Grant R. Carey, Ph.D., P.Eng.

PROFILE OF PROFESSIONAL ACTIVITIES

Dr. Carey has worked on projects across North America and Australia with a focus on:

- PFAS site characterization and remediation
- Environmental forensics and data visualization
- Groundwater and soil vapor flow and transport modeling
- NAPL delineation and remediation
- Mine dewatering and site restoration
- Regulatory negotiations
- Expert witness and litigation support services

Dr. Carey has more than 30 years of experience, and is recognized as an industry leader in modeling PFAS transport and remediation in groundwater. Dr. Carey also specializes in environmental forensics, NAPL delineation, contaminated site and sediment remediation, mining projects, and groundwater flow and transport modeling. Dr. Carey has worked on numerous projects across the United States, Canada, and Australia, providing regulatory and litigation support to various client sectors including law firms, the U.S. Department of Defense, chemical manufacturing, aerospace, and mining. Dr. Carey has also developed proprietary computer codes for PFAS modeling and visualization. Dr. Carey is currently providing expert modeling support to a number of project teams to advance PFAS research on behalf of the U.S. Department of Defense, and he is an Adjunct Research Professor at Carleton University in Ottawa, Canada. Dr. Carey has published more than 100 short courses, seminars, and papers, and he has developed and delivered professional education based on interactive classroom, e-learning, and web seminars. Dr. Carey was involved with the development of the ITRC PFAS Guidance manual and is currently participating in the development of the National Ground Water Association White Paper on PFAS Forensics. Dr. Carey also has experience and training as both a mediator and meeting facilitator.

PFAS QUALIFICATIONS

- Recognized industry leader in predicting the performance and longevity of in-situ sorbent technologies for PFAS remediation
- Widely published proprietary reactive transport model (The In-Situ Remediation Model, or ISR-MT3DMS) for evaluating the feasibility and design of PFAS remediation alternatives
- Proprietary forensic tools for visualizing PFAS source contributions, precursor transformations, redox geochemistry, and site background concentrations

- Expertise and experience gained through participation on industry-leading research teams studying PFAS adsorption to colloidal activated carbon since 2017
- 11 PFAS remediation peer-reviewed articles since 2019, including six published, two under review, and three to be submitted in 2024
- U.S. Patent Pending for an innovative process to enhance PFAS ex-situ treatment
- Currently involved with four SERDP-ESTCP projects related to PFAS remediation for the U.S. Department of Defense

SPECIALIZED PFAS CONSULTING SERVICES

In addition to standard site characterization, remediation, and litigation services, Dr. Carey is uniquely positioned to provide the following specialized PFAS services:

- Recommend site characterization methods that support the feasibility study or remedial design of in-situ sorbent alternatives
- Use proprietary reactive transport model (ISR-MT3DMS) to:
    - Predict future PFAS plume extents, and the potential for natural attenuation to reduce risk at downgradient receptors
    - Compare the performance and longevity of various in-situ sorbent technologies
    - Assess the effects of competitive adsorption on the long-term performance of in-situ sorbents
    - Conduct feasibility or remedial design studies including evaluation of integrated site-wide alternatives for source treatment and plume management
    - Evaluate the influence of rate-limited desorption or back-diffusion on the timing of the downgradient plume response to site remediation
- Apply commercial models including HYDRUS and the PFAS-LEACH Integrated Toolkit to quantify PFAS flux from the vadose zone to an underlying aquifer
- Forensic evaluation of PFAS source contributions in support of litigation

EDUCATION

Ph.D. University of Guelph, Guelph, Ontario, 2015 (Part-time): Predicting Attainable Goals and Depletion Timeframes for DNAPL Source Zones

M. Eng. Carleton University, Civil and Environmental Engineering, 2001 (Part-time): Development and Field-Validation of a Three-Dimensional, Redox-Dependent Biodegradation Transport Model

1997 One of two Canadian graduate students invited to a NATO Advanced Study Institute (Bioavailability of Organic Xenobiotics in the Environment) in the Czech Republic.

B.A.Sc. University of Waterloo, Civil Engineering, 1993: Thesis – Development and Validation of a Two-Dimensional, Density-Dependent Vapor Flow and Transport Model

EMPLOYMENT

2006-Present	President and CEO Porewater Solutions
2005-2006	Associate, and Director of Corporate Training Conestoga-Rovers & Associates
2002-2004	Senior Engineer and Training Developer Conestoga-Rovers & Associates
2000-2002	President and CEO Environmental Institute for Continuing Education (EICE)
1996-2002	President and CEO Environmental Software Solutions Inc. (ENSSI)
1997-1999	Carleton University Mediation Centre – Volunteer Mediator
1992-1996	Engineer, Conestoga-Rovers & Associates

RESEARCH COLLABORATION

2018-Present Adjunct Research Professor, Department of Civil and Environmental Engineering, Carleton University

- Currently participating in four U.S. DoD SERDP-ESTCP research projects related to PFAS transport and remediation modeling.

PROFESSIONAL AFFILIATIONS

- U.S. National Ground Water Association
- California Groundwater Resources Association
- Professional Engineers Ontario

PFAS Projects

- Confidential Mine Site – Modeled groundwater flow and PFAS transport to assess the feasibility and remedial design options for a colloidal activated carbon barrier to contain a PFAS plume which was preventing the dewatering of a large mineral body.
- ESTCP ER24-B1-8200. “Two PFAS Remediation Models for Understanding and Managing PFAS in the Saturated Zone.” Providing expert technical support and benchmarking with the proprietary ISR-MT3DMS code for the development of new PFAS reactive transport models.
- ESTCP ER20-5182. “Validation of Colloidal Activated Carbon for Preventing the Migration of PFAS in Groundwater”. Conducting pre- and post-injection modeling support for a colloidal activated carbon remedy adjacent to a former fire training area at a military facility in Florida.

- SERDP ER21-3959. “An investigation of factors affecting in situ PFAS immobilization by activated carbon”. Used a proprietary reactive transport model to support the development of publications that provide guidance on site characterization and feasibility study evaluations of colloidal activated carbon at PFAS sites. Also collaborating with a university consortium to develop and validate new modeling methods for predicting the longevity of in-situ sorbents for short-chain PFAS such as PFBS, based on laboratory and field-scale case study data.
- SERDP ER21-1070. “Hydraulic, chemical, and microbiological effects of in situ activated carbon sorptive barrier for PFAS remediation in coastal sites”. Providing expert modeling support to assist with evaluating relative adsorption isotherms for short- and long-chain carboxylates and sulfonates, and to assess the effects of aging on in-situ activated carbon.
- Confidential Site – Developing novel forensic methods for identifying PFAS source composition and evaluating PFAS precursor biodegradation to PFAAs in groundwater.
- Military Facility – Modeling the initial 18 months of performance of a colloidal activated carbon barrier, including estimation of field-scale adsorption isotherms for ten short- and long-chain PFAS.
- Military Facility – Modeled the influence of tidal fluctuations and coastal site geochemistry on the performance of colloidal activated carbon for PFAS in-situ remediation adjacent to the coast.
- South Dakota Military Facility – Modeled the viability of colloidal activated carbon for in-situ remediation of PFAS at an AFFF-impacted site with high PFOS, PFHxS, and PFOA concentrations in groundwater.
- National Ground Water Association PFAS Forensics White Paper – Participating on an NGWA committee to prepare a comprehensive white paper documenting available PFAS forensic analysis methods based on data visualization, statistics, and modeling.
- NSERC Alliance Research Project – Provided technical direction for laboratory experiments and numerical modeling of PFAS competitive adsorption to colloidal activated carbon, and the development and verification of several reactive transport model codes. Project was conducted in collaboration with the University of Waterloo, University of Toronto, and Carleton University.
- Ontario Center of Excellence Research Project – PFAS Adsorption isotherms with colloidal activated carbon and PFAS in-situ remediation model code development, in collaboration with the University of Waterloo and Carleton University.
- Central Canada site - Modeled PFAS transport and in-situ remediation performance based on colloidal activated carbon injections into the source zone.
- Various impacted sites in the United States - Assessment of initial PFAS sample results and provided technical support for further site characterization and remediation activities.

Modeling and Visualization Software Development

Dr. Carey has developed a variety of commercial and public domain software tools, including:

In-Situ Remediation (ISR-MT3DMS), 2023 – three-dimensional reactive transport model based on the MT3DMS framework, for simulating the performance of PFAS, chlorinated solvents, and metals in-situ remediation technologies, including adsorptive permeable reactive barriers, enhanced in-situ bioremediation (EISB) and in-situ chemical oxidation. Model includes an innovative local domain approach for modeling forward and back-diffusion, and also includes the reaction package from BioRedox.

Visual PFAS, 2018 – radial diagram visualization tool for visualizing PFAS at one or more impacted sites, including demonstration of PFAS natural attenuation, precursor transofrmations, relative source contributions, and background concentrations.

NAPL Depletion Model, 2015 – semi-analytical screening model for simulating the depletion timeframe for LNAPL or DNAPL source zones.

Vapor-2D, 1992 – a two-dimensional finite element model that simulates multispecies, density-dependent vapor flow and transport. Vapor-2D was modified to predict the migration of gasoline vapors from a subsurface spill area, and includes a multicomponent NAPL source model. Vapor-2D was successfully validated by simulating laboratory experiments of vapor flow and transport of heptane in the vadose zone, and Vapor-2D has been used to assess density-dependent vapor migration at field sites. Vapor-2D is currently a proprietary model.

REPRESENTATIVE PFAS SHORT COURSES, WORKSHOPS, AND TRAINING SEMINARS

- Invited instructor for an internet seminar entitled: PFAS In-Situ Remediation Case Studies and Long-term Strategies, organized by Regenesis, late May, 2024
- Instructor for the 8-hour short course entitled “In Situ Management of PFAS in Groundwater”, including recent SERDP-ESTCP research advancements, to be presented at the Battelle 2024 Chlorinated Conference in Denver on June 2, 2024.
- Invited instructor for an internet seminar with 1,400 registrations entitled “Longevity of PFAS Remediation Using Colloidal Activated Carbon at AFFF-Impacted Sites”, organized by Regenesis, January 26, 2023.
- Invited instructor for an internet seminar with 1,200 registrations entitled “Longevity of PFAS Remediation Using Colloidal Activated Carbon”, organized by Regenesis, November 19, 2020.
- Invited instructor for a PFAS short course entitled “Managing PFAS at Your Site: Key Technical and Regulatory Issues Associated with PFAS”, International Cleanup Conference, Adelaide, Australia, September 12, 2019.
- Invited instructor for a workshop entitled: “PFAS Remedial Strategies”, at the RPIC 2018 Federal Contaminated Sites Workshop, Toronto, Ontario, June 13, 2018.
- Invited instructor for a workshop entitled: “Innovative Methods for Optimizing Remediation Efficiency”, at the 2018 Battelle Conference on Remediation of Chlorinated and Recalcitrant Compounds, Palm Springs, CA, April 10, 2018.

- Invited instructor for an internet seminar with between 500 and 1,000 participants entitled: "In-Situ Remediation Modeling and Visualization Tools", organized by Regenesis on October 26, 2017.
- Invited instructor for a workshop entitled "Innovative Visualization, Modeling, and Optimization Tools for Improving Remediation Efficiency", presented at the 2017 Cleanup Conference, Melbourne, Australia, September 10, 2017.

PEER-REVIEWED PUBLICATIONS

Carey, G.R., P. Hatzinger, G. Lavorgna, D. Lippincott, B. Sleep, and A. Danko, 2024, Model Calibration to Early Performance Results for a Colloidal Activated Carbon Barrier, in preparation for submittal to the *Journal of Contaminant Hydrology*.

Carey, G.R., Danko, A., Pham, A.L-T., Soderberg, K., Hoagland, B., 2024, Modeling the influence of coastal site characteristics on PFAS In Situ Remediation, in submittal to *Ground Water*.

Mole, R., C. de Velosa, **G.R. Carey**, X. Liu, G. Li, D. Fan, A. Danko, G. Lowry, 2024, Groundwater Solutes Influence the Adsorption of Short-Chain Perfluoroalkyl Acids (PFAAs) to Colloidal Activated Carbon and Impact Performance for In Situ Groundwater Remediation, in submittal to *Journal of Hazardous Materials*.

DiGuiseppi, W.H., C.J. Newell, **G.R. Carey**, P.R. Kulkarni, Z. Xia, J. Stults, T.L. Maher, E.F. Houtz, R. Mora, R. Wice, P.W. Tomiczek, S.D. Richardson, J. Xiong, J. Hale, J.P. Hnatko, R. McGregor, J.T. McDonough, A. Oka, R. Thomas, J. Fenstermacher, J. Hatton, 2024. Available and Emerging Liquid Treatment Technologies for PFAS. In submittal the Remediation Journal.

Singh, M., S.G. Hakimabadi, P.J. Van Geel, **G.R. Carey**, A.L. Pham, 2024, Modified Competitive Langmuir Model for Prediction of Multispecies PFAS Competitive Adsorption Equilibria on Colloidal Activated Carbon, Separation and Purification Technology, 345: 127368, p. 1-12.

Carey, G.R., R.H. Anderson, P. Van Geel, R. McGregor, K. Soderberg, A. Danko, S.G. Hakimabadi, A.L.T. Pham, M. Rebeiro-Tunstall, 2023, Analysis of colloidal activated carbon alternatives for in situ remediation of a large PFAS plume and source area. *Remediation Journal*, 34(1): e21772.

Carey, G.R., S.K. Hakimabadi, M. Singh, R. McGregor, C. Woodfield, P. Van Geel, A.L. Pham, 2023, Longevity of Colloidal Activated Carbon for In-Situ PFAS Remediation at AFFF-Contaminated Airport Sites, *Remediation Journal*, 33(1): 1-21.

Bryant, J.D., R. Anderson, S.C. Bolyard, J.T. Bradburne, M.L. Brusseau, **G. Carey**, D. Chiang, R. Gwinn, B.R. Hoye, T.L. Maher, A.E. McGrath, M. Schroeder, B.R. .Thompson, D. Woodward, 2022, PFAS Experts Symposium 2: Key Advances in PFAS Characterization, Fate and Transport, *Remediation Journal*, 32(1-2): 19-28.

Carey, G.R., R. McGregor, A. Pham, and B. Sleep, and S. Hakimabadi, 2019, Evaluating the Longevity of a PFAS In-Situ Colloidal Activated Carbon Remedy, *Remediation Journal,* 29(2): 17-31.

McGregor, R. and **G.R. Carey**, 2019, The In-Situ Treatment of Synthetic Musk Fragrances in Groundwater, Remediation Journal, Spring 2019.

Carey, G.R., E.A. McBean, and S. Feenstra, 2018, Estimating Transverse Dispersivity Based on Hydraulic Conductivity, *Environmental Technology & Innovation*, 10(5): 36-45.

Carey, G.R., E.A. McBean, and S. Feenstra, 2016, Estimating Tortuosity Coefficient based on Hydraulic Conductivity, *Ground Water*, 54(4): 476-487.

Carey, G.R., S.W. Chapman, B.L. Parker, and R. McGregor, 2015, Application of an Adapted Version of MT3DMS for Modeling Back-Diffusion Remediation Timeframes, *Remediation Journal*, Autumn 2015, p. 55-79.

Carey, G.R., E.A. McBean, and S. Feenstra, 2014, DNAPL Source Depletion: 1. Predicting Rates and Timeframes, *Remediation Journal*, Summer 2014, p*. 21-47*.

Carey, G.R., E.A. McBean, and S. Feenstra, 2014, DNAPL Source Depletion: 2. Attainable Goals and Cost-Benefit Analyses, *Remediation Journal*, Autumn 2014, p. 79-106.

Schreiber, M., G.R., D. Feinstein, **G.R. Carey,** and J. Bahr, 2004, Mechanisms of Electron Acceptor Utilization, *Journal of Contaminant Hydrology*, 73(1-4), p. 99-127.

Carey, G.R., P.J. Van Geel, T.H. Wiedemeier, and E.A. Mcbean, 2003, A Modified Radial Diagram Approach for Evaluating Natural Attenuation Trends for Chlorinated Solvents and Inorganic Redox Indicators, *Ground Water Monitoring and Remediation*, 23(4): 75-81.

Carey, G.R., T.H. Wiedemeier, P.J. Van Geel, E.A. McBean, J.R. Murphy, and F.A. Rovers, 1999, Visualizing Natural Attenuation Trends: Petroleum Hydrocarbons Attenuation at the Hill Air Force Base, *Bioremediation Journal*, 3(4): 379-393

RECENT CONFERENCE AND SEMINAR PRESENTATIONS

Carey, G.R., 2024, Case Studies and Long-Term Strategies for PFAS In-Situ Remediation Using Colloidal Activated Carbon, to be presented at the Battelle 2024 Chlorinated Conference in Denver on June 2, 2024

Vanderkooy, M., A. Pham, N. Thomson, B. Sleep, G. Carey, 2023, Opportunities, Issues, and Ideas for Activated Carbon at PFAS Sites, platform presentation at the 2023 SERDP-ESTCP Symposium in Washington, D.C., November 3, 2023.

Carey, G.R., S. Hakimabadi, M. Singh, R. McGregor, C. Woodfield, P. Van Geel, A. Pham, 2022, Longevity of Colloidal Activated Carbon for In-Situ PFAS Remediation at AFFF-Contaminated Airport Sites, poster presentation at the 2022 SERDP-ESTCP Symposium in Washington, D.C., November 30, 2022.

Carey, G.R., P. Van Geel, M. Singh, 2022, New Empirical Model for Predicting PFAS Breakthrough in Granular Activated Carbon, poster presentation at the 2022 SERDP-ESTCP Symposium in Washington, D.C., November 30, 2022.

Carey, G.R., 2022, Radial Diagram Visualization and Semi-Quantitative Forensic Methods for PFAS Site Characterization, poster presentation at the 2022 SERDP-ESTCP Symposium in Washington, D.C., November 30, 2022.

Bryant D. and G.R. Carey, 2022, invited expert participant in the PFAS Experts Webinar entitled USEPA's Health Advisory Levels Explained: What, Why, and When, presentation on Background PFAS Concentrations, organized by the Remediation Journal, July 19, 2022.

Carey, G.R., 2021, Invited expert participant in the PFAS Experts Symposium 2, organized by the Remediation Journal, June 29, 2021.

Carey, G.R., 2019, State of PFAS Remediation, Invited Panelist at the PFAS Research Symposium organized by CRC Care, Adelaide, Australia, September 2019.

Carey, G.R., 2019, In-Situ PFAS Remediation Using Colloidal Activated Carbon, Invited Keynote address at the International CleanUp Conference, Adelaide, Australia, September 9-11, 2019.

Carey, G.R., 2018, Modeling LNAPL Depletion at a Former Xylene Processing Facility (Germany), accepted for platform presentation at the 2018 Battelle Conference on Remediation of Chlorinated and Recalcitrant Compounds, Palm Springs, CA, April 9, 2018.

Carey, G.R., 2017, Innovative Visualization Method for Delineating Biodegradation Zones in Groundwater, presented at the 2017 Cleanup Conference, Melbourne, Australia, September 12, 2017.

Carey, G.R., R. McGregor, and J. Birnstingl, 2017, In-Situ Remediation of a PFOS/PFOA Plume In Ontario, presented at the 2017 Cleanup Conference, Melbourne, Australia, September 12, 2017.

Carey, G.R., 2016, In-Situ Remediation (ISR-MT3DMS) For Modeling Back-Diffusion Timeframes, platform presentation at the 10th International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Battelle, Palm Springs, California, May 22-26, 2016.

Carey, G.R., 2016, Forensic Analysis of NAPL Architecture at a Field Site using the NAPL Depletion Model (NDM), poster presentation at the 10th International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Battelle, Palm Springs, California, May 22-26, 2016.

Carey, G.R., 2015, Using the NAPL Depletion Model (NDM) for Forensic Analysis of NAPL Architecture at a Field Site, presented at the 30th Biennial Groundwater Conference, Sacremento, California, October 6-7, 2015.

Carey, G.R., 2015, Using In-Situ Remediation (ISR-MT3DMS) to Model Back-Diffusion Timeframe for Thin Silts and Clays, presented at the 30th Biennial Groundwater Conference, Sacremento, California, October 6-7, 2015.

Carey, G.R., 2015, Invited to Chair the Fractured Rock Session at Cleanup 2015 Conference, organized by CRC Care, Melbourne, Australia, September 13-16, 2015.

Carey, G.R., 2015, Review of Characterization Methods for NAPL Source Zone Delineation and Mass Estimation, Invited Keynote presentation at Cleanup 2015 Conference, organized by CRC Care, Melbourne, Australia, September 13-16, 2015.

Carey, G.R., 2015, ISR-MT3DMS for Modeling Back-Diffusion Timeframe, invited platform presentation at Cleanup 2015 Conference, organized by CRC Care, Melbourne, Australia, September 13-16, 2015.

Carey, G.R., 2015, Modeling LNAPL Depletion at a Former Xylene Processing Facility (Germany), invited platform presentation at Cleanup 2015 Conference, organized by CRC Care, Melbourne, Australia, September 13-16, 2015.