that the CERCLA data summarized in Table 2-1 is at all useful for external validity the exercise could be very informative.

k) I found much of the discussion in Section 2 to be unrelated to the final Formula estimate. What, for example, is the relevance of the data in Figure 2-10? All of Section 2 could be edited with a view of relating the information and findings to the Formula. Table 2-2 is the most important portion of the section, and deserves more discussion. Source controls need to be included in the table.

l) p. 2-20, the discussion under tailings facility and process ponds incorrectly refers to heap and dump leaches.

m) p. 2-23, contingency does not describe cost overruns or project cost overruns. It is a catch-all cost element for items not explicitly contained in the engineering studies.

n) In Section 3.2 it is not clear if EPA obtained data directly from the source documents listed in Appendix G or whether it obtained secondary data from state governments who in turn claim to have taken the data from the source documents. There is no reason that for consistency of reporting EPA should not obtain the data from the primary sources.

o) The calculations in Appendix B are based on "the equations discussed in Section 2-1 of this document: (Appendix B-2)." With a view to transparency and replicability, the EPA needs to add clarity as to which equation was used for which facility. Moreover, Table 2-1 should list the response costs overall, as well as separated out for NPL and non-NPL facilities since the report quotes averages for each type of facility.

p) In equation 3-2 is C_S the same as $Cost_{2014\$}$ in equation 3-1?

q) I don't understand why some of the acreage data was normalized with +1. I do get that Log(0) is undefined, but the Formula is clear that one only puts in acreage data where it is relevant. $LogAcres_{Total}$ is always > 0, so why the +1 adjustment?
r) p. 4-14, the hazardous waste disposal cost used in the Formula is not approximately $2.6 million. It is precisely $2.6 million.
s) p. 7-6, clarify what facility features f is indexed over. Is the first facility feature open pits, or open pit #1 in the case of there being several pits? Is $k = 3$ if there are open pits, waste dumps, and leach piles, or is it equal to the total number of open pits, waste dumps, and leach piles?
t) Response costs should be defined when it is first used in the document.
u) Please add units when presenting numbers. For example, in Table G.13d are the numbers $ or $/yr?