EXHIBIT 29

(Provisionally Filed Under Seal
Pursuant to Notice of Filing Under Seal)

UNITED STATES DISTRICT COURT

BEFORE THE

EASTERN DISTRICT OF NORTHERN CAROLINA SOUTHERN DIVISION

VICTORIA CAREY, MARIE BURRIS, MICHAEL KISER, and BRENT NIX, individually and on behalf of all others similarly situated,

Plaintiff

v

E. I. DU PONT DE NEMOURS AND COMPANY and THE CHEMOURS COMPANY FC, LLC,

Defendants

Case Nos.: 7:17-CV-00189, 7:17-CV-00197, and 7:17-CV-00201

EXPERT REPORT OF

DAVID SUNDING

JULY 16, 2021

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I. QUALIFICATIONS

1. I am the president of The Brattle Group, an economics and finance consulting firm. Brattle's over 450 employees are located in eleven offices across North America, Europe, and Asia. I joined the firm as a Principal in 2011 and became Brattle's President in 2020. I have also been a professor in the Department of Agricultural and Resource Economics at the University of California, Berkeley since 2002. In 2009 I was appointed as the Thomas J. Graff Professor of Natural Resource Economics and from 2013-2019 I served as the head of my department.

2. My research concerns environmental economics, natural resources, applied econometrics, and the economics of regulation. I have won numerous awards for my research, including grants from the National Science Foundation, the U.S. Environmental Protection Agency, and private foundations. I have authored over 100 papers, chapters, and research papers in the areas of environmental economics, natural resource economics, water resources, and the economics of regulation. I teach courses at both the graduate and undergraduate levels in subjects including environmental and resource economics, microeconomic theory, law and economics, risk, and water resources.

3. I have testified before Congress on several occasions on matters relating to environmental and resource economics. I have served on expert panels convened by the National Academy of Sciences and the U.S. Environmental Protection Agency's Science Advisory Board. In 2011, I was instrumental in establishing the National Science Foundation's Engineering Research Center for Reinventing the Nation's Urban Water Infrastructure (ReNUWIt) at Stanford University. During the Clinton Administration, I served as a senior economist at the President's Council of Economic Advisors, where I had responsibility for the areas of the environment, natural resources, agriculture, and energy.

4. I have advised the State of California on a variety of matters relating to water quality regulation and water infrastructure investments.

5. Much of my research concerns the economic consequences of environmental contamination from economic activities. As part of this research agenda, I have authored papers on the measurement and regulation of environmental health risks. For example, I recently co-authored a paper addressing the adverse effect of PFAS exposure through drinking water on reproductive outcomes.[1] I have also conducted research on the subject of environmental health risks from exposure to pesticides. I have also written on the impact of environmental health risks on property values and on the economics of defensive expenditures to avoid environmental health risks.

6. I have served as an expert in federal court in cases involving groundwater and surface water contamination, natural resource damages, environmental health risk, the use of surveys, water resource management, and econometrics, among other topics. In 2017, I served as an expert for the State of Minnesota in a lawsuit brought by the Attorney General against 3M alleging natural resource damages from contamination of the state's ground and surface water with PFAS; 3M ultimately settled the case for $850 million, making it one of the largest natural resource damage recoveries in U.S. history. I have also testified as an expert in class certification.

7. I am a member of the American Economic Association, the American Law and Economics Association, the Association of Environmental and Resource Economics, and the Econometric Society.

8. I received a Ph.D. in Agricultural & Resource Economics from UC Berkeley in 1989, an M.A. in African Studies from UCLA in 1986, and a B.A. in Economics from Claremont McKenna College in 1983.

9. My curriculum vitae, which includes a list of all publications I have authored in the previous 10 years, is attached to this report as Appendix A. A list of all other cases in which I have testified as an expert at trial or by deposition during the previous four years can also be found in Appendix A.

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[1] Gina Waterfield, et al. "Reducing exposure to high levels of perflourinated compounds in drinking water improves reproductive outcomes: evidence from an intervention in Minnesota," *Environmental Health,* 19, 42 (May 2020), available at https://ehjournal.biomedcentral.com/articles/10.1186/s12940-020-00591-0.

10. Brattle charges $800/hr for my services. I have also been assisted by several Brattle staff members with rates ranging from $275/hr to $650/hr. Brattle's compensation for our efforts is not connected to the outcome of this matter.

11. I reserve the right to revise the opinions I present here should additional information become available prior to trial.

II. ASSIGNMENT

12. I have been asked by counsel for Plaintiffs in this matter to determine whether a common statistical method can be used to calculate class-wide damages arising from diminished residential property values and whether all or nearly all members of the class have been damaged. In light of this assignment, I have been asked to provide a preliminary calculation of monetary losses to proposed class members harmed by PFAS[2] contaminants from the Defendants' Fayetteville Works facility ("Fayetteville Works PFAS") who a) from February 1, 2015 to present live have lived in properties or owned residential properties or businesses serviced by public utilities drawing from the Cape Fear River in Bladen, Brunswick, Cumberland, New Hanover or Pender Counties, North Carolina; or b) live or have lived in properties or owned residential properties in an area surrounding the perimeter of the Fayetteville Works facility and receive their drinking water from groundwater sources with quantifiable concentrations of Fayetteville Works PFAS identified in Attachment C and Table 3+ of the Consent Order agreed to by Chemours and the North Carolina Department of Environmental Quality ("DEQ").[3] In particular, I have been asked to focus on owners of residential properties in the five Plaintiff counties above who are seeking damages to address injuries including the "loss of use and enjoyment of contaminated property."

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[2] PFAS are a group of contaminants including: "GenX, perfluorocarboxyl acids ("PFASAs"), perflurosulfonic acids ("PFSAs"), perfluoroalkyl ether carboxylic acids with one ether group ("mono-ether PFECAs"), perfluoroalkyl ether carboxylic acids with multiple ether groups ("multi-ether PFECAs"), perfluorooctanoic acids ("PFOAs") (including ammonium perfluorooctonate ("APFO")), perfluorooctane sulfonate ("PFOS"), Perfluoro-2-propoxypropanoic acid ("PFPrOPrA"), Nafion, and Nafion wastes and other wastes and breakdown products of these chemicals." See Complaint at ¶20.

[3] See Consent Order, State of North Carolina vs. The Chemours Company FC, LLC, No. 17 CVS 580 (Bladen Cty. Sup. Ct.), available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

13. Appendix B lists the documents that I relied on in formulating the opinions I present in this report.

III. SUMMARY OF OPINIONS

14. Based on the analysis I have completed with data currently available, I have developed an approach to calculate class-wide damages using data that are or will become available in this proceeding. I make use of publicly available data and apply well-accepted statistical methods to measure changes in property value associated with PFAS exposure that has resulted in remediation action by Chemours or public water systems.

15. I conclude that a statistical approach can be used on a class-wide basis to estimate damages arising due to property diminution. Using data currently available, I find that all or nearly all Class Members receiving public water contaminated by Fayetteville Works PFAS experienced damages and estimate these damages to total over $1 billion. The same methods that I employ here can be used to calculate property diminution for Class Members that rely on private wells with additional data that I expect to receive over the course of this proceeding. In addition, because water testing is ongoing, additional properties may be identified as affected by PFAS from the Fayetteville Works facility.

IV. EXTENT AND AWARENESS OF PFAS CONTAMINATION ALONG THE CAPE FEAR RIVER

A. PFAS CONTAMINATION ALONG THE CAPE FEAR RIVER

16. As early as 2006, the U.S. Environmental Protection Agency ("EPA") became sufficiently concerned about the health effects of PFAS to create a PFOA Stewardship Program that encouraged the eight largest PFOA and PFAS manufacturers to phase out these compounds by 2015. In May of 2016, the EPA established a lifetime health advisory level of 70 ppt for PFOA

and PFOS concentrations in drinking water.[4] In 2019, the EPA issued a PFAS Action Plan that is expected to lead to the phase-out of additional PFAS compounds.

17. PFAS continues to be an area of significant regulatory concern for the EPA. On April 21, 2021, the EPA released a memorandum establishing a new "EPA Council on PFAS" to understand and reduce the risk from PFAS chemicals.[5] The administrator who issued the memorandum stated that ""[c]oming from North Carolina, I've seen first-hand how devastating these chemicals can be for communities and the need for strong EPA leadership" and noted the need to "deliver critical protections to the American public."[6]

18. While North Carolina has not set an overall PFAS drinking water standard, the DEQ and the North Carolina Department of Health and Human Services ("DHHS") have established a provisional drinking water health goal for GenX of 140 parts per trillion (ppt) in July 2017.[7] According to the DHHS, this health goal for the level of GenX in drinking water is "a level that represents the concentration of GenX at which no adverse non-cancer health effects would be anticipated over an entire lifetime to the most sensitive population."[8] Legislation requiring PFAS regulation in North Carolina has become a topic of great discussion in recent years. Several studies between 2007 and 2016 indicated rising levels of PFAS in the Cape Fear Rive Basin.[9] In

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4 Complaint at ¶22. See also U.S. Environmental Protection Agency at Drinking Water Health Advisories for PFOA and PFOS, "FR Notice on the Health Advisories for PFOA and PFOS (May 25, 2016)," available at https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos.

5 See U.S. Environmental Protection Agency at "EPA Administrator Regan Establishes New Council on PFAS" April 27, 2021, available at https://www.epa.gov/newsreleases/epa-administrator-regan-establishes-new-council-pfas.

6 Ibid.

7 This goal was reviewed by the agencies' science advisory board on October 30, 2018. See Greg Barnes, "Review of the North Carolina Drinking Water Provisional Health Goal for GenX, Final," *North Carolina Department of Environmental Quality and North Carolina Department of Health Services*, October 23, 2018.

8 See U.S Environmental Protection Agency at "PFOA, PFOS and other PFAS, How are people exposed to PFAS?," available at https://www.epa.gov/pfas/basic-information-pfas#exposed. *See also* North Carolina DHHS at "Questions and Answers Regarding North Carolina Department of Health and Human Services Updated Risk Assessment for GenX (Perfluoro-2-propoxypropanoic acid," available at https://epi.dph.ncdhhs.gov/oee/pfas/NC%20DHHS%20Health%20Goal%20Q&A.pdf.

9 Shoji Nakayama, et.al. "Perfluorinated Compounds in the Cape Fear Drainage Basin in North Carolina," *Environmental Science & Technology*, Vol. 41, No. 15, 2007 and Mei Sun, et al., "Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina," *Environmental Science & Technology Letters*, 2016.

April of 2019, Senate Bill 518 sought to address PFAS contamination in the Cape Fear River with the creation of a task force commissioned to investigate the contamination sources and the resultant harm to human health.[10]

19. The North Carolina DEQ began an investigation of PFAS contamination (including PFOA and GenX compounds) of the Cape Fear River from the Chemours Fayetteville Works facility in 2017.[11] The Chemours Fayetteville Works facility has been identified by the North Carolina DEQ as a source of PFAS contamination in the area. The facility has discharged these compounds directly into the Cape Fear River and into groundwater, and indirectly through air emissions to groundwater.[12] This discharge has resulted in contamination of drinking water provided to citizens by water systems and private wells.

20. In 2018, the Cape Fear River Watch filed suits against the North Carolina DEQ and Chemours, calling for PFAS emissions to be controlled. Subsequently, in February 2019, the North Carolina DEQ entered into a consent order with Chemours and the Cape Fear River Watch (the "Consent Order"), which required Chemours to curtail PFAS emissions to both groundwater and the air.[13]

21. As part of the February 25th, 2019 Consent Order, certain households are eligible to receive water filtration systems from the Chemours Company to remove PFAS contamination. Included in The Consent Order the North Carolina DEQ defines a list of PFAS chemicals that are considered to originate from the Fayetteville Works plant, "unless Chemours demonstrates to the reasonable satisfaction of DEQ that the PFAS in a given well did not originate from the facility." Any "household, business, school, or public building" with a drinking water supply contaminated by over 70 ppt of total listed PFAS chemicals or 10 ppt of any one PFAS chemical

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[10] Greg Barnes, "NC getting tougher on PFAS polluters, but researchers say more action is needed," *North Carolina Health News*, September 9, 2020, https://www.northcarolinahealthnews.org/2020/09/09/nc-getting-tougher-on-pfas-polluters-but-researchers-say-more-action-is-needed/?shared=email&msg=fail.

[11] See North Carolina DEQ at "GenX Investigation," available at https://deq.nc.gov/news/key-issues/genx-investigation.

[12] Ibid.

[13] See Consent Order, State of North Carolina vs. The Chemours Company FC, LLC, No. 17 CVS 580 (Bladen Cty. Sup. Ct.), available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

is eligible for three under-the-sink reverse osmosis ("RO") filtration systems.[14] Any "household, business, school or public building" with a drinking water supply contaminated by over 140 ppt of GenX is eligible for a whole- building granular activated carbon ("GAC") filtration system.[15]

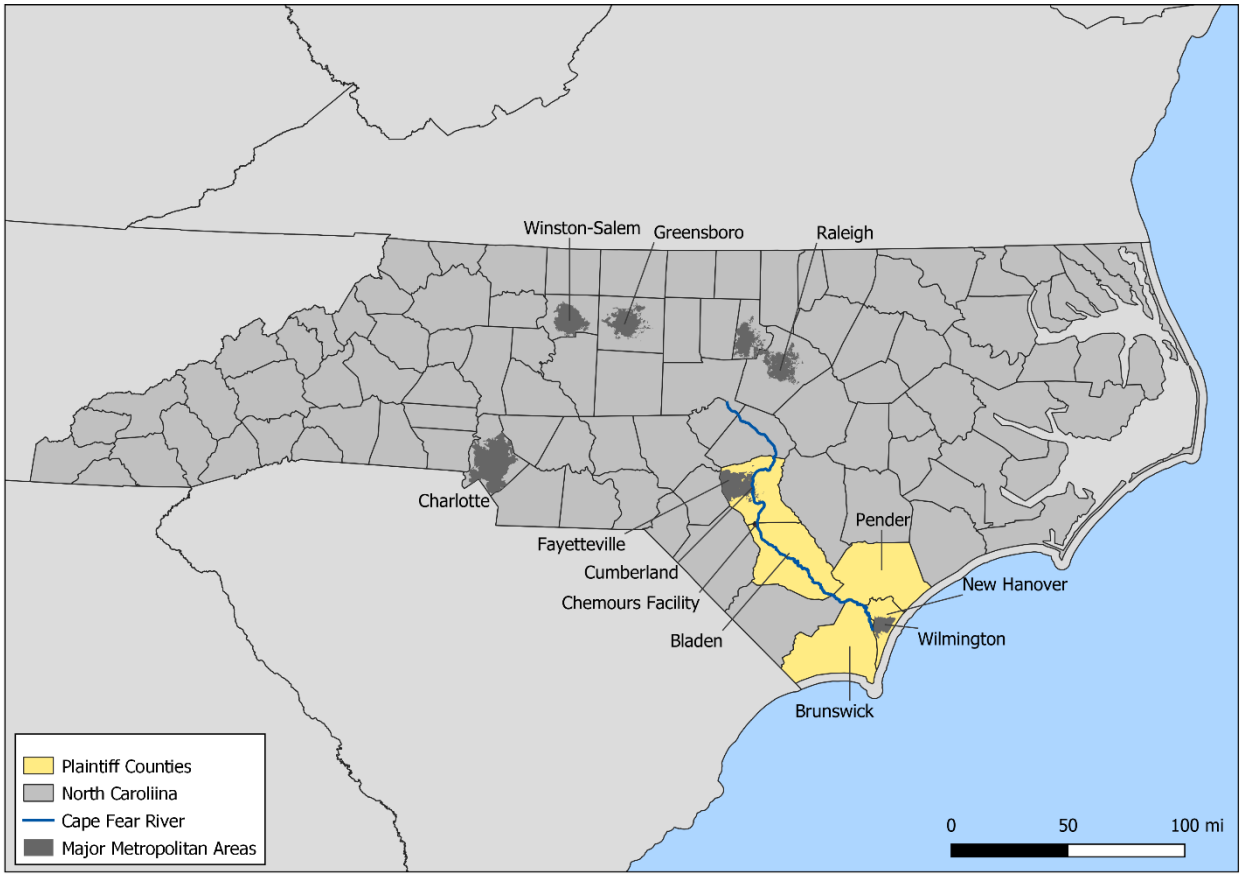
B. EXTENT OF PFAS DRINKING WATER CONTAMINATION IN PLAINTIFF COUNTIES

22. The Plaintiff counties at issue in this matter, Bladen, Brunswick, Cumberland, New Hanover, and Pender Counties, are all located in southeast North Carolina. All counties directly contact the Cape Fear River and lie downstream, or directly above, the Chemours Fayetteville Works facility (Figure 1).

[14] Consent Order at ¶20, available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

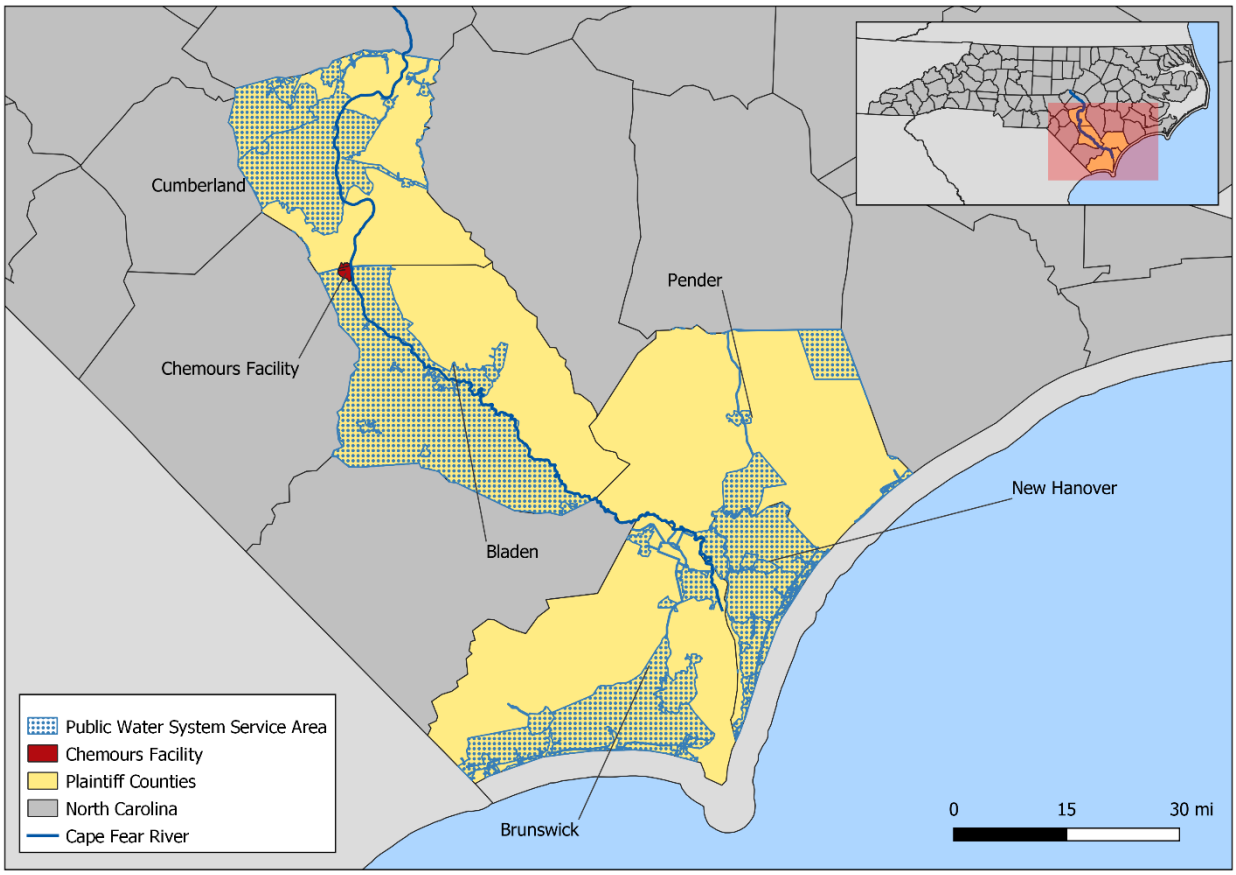
[15] Ibid. at ¶¶ 19, 20.

FIGURE 1: PLAINTIFF COUNTIES



23. Residents in the Plaintiff counties at issue face contamination in their drinking water either from reliance on public water supplies or from their own private wells. Approximately three-quarters of all residents in the Plaintiff counties at issue receive their water from a public water system, *i.e.*, either a private or public utility company; the remaining quarter of residents receive their water from private wells. Table 1 outlines the portion of counties that are serviced by public water systems and private wells, and how many public water systems operate in each county and Figure 2 shows the public water supply service territories for the Plaintiff counties at issue.

FIGURE 2: PUBLIC WATER SERVICE TERRITORIES



Source: Drinking Water Resilience Interactive Project (DRIP) and North Carolina DEQ.

TABLE 1: WATER SUPPLY TO PLAINTIFF COUNTIES

County	Population	Number of Public Water Suppliers	Population Served by Public Water Suppliers	% of Population Served by Public Water	% of Population Served by Private Wells
Bladen	33,443	9	26,868	80%	20%
Brunswick	130,859	3	87,308	67%	33%
Cumberland	330,994	19	241,073	73%	27%
New Hanover	228,728	21	206,362	90%	10%
Pender	60,719	13	36,012	59%	41%
Total	**784,743**	**65**	**597,623**	**76%**	**24%**

Sources: "Public Water Supply Water Sources," *North Carolina Department of Environment and Natural Resources*, available at https://www.nconemap.gov/datasets/public-water-supply-water-sources/explore?location=35.125611%2C-79.887000%2C7.95
Notes:
[1]: Data as of April 2018.
[2]: Public water results include publicly provided well water. Only "Community" categorized public water systems are considered.

1. Testing Water Samples for PFAS Contamination

24. To assess the extent of the contamination, public water systems, government agencies (North Carolina DEQ in particular), and individual organizations (Chemours) have tested and continue to test drinking water, groundwater, and other potential pooling sites in the area. Private well water quality testing by the DEQ began June 19, 2017 and has continued to as recently as June 28, 2021.[16,17] In 2017, the North Carolina General Assembly established a statewide research collaboration called the PFAS Testing Network tasked with testing for exposure to PFAS chemicals throughout the state of North Carolina.[18] Testing of drinking water began in April of 2019 with statewide sampling of public water systems.[19]

25. Public water systems have conducted their own testing following the disclosure of PFAS contamination in the area. Cape Fear Public Utility Authority ("CFPUA") in New Hanover County began testing for GenX and other PFAS chemicals on June 26, 2017, with initial results of 156 ppt from GenX alone.[20] Brunswick County Water System began testing for PFAS chemicals on June 29, 2017, with initial GenX results of 32 ppt.[21] In Cumberland County, the Fayetteville Public Works Commission ("FPWC") began testing for PFAS chemicals in July of 2019 with initial results of total PFAS chemicals of 128 ppt.[22] Pender County Utilities began

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16 Jamie Kritzer, "DEQ starting water quality sampling for GenX in Cape Fear River," *North Carolina Department of Environmental Quality,* June 19, 2017, available at https://deq.nc.gov/news/press-releases/2017/06/19/deq-starting-water-quality-sampling-genx-cape-fear-river

17 See North Carolina DEQ at "GenX Information for Residents" at "Well Testing," available at https://deq.nc.gov/news/key-issues/genx-investigation/genx-information-residents, accessed July 2021.

18 General Assembly of North Carolina Session 2017, Session Law 2018-5, Senate Bill 99, available at https://ncpfastnetwork.com/wp-content/uploads/sites/18487/2019/04/NCGA-Legislation.pdf

19 See NC PFAS Testing Network at "Data and Tools," available at https://ncpfastnetwork.com/data-and-tools/

20 Testing was done at the Sweeney water treatment plant, which receives water from the Cape Fear River. CFPUA also has ground water wells that provide water to the Monterey Heights and New Hanover County (NHC) service areas. These ground water wells have not been acknowledged to have PFAS contamination by CFPUA. See Cape Fear Public Utility Authority at "Archived Newsletter Updates" at "New GenX Results Now Available for Download," available at https://www.cfpua.org/DocumentCenter/View/11284/Daily-Update-History_Final-Draft-.

21 "Water Test Results – Unregulated Compounds," *Brunswick County North Carolina*, available at https://www.brunswickcountync.gov/utilities/advisories-news-press-releases/water-quality/

22 "Fayetteville Public Works Commission 2019 Water Quality Report," *Fayetteville Public Works Commission,* available at https://www.faypwc.com/wp-content/uploads/2016/04/2019-WQR.pdf

testing for GenX alone in 2017 and measured 41.53 ppt.[23] Bladen County Water District tested for GenX once in October of 2017; the water system reported GenX levels of 11 ppt and explained to property owners that water provided by the water system was "safe for human consumption."[24] No further testing has been conducted by Bladen County Water District.

2. Public Water Sources for County Residents

26. Fifty-six percent of the residents in Plaintiff counties at issue rely on water that originates in the Cape Fear River and is provided through public water systems.[25] They are served by sixty-five public water systems; New Hanover County is served by twenty-one, Bladen County by nine, Pender County by thirteen, Cumberland County by nineteen, and Brunswick County by three (see Table 1).[26]

27. Table 2 identifies major public water systems—defined as those that serve over one thousand residents—in each county. Not all residents receive surface water from the Cape Fear River, however: 64 percent of Brunswick County residents, 62 percent of Cumberland County residents, 59 percent of New Hanover County residents, and 28 percent of Pender County residents receive water from this source. The remaining residents, including all of those in Bladen County, rely on public and private wells.[27]

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[23] The Rocky Point/Topsail and Scotts Hill district are the only districts that report testing results. The Maple Hill district is supplied water from ground water wells that have not been tested. See "2017 Annual Drinking Water Quality Report," *Pender County Utilities*, available at https://www.pendercountync.gov/utl/wp-content/uploads/sites/14/2018/05/2017-Rocky-Point-Topsail-Scotts-Hill-Water-Quality-Report.pdf.

[24] See "Public Announcement," *Bladen County Public Works*, October 3rd, 2017, available at https://bladennc.govoffice3.com/vertical/sites/%7B3428E8B4-BA8D-4BCE-9B92-0A719CB4C4FB%7D/uploads/PUBLIC_ANNOUNCEMENT_Gen_X_Update_10032017.pdf.

[25] 440,535 residents are served by a public water system whose main source of water is the Cape Fear River (Table 2). 440,535/784,743 = 56% (Table 1).

[26] "Public Water Supply Water Sources," *North Carolina Department of Environment and Natural Resources*, available at https://www.nconemap.gov/datasets/public-water-supply-water-sources/explore?location=35.125611%2C-79.887000%2C7.95.

[27] Smithfield Food Packaging Plant along the Cape Fear River pumps water out of the river at the Bladen Bluffs pumping station to use at the meat packing facility. I do not consider this entity a public water system.

28. Four water systems in four Plaintiff of the counties draw water directly from the Cape Fear River: 1) CFPUA-Wilmington in New Hanover County; 2) Brunswick County Water System in Brunswick County; 3) Pender County Utilities-Rocky Point/Topsail/Scott's Hill in Pender County; and 4) FPWC in Cumberland County (see Table 2).[28] All four of these water systems have acknowledged PFAS contamination to their customers, through either direct notice or inclusion of testing results in annual water quality reports.

29. Three water systems, CFPUA-Wilmington, Pender County Utilities, and Brunswick County Water System, receive water through the King's Bluff pumping station in Bladen County, operated by the Lower Cape Fear Water and Sewer Authority (LCFWSA). These three water systems have publicly acknowledged contamination and have announced plans to invest in PFAS filtration measures.[29] There has also been government testing confirming contamination of these three water systems.[30] CFPUA and Brunswick County Water System both acknowledge Chemours as the source of PFAS in their water.[31] Pender County Utilities reports levels of GenX beginning in its 2017 Water Quality Report, citing Chemours as the source of contamination.[32]In my analysis of homes receiving public water, I consider properties within these three water districts as being contaminated by PFAS from the Fayetteville Works facility.

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[28] Only the Wilmington division of CFPUA receives water from the Cape Fear River. Other service areas of CFPUA are not acknowledged to have PFAS. See "Your Water Service Area," *Cape Fear Public Utility Authority*, available at https://www.cfpua.org/641/Your-Water-Service-Area. See also "2020 Annual Drinking Water Quality Report," *Cape Fear Public Utility Authority*, available at https://www.cfpua.org/ArchiveCenter/ViewFile/Item/789.

[29] The fourth water system, FPWC, which only recently acknowledged its contamination levels, has not yet announced plans to control PFAS.

[30] See North Carolina DHHS at "State Releases First Water Quality Data, Updated Health Information for GenX in Cape Fear River," available at https://www.ncdhhs.gov/news/press-releases/2017/07/14/state-releases-first-water-quality-data-updated-health-information-genx-cape-fear-river.

[31] See "Cape Fear Public Utility Authority: Newsflash," *Archived Newsletter Updates*, May 23, 2018, available at https://www.cfpua.org/DocumentCenter/View/11284/Daily-Update-History_Final-Draft-. See also Frank Williams, "Chemours Meeting Summary," *Brunswick County Board of Commissioners*, June 16, 2017, available at https://www.brunswickcountync.gov/wp-content/uploads/2017/06/Chemours-Meeting-Summary-FW-6-16-2017.pdf.

[32] "2017 Annual Drinking Water Quality Report," *Pender County Utilities*, available at https://www.pendercountync.gov/utl/wp-content/uploads/sites/14/2018/05/2017-Rocky-Point-Topsail-Scotts-Hill-Water-Quality-Report.pdf.

30. The fourth water system, FPWC, acquires water from the Cape Fear River at its own point of access, upstream of the Fayetteville Works facility.[33] The FPWC, reports levels of "Total PFAS" and "PFOA + PFOS" in their 2019 Water Quality Report, but does not attribute these levels to the Defendants' Fayetteville Works facility and has not announced plans to treat PFAS.[34] I understand that the PFAS contamination found by the FPWC in its water supply has not been linked to the Fayetteville Works facility or Chemours.[35] For this reason, I do not analyze the impact of PFAS contamination on the property values of homes receiving FPWC water. If additional information is provided to me indicating that the Fayetteville Works facility is linked to this contamination, I can perform a similar analysis for these properties.

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[33] FPWC also uses Glenville Reservoir, part of the Cape Fear watershed, as a water source.

[34] "Fayetteville Public Works Commission 2019 Water Quality Report," *Fayetteville Public Works Commission*, available at https://www.faypwc.com/wp-content/uploads/2016/04/2019-WQR.pdf.

[35] According to the PFAS Testing Network, less than 16% of total PFAS chemicals present in the FPWC water are attributable to those listed in the Consent Order. See PFAS Testing Network at "Data and Tools" at "Fayetteville Public Works Comm 1 & 2," available at https://ncpfastnetwork.com/data-and-tools/. See also Consent Order at ¶20, available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

TABLE 2: MAJOR WATER SYSTEMS IN PLAINTIFF COUNTIES

Major Water Supplier	County	Population Served	Source	Percent of County Population Reliant on Cape Fear River	PFAS Disclosure or Information	Upgrades to Facility to Filter PFAS	Testing of Wells/Sources
[1] Bladen Co Wtr Dist-East Bladen	Bladen	3,728	Wells		Yes	No	Yes
[1] Bladen Co Wtr Dist-West Bladen	Bladen	11,500	Wells		Yes	No	Yes
Bladenboro, Town Of	Bladen	2,155	Wells		No	No	No
Clarkton, Town Of	Bladen	1,500	Wells		No	No	No
Elizabethtown, Town Of	Bladen	4,200	Wells		No	No	No
White Lake, Town Of	Bladen	2,500	Wells		No	No	No
Bladen Total		**25,583**		**0%**			
Brunswick County Water System	Brunswick	84,163	Cape Fear River		Yes	Yes	Yes
The Village Of Bald Head Island	Brunswick	3,055	Wells		No	No	No
Brunswick Total		**87,218**		**64%**			
[2] Brookwood Comm Wtr System	Cumberland	15,665	Wells		No	No	Yes
[2] Brookwood South/Fayetteville Pwc	Cumberland	2,312	Wells		No	No	Yes
[3] Cliffdale West	Cumberland	15,288	Wells		Yes	No	Yes
Fayetteville Public Works Comm	Cumberland	203,870	Cape Fear River		Yes	No	Yes
Cumberland Total		**237,135**		**62%**			
Carolina Beach Water System	New Hanover	10,632	Wells		No	No	No
[4] Cfpua-Wilmington	New Hanover	135,204	Cape Fear River		Yes	Yes	Yes
[4] Cfpua/Monterey Heights	New Hanover	8,202	Wells		Yes	No	Yes
[4] Cfpua/Nhc	New Hanover	29,397	Wells		Yes	No	Yes
Kure Beach Water System	New Hanover	4,978	Wells		No	No	No
The Cape Master System	New Hanover	9,728	Wells		No	No	No
Wrightsville Beach Water Syst	New Hanover	5,212	Wells		No	No	No
New Hanover Total		**203,353**		**59%**			
Belvedere Plantation	Pender	3,104	Wells		No	No	No
Burgaw, Town Of	Pender	4,373	Wells		No	No	No
Pender County Utilities	Pender	17,298	Cape Fear River		Yes	Yes	Yes
Surf City, Town Of	Pender	5,606	Wells		No	No	No
Topsail Beach, Town Of	Pender	3,198	Wells		No	No	No
Pender Total		**33,579**		**28%**			

Sources: "Public Water Supply Water Sources," North Carolina Department of Environment and Natural Resources, at https://www.nconemap.gov/datasets/public-water-supply-water-sources/explore?location=35.125611%2C-79.887000%2C7.95
Notes:
Percent of county population reliant on Cape Fear River water=(Population Served where Water Source is Cape Fear River) / Total County Population.
[1]: Discloses testing of wells for PFAS and GenX but claims results are at a low level and all water is safe for human consumption.
[2]: Information from Environmental Working Group on testing but no public website found.
[3]: Part of the Aqua North Carolina Network. Mention of well testing and no detection of PFAS or GenX.
[4]: Cape Fear Public Utility Authority.

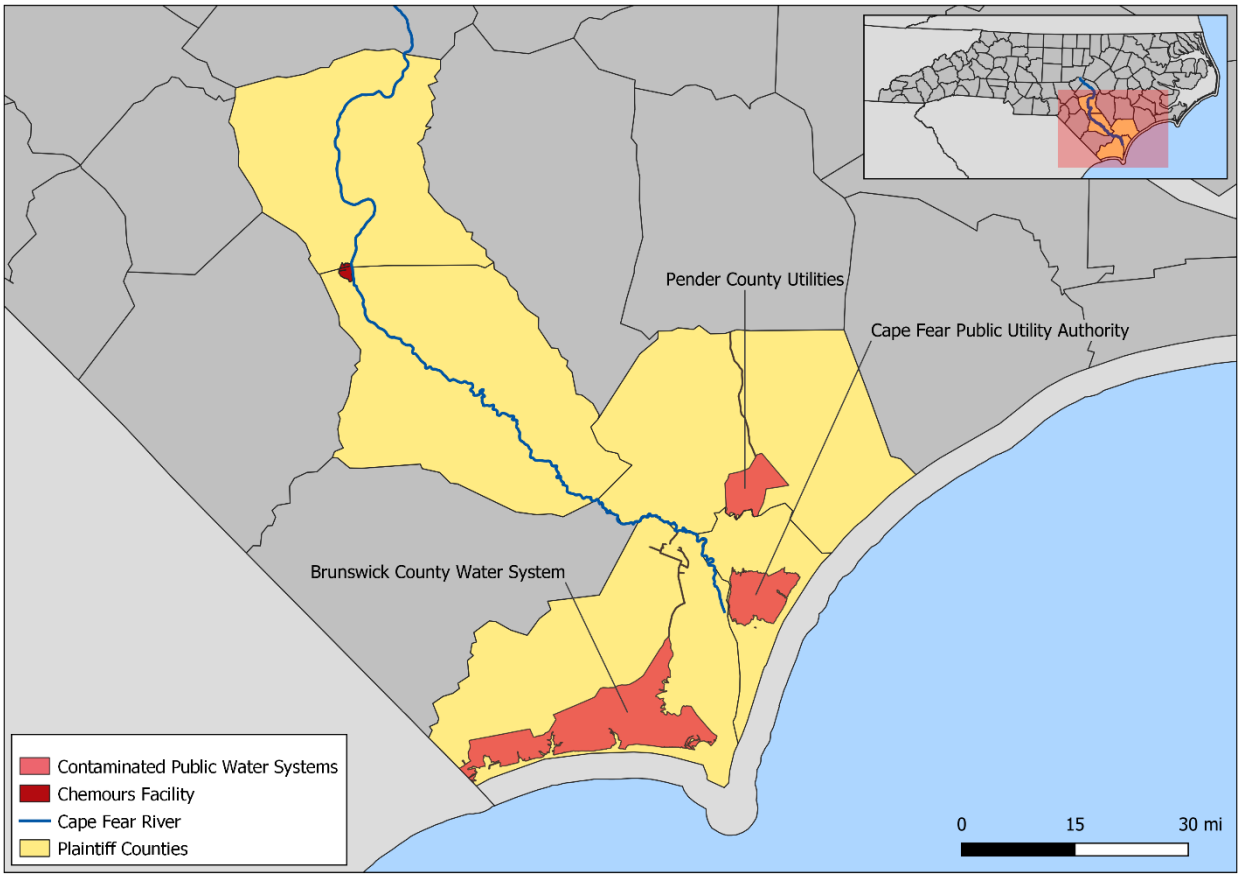
31. Within the three contaminated water systems, some households receive water from the Cape Fear River, while others receive groundwater from wells operated by the water system. In my analysis, I assume that only households receiving water originating in the Cape Fear River face contamination. I identify these households using a spatial file of public water system service territories from the Drinking Water Resilience Interactive Project ("DRIP").[36] Figure 3 shows

[36] I alter the DRIP spatial file in one way. There is a section of New Hanover County, in the Wilmington area, that is unnamed. I assign it the same name and water system ID as the CFPUA-Wilmington service territory based on the service area map from CFPUA. See "Your Water Service Area," *Cape Fear Public Utility Authority*, available at https://www.cfpua.org/641/Your-Water-Service-Area.

the service territories relying on surface water from the Cape Fear River with contamination linked to the Fayetteville Works facility.

32. Recent testing by the PFAS Testing Network has shown that there is PFAS contamination in groundwater sources in the Lower Cape Fear River Basin as well.[37] Despite these testing results, the water systems have not made disclosures concerning PFAS contamination in these water sources.

FIGURE 3: CONTAMINATED WATER SERVICE TERRITORIES



Source: Drinking Water Resilience Interactive Project (DRIP).

33. Given the public health concern caused by PFAS, three water systems in the Plaintiff counties at issue have issued plans to install additional filtration systems for their water supply. Table 3 summarizes the water filtration upgrade plans for these systems. The Brunswick County Water

[37] See PFAS Testing Network at "Data and Tools," available at https://ncpfastnetwork.com/data-and-tools/.

System plans to upgrade its Northwest Water Treatment Plant in response to PFAS contamination, at an estimated cost of over $120 million with an estimated implementation date after November 2022.[38] Brunswick County plans to fund this expansion with revenue bonds in FY 2021 and FY 2022, as well as with funding from the Water Infrastructure Finance and Innovation Act.[39] CFPUA is spending $35.9 million on an upgrade project to its Sweeney water treatment plant, to be implemented in early 2022; annual operating costs are expected to be $2.9 million each year after completion.[40] This project is funded by bonds and would be partially offset by a lawsuit brought by CFPUA against Chemours and DuPont.[41] The cost to the customer for this project is expected to be approximately $5 each on average. Pender County also plans to upgrade its water treatment facilities for the Rocky Point/Topsail and Scott's Hill districts to filter PFAS chemicals using reverse osmosis. According to a July 2020 *Wilmington Biz* article, funding is being sought from federal, state, and local sources.[42]

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[38] Brunswick County explains that all customers receive water from this plant, which pulls water from the Cape Fear River. *See* "Brunswick County Receives Two Bids for Northwest Water Treatment Plant Advanced Water Treatment and Expansion Project," *Brunswick County, NC*, March 18, 2020, available at https://www.brunswickcountync.gov/brunswick-county-receives-two-bids-for-northwest-water-treatment-plant-advanced-water-treatment-and-expansion-project/.

[39] "Water Rate Study Summary Report / January 2021," *Brunswick County, NC*, available at https://www.brunswickcountync.gov/wp-content/uploads/2021/02/Brunswick-County-Water-Rate-Summary-Report.pdf.

[40] The Sweeney water treatment plant provides water to the Wilmington service area of CFPUA. See "Sweeney Treatment Enhancements Project," *Cape Fear Public Utility Authority*, available at https://www.cfpua.org/775/Sweeney-Treatment-Enhancements-Project.

[41] Ibid.

[42] Christina Haley O'Neal, "Pender County Plans Reverse Osmosis Water Treatment Plant", *WilmingtonBiz*, July 24, 2020, available at http://www.wilmingtonbiz.com/more_news/2020/07/24/pender_county_plans_reverse_osmosis_water_treatment_plant/20682

TABLE 3: WATER SYSTEM UPGRADE PLANS

Water Supplier	Type of PFAS Filtration	Capital Cost	Estimated Implementation
[1] Brunswick County Water System	Reverse Osmosis	$122,600,000	Jun-23
[2] CFPUA-Wilmington	Granular Activated Carbon	$35,900,000	Mar-22
[3] Pender County Utilities	Reverse Osmosis	$67,000,000	NA

Sources and Notes:
[1]: Brunswick County, "Northwest Water Treatment Plant Expansion & Reverse Osmosis Treatment Upgrades."
[2]: Cape Fear Public Utilities Authority, "Sweeny Treatment Enhancements Project."
[3]: Wilmington Biz, "Pender County Plans Reverse Osmosis Water Treatment Plant," July 24, 2020.

3. Contamination of Private Well Water

34. I consider contamination of private well water for residents of Bladen and Cumberland County, as these are the only Plaintiff counties at issue where extensive private well testing has been completed.[43] Approximately 20 percent and 27 percent of these counties' residents rely on private well water, respectively, as shown in Table 1. Residents of these counties with private wells that are within a roughly ten mile radius (dependent on the bearing) are close enough to be impacted by either leaching of PFAS chemicals from the Fayetteville Works facility or air deposition of PFAS chemicals.[44] Well water in other counties may also be contaminated as a result of air deposition, but I do not have information on the extent of this exposure at this time.

35. The North Carolina DEQ, with cooperation from Chemours, publishes testing results for private wells beginning in June of 2017, and updates them weekly to monthly.[45] I use this testing data to establish households that are impacted by PFAS contamination. Figure 4 shows testing results as of June 22, 2021 by parcel. Well testing in Bladen and Cumberland Counties is ongoing and may result in findings of contamination for additional parcels.

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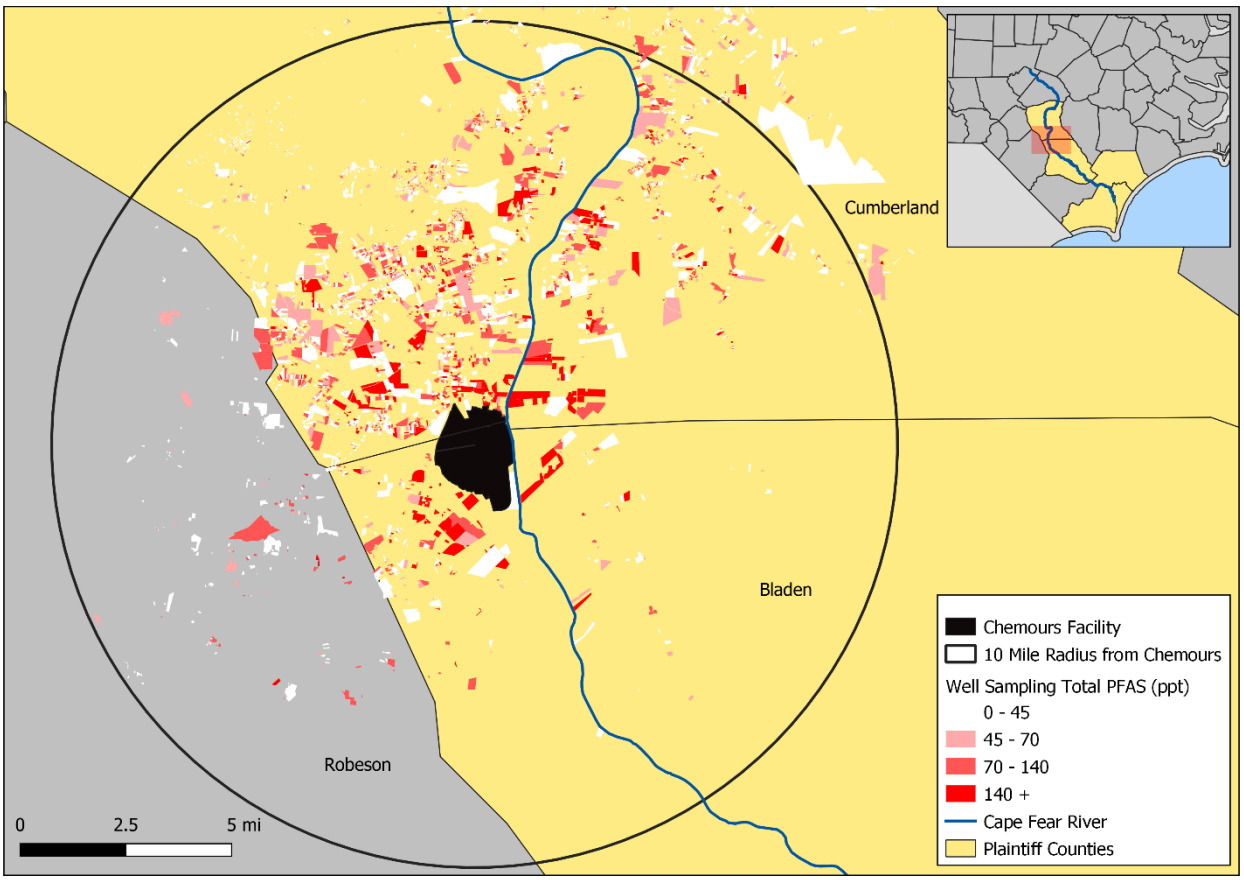
[43] Well testing has been implemented in Robeson County, but I do not consider it because it is not named in the complaint.

[44] North Carolina DEQ indicates that property owners up to 16 miles north and 8 miles south of the Chemours facility are eligible for testing at this time. See North Carolina DEQ at "GenX Information for Residents," available at https://deq.nc.gov/news/key-issues/genx-investigation/genx-information-residents.

[45] See North Carolina DEQ at "GenX Information for Residents" at "Well Testing," available at https://deq.nc.gov/news/key-issues/genx-investigation/genx-information-residents.

FIGURE 4: PRIVATE WELL TESTING RESULTS



Source: Chemours and North Carolina DEQ Sampling Results.

C. PUBLIC AWARENESS OF PFAS CONTAMINATION

36. The method I rely on to measure property diminution requires knowledge of when the public became aware of the injury. I have relied on several sources to identify when citizens of the Plaintiff counties at issue would have become aware of PFAS contamination and the health and environmental risks associated with it. These sources include LexisNexis, Google Trends, and a review of news items, government and water utility communications, and public documents.

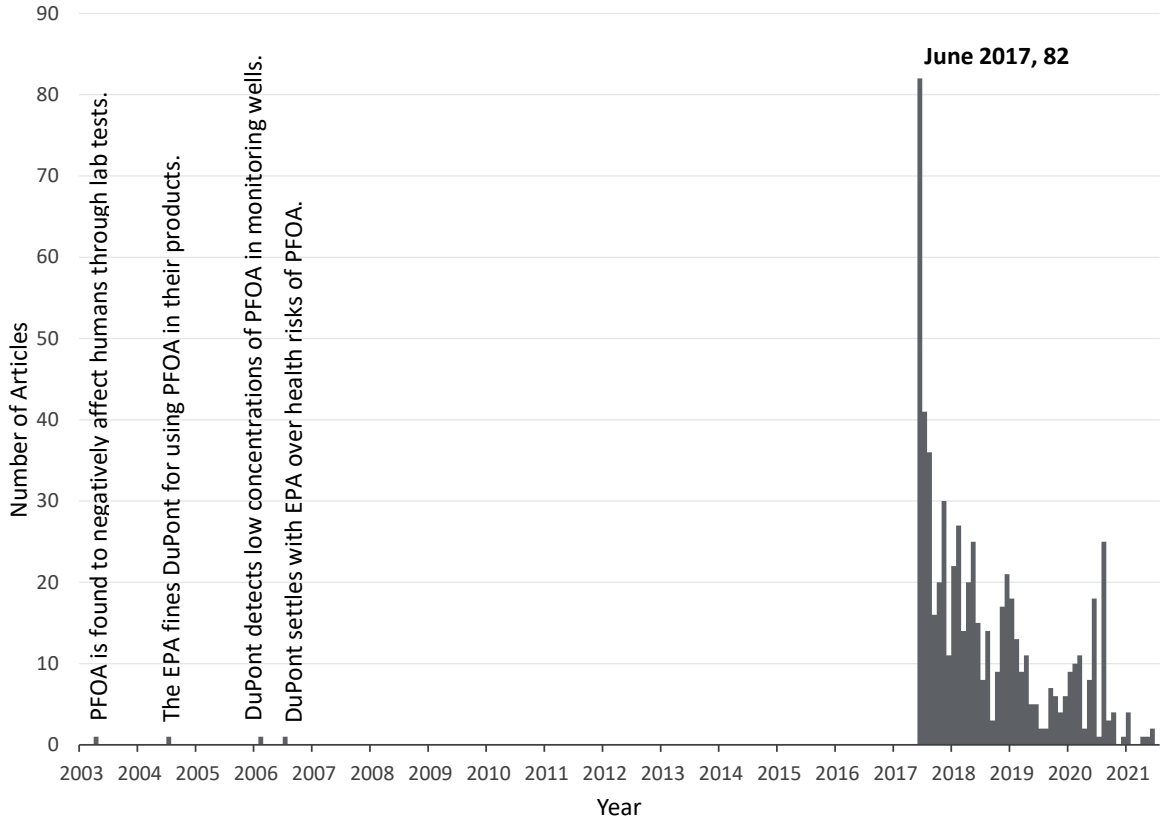
1. News Reports in LexisNexis

37. LexisNexis, a commercial news aggregator, provides searchable archives of public records. Using LexisNexis, I searched for news articles or other public disclosures in North Carolina related to the contamination of water by the Chemours Company. I searched for articles that

include at least one of "PFAS," "PFOA," or "GenX," along with either "Fayetteville Works plant," "DuPont," or "Chemours." I also included the term "water" so the results would only consist of articles about water contamination. In order to isolate the date of public knowledge concerning drinking water contamination, I excluded mention of "fish," "food," or "military." I then applied filters for subject matter relevant to "Environment & Natural Resources" and industry pertaining to "Chemicals and Manufacturing." Finally, I excluded obituaries, leaving 620 articles that matched my search criteria.[46] Figure 5 summarizes the count of articles by month resulting from this search process and reveals that these articles began appearing in substantial numbers in June 2017.

[46] Search performed July 14th, 2021.

FIGURE 5: ARTICLES RELATED TO FAYETTEVILLE WORKS PFAS IN LEXISNEXIS



Source: LexisNexis News and Reports Database.

38. These articles highlighted concerns about the health risks from exposure to PFAS. One June 2017 article from *The Daily News* (Jacksonville, NC) noted that ahead of a meeting among officials from Brunswick, New Hanover, and Pender Counties, the mayor of Wilmington "[expected] to ask questions of both Chemours and regulators, focusing on GenX's impacts to public health," saying "when you slice and dice all the science and you get down to the core of this thing, can we drink the water or not? [...] 'That's all we want to know."[47] Another local news source reported in June 2017 that "as fears [mounted]" about the effect that GenX had on health,

[47] Adam Wagner, "NC starts Chemours investigation over GenX," *JDNews.com*, June 14, 2017, available at https://www.jdnews.com/news/20170614/nc-starts-chemours-investigation-over-genx.

"water treatment companies in the Cape Fear region have been flooded with orders for reverse-osmosis systems."[48]

39. Additionally, local news articles have noted that PFAS may be linked to cancer. One July 2017 article published by *Star-News* in Wilmington noted that "the state Department of Health and Human Services issued a statement saying studies on animals revealed that GenX causes testicular, pancreatic and liver cancer," though it is unknown "if it would have the same effect in humans" and claimed that "nobody should have to fear the water coming out of their taps."[49]

40. Local news sources were also aware of the impact that PFAS contamination had on real estate sales. One article in *The Fayetteville Observer* described a citizen who said "he knew almost nothing about GenX and…PFAS or…before he and his family moved in"; when asked, he and "some of the new homeowners say they would have chosen another place to live had they been told about the contamination," including one family who bought their home in December 2018.[50]

2. Search Patterns on Google Trends

41. Google Trends is an application that shows the number of searches for a particular term or terms on a Google-defined standardized scale. I use Google Trends as a proxy for public awareness of PFAS exposure by measuring the number of searches for "PFAS," "PFOA," or "GenX" in both North Carolina and the Wilmington region of North Carolina. Though this tool does not provide the number of searches conducted, the standardized scale provided by Google reveals trends in search behavior. Once again I find June 2017 as the start of substantial search volumes for PFAS-related terms in the region.

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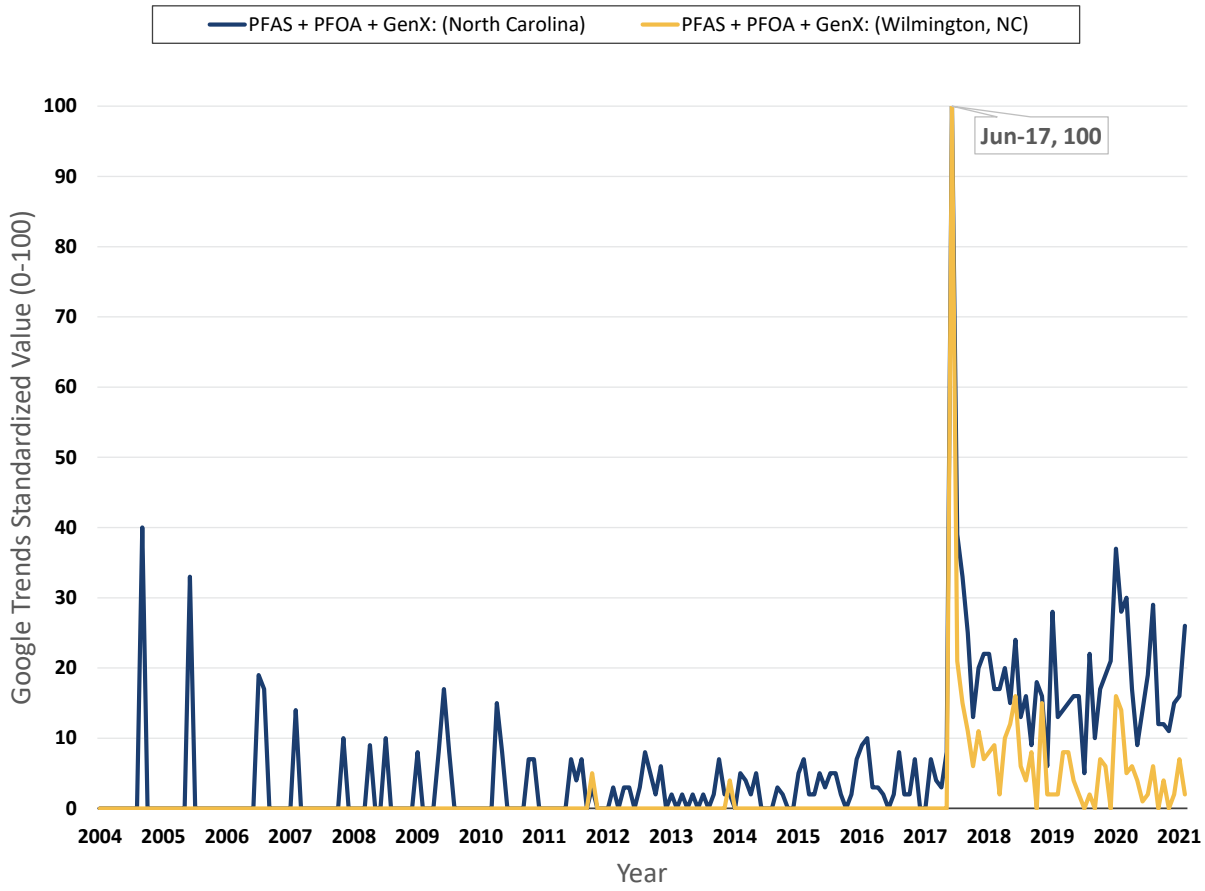
[48] Cammie Bellamy "GenX fears fuel reverse osmosis sales," *StarNews Online*, June 16, 2017, available at https://www.starnewsonline.com/news/20170616/genx-fears-fuel-reverse-osmosis-sales.

[49] Scott Nunn, "Cape Fear needs more protection," *Star-News, Wilmington, NC,* July 25, 2017.

[50] Greg Barnes, "People in Cumberland County are buying houses unaware of 'forever chemicals' in their well water," *The Fayetteville Observer*, January 12, 2020, available at https://www.fayobserver.com/story/lifestyle/fort-bragg-life/2020/01/12/people-in-cumberland-county-are-buying-houses-unaware-of-lsquoforever-chemicalsrsquo-in-their-well-w/112375044/.

FIGURE 6: TRENDS IN PFAS-RELATED SEARCHES



Source: Google Trends.
Note: Search performed on June 28th, 2021 for the date range 1/1/2004 through 6/28/2021.

3. Government and Public Water System Announcements

42. Major public water systems in the affected counties published information on their websites related to the Fayetteville Works facility emissions. The Cape Fear Public Utility Authority notified their customers of drinking water contamination on June 7, 2017. Brunswick County Water System followed suit on June 8, 2017. Bladen County published well testing results in October of 2017, and Pender County Utilities and the FPWC began publishing testing results in 2018 and 2020, respectively.[51] Plaintiff and proposed class representative, Victoria Carey, recalls

[51] See "Public Announcement," *Bladen County Water District*, October 3, 2017, available at https://bladennc.govoffice3.com/vertical/sites/%7B3428E8B4-BA8D-4BCE-9B92-0A719CB4C4FB%7D/uploads/PUBLIC_ANNOUNCEMENT_Gen_X_Update_10032017.pdf; See also "2019

a pamphlet being included with a bill in 2017 that explained residents, "should clean out their water heaters and so forth because of contaminants."[52]

43. Further, the NC DHHS administered a community survey to individuals in Bladen, Cumberland, and Robeson Counties on the Cape Fear River and PFAS in 2019 that raised public awareness.[53] Under the "Communications" section of the survey, it notes that "Since June 2017, the North Carolina Department of Health and Human Services (NCDHHS) has assisted the North Carolina Department of Environmental Quality in the response to GenX and other PFAS in your community."[54]

4. Plaintiff County Residents Were Generally Aware of PFAS Contamination by June 2017

44. Given the various disclosure dates provided to the dates of disclosure to the public from the aforementioned sources, I have determined that most citizens in the Plaintiff counties at issue were aware of the risk of PFAS contamination by June 14, 2017.[55] As shown in Table 4, this conclusion is based upon government communications, including a survey about announcements from various water authorities. Furthermore, various local news reports, interviews with real estate sales representatives, and testimony at local public meetings (including those for water companies or local government) indicate that current and potential homeowners were aware of and concerned about PFAS contamination by mid-2017.

Water Quality Report," *Fayetteville Public Works Commission,* available at https://www.faypwc.com/wp-content/uploads/2016/04/2019-WQR.pdf; See also "2017 Annual Drinking Water Quality Report," *Pender County Utilities*, available at https://www.pendercountync.gov/utl/wp-content/uploads/sites/14/2018/05/2017-Rocky-Point-Topsail-Scotts-Hill-Water-Quality-Report.pdf; See also "Cape Fear Public Utility Authority: Newsflash," *Archived Newsletter Updates*, May 23, 2018, available at https://www.cfpua.org/DocumentCenter/View/11284/Daily-Update-History_Final-Draft-.

52 Carey Tr. at 77:3-11.

53 See Cape Fear PFAS Community Survey, available at https://epi.dph.ncdhhs.gov/oee/pfas/PFAS_Appendix_1.2.20.pdf

54 See Cape Fear PFAS Community Survey instrument at pg. A-7, available at https://epi.dph.ncdhhs.gov/oee/pfas/PFAS_Appendix_1.2.20.pdf.

55 See North Carolina DEQ at "DEQ, DHHS investigating reports of unregulated chemical in Cape Fear River," June 14th, 2017, available at https://deq.nc.gov/news/press-releases/2017/06/14/deq-dhhs-investigating-reports-unregulated-chemical-cape-fear-river.

TABLE 4: SUMMARY OF INITIAL AWARENESS DATES

Source	Disclosure Date
[1] LexisNexis	June 1, 2017
[2] Google Trends	June 1, 2017
[3] Department of Environmental Quality	June 7, 2017
[4] Cape Fear Public Utility Authority (New Hanover County)	June 7, 2017
[5] Brunswick County Utilities	June 15, 2017
[6] Pender County Utilities	May 17, 2018

Sources and Notes:
[1]: LexisNexis.
[2]: Google Trends.
[3]: DEQ, DHHS investigate reports of unregulated chemical in Cape Fear River.
[4]: Archived Newsletter Updates, Cape Fear Public Utility Authority.
[5]: GenX/PFAS Information, Brunswick County.
[6]: Pender County published its 2017 Drinking Water Quality Report on May 16th, 2018, which outlines GenX contamination in drinking water.
[7]: FPWC first disclosed PFAS levels in its 2019 Water Quality Report, which was released in early 2020. I do not consider this information when determining the date of public awareness as FPWC does not mention Chemours as the sources of contamination.

V. A COMMON METHODOLOGY CAN BE USED TO CALCULATE PROPERTY VALUE LOSSES ON A CLASS-WIDE BASIS

45. In this section, I first discuss the channels through which PFAS contamination can reduce property values. Next, I present the approach that I use to estimate this impact. This methodology compares how the sale prices of specific properties sold and resold before and after the revelation of water contamination differ from properties in similar regions of North Carolina that were not impacted by PFAS. This requires identifying similar regions; I discuss my methodology for this as well. I then present the overall class-wide impact of contamination and show that homes in each contaminated water district were negatively impacted. At present, I do not have sufficient data to perform this analysis for parcels near Fayetteville Works facility on well water, but I discuss how this methodology can be used for these properties as more data is generated through additional water testing. Based on these analyses, I conclude that the methodology that I present can be used to calculate class-wide damages and that all or nearly all class members receiving public water contaminated by Fayetteville Works PFAS were impacted.

A. WATER CONTAMINATION LIKELY LEADS TO REDUCED PROPERTY VALUES

46. Economists take several approaches to estimating damages attributable to environmental contamination depending on what is contaminated.[56] In the case of residential property losses, there is a conventional marketplace where choices and prices can be observed. Indeed, there is a rich academic literature presenting econometric methods to measure residential property losses that can be attributed to pollution. These methods are designed to isolate the effect of pollution by comparing homes exposed to pollution to similar homes that have not been exposed. As I explain further below, I rely on a particular method referred to as a repeat sales model to calculate property diminution from PFAS contamination arising from the Fayetteville Works facility.

47. Drinking water contamination is expected to generate property value losses because rational homebuyers are willing to pay less to live in areas that are contaminated, all other factors being equal. Not only is there the potential for health risk, there may also be higher home operating costs required to protect against exposure.

48. Property losses arising from contamination accrue largely to those who owned the property at the time contamination was revealed. These losses arise through three channels. First, a property owner with their own well may install remediating equipment, such as reverse osmosis filters, and pay for the maintenance of that equipment so long as they continue to own the property. For owners with access to public water, they may also install filtration or treatment devices or face higher utility bills that compensate the water district for its remediation expenditures (including both amortized capital costs and ongoing maintenance).[57]

49. Second, they "pay" for future maintenance (of either their own or the water district's equipment) when they sell their property by receiving lower sale prices. This is because ongoing costs reduce buyers' willingness-to-pay for the property.

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[56] See for example, A. Myrick Freeman III, "The Measurement of Environmental and Resource Values, Theory and Methods," *Washington D.C.: Resources for the Future*, Chapter 11.

[57] I understand that Mr. Bruce Gamble, an expert for Plaintiffs in this matter, has presented the estimated costs of installing GAC filters or RO treatment equipment at affected housing units.

50. Within these categories, the direct costs may be borne by the owner at the time contamination is revealed or they may be passed on to future owners. For example, an owner who realizes their home's water is contaminated may elect to install a filtration system or sell the property as-is, thereby placing those costs on the future owner. In the latter case, the sale price of the home will be lower than that of the former case because the original owner failed to perform the remediation prior to the sale.

51. In the data available to me, I am not able to observe whether homes have remediating equipment in place at the time of sale. As more time passes from the announcement of contamination, homeowners are more likely to have undertaken remediating action. For this reason, I expect the largest reduction in home prices to be around the time of the announcement, as a larger share of the costs of remediation will be shifted to the buyer, and for this impact to decrease over time as homeowners will be more likely to have paid remediating costs themselves prior to the sale.

52. Lastly, property values may also fall due to "stigma" arising from uncertainty in future remediation costs, lingering concerns over health risks, or other reasons that reduce the perceived value of the property. Note that this "stigma" would include real costs associated with health conditions that arose due to the contamination.[58]

53. For these reasons, a house in a neighborhood with a drinking water supply contaminated by PFAS would sell at a lower price than an identical house in an uncontaminated, but otherwise identical neighborhood. The difference in sale prices between the two houses captures the magnitude of the willingness to pay to avoid PFAS contamination—that is, the property value damages arising from contamination. The next section discusses the methodology I use to calculate these losses.

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[58] I understand that Mr. Bruce Gamble in this matter has estimated the cost to affected households who choose to buy bottled water to reduce the potential health risk from public drinking supplies.

B. REPEAT SALES MODELS CAN BE USED TO DETERMINE CLASS-WIDE PROPERTY DIMINUTION

54. To calculate losses arising from property diminution, I follow a repeat sales approach. At a high level, this approach compares how the sale price of a parcel changes after contamination is revealed relative to prevailing trends in market prices. This is a widely used approach in the economics profession and fits within the broader class of difference-in-difference models.[59]

55. To expand on this concept, the first "difference" that is considered is how a parcel's sales price changes after contamination is announced relative to before. This comparison requires parcels that were sold repeatedly in the relevant time period, hence the name of the methodology used in this specific application. This metric only represents damages if sale prices were not expected to go up or down, an unlikely assumption in housing markets. Instead, to obtain an estimate of damages, I need to compare the change in contaminated properties to that for non-contaminated properties. This is the second "difference" in the methodology.

56. The non-contaminated properties used for comparison need to be similar "on average" to the contaminated properties. Ensuring comparability begins by choosing comparison regions that are similar to those that contain the contaminated properties.

57. I identify comparison regions by collecting eleven socioeconomic variables for every county in the state of North Carolina. These metrics cover the degree of urbanization of the county and the age structure, races, education, and incomes of its residents. I then compare each Plaintiff county at issue to counties in areas of the state that have not been found to have PFAS contamination to find the most similar county according to these metrics, thereby creating a matched pair.[60] These matched Plaintiff and "control" pairs become the regions compared in my econometric model.

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[59] See Raymond B. Palmquist, "Measuring Environmental Effects on Property Values without Hedonic Regressions," *Journal of Urban Economics*, 11(3) (May 1982): pp. 333-347 See also Robert Mendelsohn, et al., "Measuring Hazardous Waste Damages with Panel Models," *Journal of Environmental Economics and Management*, 22(3) (1992): pp. 259-271.

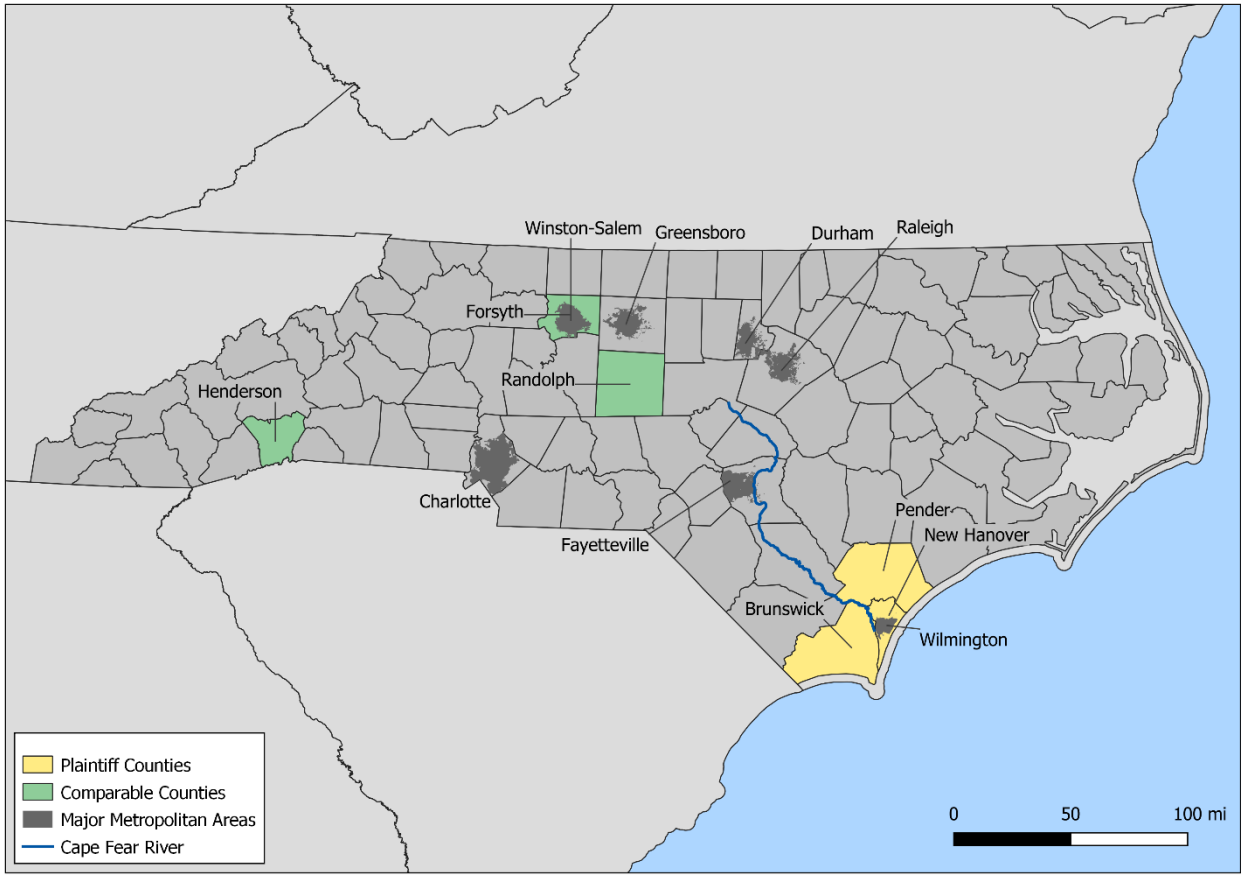
[60] This is a form of "nearest neighbor" matching, where "nearest" refers not to geography, but to the socioeconomic characteristics that I collect for each county. See Donald B. Rubin, "Using Multivariate Matched Sampling and Regression Adjustment to Control Bias in Observational Studies," in *Matched Sampling for Causal Effects*, ed. Donald B. Rubin (Cambridge University Press, 2006).

The specific counties that are matched are shown in Table 5, as well as Figure 7 below. Additional discussion of my approach to selecting the matched pairs can be found in Appendix C. Also in that appendix, I present an alternative approach for identifying control counties that I use as a check of the robustness of my results.

TABLE 5: COUNTY MATCHES FOR PUBLIC WATER DISTRICTS

Treatment	Control
Brunswick County	Henderson County
New Hanover County	Forsyth County
Pender County	Randolph County

FIGURE 7: COMPARABLE COUNTIES FOR THE PUBLIC WATER MODEL



58. The repeat sales model is implemented using a standard linear model (or "regression") approach. This model predicts the natural logarithm of the property sale price as a function of whether the

sale is for of a property revealed to be contaminated (generating the second "difference" described above). It controls for property-specific characteristics by including variables that identify the particular property (thereby generating the first "difference" discussed above). These are called parcel "fixed effects." I also include fixed effects for the month-year of the sale to capture trends in real estate prices. Using the logarithm of the sale price, rather than the price itself, is standard in modeling home prices and leads to coefficients that can be interpreted as percent changes.

C. PFAS CONTAMINATION REDUCED PROPERTY VALUES BY APPROXIMATELY 5% FOR HOMES IN CONTAMINATED PUBLIC WATER DISTRICTS

59. To estimate the repeat sales model, I use property transaction data for the state of North Carolina from June 2013 to April 2021 provided by CoreLogic, a private firm that obtains this information from publicly available state and local records.[61] CoreLogic data is commonly used in the academic literature by economists to explain variations in land prices.[62] I include sales from four years preceding and nearly four years following the June 2017 announcements of contamination in the Cape Fear River by Chemours. These data enable me to identify which homes that have sold multiple times during the period and at what prices.

60. I also determine whether the water supply has been contaminated by PFAS from the Fayetteville Works facility. In the case of public water, I can determine whether a residence's water is contaminated simply by considering whether the home receives water from a district whose

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[61] The data I obtained includes all residential properties. It does not include commercial or industrial properties.

[62] There are numerous examples including these four papers: Okmyung Bin, Craig E.Landry, "Changes in implicit flood risk premiums: Empirical evidence from the housing market," *Journal of Environmental Economics and Management,* 65(3) (2013), 360. and Steven Buck, Maximilian Auffhammer, David Sunding, "Land Markets and the Value of Water: Hedonic Analysis Using Repeat Sales of Farmland," *American Journal of Agricultural Economics,* 96(2014), 950. and Justin Gallagher, "Learning about an Infrequent Event: Evidence from Flood Insurance Take-Up in the United States," *American Economic Journal: Applied Economics,* 6(3) (2014), 200. and Jaren C. Pope, "Buyer information and the hedonic: The impact of a seller disclosure on the implicit price for airport noise," *Journal of Urban Economics*, 63(2) (2008), 490.

source water is contaminated.[63] Hence, in my public water model, I include all parcels sold multiple times that are located in the territory of a water district with a contaminated source (*i.e.,* parcels in territories shown in Figure 3). Comparison parcels are residences that sold multiple times located in the territories of uncontaminated water districts in the counties identified in Table 5.[64]

61. Descriptions of the data, control county selection procedure, model equation, and detailed results are presented in Appendix C. Table 6 below summarizes the property diminution attributable to PFAS contamination for those homes with contaminated public water. The coefficients can be interpreted as the proportion change in home sale prices in the presence of PFAS contamination; or, equivalently, when the coefficients are multiplied by 100, the percentage change in home prices.

62. For residences on public water, Table 6 shows that, when homes with contaminated public water are combined across all Plaintiff counties at issue ("pooled"), home prices fall by about 4.4% after the announcement of PFAS contamination. The other columns in Table 6 show that, when each contaminated water district is considered separately with its matched control county (see Table 5 for the pairs), each contaminated water district has negative price impacts that range from 2.0% to 11.9%. These water district-specific estimates are all statistically significant at the 5% level, implying a high level of confidence that these results are not spurious.

63. In Appendix C, I outline an alternative approach to identify comparison counties and estimate repeat sales models using these groups. I find these alternative matches yield very similar estimates of property diminution to those in Table 6. This gives me further confidence in these results.

64. Based on these findings, I conclude that the repeat sales approach provides a methodology that is common to all class members that can be used to estimate impacts of PFAS contamination on

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[63] I base this in part on conversation on April 30, 2021 with Brien Gidlow, a professional engineer, who explained how PFAS would spread through a public water system network over time and where it would remain. I understand that he will be submitting a report in this proceeding.

[64] For both Plaintiff class and control counties, I exclude properties within these areas that the CoreLogic data indicate have wells.

home values and, as I show in the following section, for calculating class-wide damages. Additionally, I conclude that all or nearly all members of the class receiving water from a contaminated public water source were impacted by Fayetteville Works PFAS.

TABLE 6: PROPERTY DIMINUTION FOR CONTAMINATED PUBLIC WATER SYSTEMS

Dependent Variable:	Sale Amount (natural logarithm)			
	Brunswick	New Hanover	Pender	Pooled
Model:	(1)	(2)	(3)	(4)
Variables				
Contamination Indicator	-0.0939***	-0.0197***	-0.1194***	-0.0439
	(0.0175)	(0.0024)	(0.0292)	(0.0316)
Fixed-effects				
Sale Month-Year	Yes	Yes	Yes	Yes
Property Indicator	Yes	Yes	Yes	Yes
Observations	8,583	29,890	2,967	41,440

One-way (Water District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

D. WITH ADDITIONAL DATA LIKELY TO BE GENERATED DURING THIS LITIGATION, I CAN CONDUCT A SIMILAR ANALYSIS FOR PROPERTIES WITH CONTAMINATED WELL WATER

65. When public water districts source contaminated water, they can spread the impact of that contamination across many properties in a broad geographic area. For my analysis, this means that I am able to identify many repeat sales of properties that receive contaminated public water. Furthermore, I am able to assume that every parcel receiving water from a (single, specific) contaminated source is receiving contaminated water.[65]

66. No broad heuristic exists for identifying homes with contaminated private wells, however. Here I need to rely on property-specific testing results to identify such properties. This substantially limits the number of contaminated homes available for my analysis. Specifically, I consider

[65] Based on the conversation with Brien Gridlow on April 30, 2021 noted above.

properties with wells that, when tested, have concentrations of PFAS above 10 ppt for a single PFAS chemical or 70 ppt for the sum of all PFAS chemicals.[66] Table 7 below shows how many parcels with repeat sales I observe in each contaminated public water district and the number of parcels with contaminated wells for which I observe repeat sales.

TABLE 7: NUMBER OF PARCELS EXPERIENCING REPEAT SALES BY COUNTY AND WATER SOURCE

	Number of Parcels with Repeat Sales
Contaminated Public Water Districts	
Brunswick County Water System	1,390
Cape Fear Public Utility Authority	3,314
Pender County Utilities	120
Counties with Contaminated Wells	
Bladen	7
Cumberland	174

67. Because there are relatively few repeat sales of properties with contaminated wells near the Fayetteville Works facility, I am not able to perform a reliable repeat sales analysis at this time. However, I understand that the North Carolina DEQ testing is ongoing and continues to identify parcels with well water contamination. Therefore, I believe that, as this litigation progresses I will receive additional data that will better enable me to perform a repeat sales analysis for these properties as well.

68. Furthermore, as I mentioned in Section V.A, remediating action taken prior to the sale of a home will prevent further decreases in home prices. Following similar logic, the promise to pay those costs also prevents those declines. I understand that Chemours has offered such assurances, having already paid for remediation to some properties and offered to remediate additional

[66] I consider only PFAS chemicals listed as attributable to the Fayetteville Works. See Consent Order Attachment C, available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

properties that exceed specified testing thresholds.[67] For these properties, I would expect to find smaller price impacts. To date, I have not received information on which parcels have been remediated. This is additional information that I hope to receive in the course of the litigation and incorporate into my final damages analysis.

69. To preview the shape of that analysis, it will proceed along the same lines as the public water district analysis that I present above. The primary difference will be the choice of comparison regions. While I will use the same (or similar) metrics to identify comparable regions, I intend to match townships with contaminated wells to townships without known PFAS contamination (recall that I matched counties in the public water district models). I switch to townships because the geographic reach of well water contamination is smaller than that of water district contamination. With these comparison regions in hand, I will follow a repeat sales approach analogous to the water district models I present above.

VI. TOTAL DAMAGES TO CLASS MEMBERS ARE LIKELY TO EXCEED $1 BILLION

70. Using the results of my repeat sales model, I provide a preliminary estimate of class-wide property losses resulting from PFAS contamination to property owners relying on Cape Fear River water. As shown in Table 8, based on the number of residential connections for each affected water system and average home prices in 2016, property value losses total more than $1 billion adjusted to 2021 dollars. This estimate reflects a one-time diminution of value as of 2016, just prior to widespread knowledge of PFAS contamination and health risks.

71. As I explained above, these damages reflect three channels or cost categories: 1) remediation capital costs; 2) remediation operating and maintenance costs; and 3) costs associated with ongoing health risks. Consequently, care must be taken to avoid double counting when multiple damages analyses are considered. For example, my estimates reflect anticipated remediation costs, implying that a separately estimated class-wide remediation cost is not strictly additive to

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[67] Households are eligible for remediation if one of the prescribed PFAS chemicals occurs at a rate higher than 10 ppt, or the sum of all prescribed PFAS chemicals is over 70 ppt. See Consent Order ¶ 20 , available at https://files.nc.gov/ncdeq/GenX/2019-02-25-Consent-Order---file-stamped-and-fully-executed--b--w-.pdf.

my estimate of damages. The same logic holds for an independent estimate of water rate increases arising from public water service remediation costs.

72. I rely on a one-time loss because, as I discuss above, over time, some homeowners will elect to invest in remediation. They will incur these costs directly, rather than experience them indirectly through lower home sale prices. Because they are not experienced through reduced home prices, they would not be captured in the impacts that I estimate, making my damages estimates conservative.

TABLE 8: ESTIMATED DAMAGES TO HOMEOWNERS ON PUBLIC WATER

County	Public Water System		Residential Connections	Average Home Price	Estimated Property Diminution	Estimated Damages (2016 $)	Estimated Damages (2021 $)
[1]	[2]		[3]	[4]	[5]	[6]	[7]
Brunswick	Brunswick County Water System		40,934	$181,364	9.39%	$697,107,636	$769,685,499
New Hanover	Cape Fear Public Utility Authority		65,480	$232,690	1.97%	$300,159,904	$331,410,407
Pender	Pender County Utilities		6,767	$110,805	11.94%	$89,528,117	$98,849,144
Total Estimated Damages, Homes on Public Water		**[A]**					**$1,199,945,050**
Average Property Diminution		*[B]*					*5.13%*

Sources and Notes:
[3]: North Carolina DEQ Divisions of Water Resources, Local Water Supply Planning.
[4]: Average of the 2016 *Total Value Calculated* of all parcels contained in the Historical Property CoreLogic data that are located within the specified Public Water System.
[5]: Table 6.
[6]: [3] x [4] x [5].
[7]: [6], adjusted from January 2016 to January 2021 dollars using CPI from https://data.bls.gov/timeseries/CUUR0000SA0.
[A]: Total of [7].
[B]: ([3] x [4]) / [A].

David Sunding

July 16, 2021

Date

APPENDIX A – CURRICULUM VITAE

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EMPLOYMENT

University of California, Berkeley

Professor of the Graduate School, 2020 – Present
Thomas J. Graff Endowed Chair, 2009 – 2020
Professor, Agricultural and Resource Economics, 2002 – 2020
Affiliated Faculty, Energy and Resources Group, 2013 – 2020
Department Chair, Agricultural and Resource Economics, 2013 – 2019
Berkeley Water Center, Founder and Director, 2005 – 2013
Associate Professor, Agricultural and Resource Economics, 2000 – 2002
Center for Sustainable Resource Development, Director, 1997 – 2004
College of Natural Resources, Specialist, 1997 – 2015
Visiting Assistant Professor, 1992 - 1996

The Brattle Group

President, 2020 – Present
Board of Directors, 2020 – Present
Principal, 2011 – Present
San Francisco, CA and Boston, MA

Stanford University

Woods Institute of the Environment
Visiting Professor, 2010 – 2011

The White House

President's Council of Economic Advisers
Senior Economist, 1996 – 1997

Boston College

Department of Economics and School of Law
Assistant Professor, 1989 – 1992

U.S. Department of State

Freetown, Sierra Leone, 1984

EDUCATION

University of California, Berkeley

Ph.D. in Agricultural and Resource Economics, 1989

University of California, Los Angeles

M.A. in African Area Studies, 1986

Claremont McKenna College

B.A. in Economics, 1983

UNIVERSITY SERVICE

Chair, Department of Agricultural and Resource Economics, 2013 – 2019

Vice Chair, Department of Agricultural and Resource Economics, 2010 – 2013

Co-Director and Founder, Berkeley Water Center, 2005 – 2013

Member, Academic Senate Committee on Faculty Welfare, 2010-2012

Member, UC Division of Agricultural and Natural Resources Strategic Planning Committee, 2008

Reviewer, California Policy Research Center, UC Office of the President, 2007

Member, Search Committee, Ecosystem Sciences Division, Department of Environmental Science, Policy and Management, 2005-2006

Member, Giannini Hall Seismic Retrofit Design Committee, 2005 – 2006

Member, Academic Senate Committee on Amrican Cultures Requirements, 2004-2005

Member, CNR Executive Committee, 2003-2005

Member, CNR Committee on Directions, Opportunities and Initiatives, 2003

Co-Director, Center for Sustainable Resource Development, College of Natural Resources, UC Berkeley, 1997 – 2004

Faculty, Beahrs Environmental Leadership Program, 2001-2005

Member, CNR Dean Search Committee, 2001-2002

Chair, Specialist Search Committee, Department of Agricultural and Resource Economics, 2001-2002

Member, CNR Advisory Board Development Committee, 2001-2002

Member, Faculty Search Committee, Department of Agricultural and Resource Economics, 1999-2000

Member, CNR Dean Search Committee, 1999–2000

Member, Workgroup Review Committee, University of California Division of Agriculture and Natural Resources, 1999–2002

UC Berkeley Representative, Academic Assembly Council, University of California Division of Agriculture and Natural Resources, 1999–2001

Departmental Affirmative Action Representative, 1999–2000

Member, Faculty Search Committee (Environmental Health), Department of Agricultural and Resource Economics, 1998–2000

PROFESSIONAL SERVICE

Chief Economic Adviser, California WaterFix/Bay Delta Conservation Plan, California Natural Resources Agency, 2012 – 2019

Research Thrust Leader for Urban Water Systems, National Science Foundation Research Center on Urban Water Infrastructure (ReNUWIt), 2011 – 2013

National Science Foundation Workshop on Engineering and Economics, 2011

Academic Affiliate, Natural Heritage Institute, 2009 – 2014

Advisory Board, Water Policy Institute, 2008 – 2013

Advisory Board, American Groundwater Trust, 2008 – 2013

Board of Trustees, Bay Area Council Economic Institute, 2008 – 2013

Reviewer, Delta Risk Management Study (DRMS), California Department of Water Resources, 2007-2008

Member, Economic Advisory Committee on North of Delta Offstream Storage, California Department of Water Resources, 2006-2007

Member, Panel on Illegal Competitive Advantage Economic Benefit, Science Advisory Board, U.S. Environmental Protection Agency, 2004-2005

Mentor, American Economic Association Pipeline Project for Minority Graduate Students, 2004 – 2005

President, International Water Resource Economics Consortium, 2003-2009

Member, Science Advisory Board, National Center for Housing and the Environment. 2003 – 2005

Member, Expert Panel on Cost Allocation, CalFed Bay-Delta Program, 2001-2002

Member, National Academy of Sciences Panel on Water Conservation and Reuse, 2001-2002

Member, Technical Advisory Committee on Water Use Efficiency, CalFed Bay-Delta Program, 1997–1998

Referee: *Agricultural Economics*, *American Journal of Agricultural Economics*, *California Agriculture*, *Contemporary Economic Policy*, *Environmental and Resource Economics*, *Journal of Agricultural and Resource Economics, Journal of Business and Economic Strategy*, *Journal of Environmental Economics and Management*, *Journal of Political Economy*, *Journal of Public Economics*, *Journal of Regulatory Economics*, *Journal of Law and Economics*, *Land Economics*, *Natural Resources Modeling*, *Resource and Energy Economics*, *Review of Economics and Statistics*, *Social Choice and Welfare*, *Water Resources Research*

Reviewer: University of Chicago Press, Kluwer Academic Publishers

WORKING PAPERS

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"Managing Groundwater Quality under Uncertainty." With David Zilberman and Gordon Rausser. In: Michelle Marra (ed.), *Quantifying Long-Run Agricultural Risks*. Orono: University of Maine, 1993.

"Natural Resource Cartels." With David Teece and Elaine Mosakowski. In: Allen Kneese and James Sweeney (eds.), *Handbook of Natural Resource and Energy Economics*, Volume III. Amsterdam: Elsevier, 1993.

"Joan Robinson as a Development Economist." With Irma Adelman. In: George Feiwel (ed.), *Joan Robinson and Modern Economic Theory*. London: Basil Blackwell, 1988.

"Economic Policy and Income Distribution in China." With Irma Adelman. *Journal of Comparative Economics* 11(September 1987): 444–461. Reprinted in Bruce Reynolds (ed.), *China's Economic Development: How Far, How Fast?* New York: Academic Press, 1989. Reprinted in Joseph C. H. Chai (ed.), The Economic Development of Modern China. London: Edward Elgar, 1999.

EXPERT TESTIMONY

Natural Resources and the Environment

Expert report concerning the economics of groundwater recharge in the Tulare Lakebed. In the Matter of 2021 Hearing to Revoke or Revise the Declaration of Fully Appropriated Stream Systems with Respect to the Kings River System. California State Water Resources Control Board.

Rebuttal report, deposition testimony and trial testimony on alleged land value diminution resulting from changes in federal flood operations on the Missouri River. Ideker Farms et al. v. United States, No. 14-183L, U.S. Court of Federal Claims.

Authored an expert report on property value impacts of groundwater contamination adjacent to the Willow Grove Naval Air Station in Horsham Township, Pennsylvania. Penna v. U.S. Department of the Navy, Case 1:16-cv-01571, U.S. Court of Federal Claims.

Filed expert reports and testified at deposition concerning the injury to the State of Texas resulting from New Mexico's non-compliance with the Rio Grande Compact. Texas v. New Mexico and Colorado, No. 141 Orig., U.S. Supreme Court.

Filed testimony with the Federal Energy Regulatory Commission relating to the economic impacts of license conditions imposed on the Don Pedro Project. Don Pedro Relicensing Project, No. 2299, Federal Energy Regulatory Commission.

Developed and implemented a model of the cost of relicensing proposals for the Don Pedro Project under consideration by the Federal Energy Regulatory Commission and the State of California. Don Pedro Relicensing Project, No. 2299, Federal Energy Regulatory Commission.

Written report and deposition testimony concerning natural resource damages resulting from PFAS contamination of groundwater and surface water resources in the eastern Minneapolis-St. Paul metro region. Assessed the human health impacts of exposure to PFAS in drinking water. Conducted surveys of homeowners and anglers in the State of Minnesota. State of Minnesota, et al. v. 3M Company, No. 27-CV-10-28862, Hennepin County District Court.

Authored testimony concerning the proper penalty to be paid by a manufacturing company as a

result of alleged violations of its permit to discharge wastewater into the Columbia River, Columbia Riverkeeper v. Sandvik Special Metals, No. 4:15-CV-05118-LRS, U.S. District Court, Eastern District of Washington.

Examined the economic impacts of a cap on Georgia's consumptive use of the Flint and Chattachoochee Rivers for urban and agricultural water supplies. Assessed public support for various policy interventions to enhance instream flows using a survey of households in Florida, Georgia and Alabama. Florida v. Georgia, No. 142 Original, U.S. Supreme Court.

Testified regarding the penalty to be paid by an investor-owned utility resulting from alleged violations of the Clean Water Act. Congaree Riverkeeper v. Carolina Water Service, Inc., No. 3:15-CV-00194-MBS, U.S. District Court for the District of South Carolina, Columbia Division.

Submitted a declaration as part of an amicus brief filed with the U.S. Supreme Court on behalf of Cargill, The Irvine Company, Port Blakely Companies, the Utility Water Act Group, et al., concerning the immediate economic consequences of environmental permitting requirements. U.S. Army Corps of Engineers v. Hawkes Co., Inc., No. 15-290, U.S. Supreme Court.

Testimony regarding the proper civil penalty to be paid by a non-operating investor in an offshore oil and gas well. U.S. v. BP Exploration & Prod. Co., No. 2:10-cv-04536, U.S. District Court for the Eastern District of Louisiana.

Testified regarding the measurement of natural resource damages associated with air emissions and groundwater contamination from a landfill site in the St. Louis, MO region that was undergoing a subsurface reaction. State of Missouri v. Republic Services, Inc., Allied Services, Inc., and Bridgeton Landfill, LLC, Case No. 13SL-CC01088, Circuit Court of St. Louis County, State of Missouri.

Determined just compensation for takings and presented testimony. Klamath Irrigation District v. United States, No. 01-591 L, U.S. Court of Federal Claims.

Testified regarding the foreseeable economic consequences of several operating requirements proposed by FERC. Don Pedro Relicensing Project, No. 2299, Federal Energy Regulatory Commission.

Authored an economic study of the incentive effects of EPA's ex post veto authority under the Clean Water Act. Mingo Logan Coal Company v. United States Environmental Protection Agency, No. 1:10-cv-00541, U.S. District Court for the District of Columbia.

Prepared testimony on the consequences of invalidating a water storage project in Kern County. Central Delta Water Agency, et al. v. California Department of Water Resources, et al., No. 34-2010-80000561, Sacramento County Superior Court.

Testified regarding damages and unjust enrichment resulting from the State of Nebraska's alleged violation of the Republican River Compact. Kansas v. Nebraska, No. 126 Original, U.S. Supreme Court.

Testified on behalf of the State of Texas regarding the economic impacts on the electricity and water sectors of endangered species-related modifications to the State's water permitting system. The Aransas Project v. Shaw, et al., No. 2:10-cv-00075, U.S. District Court for the Southern

District of Texas.

Authored testimony on the economic impacts of outflow criteria to protect salmonid species in the Sacramento-San Joaquin Delta. San Luis & Delta-Mendota Water Authority v. Locke, et al., No. 1:09-cv-1053, U.S. District Court for the Eastern District of California.

Assessed the benefits to ratepayers and the public of a proposed desalination project in Monterey County. California Public Utilities Commission, Application of California American Water Company (U 210 W) for a Certificate of Convenience and Necessity to Construct and Operate its Coastal Water Supply Project to Resolve the Long-Term Water Supply Deficit in its Monterey District and to Recover all Present and Future Costs in Connection Therewith in Rates, Application 04009-019.

Developed testimony on groundwater allocation and the prevention of seawater intrusion on the Monterey Peninsula. California-American Water v. City of Seaside, et al., and Monterey Peninsula Water Management District, No. H034335, Monterey County Superior Court.

Testimony regarding the civil penalty to be paid by a major food processing company for alleged violations of its wastewater discharge permit. California Regional Water Quality Control Board, Central Valley Region, ACL Complaint No. R5-2005-0501.

Product Liability

Expert report regarding the farm-level and regional economic benefits from the development and adoption of a class of soil fumigants. Case No.: 2:2018cv10139, U.S. District Court for the Central District of California.

Expert report and deposition testimony concerning the economics of the development, adoption and diffusion of an herbicide. Hoffman v. Syngenta Crop Protection LLC, Syngenta AG, Chevron Phillips Chemical Company LP and Growmark Inc., No. 17-L-517, Circuit Court, Twentieth Judicial District, St. Clair County, Ilinois.

Expert report on analysis of fish consumption survey data from the Lower Duwamish Waterway to evaluate exposure to PCBs. City of Seattle v. Monsanto Company, Solutia, Inc. and Pharmacia Corporation, Case No.: 2:16-cv-00107-RSL, U.S. District Court for the Western District of Washington.

Expert report on the historic economic benefits from the use of 1,3-D soil fumigants in Riverside County, CA as part of a product liability matter. City of Hemet v. Dow Chemical Company and Shell Oil, Case: 5:18-cv-02022, U.S. District Court for the Central District of California.

Filed written testimony regarding fish consumption and recreational participation along the Spokane River. City of Spokane v. Monsanto Company, Solutia, Inc. and Pharmacia Corporation, Case No. 2:15-cv-00201-SMJ, U.S. District Court for the Eastern District of Washington.

Filed written testimony and testified at deposition regarding fish consumption and angling rates in San Diego Bay. San Diego Unified Port District and City of San Diego v. Monsanto Company, Solutia, Inc. and Pharmacia Corporation, CL-05285, U.S. District Court for the

Southern District of California.

Testified in deposition and at trial on product liability for the 1,3-D class of soil fumigants in a case involving groundwater contamination. City of Atwater v. Shell Oil and Dow Chemical, No. SCVSS-120627, Fresno County Superior Court.

Testified in a product liability case involving the chemical TCP. Research concerned a variety of issues including the demand for the products at issue, the distribution of benefits from use of the products, and the role of public institutions in developing and promoting the products. City of Redlands v. Shell Oil Company, et al., No. SCVSS 120627, San Bernardino County Superior Court.

Antitrust/Competition

Expert report regarding damages to consumers in the State of Washington from a price-fixing conspiracy. The State of Washington v. StarKist Company, et. al., No. 20-2-09491-9 SEA, Superior Court of Washington for King County.

Expert reports and deposition testimony regarding certification of a class of indirect purchasers of fresh chicken. Broiler Chicken Antitrust Litigation, Case No. 1:16-cv-08637, U.S. District Court for the Northern District of Illinois.

Filed expert reports and testified at deposition and trial on matters relating to class certification in a case concerning an alleged price fixing conspiracy in the packaged seafood products industry. In Re. Packaged Seafood Products Antitrust Litigation, MDL No. 15-MD-2670 JLS MDD, U.S. District Court for the Southern District of California.

Authored an ecxpert report and testified at deposition in a matter concerning alleged collusion among haulers and recyclers in the market for reformulated and recycled architectural paint products. GreenCycle Paint, Inc. v. PaintCare, Inc., et al., No. 3:15-cv-04059-MEJ, U.S. District Court for the Northern District of California.

Expert report and deposition testimony regarding an econometric reduced-form price equation for the fluid milk industry in 16 states to quantify the price increase resulting from a program to cull dairy cows. Edwards, et al. v. National Milk Producers Federation, et al., U.S. District Court for the Northern District of California, No. 3:11-CV-04766-JSW [consolidated with 11-CV-04791-JSW and 11-CV-05253-JSW].

Damages and Valuation

Submitted an expert report on damages resulting from breach of contract. City of Fresno et al. v. United States. No. 16-1276L, U.S. Court of Federal Claims.

Authored a report and testified in deposition in a matter regarding a taking claim brought by a chemical company as the result of a stop sale order issued against products containing the pesticide PCNB. American Vanguard v. United States, No. 16-694 C, U.S. Court of Federal Claims.

Analyzed the allocation of costs for construction and operating a regional wastewater treatment facility City of Riverside v. Rubidoux Community Services District, et al., Case No. CIV DS

1310520, San Bernardino County Superior Court.

Conducted an econmic analysis of Defendant's sales efforts as part of a breach of contract claim. Conducted other analyses concerning equipment leasing, prices paid for certain commodities, allocation of joint costs, and other issues. Testified on several occasions before the arbitration panel. The Paramount Group, et al. v. SP Group, et al., Commercial Arbitration Tribunal.

Testified on behalf of a public agency regarding whether certain charges violated California's Proposition 218. City of Cerritos, et al. v. Water Replenishment District of Southern California, No. BS128136, Los Angeles County Superior Court.

Valued certain land and farming assets held by debtor and developed a plan for optimal disposal of inventory. In re Cocopah Nurseries of Arizona Inc., Case No. 12-15292, U.S. Bankruptcy Court for the District of Arizona.

Testified on damages and related issues in a breach of contract matter. Stockton East Water District and Central San Joaquin Water District v. United States, No. 04-541L, U.S. Court of Federal Claims.

Testified on behalf of an investor-owned utility regarding alleged violations of the California Public Utilities Code. Primex LLC v. Roll International Corporation, No. 10CECG01114, Fresno County Superior Court.

Developed testimony regarding damages from breach of contract. Casitas Municipal Water District v. United States, No. 05-168L, U.S. Court of Federal Claims.

Assessed the distribution of economic benefits of a proposed set of amendments to a groundwater adjudication in the Los Angeles Basin. Central Basin Municipal Water District, et al. v. Water Replenishment District of Southern California, No. BS132202, Los Angeles County Superior Court.

CONSULTING REPORTS

Update to 2015 Long-Range Water Demand Forecast for Southern California on behalf of the Metropolitan Water District of Southern California.

Working on behalf of the Blueprint for the San Joaquin Valley, analyzed the economic impacts of the Sustainable Groundwater Management Act and likely future reductions in surface water deliveries to San Joauqin Valley agriculture.

Working on behalf of World Oil, the major producer of asphalt in Southern California, authored a study concerning the potential anticompetitive effects of Marathon Petroleum's control of asphalt terminals through its proposed acquisition of Andeavor.

On behalf of ConocoPhillips, developed an econometric model to measure the diminution in value of a large coastal property in the State of Louisiana as a result of oil contamination.

On behalf of PolyMet Mining, a mining company developing a copper-nickel deposit in northern Minnesota, assessed a proposed valuation of ecosystem services of the St. Louis River watershed

in Minnesota.

Chief economic adviser to the State of California for the $15-billion Bay Delta Conservation Plan/California WaterFix project.

Working for the California Air Resources Board, developed a conceptual model and conducted an empirical analysis of emissions leakage potential associated with California's implementation of AB32. Results of the analysis used in part to make the State's initial direct allocation of emissions credits under its cap and trade program.

Working on behalf of the American Petroleum Institute, Farm Bureau, National Association of Home Builders, and Utility Water Act Group, assessed the federal government's economic analysis of the Waters of the United States Rule, and offered guidance on how to improve the analysis. Briefed Congress and OMB on the results of the study.

Conducted a fish consumption survey and other empirical analyses on behalf of Schnitzer Steel, Vigor Industrial, Greenbrier Companies to quantify the public health benefits of proposed remediation alternatives for the Portland Harbor Superfund site.

On behalf of Demenno/Kerdoon, the largest oil recycler in California, conducted an analysis of public policies to encourage collection and re-use of lubricating oil. Demonstrated that California's existing deposit-refund system for motor oil is highly beneficial to the industry and the public.

Conceived and implemented an integrated, econometric land use-water demand forecasting model of Southern California. Results form the basis of the Metropolitan Water District's 2015 Integrated Resources Plan.

Working for Plum Creek Timber, examined the economic benefits of excluding certain commercial forestlands and areas slated for future residential development from federal critical habitat for the Canada lynx.

On behalf of ExxonMobil, assessed the economic costs and benefits of proposed designation of critical habitat for the polar bear. Analysis focused on impacts to oil and gas exploration and production on the North Slope of Alaska, and on the prevention of accidental discharges of hydrocarbons in areas of critical habitat.

Worked for General Electric to conduct an economic analysis of remediation costs and benefits to public health and the environment of proposed water quality and sediment standards for PCBs and mercury in the San Francisco Bay.

On behalf of the Transportation Corridor Agencies, measured the economic impacts of environmental permitting requirements affecting two toll road projects in Southern California.

Developed an approach for measuring the economic costs of critical habitat designation. Applied the method on behalf of the California Building Industry Association to the case of critical habitat for the red-legged frog and the coastal California gnatcatcher.

Member of the team negotiating the Quantification Settlement Agreement for the Colorado River on behalf of the San Diego County Water Agency. The Revised Fourth Amendment to the QSA

resulted in the Imperial Irrigation District – San Diego water transfer, the largest water transfer arrangement in U.S. history.

LEGISLATIVE AND ADMINISTRATIVE TESTIMONY

"Models for Financing Public Infrastructure Projects," California Water Commission. December 2020.

"Statewide Economic Benefits of the Bay Delta Conservation Plan," California State Senate, Committee on Natural Resources and Water. August 2013.

"The Economic Implications of EPA's After the Fact Veto of a Discharge Permit." Subcommittee on Water and Energy, Committee on Transportation & Infrastructure, U.S. House of Representatives. June 2011.

"Cost Benefit Analysis as a Tool for Regulation of Once Through Cooling." State of California Water Resources Control Board. May 2010.

"Economic Impacts of the Proposed Construction General Permit for Stormwater Discharges." State of California Water Resources Control Board. June 2008.

"Climate Change, Energy Prices and Commodity Markets." Subcommittee on Energy and Environment, Committee on Science and Technology, U.S. House of Representatives, May 2008.

"Consideration of Economic Impacts of TMDL for PCBs in theSan Francisco Bay." San Francisco Regional Water Quality Control Board. February 2008.

"Economic Impacts of Sediment Quality Objectives for Enclosed Bays and Estuaries." State of California Water Resources Control Board. February 2008.

"Economic Aspects of the Proposed TMDL for PCBs in the San Francisco Bay." San Francisco Regional Water Quality Control Board. September 2007.

"Economic Impacts of Drought-Induced Water Shortage in the San Francisco Bay Area." San Francisco Public Utilities Commission. June 2007.

"Economic Considerations Relating to the Designation of Critical Habitat." Committee on Resources, U.S. House of Representatives, April 2004.

"Fiscal and Socioeconomic Impacts of of Implementing the California Coho Salmon Recovery Plan." California Fish and Game Commission, February 2004.

"Economic Impacts of Critical Habitat Designation." Subcommittee on Fisheries, Wildlife and Water, Committee on Environment and Public Works, U.S. Senate, April 2003.

"Performance of the Federal Wetlands Permitting Program." Subcommittee on Water and Wetlands, Committee on Transportation and Infrastructure, U.S. House of Representatives. September 2001.

"Economic Observations on Water Infrastructure Investment in California." Subcommittee on Water and Power, Committee on Transportation and Infrastructure, U.S. House of Representatives. July 2001.

"Economic Impacts of Reduced Water Supplies on Westside Agriculture." Bay-Delta Advisory Committee. June 1998.

"Economic Impacts of the Central Valley Project Improvement Act." Subcommittee on Water and Power, Committee on Transportation and Infrastructure, U.S. House of Representatives. April 1998.

"Forest Service Losses on Below-Cost Timber Sales." Committee on Energy and Natural Resources, U.S. Senate. February 1997.

"Benefits and Costs of Enhanced Flood Protection in the American River Valley." Committee on Transportation and Infrastructure, U.S. House of Representatives. February 1996.

"Economic Impacts of Banning Methyl Bromide Use in California." Committee on Appropriations, California Senate. February 1996.

"Economic Impacts on Leeward Agriculture of Eliminating Waiahole Ditch Diversions." Hawaii Water Commission. January 1996.

"Least-Cost Implementation of Bay/Delta Water Quality Standards." State of California Water Resources Control Board. July 1994.

"The Potential for Agricultural Water Conservation." State of California Water Resources Control Board. June 1992.

"Economic Impacts of the Central Valley Project Improvement Act." Committee on Energy and Natural Resources, U.S. Senate. April 1992.

GOVERNMENT BRIEFINGS

"Innovative Approaches to Infrastructure Finance." California Water Commission. April 2020.

"Economic Impacts of the Sustainable Groundwater Management Act." California Governor's Office. February 2020.

"Review of the Waters of the United States Regulatory Impact Analysis." Sponsored by Edison Electric Institure, American Farm Bureau, National Association of Manufacturers, American Petroleum Institute, INGAA, American Gas Association, National Association of Home Builders. February 2019.

"Economic Analysis of Draft Guidance for Defining Waters of the United States," Briefings for U.S. House of Representatives and Senate Staff. February 2014.

"Assessment of the Government's Economic Analysis of the Waters of the United States Rule." White House Office of Management and Budget. December 2013.

"Economic Benefits Analysis of the Bay-Delta Conservation Plan," BDCP Finance Committee Meeting. Sacramento, CA. July 2012.

"Employment Impacts of Constructing an Isolated Conveyance Facility," California State Senate Town Hall Meeting. Fresno, CA. November 2011.

"System Integration and California Water Management." California Assembly and Senate Members and Staff. Sacramento, CA. August 2006.

"The Endangered Species Act at 30: Lessons for Reform." Organized with U.S. Senate Committee on Energy and Natural Resources. Washington, DC. December 2004.

"Non-Federal and Non-Regulatory Approaches to Wetland Conservation." House Transportation and Infrastructure Committee Staff. Washington, DC. February 2003.

"Removing Barriers to Water Marketing." California Senate Committee on Agriculture and Water and the California Foundation for Environment and Economy. Berkeley, CA. January 2003.

"Agricultural Water Pricing and Water Use Efficiency." U.S. Bureau of Reclamation. Sacramento, CA. May 2002.

"Assessing Recent Changes to the Wetlands Permitting Process." Congressional Real Estate Caucus. Washington, DC. September 2000.

"Water Markets in California." California Assembly and Senate Staff. Sacramento, CA. May 2000.

"Economic Analysis of Proposed Changes in Wetlands Permitting Policies." U.S. House of Representatives and Senate Staff. Washington, DC. March 2000.

"Groundwater Implications of Water Trading." California Assembly Water Parks and Wildlife Committee and Senate Agriculture and Water Committee. Sacramento, CA. November 1999.

"Economic Aspects of the 1996 Food Quality Protection Act." Office of Policy, U.S. Environmental Protection Agency. Washington, DC. October 1998.

"Innovative Approaches to Water Conservation: The Westside Case." Joint U.S. Bureau of Reclamation and the California Department of Water Resources Water Conservation Information Committee. San Diego, CA. August 1998.

"Climate Variability and U.S. Agriculture: Mitigating the Impacts." U.S. Environmental Protection Agency. Washington, DC. May 1998.

"New Approaches to Agricultural Water Conservation." Congressional Water Caucus. Washington, DC. February 1996.

CONFERENCES ORGANIZED

Finding the Right Balance: Tradeoffs in the Water-Energy Nexus. Water Policy Institute –

Berkeley Water Center. Washington, DC. February 2011.

International Water Resource Economics Consortium. Berkeley, CA. November 2009.

"Water and Economics." Water Policy Institute – Berkeley Water Center. Washington, DC. October 2009.

"Mixing Water and Oil: Biofuels and their Implications for California's Natural Resources." Parlier, CA. May 2008.

"Assessing Investments in Clean Water and Hygiene in Developing Countries." Sponsored by the Bill & Melinda Gates Foundation. Berkeley, CA. November 2006.

"The Endangered Species Act at 30: Lessons for Reform." Washington, DC. December 2004.

"A Decade of Water Policy Reform: The Central Valley Project Improvement Act in 2003." San Francisco, CA. September 2003.

"The Future of the San Joaquin Valley." Parlier, CA. March 2002.

"Pest Management Strategies and Policies." Berkeley, CA. May 2001.

Invited Presentations

"Impacts of SGMA in California's San Joaquin Valley," Urban Water Institute, February 2021.

"Water Trade in General Equilibrium: Discussant," American Economic Association Meeting, San Diego, January 2020.

"Water Rights: Basics," Water Asset Management Investor Meeting, San Francisco, CA, October 2019.

"Electric Utilities and Wildfire: Optimal Allocation of Liability," LSI Conference on Utility Planning, San Francisco, September 2019.

"Effects of Critical Habitat Designation," Conference on Incentives for Wildlife Conservation, Political Economy Research Center, Bozeman, MT, August 2019.

"Machine Learning Methods for Urban Water Demand Forecasting," International Conference on Water Futures, University of Padua, July 2019.

"Just Compensation for Takings," American Bar Association, Orlando, FL, April 2018.

"Use of Big Data in Water Resource Management," WaterNow Annual Conference, University of Utah School of Law, March 2018.

"Economic Incentives and Efficiency," Southern California Water Committee, Los Angeles, June 2017.

"Innovative Water Financing," Woods Institute of the Environment, Stanford University, June 2017.

"Trends in California Agriculture," Kern County Economic Summitt, March 2017.

"Climate Change and California's Urban Areas," Swig Family Foundation, February 2017.

"Rethinking Model Selection for Forecasting," ASSA Meetings, Chicago, January 2017.

"Economic Analysis of California WaterFix," San Diego County Water Authority, San Diego, October 2016.

"Fluid State of Water," Public Policy Institute of California, San Francisco, September 2016.

"Recent Developments in Environmental Regulation," UC Redwood Symposium, Eureka, CA, September 2016.

"Economic Losses from a Water Consevation Mandate." American Agricultural Economic Association, Boston, MA, August 2016.

"Economics of Water Infrastructure Investment." Water Law Forum, Portland, OR, May 2016.

"California's Water Future." UC Berkeley Trustees' Meeting, Los Angeles, CA, March 2016.

"Economic Impacts of the Waters of the United States Rule." ABA Water Law Conference, Austin, TX, March 2016.

"Lessons from Utility Rate Reform." UC Conference on Water Pricing, UC Riverside, February 2016.

"Financing Large-Scale Infrastructure Projects." Hoover Institution, Stanford University, January 2016.

"Environmental Finance." Goldman Sachs Conference on Environmental Finance, New York, NY, November 2015.

"Blue Skies for the Golden State: California's Water Future." Discover Cal Lecture Series, Los Angeles, Orange County and San Francisco, CA, October-November 2015.

"Water Challenges in the Arid West." South by Southwest, Austin, TX, October 2015.

"Financing Innovation in the Water Sector," Milken Innovation Center – Jerusalem Institute for Israel Studies, Jerusalem, Israel, July 2015.

"Welfare Impacts of Urban Water Shortages," Agricultural and Applied Economic Association Meetings, San Francisco, July 2015.

Forecasting Urban Water Demand," Agricultural and Applied Economic Association Meetings, San Francisco, July 2015.

"Impacts of the Drought on California's Economy," Water Scarcity Conference, NSF-IGERT Program, UC Davis, April 2015.

"Economics of Drought Response," San Gabriel Valley Water Forum, October 2014.

"An Econometric Model of Water Availability and Land Use Change," International Water Resorce Economics Consortium, Washington, DC, September 2014.

"A Forecasting Model for Urban Water Demand," Metropolitan Water District of Southern California, July 2014.

"Effects of Climate Change on California's Water Supply," Giannini Foundation Conference on Climate Change, Sacramento, CA, April 2014.

"Economic Consequences of the Drought," UC Drought Science Summit, Sacramento, CA, April 2014.

"Labor Market Effects of Water Shortages," UC Davis School of Law Conference on Labor and Water, April 2014.

"The Once and Future Delta," Commonwealth Club, San Francisco, CA, September 2013.

"Examining Bay-Delta Alternatives," Southern California Water Committee, Los Angeles, July 2013.

"Water: Debunking the Myths," Goldman Sachs-GE-World Resources Institute, New York, NY, February 2013.

"Financing California's Water Infrastructure," California Foundation for Environment and the Economy, Half Moon Bay, CA, December 2012.

"Economic Impacts of the Bay Delta Conservation Program," Association of California Water Agencies, San Diego, CA, December 2012.

"Overview of Current Issues in the Delta," UCANR Statewide Conference, Davis, CA, November 2012.

"Optimal Management of a Groundwater Storage Bank," Stockholm International Water Week, Stockholm, Sweden, August 2012.

"Economic Reform of America's Water Systems." Water Resources Law Forum, Las Vegas, NV, May 2012.

"Employment Impacts of Water Infrastructure Investment." Association of California Water Agencies, March 2012.

"Novel Approaches to Infrastructure Finance," California Foundation for the Environment and the Economy, Palos Verdes, CA, October 2011.

"The Economics of Bay-Delta Restoration," California Foundation for the Environment and the Economy, Sonoma, CA, Sonoma 2011.

"The Economics of Water Reuse," From Used to Useful, Riyadh, Saudi Arabia, April 2011.

"The Economics of Isolated Conveyance in the Delta," California Water Policy Conference, Santa Barbra, April 2011.

"Managing a Groundwater Storage Bank." American Groundwater Trust, New York, NY, March 2011.

"The Economics of Future Water Supplies." California Water Association. Monterey, CA. November 2010.

"Vulnerability of Water Infrastructure to Seismic Events." Southern California Water Committee. September 2010.

"Economics of Water Allocation." American Bar Association. Orlando, FL. May 2010.

"Expanding the Role of the Private Sector in Water: Opportunities and Challenges." General Electric. Los Angeles, CA. May 2010.

"Adapting to Unreliable Water Supplies." University of the Pacific McGeorge School of Law, Sacramento, CA, February 2010.

"The Economics of Water Exports from the Delta," American Society of Agronomy, Tulare, CA, January 2010.

"Long Term Contracts, Storage Incentives and Conjunctive Use: The Case of the Central and West Coast Basins in Los Angeles County." International Water Resource Economics Consortium Meetings. Berkeley, CA. November 2009.

"Economic Barriers to Recycled Water." General Electric Corporation Leadership Summit, Crotonville, NY. November 2009.

"Habitat Protection in a Dynamic Landscape." California HCP/NCCP Conference. Vacaville, CA. November 2009.

"New Approaches to Financing Water Infrastructure." Water Policy Institute – Berkeley Water Center Conference on Water and Economics. Washington, DC. October 2009.

"The Economics of Federal Land Use Regulation." AEI-Brookings Joint Center on Regulation. Washington, DC. September 2009.

"Water Policy in the United States." New York Bar Association. New York, NY. June 2009.

"The Role of the Private Sector in Water Resource Management." American Law Institute – American Bar Association. Denver, CO. March 2009.

"Economic Analysis of Water Resources." American Bar Association Annual Water Law Conference. San Diego, CA. February 2009.

"Benefits of Drought-Resistant Seed Varieties." Conference on Biotechnology and Water Use. Gates Foundation and Giannini Foundation. Berkeley, CA. January 2009.

"U.S. Agriculture in Transiton." Northwest Food Processing Association. Portland, OR. January 2009.

"Economic Perspectives on Water Resources." Water Policy Institute. Washington, DC. October 2008.

"Climate Change and Groundwater Resources." Groundwater Resource Association. Sacramento, CA. August 2008.

"Climate Change, Energy Prices and California's Water Resources." BWC Conference on Biofuels and California Agriculture. Parlier, CA. May 2008.

"Sustainability and the Role of Private Investment in the Water Sector." American Groundwater Trust. New York, NY. April 2008.

"Recent Development in Designating Critical Habitat." Endangered Species Law. American Law Institute-American Bar Association. San Diego, CA. June 2008.

"Assessing Risks to California's Water Systems." Discover Cal. Redwood City, CA. November 2007.

"New Settings for HCPs and New Approaches to ESA Compliance." CLE International. San Francisco, CA. November 2007.

"Policies to Control Point Source Discharges of Salts in the San Joaquin Valley." Regional Water Quality Control Board. Modesto, CA. October 2007.

"Federal Land Use Controls." Pacific Rivers Council. San Francisco, CA. October 2007.

"The Economic Implications of Conjunctve Use and Groundwater Banking." Theis Conference, National Groundwater Association. Park City, UT. September 2007.

"Evaluating Investments in Groundwater: Hard Science or Black Art?" Groundwater Resource Association. San Francisco, CA. June 2007.

"Delta Futures and California's Water Economy." Public Policy Institute of California. San Francisco, CA. February 2007.

"California's Water Infrastructure Needs." Bay Area Economic Forum. San Francisco, CA. February 2007.

"Management of a Coastal Aquifer under Multiple Uncertainty." Association of Environmental and Resource Economists. Chicago, IL. January 2007.

"Growth, Environment & Efficiency: California's Water Future." UC Berkeley Homecoming. Berkeley, CA. October 2006.

"Water Supply and the Bay Area Economy." League of Women Voters Know Your Bay Area Day. San Francisco, CA. September 2006.

"Economics of Water Quality Regulation." Interational Agricultural Economics Association Pre-Conference Workshop on Water Resources. Brisbane, Australia. August 2006.

"Measuring the Groundwater Pumping Externality." American Agricultural Economics Association. Long Beach, CA. July 2006.

"Costs and Benefits of Wetland Regulation." American Law Institute – American Bar Association Wetlands Conference. Washington, DC. June 2006.

"Economics of Water Resource Management in California." University-Industry Consortium. Oakland, CA. May 2006.

"Regulating Water Quality in California." University of California Water Resources Center Continuing Conference. Davis, CA. May 2006.

"Natural Disasters and the Resilience of the Urban Economy." Symposium on Real Estate, Catastrophic Risk and Public Policy. Berkeley, CA. March 2006.

"Economics and the Endangered Species Act: The Role of Critical Habitat." Annual Conference on the Endangered Species Act and Habitat Conservation Planning. San Francisco, CA. December 2005.

"Economics of Groundwater Management." Groundwater Resources Association. Pasadena, CA. September 2005.

"The Economics of Waer Quality Regulation." Central Valley Clean Water Association. Sacramento, CA. May 2005.

"Economics of Technology Adoption and Diffusion." Conference on Sustainable Energy Futures. Berkeley, CA. April 2005.

"Consideration of Economics under Porter-Cologne." Urban Water Institute. Newport Beach, CA. April 2005.

"Tools for a New Era of Sustainable Water Management." Barcelona, Spain. March 2005.

"Bad Neighbors: The Economics of Conflict over New Housing." Conference on Urban Policy. Berkeley, CA. January 2005.

"Economic Analysis of Water Quality Regulations: When is It Worth the Trouble?" Industrial Environmental Association. San Diego, CA. November, 2004.

"Measuring the Cost of Conservation by Permitting." Association of Environmental and Resource Economists. Denver, CO. August 2004.

"Panel Estimation of Agricultural Water Demand Based on an Episode of Rate Reform." American Agricultural Economics Association. Denver, CO. August 2004.

"Local Public Goods and Ethnic Diversity." American Agricultural Economics Association. Denver, CO. August 2004.

"Prices vs. Quantities Revisited." American Agricultural Economics Association. Denver, CO. August 2004.

"Managing Groundwater with Localized Externalities." American Agricultural Economics Association. Denver, CO. August 2004.

"Fat Taxes and Thin Subsidies." American Agricultural Economics Association. Denver, CO. August 2004.

"Environmental Regulation and California Agriculture: Focus on ESA and the Clean Water Act." Western Growers' Association. Sacramento, CA. June 2004.

"Endangered Species Regulation and California Agriculture." Giannini Foundation Conference

on the Future of California Agriculture. Sacramento, CA. May 2004.

"Environmental Regulation and Housing Affordability." U.S. Department of Housing and Urban Development Conference on Regulatory Barriers to Housing Affordability. Washington, DC. April 2004.

"Economic Analysis of Evironmental Regulation." Clean Water Act Summit Meeting. Irvine, CA. March 2004.

"Economic Impacts of Endangered Species Regulation: A Project-Level Perspective Focusing on the Housing Industry." Conference on the Endangered Species Act at 30. Santa Barbara, CA. November 2003.

"Whither Reclamation Reform? Looking to the Next 100 Years of Reclamation Law." Berkeley Conference on Water Policy Reform. San Francisco, CA. September 2003.

"Simultaneous Estimation of Technology Choice and Land Allocation." American Agricultural Economics Association. Montreal, Canada. July 2003.

"Advertising in Markets with Product Differentiation and Imperfect Competition." Food Systems Research Group, University of Wisconsin. June 2003.

"Wetlands Protection Beyond Section 404." American Law Institute – American Bar Association Wetlands Conference. Washington, DC. May 2003.

"Prioritizing Habitat Conservation." Conference on the Endangered Species Act. Land Use Research Foundation of Hawaii and the Hawaii State Bar Association Section on Real Property and Finance. May 2003.

"Government Regulation of Product Quality in Markets with Differentiated Products: Looking to Economic Theory." Allied Social Science Association. Washington, DC. January 2003.

"Non-Regulatory and Non-Federal Approaches to Wetland Protection." National Association of Home Builders. Las Vegas, NV. January 2003.

"Agricultural Water Use and the Role of Prices." Joint Meeting of the U.S. and Iranian Academies of Sciences. Tunis, Tunisia. December 2002.

"Economic Megatrends and Water Use in the United States." National Academy of Sciences. Washington, DC. September 2002.

"Pesticide Regulation and Changes in Human Health." World Congress of Environmental Economics. Monterey, CA. June 2002.

"Mechanisms for Risk Trading." World Congress of Environmental Economics. Monterey, CA. June 2002.

"Economic Damage from Water Supply Disruptions Following an Earthquake in the San Francisco Bay Area." Bay Area Water Users' Association. Foster City, CA. June 2002.

"Economic Perspectives on Federal Wetland Regulation." American Law Institute – American Bar Association. Washington, DC. May 2002.

"Reconciling Competing Interests in the West Side." CSRD Conference on the Future of the West Side. Parlier, CA. March 2002.

"Protecting Public Interests on Private Land." Center for Sustainable Resource Development, UC Berkeley. February 2002.

"Cost-Shifting and Environmental Quality." POWER Annual Conference. Los Angeles, CA. December 2001.

"Factor Price Risk and the Diffusion of Conservation Technology." California Conference on Environmental and Resource Economics. UC Santa Barbara. November 2001.

"Valuation of Water Supply Reliability." American Agricultural Economics Association. Chicago, IL. August 2001.

"Allocating Water by Markets." American Society of Horticultural Sciences. Sacramento, CA. July 2001.

"The Farm Bill and Resource Conservation: Success Stories." CSRD Conference on Agriculture and the Environment. Washington, DC. June 2001.

"Does Factor Price Risk Encourage Conservation?" International Water Resource Economics Consortium. Girona, Spain. June 2001.

"Optimal Control of Groundwater Over Space and Time." International Water Resource Economics Consortium. Girona, Spain. June 2001.

"Trading Behavior in an Informal Market." International Water Resource Economics Consortium. Girona, Spain. June 2001.

"Economics of Pesticide Cancellation: The Food Quality Protection Act of 1986." University of California Agricultural Economics and Management Workgroup. UC Davis. May 2001.

"Economic Aspects of Biological Control." University of California Conference on Urban Pest Management. UC Riverside. October 2000.

"Price Volatility and Resource Conservation." American Agricultural Economics Association. Tampa, FL. July 2000.

"Economics of Water Trading in California." UC Berkeley Water Working Group. Berkeley, CA. March 2000.

"Reforming Public Lands Policy." Painting the White House Green: Economics and Environmental Policy-Making in the Clinton Administration. Laramie, WY. September 1999.

"Transaction Costs and Trading Behavior in a Permit Market." American Agricultural Economics Association. Nashville, TN. August 1999.

"Facilitating Water Transfers with the WaterLink System." American Society of Civil Engineers. Seattle, WA. August 1999.

"Valuing Agricultural Water Supply Reliability." International Water Resource Economics

Consortium. Waikoloa, HI. July 1999.

"Economics of Inter-District Water Transfers." Western Economics Association. San Diego, CA. June 1999.

"The Value of Water Supply Reliability in Westside Agriculture." CalFed Economics Workgroup. Sacramento, CA. June 1999.

"Economic Impacts of Pesticide Regulation." Center for Sustainable Resource Development Conference on Pest Management. UC Berkeley. May 1999.

"Water Marketing within Irrigated Agriculture." American Agricultural Economics Association. Salt Lake City, UT. August 1998.

"Welfare Impacts of Climate Change: Focus on Pest Problems and Water Resources." American Agricultural Economics Association. Salt Lake City, UT. August 1998.

"Water Trading and the Costs of Bay/Delta Protection." Water Education Foundation. San Diego, CA. July 1998.

"Federal Public Land Policy: Litmus Test Issues." Berkeley Commons Club. Berkeley, CA. June 1998.

"Recent Developments in American Agricultural Policy." Commonwealth Club. San Francisco, CA. October 1997.

"Performance of a Voluntary Water Purchase Program." Western Regional Water Economics Conference. Lihue, HI. October 1997.

"Water Marketing for the Environment: The Clinton Administration's Perspective." Conference on Regional Water Markets. Berkeley, CA. July 1997.

"Returns to Public Investment in Agriculture with Imperfect Downstream Competition." American Agricultural Economics Association. Toronto, Canada. July 1997.

"Markets for Crop Germplasm." Invited Paper, American Agricultural Economics Association. Toronto, Canada. July 1997.

"Land Allocation, Soil Quality and Irrigation Technology Choice." Western Agricultural Economics Association. Reno, NV. July 1997.

"Product Liability and Entry Incentives." Western Agricultural Economics Association. Reno, NV. July 1997.

"Agricultural Policy in the Post-1996 Farm Act World." Signature Lecture, USDA Economic Research Service. Washington, DC. May 1997.

"Federal Water Policy in the United States." International Conference on Coordination and Decentralization in Water Resources Management. Annapolis, MD. April 1997.

"Non-Uniform Regulation of Groundwater Quality." American Agricultural Economics Association. San Antonio, TX. July 1996.

"The Effect of Farm Supply Shifts on Concentration and Market Power in the Food Processing Industry." American Agricultural Economics Association. San Antonio, TX. July 1996.

"Differential Property Tax Assessment, Land Allocation and Land Values at the Urban Fringe." American Agricultural Economics Association. San Antonio, TX. July 1996.

"Efficient Strategies for Acquiring Agricultural Water Rights." Invited Paper, Australian Agricultural and Resource Economics Society. Melbourne, Australia. February 1996.

"Strategies for Agricultural Water Conservation." U.S. Bureau of Reclamation Water Users Conference. Concord, CA. January 1996.

"Voting on Environmental Health Risks." American Agricultural Economics Association. Indianapolis, IN. August 1995.

"Explaining Irrigation Technology Choice: A Microparameter Approach." American Agricultural Economics Association. Indianapolis, IN. August 1995.

"The Economics of United States Environmental Laws." Symposium at Far Eastern State University. Vladivostok, Russia. March-April 1995.

"The Endangered Species Act: Impact on California Agriculture and Policy Options." University of California Executive Seminar on Agricultural Issues. Sacramento, CA. December 1994.

"Economics of Tort Liability Rules for Pesticide Damage." Second Occasional California Conference on Environmental and Resource Economics. Santa Barbara, CA. October 1994.

"Water Law as a Regulating Mechanism." International Conference on Coordination and Decentralization in Water Resources Management. Rehovot, Israel. September 1994.

"Contaminant Dynamics and the Cost of Groundwater Quality Regulations." Conference on Pesticide Economics and Policy in Memory of Carolyn Harper. Amherst, MA. April 1994.

"Water Markets and Water Quality." University of California Conference on Regional Water Constraints. Berkeley, CA. October 1993.

"Irreversibility, Contaminant Dynamics and the Cost of Groundwater Quality Regulations." American Agricultural Economics Association. Orlando, FL. August 1993.

"Methodological Issues in Pesticide Regulation." First Occasional California Conference on Environmental and Resource Economics. Santa Barbara, CA. May 1993.

"Economic Impacts of the Central Valley Project Improvement Act." First Occasional California Conference on Environmental and Resource Economics. Santa Barbara, CA. May 1993.

"Majority Rule with Rational Abstention is Globally Transitive." Sixth World Congress of the Econometric Society. Barcelona, Spain. August 1990.

COURSES TAUGHT

Advanced Topics in Environmental and Resource Economics (Graduate)

Risk, Technology and the Environment (Graduate)

Environmental and Resource Economics (Graduate)

Economics of Water Resources (Undergraduate)

Natural Resource Economics (Undergraduate)

Economics of Public Law (UC Berkeley School of Law)

Environmental Policy (Undergraduate)

Public Finance (Graduate)

Microeconomic Theory (Graduate and Undergraduate, UC Berkeley and Boston College)

Law and Economics (Boston College School of Law)

ACADEMIC SEMINARS

University of Arizona, Boston College, Boston University, UC Berkeley, UC Davis, UC Irvine, UCLA, UC Riverside, UC Santa Barbara, University of Colorado, Harvard University, Hebrew University of Jerusalem, Johns Hopkins University, Kansas State University, University of Maryland, Massachusetts Institute of Technology, University of Massachussetts, Montana State University, Ohio State University, University of Pennsylvania, Purdue University, Stanford University, U.S. Department of Agriculture, U.S. Department of the Interior, U.S. Environmental Protection Agency, U.S. Department of Housing and Urban Development, University of Wisconsin, University of Wyoming.

GRADUATE STUDENTS AND POSTDOCTORAL RESEARCHERS SUPERVISED

Molly VanDop
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David McLaughlin
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Andrew Stevens
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Cal Poly San Luis Obispo

Steven Buck
University of Kentucky

Howard Chong
Cornell University

Sarah Dobson
University of Alberta

Deepak Rajagopal
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Brian Gross
University of British Columbia

Karina Schoengold
University of Nebraska

Aaron Swoboda
University of Pittsburgh

Nicholas Brozovic
University of Illinois

Sean Cash
University of Alberta

Georgina Moreno
Scripps College

Daniel Osgood
University of Arizona

Mark Metcalf
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Janis Carey
Colorado School of Mines

Joshua Zivin
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Katrin Millock
EUREQua, CNRS and Université Paris I

Sabrina Ise
U.S. Environmental Protection Agency

Steven Hamilton
University of Arizona

Gareth Green
Washington State University

PROFESSIONAL ASSOCIATIONS

American Economic Association
American Law and Economics Association
Association of Environmental and Resource Economists
Econometric Society

APPENDIX B –DOCUMENTS CONSIDERED

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APPENDIX C

CONSTRUCTION OF PARCEL DATA

1. From CoreLogic, I obtained two sets of data covering property characteristics and sales in North Carolina. The property characteristics come from the complete tax history of each property. This tax dataset contains 50,934,756 observations of 219 variables, including housing characteristics such as year built, number of bedrooms and bathrooms, water source, location data, and the assessed value of the home. The property sales information comes from sale deed records for all available residential observations from 1900 to April 2021. This deed dataset contains 7,631,092 observations of 102 variables, including fields to identify the sale date and sale amount. To join and clean the datasets, columns relevant to the analysis were selected from the larger datasets, then the tax information for the given parcel and year (or for the closest year, if the exact year is missing from the data) to the sale was joined to the deed data.

2. I subset the dataset to only include observations for which I have complete records and limit to sales that occur between June 2013-April 2021 (approximately four years before and four years after the awareness date of June 14, 2017).

DETERMINATION OF CONTAMINATED HOUSEHOLDS

3. The water source identifier in the CoreLogic data is missing for 86% of observations. As such, for the purposes of the public water system model, I instead limit to parcels which lie within the service area of a public water system, but exclude any properties that CoreLogic indicates have wells. I use the latitude and longitude information provided in the CoreLogic data to map the North Carolina parcels within a spatial file of public water system service territories obtained from the Drinking Water Interactive Resilience Project ("DRIP").

4. Next, I determine which households have been exposed to PFAS contamination through a public water system. As I explain in Section IV.B.2, there are three water systems that I identify as contaminated in the Plaintiff counties at issue: CFPUA-Wilmington, Brunswick County Water

System, and Pender County Utilities-Rocky Point/Topsail/Scotts Hill. I classify all homes that lie within the service area of one of these three systems as contaminated for use in my econometric model.

MATCHING PLAINTIFF AND COMPARABLE COUNTIES

5. In order to apply my econometric model, I must identify control, areas of the state that are demographically similar to the contaminated region, but that have not had PFAS detected in the water supply. I consider only counties in North Carolina as potential controls. I determine these control areas by systematically eliminating potential counties and comparing the remaining counties to the contaminated counties based on eleven demographic measures.

6. First, I eliminate counties in North Carolina that have public water systems with levels of PFAS above the EPA health advisory limit (70 ppt of PFOA +PFOS) according to the North Carolina PFAS Testing Network.[78] I then restrict the search to only counties with a Rural Urban Classification Code ("RUCC") of 2, which aligns with the Plaintiff counties' urban classification.[79] There are 19 potential control counties meeting these preliminary requirements.

7. Next, using eleven demographic metrics, I compute the standard deviation of all counties in the state and the average for contaminated counties. These metrics are: percent of population with a bachelors degree, percent of population that is white, median income, poverty rate, unemployment rate, homeownership rate, population growth rate (2010-2016), population density, percent of population under 18 years of age, percent of population over 65 years of age, and the Zillow home value growth rate (2010-2016).[80]

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[78] The PFAS Testing Network began testing public water systems in April of 2019. I do not use contamination values from the network in my econometric model, only for determination of contaminated areas of North Carolina. See PFAS Testing Network at Data and Tools, available at https://ncpfastnetwork.com/data-and-tools/. See also EPA at "Drinking Water Health Advisories for PFOA and PFOS," available at https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos#:~:text=To%20provide%20Americans%2C%20including%20the,at%2070%20parts%20per%20trillion.

[79] The USDA classifies counties based on their urban population and/or proximity to an urban center. Data is produced every 10 years, most recently published in 2013. See USDA at Rural-Urban Continuum Codes, available at https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx.

[80] Data from the American Community Survey of 2016 (5-year estimates) available at https://data.census.gov/cedsci/advanced?q=population.

8. I then standardize the metrics to place them all on the same scale, thereby ensuring that differences in one metric are measured similarly to differences on another. In order to standardize, I compute a deviance measure for each county and each metric, using the following equation:

$$d_{it} = \frac{y_{it} - \bar{y}_t}{\sigma_t},$$

where: d_{it} is the deviance value of county i for metric t; y_{it} is the raw value of metric t for county I; $\bar{y}_t$ is the contaminated county average for metric t; and σ_t is the standard deviation of all counties in the state for metric t.

9. After computing deviance values for all counties, I determine individual matches by computing the sum of squared differences across metrics for each potential comparable county, as compared to each contaminated county. I use the county with the smallest value for the sum of squared differences as the best individual match for each of the three contaminated counties. This is a version of "nearest neighbor" matching.[81] As a final test, I research each potential match's water districts to determine whether they made any public PFAS-related disclosures. If so, I remove it as a potential match and use the next closest match. This research led me to exclude Chatham and Guilford Counties.[82]

10. I also prepare alternative comparable groups as robustness checks for my analysis based on "propensity score" matching.[83] First, I label each of the 19 RUCC 2 counties with PFAS Testing Network test results below the EPA guidelines as potential control counties and the three counties containing the contaminated water districts at issue here as treatment counties. I then

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[81] See Donald B. Rubin, "Using Multivariate Matched Sampling and Regression Adjustment to Control Bias in Observational Studies," in *Matched Sampling for Causal Effects*, ed. Donald B. Rubin (Cambridge University Press, 2006).

[82] See Chatham County at "Chatham County Response to Water Concerns," available at https://www.chathamcountync.gov/home/showdocument?id=46131. See also City of Greensboro at "Greensboro's Response to PFAS at Community Meeting 12-4-18 Presentation," available at https://www.greensboro-nc.gov/home/showpublisheddocument/41536/636862607051570000.

[83] See Paul R. Rosenbaum and Donald B. Rubin, "The Central Role of the Propensity Score in Observational Studies for Causal Effects," in *Matched Sampling for Causal Effects*, ed. Donald B. Rubin (Cambridge University Press, 2006).

develop econometric models that use the socioeconomic factors that I collected to predict whether a county falls into the treatment or control group. The prediction for whether a county belongs to the treatment group is known as the "propensity score."

11. Because I have a high number of factors (11) relative to counties (22), I use two machine learning classification models, known as the LASSO and ridge regression approaches.[84] Standard regression approaches tend to "overfit" when the ratio of observations to factors is low, whereas these machine learning approaches "penalize" overfitting.[85] The two models use different methods of penalization. LASSO restricts most factors to have coefficients of 0; that is, it excludes most factors from the model entirely, preventing irrelevant factors from having a spurious impact. Ridge regression includes all factors, but pushes their coefficients toward 0; that is, it weakens the impact of each factor.

12. These two machine learning models take different and therefore complementary approaches to estimating the propensity score. For this reason, to identify the appropriate control county for each treated county, I use both the county chosen by the LASSO model as well as the county chosen by the ridge regression model.[86] Specifically, I calculate the propensity score for each county using the LASSO model. Then, for each treated county, I find the control county with the closest propensity score to that of the treated county. I perform the analogous calculation using the ridge regression model, creating the matched triplet. After identifying the potential control counties, I research their water districts to determine whether those districts made any PFAS-related disclosures on their websites. This research removes Durham County.[87] The final matches are shown in Table C-1 below.

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[84] See Trevor Hastie, Robert Tibshirani, and Jerome Friedman, *The Elements of Statistical Learning: Data Mining, Prediction, and Inference*, 2nd edition (Springer, 2016).

[85] The extent of penalization is determined by a parameter in the model, typically referred to as lambda. I choose lambda optimally using leave-one-out cross validation.

[86] This is a "many-to-one" matching approach.

[87] See City of Durham at Water Management at "About Water," available at https://durhamnc.gov/1187/Water-Quality.

TABLE C-1: PROPENSITY SCORE COUNTY MATCHES

Treatment	LASSO Model	Ridge Model
Brunswick County	Hoke County	Forsyth County
New Hanover County	Buncombe County	Forsyth County
Pender County	Hoke County	Forsyth County

13. Lastly, I do not consider properties in water districts in Plaintiff counties at issue that I do not consider contaminated by Fayetteville Works PFAS as potential controls for a few reasons. First, it would require a high degree of knowledge for homebuyers to know whether a particular water district within a county is contaminated by PFAS or not. Second, water districts that are not currently contaminated by Fayetteville Works PFAS may become contaminated in the future due to additional groundwater leeching or air deposition. Lastly, some of these districts may be contaminated by PFAS from other or unknown sources.

ECONOMETRIC MODEL

14. In Section V, I provide a high level discussion of my econometric approach to estimate property diminution. Here, I provide additional detail. The model can be written as:

$$\ln y_{it} = \alpha_i + \beta x_{it} + \gamma_t + \delta_t + \epsilon_{it},$$

where: y_{it} is the sale price of property *i* at time *t*; x_{it} is an indicator that is 1 for contaminated properties (after contamination is revealed); α_i is a set of property fixed effects; γ_t is a set of month fixed effects; δ_t is a set of year fixed effects; and ϵ_{it} is a statistical error term.

15. A property in a public water district is considered to be contaminated if it is in a water district with a source that is contaminated (see Section IV.B.2) and the sale date is on or after June 14, 2017.

ROBUSTNESS CHECKS

16. In Section V.C, I present the results of the above specification applied to properties in the Plaintiff regions compared to their matched regions using a nearest neighbor matching

assignment. Above I describe how I identified these matched pairs. I also discuss a propensity score matching approach to create matched triplets; these are shown in Table C-1.

17. In Table C-2, I provide the results of my repeat sales model when applied to properties in these propensity score matched triplets. These results serve to check the robustness of my results to the choice of different sets of control counties. These alternative estimates are close to those found using my nearest neighbor matching approach (Table 6 in the body of this report). Therefore, I conclude that my estimates are robust to the choice of control counties.

TABLE C-2: PROPERTY DIMINUTION USING PROPENSITY SCORE MATCHED TRIPLETS

Dependent Variable:	Sale Amount (natural logarithm)			
	Brunswick	New Hanover	Pender	Pooled
Model:	(1)	(2)	(3)	(4)
Variables				
Contamination Indicator	-0.1138***	-0.0266***	-0.1386***	-0.0469
	(0.0198)	(0.0072)	(0.0207)	(0.0321)
Fixed-effects				
Sale Month-Year	Yes	Yes	Yes	Yes
Property Indicator	Yes	Yes	Yes	Yes
Observations	28,532	41,769	25,750	48,064

One-way (Water District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*