Trichloroethylene Contamination of American Military Bases: An Alternative Toxic Waste History

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Introduction

On an October Wednesday morning, geologist Grant McIntyre and his team set up their drill rig on the perimeter of Hill Air Force Base in Utah. Surrounding them were picturesque mountains and the grasslands of the facility's undeveloped outskirts. Down the hill from their worksite, water flowed gently through the Davis-Weber canal as livestock grazed nearby. Beyond the pastures, a row of small homes dotted the landscape along the two-lane South Weber Drive. The rig bored into the earth, allowing McIntyre to make detailed notes of the soil and groundwater composition. Ten feet down: silt, "medium brown with traces of black staining." Fifty feet down: clay, "medium brown to pale gray, silty, moist. Visual observation of black dense liquid contamination. Draeger TCE [trichloroethylene] test = 200-250 ppm [parts per million]."[1]

Over the past century, military installations across the United States have used and discarded a vast array of toxic substances. Before the modern framework of hazardous waste regulation was established during the 1970s and 1980s, toxic materials were often buried in un-lined pits and landfills or dumped onto soils. Though common and legal at the time, such practices have led to widespread environmental contamination. In 2010, there were 141 Department of Defense (DoD) facilities on the National Priorities List (NPL), an inventory of the most polluted sites in the United States.[2] With 1,281 total NPL sites in 2010, military installations comprised over 10% of the list.[3]

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1. "Draft Lithologic Logs for Chemical Disposal Pit 3, Hill AFB, Utah" (Radian Corporation, September 1989), 75-76.

2. "Interagency Agreements and Improved Project Management Needed to Achieve Cleanup Progress at Key Defense Installations" (Government Accountability Office, July 2010), 59.

3. "Number of NPL Sites of Each Status at the End of Each Fiscal Year," Data and Tools, EPA, August 19, 2015, https://www.epa.gov/superfund/number-npl-sites-each-status-end-each-fiscal-year.

This essay will focus on the contamination of military bases with trichloroethylene (TCE), a solvent used extensively by the DoD. I will not address the occupational exposure of servicemembers or contractors to TCE, as this involves a separate set of regulations, narratives, and themes.[4] Though TCE's notoriety pales in comparison to lead, dioxins, or radioactive wastes, the solvent is a common pollutant of drinking water and is found at more than half of proposed NPL sites.[5] According to the Environmental Working Group's tap water database, over 20 million Americans were served by water systems with detectable levels of TCE during 2017-2019.[6] In addition to causing acute illness, there is a broad consensus among regulatory agencies and medical researchers that TCE is carcinogenic to humans.[7]

Histories of toxic materials and hazardous waste often depict citizen activists and visionary reformers doing battle against institutional malfeasance. The tale of Love Canal, usually framed as a conflict between local homeowners and a negligent chemical firm (Hooker) plus sluggish environmental agencies, provides an archetype of this narrative.[8] Analyses of Rachel Carson's monumental book *Silent Spring* similarly portray Carson as a renegade scientist who inspired a movement by confronting orthodox views in the Forest Service and other federal

4. I will, however, cover exposure via contaminated groundwater at Camp Lejeune.

5. "Toxicological Profile for Trichloroethylene" (ATSDR, June 2019), 305.

6. Environmental Working Group, "EWG's Tap Water Database: Contaminants in Your Water," accessed March 8, 2021, https://www.ewg.org/tapwater/contaminant.php?contamcode=2984?contamcode=2984.

7. "Toxicological Profile for Trichloroethylene," 364-6.

8. See, for instance, part two of: Richard S. Newman, *Love Canal: A Toxic History from Colonial Times to the Present* (New York: Oxford University Press, 2016). Other examples include the chapters on Love Canal and toxics history in *American Environmentalism: The US Environmental Movement, 1970-1990* (Taylor & Francis, 2014)., Brian Black and Donna L. Lybecker, *Great Debates in American Environmental History*, electronic resource (Westport, Conn: Greenwood Press, 2008)., and Carolyn Merchant, *The Columbia Guide to American Environmental History*, Columbia Guides to American History and Cultures (New York: Columbia University Press, 2002).

bureaucracies.[9] Works on lesser-known topics also exemplify this narrative tendency. For instance, Sarathy's chapter on the Stringfellow Acid Pits in *Inevitably Toxic* credits citizen complaints with pressuring the government to close the leaky, hazardous facility after prior intransigence.[10] Similarly, Bohme's *Toxic Injustice* tells the story of dibromochloropropane -- a pesticide which causes male infertility -- by highlighting workers' struggles against deliberate obfuscation by Dow Chemical.[11] And the compilation *NIMBY is Beautiful: Cases of Local Activism and Environmental Innovation Around the World* includes numerous essays highlighting grassroots opposition to corporate and government hazardous waste pollution.[12] These are but a few examples of a remarkably common framing.

To be clear, the works cited above do not contain erroneous analysis, nor should activism be discounted in toxic waste histories. It is undeniable that grassroots pressures have played a crucial role in the advancement of hazardous waste regulation and that the negligence of corporations and governments has frequently harmed society and nature alike. Historians are justifiably interested in exploring protest-driven episodes because they yield broader insights on democratic accountability, social movements, bureaucratic inertia, the media, and other critical subjects. However, there are many cases where activism has not been the driving force behind the recognition of specific environmental hazards or subsequent cleanup efforts, and TCE

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9. For an archetypal example, consult: Linda J. Lear, "Rachel Carson's 'Silent Spring,'" *Environmental History Review* 17, no. 2 (1993): 23–48. Also: Peter Dreier, "How Rachel Carson and Michael Harrington Changed the World," *Contexts* 11, no. 2 (May 1, 2012): 40-46.

10. Brinda Sarathy, "Making Way for Industrial Waste: Water Pollution Control in Southern California," in Brinda Sarathy, Vivien Hamilton, and Janet Farrell Brodie, eds., *Inevitably Toxic: Historical Perspectives on Contamination, Exposure, and Expertise* (University of Pittsburgh Press, 2018).

11. Susanna Rankin Bohme, *Toxic Injustice: A Transnational History of Exposure and Struggle* (Oakland, California: University of California Press, 2015).

12. Carol Hager and Mary Alice Haddad, *Nimby Is Beautiful: Cases of Local Activism and Environmental Innovation Around the World* (New York, NY: Berghahn Books, Incorporated, 2015).

contamination of military bases provides one example. In order to fully understand the dynamics at play in toxic waste regulation and remediation, these alternative narratives must also be understood.

My account emphasizes the banality of toxic pollution and the crucial, often unglamorous role played by government regulators and scientists in the discovery and cleanup of hazardous substances. As opposed to a malicious polluter held accountable by grassroots resistance, I portray a sometimes indifferent, sometimes compliant DoD kept in check by the Environmental Protection Agency (EPA) and state regulatory agencies.

In tracing this story, I have relied largely on government documents, including reports, meeting minutes, interview transcripts, and correspondences. These provide crucial information on agency rulemaking, community feedback, cleanup technologies, inter-agency relations, and other pertinent matters. In addition, journal articles -- especially those pertaining to hazardous waste disposal and TCE's health effects -- help trace the development of scientific knowledge over time. Newspaper articles, drawn from the vast Newspapers.com archive, provide factual information and reveal how TCE was discussed by the print media. Lastly, I conducted two interviews: one with Ken Alex, a former Senior Assistant Attorney General for the state of California,[13] and one with Joe Healy, a former EPA Remedial Project Manager at two TCE-contaminated military bases.[14]

Chapter I addresses the origins of TCE, describing the chemical's uses and exploring early perceptions of its health effects. Chapter II considers TCE disposal practices before 1970,

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13. Alex headed the environmental division of the California Attorney General's office and oversaw litigation related to military cleanups.

14. Healy was the EPA's Remedial Project Manager at McLellan Air Force Base and Edwards Air Force Base, both located in California.

arguing that -- due to TCE's material qualities and the gaps in scientific knowledge -- the solvent's potential as a serious environmental pollutant was not widely understood. This sets the stage for Chapter III, which describes military TCE disposal practices. These contextual chapters help explain why government mechanisms -- namely a cancer study by the National Cancer Institute (NCI) and public health bulletins by the National Institute for Occupational Safety and Health (NIOSH) -- first brought public awareness to the substance's harmful effects. This critical research, along with the development of the federal regulatory framework that would guide TCE cleanups, is described in Chapter IV.

The remaining two chapters concern the detection, regulation, and remediation of TCE at military bases. In Chapter V, I trace the Environmental Protection Agency (EPA)'s formulation of TCE limits for drinking water and the discovery of groundwater contamination at Camp Lejeune. This episode highlights some pitfalls of reliance on government regulation for protection against pollution and illustrates the role of materiality in restricting community responses to certain contaminants. Chapter VI discusses TCE remediation efforts at military bases, arguing that regulatory agency oversight has guided the military's TCE cleanups in the absence of substantial grassroots pressure and oversight.

Chapter I: TCE Overview, Early Medical Research

To understand the particular environmental challenges posed by trichloroethylene, a brief overview of the substance's physical characteristics is necessary. TCE is an organic chemical with a molecular formula of C_2HCl_3 and is a sweet-smelling, transparent liquid at room temperature.[15] Because TCE contains chlorine atoms, it belongs to a class of environmentally problematic substances known as chlorinated solvents. Due to its relatively high vapor pressure, TCE is a volatile organic compound (VOC) with a tendency to evaporate at room temperature. In outdoor air and surface water, TCE decomposes fairly quickly.[16] However, TCE can be long-lived in groundwater and may gather at the bottom of aquifers in a concentrated form known as a dense non-aqueous phase liquid, or DNAPL.[17] Agglomerations of TCE DNAPL leech into the surrounding water and can take centuries to naturally degrade.[18]

In 1864, the German chemist Emil Fisher discovered TCE inadvertently, although there is speculation that Auguste Laurent may have unknowingly created the chemical in 1836.[19] Commercial production began in Austria circa 1905, and the rest of Europe soon followed.[20] American adoption of TCE was apparently somewhat slower. Congressional legislation established a 25% duty on foreign TCE imports in 1921, suggesting the chemical was in use by

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15. "Toxicological Profile for Trichloroethylene," 296-7.

16. "Toxicological Profile for Trichloroethylene," 318-22.

17. "Toxicological Profile for Trichloroethylene," 321-2. One of the main factors dictating the speed of natural TCE attenuation below ground is the environment's suitability for biodegradation. The rate of natural attenuation varies considerably from site to site, so no two instances of contamination are exactly the same.

18. Even with active remediation, the highly contaminated OU2 at Hill Air Force Base (to be discussed) will not be completely remediated until more than a century after the initial contamination.

19. Robert D. Morrison and Brian L. Murphy, *Chlorinated Solvents: A Forensic Evaluation*, 1st edition (Royal Society of Chemistry, 2015), 119.

20. "Tariff Bill H.R. 7456," Pub. L. No. 318 (1921), 3.

this time, but large-scale domestic production would not begin until 1925 at the Roessler and Hasslacher Chemical Company's Niagara facility.[21] [22] [23]

TCE was valued as a powerful solvent of organic compounds, particularly oils. Its rapid evaporation and inflammability made TCE ideal for applications where other solvents (many based on hydrocarbons) were hazardous or left unsavory odors.[24] One example was dry cleaning, where TCE's relative inertness was greatly appreciated, as hydrocarbon-based solvents had resulted in many explosions and mishaps.[25] The advent of vapor degreasing was another major driver of TCE consumption. With this technique, solvents are boiled to create vapors which condense on soiled items, drenching them uniformly. Vapor degreasing allowed metal parts to be easily and rapidly cleaned at an industrial scale prior to plating, finishing, or assembly. Though dry cleaning and degreasing consumed the majority of TCE, the chemical was also used in fire extinguishers, as a flame retardant plywood additive, to fumigate grain, to extract caffeine from coffee, to clean wounds, and to manufacture other chemicals (including refrigerants).[26]

TCE was linked to military activities from early on, as the German military utilized the chemical during World War I.[27] One defense application was manufacturing, where the aforementioned vapor degreasing process was ideally suited to the mass production of defense

21. Michael O. Rivett, Stanley Feenstra, and Lewis Clark, "Lyne and McLachlan (1949): Influence of the First Publication on Groundwater Contamination by Trichloroethene," *Environmental Forensics* 7, no. 4 (December 2006): 313–23.

22. "Roessler & Hasslacher -- Partners" (American Chemical Society, October 1929), 991.

23. Robert D. Morrison and Brian L. Murphy, *Chlorinated Solvents: A Forensic Evaluation*, 119.

24. Richard E. Doherty, "The Manufacture, Use, and Supply of Chlorinated Solvents in the United States During World War II," *Environmental Forensics* 13, no. 1 (March 2012), 58.

25. Richard E. Doherty, "The Manufacture, Use, and Supply of Chlorinated Solvents in the United States During World War II," 70.

26. "Friday, October 17, 1941," *Federal Register* 6, no. 203 (October 17, 1941): 5292.

27. Cecil Striker et al., "Clinical Experiences with the Use of Trichlorethylene in the Production of Over 300 Analgesias and Anesthesias," *Anesthesia & Analgesia* 14, no. 2 (April 1935): 68–71.

machinery. The chemical was also used at military bases and in the field to remove lubricants and other contaminants from parts while conducting repairs or maintenance.[28]

Soon after TCE's introduction, people began to notice that its vapors could produce intoxicating effects.[29] This prompted some doctors to speculate on TCE's potential utility as an anesthetic, especially given its chemical similarities to chloroform. The earliest large-scale trial of TCE anesthesia with human subjects was described in a 1935 journal article by the American doctors Cecil Striker, Samuel Goldblatt, Irwin Warm, and D.E. Jackson. Over the course of their experiment, 304 patients inhaled vaporized TCE while undergoing a variety of surgical procedures. The researchers found TCE a satisfactory anesthetic, with less tendency to produce nausea and vomiting than contemporary alternatives. Moreover, follow-up yielded no evidence of lasting adverse effects.[30]

Nonetheless, doctors were aware that TCE could be acutely poisonous at high concentrations. One investigation was carried out by Dr. Carey McCord of Cincinnati and published in 1932. McCord tested a number of aerial TCE concentrations from 20,000 parts per million (ppm) to 500 ppm and noted that all proved fatal to rabbits -- 20,000 ppm killed in two hours, while 500 ppm caused death after 19 days. Daily application of a sufficient quantity to the skin of the rabbits was also fatal.[31] In a 1936 journal article titled "Trichloroethylene Intoxication," Baltimore MD Herbert Eichert noted that over 280 cases of industrial poisoning by

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28. Richard E. Doherty, "The Manufacture, Use, and Supply of Chlorinated Solvents in the United States During World War II," 11.

29. Cecil Striker et al., "Clinical Experiences with the Use of Trichlorethylene in the Production of Over 300 Analgesias and Anesthesias," 68.

30. Cecil Striker et al., "Clinical Experiences with the Use of Trichlorethylene in the Production of Over 300 Analgesias and Anesthesias," 70-71.

31. McCord, Carey P. "Toxicity of Trichloroethylene," *Journal of the American Medical Association* 99, no. 5 (July 30, 1932): 409.

TCE had been recorded in the literature, including 26 deaths. However, Eichert and many others suspected that these incidents were not attributable solely to TCE, in part because medical use had proven relatively safe. Instead, Eichert echoed earlier proposals that additives, contaminants, and decomposition byproducts were probable culprits.[32] These inquiries were part of the burgeoning field of occupational hygiene, which took hold in America during the early 20th century.[33] However, reports of acute toxicity did not slow or prevent the usage of TCE; after all, many alternative solvents and anesthetic agents seemed to have comparable, if not worse, health effects.

By the early 1940s, the federal government had come to recognize TCE as a critical national security resource, especially in the manufacture and maintenance of airplane parts. In 1941, the Office for Emergency Management's Supply Priorities Board issued Order M-41, which declared that the "public interest and . . . defense of the United States" required "conserv[ing] the supply and direct[ing] the distribution" of chlorinated solvents, including TCE. The order placed all TCE sales under strict regulation and established preference ratings for various uses based on their perceived importance.[34] Once the US entered the war, stewardship of the chlorinated solvent supply was subsumed by the War Production Board, which oversaw a substantial increase in yearly production capacity from 15 million pounds in 1942 to 75 million pounds in 1944.[35]

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32. Herbert Eichert, "Trichloroethylene Intoxication," *Journal of the American Medical Association* 106, no. 19 (May 9, 1936): 1652.

33. Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science*, electronic resource (Chapel Hill: University of North Carolina Press, 1997), 70-72.

34. "Friday, October 17, 1941," 5292.

35. Richard E. Doherty, "The Manufacture, Use, and Supply of Chlorinated Solvents in the United States During World War II," 11.

Documents from this era suggest the military was aware of the literature on TCE's acute toxicity. In a memo, Brigadier General Charles Glenn noted that all chlorinated solvents, including TCE, were poisonous to the liver and kidney, and he cited a "permissible limit" of 200 parts per million (ppm) for TCE vapor.[36] This was equivalent to the *Manual of Industrial Hygiene*'s maximum allowable concentration.[37]

Although early researchers were aware that TCE could be poisonous, they lacked an appreciation of the chemical's insidious carcinogenic effects. Early studies typically involved lethal or near-lethal doses administered for a relatively short duration, the sort of methodology necessary to establish maximum allowable concentrations for preventing acute occupational deaths. This type of research helped instill confidence that TCE's harmful characteristics were well-understood and could be easily mitigated.[38] Unfortunately, early researchers were missing a key insight: TCE is carcinogenic even at very low concentrations. This lacuna would affect environmental assessments of TCE, as will be discussed.

Overall, the field of cancer research made great strides in the early 20th century. Key milestones included the recognition of some widespread occupational carcinogens (such as aromatic hydrocarbons in coal tar) and the development of radiotherapies. By the dawn of World War II, scientists had identified hundreds of carcinogenic substances through both observation

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36. Richard E. Doherty, "The Manufacture, Use, and Supply of Chlorinated Solvents in the United States During World War II," 11.

37. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA* (University of Texas Press, 2010), 37.

38. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 37-39.

and experimentation.[39] But the linkage between TCE and cancer would prove relatively difficult to draw.

In humans, TCE-related cancers take years to emerge, a lag which helped obscure the relationship, especially since exposed workers often handled other hazardous materials.[40] [41] Moreover, the ease of connecting a specific disease to toxic exposure is partially contingent on the ailment's distinctiveness. Phosphorus was one of the first occupational hazards identified definitively by American researchers because phosphorus necrosis is a highly unusual condition.[42] Similarly, chimney soot -- one of the first recognized carcinogens -- produced a distinctive scrotal cancer known as chimney sweeps' carcinoma.[43] TCE is most strongly associated with cancer of the liver, a relatively common disease.[44] Perhaps most importantly, TCE is not a substance which produces large increases in risk ratio among exposed populations. Of the numerous occupational exposure studies compiled by the International Agency for Research on Cancer (IARC), the majority did not find statistically significant increases in cancer incidence.[45] Only by conducting a meta-analysis has the IARC concluded that occupational TCE exposure is definitively associated with an increase in cancer mortality.

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39. Steve I. Hajdu and Farbod Darvishian. "A Note from History: Landmarks in History of Cancer, Part 5." *Cancer* 119, no. 8 (2013): 1450–66.

40. Michael Goodman et al., "Cancer Cluster Investigations: Review of the Past and Proposals for the Future," *International Journal of Environmental Research and Public Health* 11, no. 2 (February 2014): 1479.

41. "Special Occupational Hazard Review of Trichloroethylene" (National Institute for Occupational Safety and Health, January 1978), 43-44.

42. Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science*, electronic resource, 62.

43. D. J. Gawkrodger, "Occupational Skin Cancers," *Occupational Medicine* 54, no. 7 (October 1, 2004): 458–9.

44. "Trichloroethylene, Tetrachloroethylene, and Some Other Chlorinated Agents," IARC Monographs on the Evaluation of Carcinogenic Risks to Humans (Geneva, Switzerland: IARC, 2014), 184.

45. "Trichloroethylene, Tetrachloroethylene, and Some Other Chlorinated Agents," 51-63. When statistical significance is defined as a risk ratio 95% confidence interval that does not overlap with the null hypothesis risk ratio (typically 1).

Nor did animal research offer an easy means of establishing TCE's carcinogenicity. The first animal study to connect TCE and carcinogenesis lasted over a year, employed sophisticated statistical analysis, included over 400 rats and mice, and searched specifically for cancer with a biopsy of each subject.[46] Earlier experiments, which lacked these essential features, did not reveal any unexpected increase in cancer incidence.

As a result of these factors, TCE's carcinogenicity would not be established until the 1970s. Before then, a confluence of TCE's material characteristics and the general state of medical research meant the chemical was viewed as an intoxicating industrial solvent rather than a dangerous carcinogen. This knowledge gap helped encourage poor disposal practices, as will soon be explored.

46. "Carcinogenesis Bioassay of Trichloroethylene" (U.S. Department of Health, Education, and Welfare, February 1976), vii.

Chapter II: Hazardous Waste Regulation and Historical TCE Disposal Practices

In a broad sense, the dangers of improper waste disposal have been recognized for well over a century. Organic and biological wastes were initially the focus of policymakers and scientists. From the mid-1800s onwards, officials sought to limit the presence of human waste in cities by constructing sewers.[47] Other problematic substances included "distillery slop, slaughterhouse refuse, and textile and paper mill effluent," which could lead to the growth of undesirable organisms or render waterways inhospitable to life.[48] By the 1920s, scientists with the Bureau of Fisheries testified on the harmful effects of oil discharges and won passage of a law restricting hydrocarbon disposal into ocean waters. Trade groups for the water utility industry recognized that specific industrial wastes (like cyanide) were undesirable in water supplies, and some municipalities monitored their water for pollutants.[49] During the late 1940s, the professional journal *Sewage Works* published a series of articles called "The Industrial Waste Problem." Subjects included "Packinghouse, Brewery, and By-Products Coke Wastes," "Strawboard, Petroleum, and Distillery Wastes," "Pulp and Paper Waste Treatment and Research," and "Brass and Copper, Electroplating, and Textile Wastes." Some of these waste categories -- especially electroplating and petroleum wastes -- would now be considered "hazardous." During the 1950s, a water resources commission created by President Truman

47. Joel A. Tarr, "The Search for the Ultimate Sink: Urban Air, Land, and Water Pollution in Historical Perspective," *Records of the Columbia Historical Society, Washington, D.C.* 51 (1984): 3-9.

48. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 43-44.

49. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 46-47.

concluded that “the industrial waste pollution problem today is greater and more crucial than . . . domestic sewage.”[50] Evidently, scientists and industry professionals were broadly aware that some industrial wastes could be hazardous and required special disposal considerations.

However, recognition of the problem did not lead to a coherent regulatory or legal framework guiding hazardous waste disposal at the federal level until the 1970s. Some states did take independent action; California, for instance, established hazardous waste landfills beginning in the 1950s.[51] By 1939, most states had regulations addressing the discharge of industrial wastes directly into public waters, where they caused a litany of issues like fish die-offs, the fouling of beaches, problems with irrigation, etc.[52] And some municipalities took enforcement into their own hands -- for instance, Suffolk county in New York went after polluters emitting highly toxic metal plating wastes during the 1950s and early 1960s.[53] But these piecemeal approaches did not provide for systematic regulation, evaluation, and classification of hazardous materials, and so their effectiveness was limited. In California, for example, hazardous wastes were often discharged improperly, and the Stringfellow Acid Pits hazardous landfill was sited carelessly, leading to groundwater contamination and runoff issues that authorities chose to ignore.[54]

One non-statutory check on polluters was the civil nuisance suit. There was a legal basis under common law to sue companies which inflicted damages upon others by rendering

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50. *A Water Policy for the American People: The Report of the President’s Water Resources Policy Commission* (Washington, D.C.: Government Printing Office, 1950), 189.

51. Brinda Sarathy, “Making Way for Industrial Waste: Water Pollution Control in Southern California,” 121.

52. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 108.

53. “Ground Water Contamination: Proceedings of the 1961 Symposium” (U.S. Department of Health, Education, and Welfare, 1961), 155.

54. Brinda Sarathy, “Making Way for Industrial Waste: Water Pollution Control in Southern California,” 134-46.

groundwater supplies un-usable, polluting rivers, etc.[55] This threat, and a general desire among some industry figures to practice good environmental stewardship, led some companies to exhibit a degree of care in their landfill practices even when no regulations existed. But civil suits had serious flaws as a means of discouraging harmful disposal practices, foremost being that courts weighed plaintiffs' losses against factors such as "good faith, technological feasibility, and the importance of the [polluting] activity to the local economy" when deciding cases.[56] [57] One *Sewage Works* article stated plainly that "fear of having to pay high damages has not provided general incentive to abate pollution."[58]

Even if more stringent and comprehensive regulatory mechanisms had been in place, they probably would not have included TCE, as the solvent was not a widely recognized environmental pollutant until the 1970s. This assertion is contested in the literature, so a brief discussion of the evidence is warranted. Colten and Skinner assert that much of the knowledge necessary to anticipate and prevent chlorinated solvent pollution was in place following World War II and that TCE was recognized as a groundwater contaminant, an argument also advanced by Amter and Ross.[59] [60] Conventional wisdom holds that chlorinated solvents were not known to

55. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 106-110.

56. Roy F. Weston, "Some Fundamentals on Water Pollution for Industry," *Sewage Works Journal* 20, no. 4 (1948): 683.

57. Ronald J. Rychlak, "Common-Law Remedies for Environmental Wrongs: The Role of Private Nuisance Symposium on Environmental Law," *Mississippi Law Journal* 59, no. 3 (1989): 692.

58. Roy F. Weston, "Some Fundamentals on Water Pollution for Industry," *Sewage Works Journal* 20, no. 4 (1948): 685.

59. Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA*, 166-7.

60. Steven Amter and Benjamin Ross, "Was Contamination of Southern California Groundwater By Chlorinated Solvents Foreseen?," *Environmental Forensics* 2, no. 3 (September 2001): 179-184.

pollute groundwater until the late 1970s and early 1980s, which makes the position of Colten, Skinner, Amter, and Ross somewhat revisionist.[61]

These revisionist authors cite a 1949 study by Lyne and McLachlan as evidence that the hazard was known to scientists. Lyne and McLachlan's brief article, which included only one reference and was published in the "Notes" section of a British chemistry journal, described TCE contamination of two wells in the town of Reading. One of the wells became polluted when a nearby TCE tank burst, and the other was located near a pit used for TCE disposal.[62] In both instances, the culprit was Reading's aircraft industry, which produced thousands of planes during World War II.[63] Lyne and McLachlan noted a "slight odour of trichloroethylene" in water from the well near the disposal pit, suggesting a very high level of contamination. Testing bore this out, indicating approximately 18 parts per million (ppm) of TCE, or 18,000 parts per billion (ppb). The EPA's maximum contaminant level (MCL) for TCE in drinking water is 5 ppb. Yet, Lyne and McLachlan described the concentration of TCE in the well as "very low." This reflects the state of medical knowledge at the time (discussed in Chapter I) and the lack of any prior research on TCE's health effects in drinking water. Compared to the maximum allowable concentration of 200 ppm in air, it would be reasonable to characterize 18 ppm in water as "very low." Nonetheless, Lyne and McLachlan did note that the water was "said to cause stomach disorders, giddiness, etc."[64]

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61. Richard E. Jackson, "Chlorinated Solvents and the Historical Record: A Response to Amter and Ross," *Environmental Forensics* 4, no. 1 (March 2003): 3.

62. F. A. Lyne and T. McLachlan, "Notes," *The Analyst* 74, no. 882 (1949): 510.

63. Michael O. Rivett, Stanley Feenstra, and Lewis Clark, "Lyne and McLachlan (1949): Influence of the First Publication on Groundwater Contamination by Trichloroethene," 315-6.

64. F. A. Lyne and T. McLachlan, "Notes," *The Analyst* 74, no. 882 (1949): 510.

To support the argument that Lyne and McLachlan's research did not lead to a general awareness of TCE pollution in groundwater, Rivett et al. have conducted a retroactive literature review to determine the article's impact. Lyne and McLachlan's study was cited in abstract form by a few American chemistry and pollution reviews and compilations during the 1950s and early 1960s, but it was one article among hundreds in this context, and it never made a serious impact. There is no record of follow-up research into the chlorinated solvent contamination issue, by Lyne and McLachlan or any others.[65] Moreover, it does not appear Lyne and McLachlan's article brought government awareness to Reading's groundwater problem, as official documentation of TCE pollution in the area first appears in the 1980s. Lyne and McLachlan's research would not be cited again until the late 1990s, when it was unearthed by authors making historical claims about chlorinated solvents.[66]

When one considers the knowledge available to readers at the time, it is relatively unsurprising that Lyne and McLachlan's study was not widely circulated and received no follow-up. After all, stomach disorders and giddiness were not lethal illnesses, and contamination at circa 18,000 ppb would only occur in wells near large dump sites -- certainly not a widespread issue. Without an understanding that TCE was carcinogenic in low concentrations, its presence in groundwater would have seemed far less concerning to early observers.

In attempting to establish whether chlorinated solvents were known pollutants, authors have also debated whether statements directed at "solvents" in general were understood to implicate chlorinated solvents specifically. Amter and Ross cite bulletins which mention the

65. Michael O. Rivett, Stanley Feenstra, and Lewis Clark, "Lyne and McLachlan (1949): Influence of the First Publication on Groundwater Contamination by Trichloroethene," 315-6.

66. Michael O. Rivett, Stanley Feenstra, and Lewis Clark, "Lyne and McLachlan (1949): Influence of the First Publication on Groundwater Contamination by Trichloroethene," 317.

dangers of dumping organic solvents in surface water, un-lined pits, and wells.[67] None of these documents specifically mention chlorinated solvents like TCE, an objection Amter and Ross dismiss by noting that "organic solvents" would have been understood to include chlorinated solvents. However, as the remedial engineer Jackson notes, this argument is substantially weakened by the diversity of "organic solvents" as a class -- it is entirely possible these advisories were prompted by pollution from other types of organic solvents, such as hydrocarbon-based solvents, and the authors simply chose broad language.[68] Moreover, industry guidebooks and the American Insurance Association continued to list the dumping of solvents as an acceptable disposal method into the 1960s and early 1970s, suggesting the risks were not broadly appreciated despite the presence of a few warnings in the historical record.[69]

One reason chlorinated solvents were overlooked as groundwater pollutants was their volatility. A newspaper report from the late 1970s -- when the TCE pollution issue was beginning to be recognized -- encapsulates this misunderstanding perfectly, and is worth quoting at length:

> There was no biological or technical reason 10 years ago to be more than casual" in handling solvents, said Robert B. Taylor, director of water compliance at the [Connecticut] Department of Environmental Protection. "People who threw it in the ground just assumed it would evaporate." . . . Mott Metallurgical Co. president Lambert A. Mott said it "never dawned on us" that the small quantity of solvents used at the factory could ever end up in a public water supply.[70]

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67. Steven Amter and Benjamin Ross, "Was Contamination of Southern California Groundwater By Chlorinated Solvents Foreseen?," 181-3.

68. Richard E. Jackson, "Chlorinated Solvents and the Historical Record: A Response to Amter and Ross," 5.

69. Richard E. Jackson, "Chlorinated Solvents and the Historical Record: A Response to Amter and Ross," 4-5. Jackson makes an excellent point that the American Insurance Association has paid out substantial settlements stemming from improper TCE disposal. Presumably, if chlorinated solvents were broadly known to be groundwater contaminants, this group would not have given advice that later compelled its members to make substantial payouts.

70. Nancy Pappas, "Toxic Solvents in Public Water Supplies Cause Safety Dilemma," *Hartford Courant*, February 6, 1977, Newspapers.com, 6.

Since TCE is a volatile compound, many users assumed it would evaporate safely once poured onto the ground, especially in relatively small quantities. This erroneous assumption is found in American Society of Metals' disposal guidelines, which stipulated that sludges be poured on to dry ground so that solvents could be "allowed to evaporate."[71] Unfortunately, much of the TCE disposed using this method would not evaporate; instead, it would travel downwards through the soil. From the 1960s onwards, the US Geological Service (USGS) initiated research into the groundwater migration of various pollutants, including chlorinated pesticides. However, the USGS never studied the fate of chlorinated solvents, an oversight which allowed faulty assumptions to persist.[72]

In sum, multiple factors coincided to permit indiscriminate disposal of TCE before the 1970s. First, the US lacked a coherent federal regulatory framework to control the release of hazardous wastes or inform waste generators of best practices. Second, neither scientists nor industry were broadly aware that TCE would become a persistent contaminant of soil or groundwater when dumped onto land, due in part to its volatile characteristics. And third, because TCE's toxicity and carcinogenicity were not well-understood, there was little reason to suppose that its release into the environment would have severe effects on humans.

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71. Richard E. Jackson, "Chlorinated Solvents and the Historical Record: A Response to Amter and Ross," 4.

72. Richard E. Jackson, "Recognizing Emerging Environmental Problems: The Case of Chlorinated Solvents in Groundwater," 74-75.

Chapter III: Usage and Disposal of TCE at Military Bases

After World War II, American TCE usage continued to increase. By 1960, annual production reached 320 million pounds, more than quadrupling since 1944. Expanding US industrial capacity helped vapor degreasing eclipse dry cleaning as the solvent's most widespread application; by 1952, around 92% of TCE was purchased for vapor degreasing.[73] The DoD remained a prolific consumer of the chemical throughout the 1950s and 1960s, and the proliferation of military bases helped spread TCE to locales across the US. This chapter describes the activities and disposal procedures that created TCE contamination of soils and groundwater. Three installations will be examined as case studies: Hill Air Force Base, Fort Ord, and Camp Lejeune.

Case studies are useful because TCE usage and disposal practices were not regulated by the DoD and thus varied from base to base. Commanders could order TCE at their whim, either through the military's procurement systems or using private suppliers.[74] Wastes were handled in whatever fashion base leadership happened to see fit, and recordkeeping was highly inconsistent -- some facilities knew exactly where TCE was dumped, while others were surprised to find extensive pollution in general purpose landfills and other un-documented areas. Unfortunately, only a portion of the bases researched for this project can be discussed, but the examples chosen -- from the Air Force, Army, and Marines -- should give a sense of typical practices and idiosyncrasies.

73. Robert D Morrison and Brian Murphy, *Chlorinated Solvents: A Forensic Evaluation*, 121.

74. B. A. Donahue and M. B. Carmer, "Solvent 'Cradle-to-Grave' Management Guidelines for Use at Army Installations" (US Army Corps of Engineers, December 1983), 15.

Hill Air Force Base, a large facility 30 miles north of Salt Lake City in Utah, produced the most highly concentrated pollution of all three sites. This installation, which remains in service, was established in the 1930s as an Army airfield and grew substantially during World War II into an important maintenance depot. Following the war, it was subsumed by the newly-created US Air Force and remained a maintenance hub.[75]

At Hill AFB, vapor degreasing was used by various maintenance shops to clean oily aircraft parts, which involved large quantities of TCE. Waste TCE "sludge bottoms" from the degreasing units were dumped in an area known as "Chemical Disposal Pit No. 3" from 1967-1975. This site consisted of two un-lined trenches located near the edge of Hill AFB. "Large volumes" of waste -- recent estimates suggest around 50,000 gallons of solvents, mostly TCE -- were deposited there.[76] [77] Chemical waste slurries were burnt periodically in other pits on base, but this practice was halted during the late 1960s.[78] The base also had a generic chemical waste landfill that, in addition to drums of spent TCE, accepted methyl ethyl ketone (MEK) and methanol.[79]

The US Army had a presence at Hill, operating a railroad shop used to maintain rolling stock. One document states that the Army placed degreasing wastes from this facility in a tank and sold them to private contractors beginning in 1959. In addition, waste TCE was sent to an

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75. "Hill Air Force Base Heritage" (75th Air Base Wing History Office, May 2013), 1-16.

76. "Installation Restoration Program Phase 1: Records Search, Hill AFB, Utah" (Engineering Science, January 1982), "4-33." Documents produced by the military often have paginations such as "1-9," with "1" being the section number and "9" being a page within the section. I place such dashed paginations in quotation marks and use "to" in lieu of the normal dash indicating a page span.

77. "Final Treatment System Operations Report; Operable Unit 2, Hill AFB, Utah" (Radian International, December 1999), "1-3."

78. "Installation Restoration Program Phase 1: Records Search, Hill AFB, Utah," "4-24."

79. Tim Goering, "Monitoring Activity and Waste Disposal Review and Evaluation at Hill Air Force Base Ogden, Utah," October 2, 1984, 11.

Army depot from 1949-1964. The report does not explain why the practices of selling TCE and shipping TCE to the depot co-existed during the 1959-1964 period.[80] One might assume these were early hazardous waste disposal schemes hatched by forward-thinking military officials; indeed, Amter and Ross mention a chlorinated solvent reclamation program in Southern California as evidence that the substances' hazardous nature was recognized.[81] However, the Army ceased shipping its TCE to the depot in 1964 and began conducting burials in open pits, just like the Air Force. This suggests earlier recovery efforts did not stem from a TCE dumping prohibition but were a financially-motivated effort to have TCE recycled.[82] That chlorinated solvents could be reclaimed in a cost-effective fashion from certain types of waste is attested to by military documents.[83]

Another user of TCE was the Army's Fort Ord base in California. This installation was established in 1917 and served as an artillery target range before swelling to 50,000 troops during World War II. In 1957, Ft. Ord was assigned to Training and Doctrine Command and used for infantry training until 1974, when the facility regained a combat unit: the 7th Infantry Division.[84] While hosting the 7th Infantry Division, Ft. Ord was home to around 30,000 military personnel and their spouses.[85] The fort was closed in the 1990s by BRAC, but a small DoD contingent -- the Ord Military Community -- occupies a portion of the base's former extent.

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80. "Installation Restoration Program Phase 1: Records Search, Hill AFB, Utah," "4-10 to 4-11."

81. Steven Amter and Benjamin Ross, "Was Contamination of Southern California Groundwater By Chlorinated Solvents Foreseen?," 183.

82. "Installation Restoration Program Phase 1: Records Search, Hill AFB, Utah," "4-10 to 4-11."

83. B. A. Donahue and M. B. Carmer, "Solvent 'Cradle-to-Grave' Management Guidelines for Use at Army Installations" (US Army Corps of Engineers, December 1983), 34.

84. "Draft Site Investigation Report; Fort Ord and Fort Hunter Liggett, California" (EA Engineering, Science, and Technology, October 12, 1989), "1-5 to 1-6."

85. "Draft Site Investigation Report; Fort Ord and Fort Hunter Liggett, California," "1-1."

At Ft. Ord, documents indicate approximately 3,800 kg per year of waste solvents were generated during the mid-1980s. The base had phased out TCE by this time, but usage was likely similar when TCE was employed. Like the Air Force and Navy, the Army used solvents extensively in the upkeep of mechanical equipment. One Army document listed typical solvent applications as “degreasing operations, tank and locomotive maintenance, motor vehicle maintenance, heavy and light equipment maintenance, small and heavy arms maintenance, [and] helicopter washdown.” [86] Illustrating the frequency of solvent use in maintenance procedures, an excavator field manual included the word “solvent” 132 times across dozens of routine operations.[87]

One site of TCE contamination was the base’s landfill area, which consisted of a large, relatively-new facility and two smaller, older dumps immediately to the north. The newer landfill accepted household refuse and a small volume of industrial and sewage wastes. However, the base had no records whatsoever of the materials placed in the older landfills.[88] Evidently, these dumps had accepted a considerable quantity of TCE, as later testing would turn up groundwater pollution (albeit less severe than the other bases discussed here).[89]

A second TCE-contaminated site was the so-called “cannibalization yard,” where base personnel salvaged usable parts from broken machines. TCE was employed to clean the spares

86. B. A. Donahue and M. B. Carmer, “Solvent ‘Cradle-to-Grave’ Management Guidelines for Use at Army Installations,” 8-12.

87. “Operator and Organizational Maintenance Manual Crane-Shovel, Basic Unit, Crawler Mounted, 40 Ton, 2 Cu Yd, Diesel Driven (W/Harnischfeger Engine Model 687c-18-Es) (W/Caterpillar Engine Model D333ta) (Harnischfeger Model 855bg-2) Non-Winterized, Fsn 3810-542-3048 Winterized, Fsn 3810-542-3049 (Harnischfeger Model 855bg-31) Non-Winterized, Fsn 3810-786-5200” (US Army, March 14, 1969).

88. Nicholas Pogonchef and Christopher Smith, “Final Ford Ord Landfills Preliminary Hydrogeologic Investigation” (Harding Lawson Associates, April 1, 1990), 12-13.

89. Nicholas Pogonchef and Christopher Smith, “Final Ford Ord Landfills Preliminary Hydrogeologic Investigation,” 43-44.

extracted from the dirty, worn equipment condemned to disassembly. Assessment studies noted that soil in the cannibalization yard was oil-stained and that vegetation in the vicinity was "distressed" by toxic runoff.[90]

Camp Lejeune, a large Marine Corps facility on the coast of North Carolina, is undoubtedly the most infamous TCE-contaminated military installation. Lejeune was established during World War II and boasts numerous beaches and port facilities ideal for simulated landing exercises and other forms of amphibious training. The base remains operational and is home to the Second Marine Expeditionary Force and Marine Special Operations Command. The groundwater contamination at Lejeune is particularly noteworthy because the facility used on-site wells for its drinking water, resulting in human exposure. The eventual discovery of TCE in Lejeune's water will be addressed extensively in Chapter V.

At Lejeune, aircraft and ground vehicle maintenance were conducted on-base. The Hadnot Point Industrial Area (HPIA), a cluster of buildings including "maintenance shops, gas stations . . . warehouses, storage yards, and a dry cleaning facility" was a center of base activity and housed underground TCE storage tanks. The extent of TCE usage at the HPIA, primarily by mechanical shops, led to pollution via numerous routes, including "improper waste disposal, underground storage tank leakage, solvent spills, and sludge disposal."[91]

Personnel also engaged in suspect waste disposal practices at the "Rifle Range chemical dump." One document described the standard procedure: "As a need arose to dispose of material, it was taken to the site, a hole dug and the container of waste or other toxic material was placed

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90. "Draft Site Investigation Report; Fort Ord and Fort Hunter Liggett, California," "1-6 to 1-7."

91. "Final Interim Remedial Action Proposed Plan for the Shallow Aquifer at the Hadnot Point Industrial Area Operable Unit" (Baker Environmental, May 8, 1992), 3-5.

in it and covered with dirt."[92] Although exact records were "lost," TCE was known to be among the materials buried at this dump site. In one incident, 55-gallon drums and 5-gallon cans of various incompatible hazardous materials -- including TCE -- were buried together, resulting in an explosion and fire.[93]

This brief survey illustrates the haphazard nature of military solvent disposal. In retrospect, all these practices were clearly insufficient to protect soil and groundwater supplies from harmful contamination. Nonetheless, the military utilized generally accepted chlorinated solvent disposal methods, as described in Chapter II. That users of chlorinated solvents (including the DoD) should have more thoroughly researched the potential implications of their waste handling methods is a valid and widely agreed upon criticism. The military can be faulted for its careless adoption of poorly understood means of disposal, but there are no indications that its leadership anticipated the pollution.

92. "Initial Assessment Study of Marine Corps Base Camp Lejeune North Carolina" (Naval Energy and Environmental Support Activity, April 1983), "6-78."

93. "Initial Assessment Study of Marine Corps Base Camp Lejeune North Carolina," "2-11."

Chapter IV: Establishing the Scientific and Regulatory Framework

Chapters I to III explored how the contamination of military bases with TCE was permitted by a confluence of TCE's material characteristics and prevailing knowledge in the medical and waste disposal fields. The following chapters turn to regulation and remediation: how did TCE become recognized as a hazardous carcinogen, and what actors shaped the military's response at the aforementioned facilities? As this chapter will show, it was primarily researchers with the National Cancer Institute and employees with the National Institute for Occupational Safety and Health who established and publicized the initial findings of TCE carcinogenicity essential to later regulation and remedial action. The landmark environmental laws of the 1970s and early 1980s -- which have governed TCE detection and cleanup -- are another essential piece of the story. These acts were responses to activism and high-profile incidents such as Love Canal, illustrating that broader trends in popular environmentalism did help facilitate the cleanup of TCE, but at a more indirect level.

During World War II, the British scientists and doctors Hadfield, Hewer, and Chalmers conducted further research into TCE anesthesia. Their findings led to increased medical usage of the substance, especially in the UK, which helped contribute to further scrutiny of TCE's toxicological qualities.[94] By the early 1960s, a substantial body of research on TCE had been established -- one remarkably comprehensive literature review by the anesthesiologist Ray Defalque cited over 400 other papers, the majority of which focused specifically on TCE. Many were case studies and reports on various anesthesia methods, but some research into TCE metabolism had begun taking place as well. A great many animal studies had been carried out,

94. Ray J. Defalque, "Pharmacology and Toxicology of Trichloroethylene: A Critical Review of the World Literature," *Clinical Pharmacology & Therapeutics* 2, no. 5 (1961): 666.

with a focus on aspects of TCE more relevant to anesthetic use, such as capillary oozing and tachypnea.[95]

However, the insidious dangers of low-level chronic exposure had still not been recognized. Defalque's review did summarize some investigations of long-term toxicity, but these all focused on non-cancerous effects -- such as central nervous system degradation and anemia -- in those who were exposed to relatively high concentrations of TCE in an industrial context.[96] [97] The only mention of cancer was a sentence on the administration of TCE to cancer patients for pain relief.[98]

Based on an improved understanding of TCE's metabolism and advancements in research design, breakthroughs finally came in the 1970s. Without a doubt, the most impactful development was the National Cancer Institute (NCI) bioassay of TCE, which began in 1972 but was not published until 1976.[99] This research was part of an NCI program which aimed to screen several hundred chemicals for carcinogenicity.[100] The procedure was carried out by a contractor, Hazleton Laboratories, which followed guidelines developed by the NCI. Key methodological advancements included the long duration of the exposure -- 78 weeks -- and the use of 480 animal subjects, with dissections carried out in search of cancers.[101]

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95. Ray J. Defalque, "Pharmacology and Toxicology of Trichloroethylene: A Critical Review of the World Literature," 669-70.

96. Ray J. Defalque, "Pharmacology and Toxicology of Trichloroethylene: A Critical Review of the World Literature," 673-4.

97. Richard E. Jackson, "Recognizing Emerging Environmental Problems: The Case of Chlorinated Solvents in Groundwater," 61. During the 1950s and 1960s, researchers gained an increased understanding of TCE's non-carcinogenic toxicity to the nervous system and other organs.

98. Ray J. Defalque, "Pharmacology and Toxicology of Trichloroethylene: A Critical Review of the World Literature," 667.

99. "Carcinogenesis Bioassay of Trichloroethylene" (U.S. Department of Health, Education, and Welfare, February 1976), CAS No. 79-01-6, ii.

100. "Carcinogenesis Bioassay of Trichloroethylene," i-ii.

101. "Carcinogenesis Bioassay of Trichloroethylene," vii.

In explaining their decision to assess TCE, the authors of the report stated that, "In the late 1960s, scientists at the [NCI] noted that a group of halogenated compounds extensively used as solvents in industrial processes had not been tested for chronic toxicity."[102] Carbon tetrachloride is structurally similar to chlorinated solvents like TCE and was known to be carcinogenic at the time, so the NCI researchers were concerned by this gap in the literature.[103] Another researcher, Benjamin Van Duuren, speculated in 1975 that vinyl chloride may be carcinogenic based on the inferred production of toxic epoxides during metabolism.[104] From this, he extrapolated that TCE was also "likely to be carcinogenic," since the two chemicals are very similar in structure.[105] [106] Van Duuren's 1975 paper did not cite or otherwise mention the NCI report, and it appears he came to this conclusion independently.

Ultimately, the NCI's findings "clearly" indicated that TCE was a hepatocarcinogen in mice, with strong and statistically significant differences in liver cancer incidence between the control and test groups, providing the first experimental evidence of TCE carcinogenicity.[107] The study concluded that "the identification . . . of trichloroethylene as a carcinogen in animals serves as a warning of its possible carcinogenicity in humans."[108] In 1975, before the NCI study's publication, NIOSH publicized the findings in a "Current Intelligence Bulletin" on TCE:

> Preliminary evaluation of the carcinogenic activity of trichloroethylene in laboratory rodents by the National Cancer Institute indicates that this material is a potent liver carcinogen. Trichloroethylene is a significant commerical [sic] product with a wide variety of industrial uses. In light of the potential risks of human exposure in the work

102. "Carcinogenesis Bioassay of Trichloroethylene," 1.

103. "Carcinogenesis Bioassay of Trichloroethylene," 1.

104. B. L. Van Duuren, "On the Possible Mechanism of Carcinogenic Action of Vinyl Chloride," *Annals of the New York Academy of Sciences* 246 (January 31, 1975): 258.

105. Vinyl chloride is a decomposition product of TCE.

106. B. L. Van Duuren, "On the Possible Mechanism of Carcinogenic Action of Vinyl Chloride," 263-5.

107. "Carcinogenesis Bioassay of Trichloroethylene," 41, 44.

108. "Carcinogenesis Bioassay of Trichloroethylene," 47.

> environment, the National Institute for Occupational Safety and Health (NIOSH) is alerting the occupational health community to these findings. Additional animal studies as well as detailed epidemiologic investigations are anticipated.[109]

After the NCI's study and amidst a broader chlorinated solvent reckoning, the pace of research into TCE accelerated considerably. Within three years of the intelligence bulletin, NIOSH published a "Special Occupational Hazard Review with Control Recommendations" on TCE. Special Occupational Hazard Reviews were used by NIOSH to "analyze and document, from a health standpoint, the problems associated with a given industrial chemical" and disseminate this information to key stakeholders including trade associations, industry, unions, and scientists.[110] This document again focused on the NCI's study, but cited additional research conducted with cell cultures. The review also stated that no conclusive evidence of TCE carcinogenicity in humans had been found, despite the completion of some European occupational studies.[111] Ultimately, the authors concluded that TCE was most likely carcinogenic in humans but was "not considered to be a potent carcinogen."[112] A series of recommendations were made, including a proposal to reduce the permissible airborne concentration from 100 ppm to 25 ppm.[113]

Research on TCE continues into the present, but these initial studies were sufficient to establish the solvent as a carcinogen in the view of the public and regulatory agencies. In addition, California began to regulate TCE as an air pollutant in 1966, and the federal

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109. "Current Intelligence Bulletin 2 - Trichloroethylene (TCE)" (National Institute for Occupational Safety and Health, June 6, 1975).

110. P. Page Norbert and Jack L. Arthur, "Special Occupational Hazard Review of Trichloroethylene," iii.

111. P. Page Norbert and Jack L. Arthur, "Special Occupational Hazard Review of Trichloroethylene," v.

112. P. Page Norbert and Jack L. Arthur, "Special Occupational Hazard Review of Trichloroethylene," v.

113. P. Page Norbert and Jack L. Arthur, "Special Occupational Hazard Review of Trichloroethylene," iv.

government followed in 1970.[114] A combination of increasing regulatory burdens and revelations of carcinogenicity led to a sharp decrease in TCE's usage as a general-purpose solvent; the military bases covered in Chapter III all discontinued TCE use during the 1970s. However, the solvent remains popular for certain niche applications where inflammability and maximum solvent efficacy are desired.[115]

In addition to recognizing the chemical's carcinogenicity, addressing TCE contamination would require a hazardous waste regulation and remediation framework. The remainder of this chapter will explore how such a regime arose, providing a brief summary of events that have been discussed extensively in other works and emphasizing developments most pertinent to TCE contamination of defense installations.

In the period after World War II, America's population expanded rapidly, and there were commensurate increases in the generation of various pollutants. Moreover, continuing advances in synthetic chemistry helped produce a litany of novel toxic chemicals. Pesticides like DDT, which was lauded as a modern wonder chemical for its role combating malaria in World War II, became commercially available and saw liberal usage.[116] However, Americans soon began to realize that their new chemicals had some undesirable effects. Rachel Carson was not the first to raise concerns surrounding DDT, but her pivotal 1962 book *Silent Spring* prompted an unprecedented public backlash against the chemical, culminating in a lobbying campaign

114. Richard E. Doherty, "History of TCE," in *Trichloroethylene: Toxicity and Health Risks*, ed. Kathleen M. Gilbert and Sarah J. Blossom, Molecular and Integrative Toxicology (London: Springer, 2014), 1-14.

115. Maria Hegstad, "Draft EPA Ban On TCE Uses Prompts Competing Claims Over Plan's Merits," *Inside EPA's Risk Policy Report* 24, no. 12 (2017): 13-14.

116. Elena Conis, "Polio, DDT, and Disease Risk in the United States after World War II," *Environmental History* 22, no. 4 (October 1, 2017): 698-9.

directed at the USDA, PHS, and FDA.[117] Throughout the 1960s, environmental activism gained steam; the Sierra Club, the Audubon Society, and the National Parks & Conservation Association each saw their membership more than triple from 1960 to 1969, and significant legislative victories were achieved, including the 1963 Clean Air Act and the 1969 National Environmental Policy Act. The latter was signed into law by Nixon on January 1, 1970, establishing the Environmental Protection Agency.[118]

The 1970s kicked off with Earth Day, a monumental show of grassroots support for environmentalism which featured demonstrations across the country.[119] Throughout the decade, a majority of national poll respondents supported increased environmental regulation and spending, and membership in environmental advocacy organizations continued to expand at a rapid pace.[120] These groups focused their newfound resources on achieving legislative reform -- the number of full-time environmental lobbyists in DC grew from two to forty between 1969 and 1975.[121] Broadly speaking, environmentalists were successful in their efforts, and a raft of new laws were passed during the 1970s. The 1974 Safe Drinking Water Act (SDWA), which established EPA regulation of water utilities nationwide, and the 1976 Resource Conservation and Recovery Act (RCRA), which gave the EPA jurisdiction over hazardous wastes, are two particularly relevant examples. In 1980, the EPA promulgated an RCRA rule establishing the

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117. Brian Black and Donna L. Lybecker, *Great Debates in American Environmental History*, electronic resource (Westport, Conn: Greenwood Press, 2008), 301.

118. Riley E Dunlap and Angela G Mertig, *American Environmentalism: The U.S. Environmental Movement, 1970-1990* (New York: Taylor & Francis, 2013), 13.

119. Riley E Dunlap and Angela G Mertig, *American Environmentalism: The U.S. Environmental Movement, 1970-1990*, 94.

120. Riley E Dunlap and Angela G Mertig, *American Environmentalism: The U.S. Environmental Movement, 1970-1990*, 98.

121. Riley E Dunlap and Angela G Mertig, *American Environmentalism: The U.S. Environmental Movement, 1970-1990*, 20.

modern “cradle to grave” approach to hazardous waste management, and TCE was among the substances regulated.[122]

For all the advances made during the 1970s, it was the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) that proved instrumental in facilitating TCE cleanup at defense installations. CERCLA established mechanisms for adding sites heavily polluted with hazardous wastes to the National Priorities List (NPL), whereupon the EPA would have jurisdiction over the contaminated area and subsequent cleanup efforts. Remediation under CERCLA is funded by the polluters whenever possible, although the diffusion of responsibility among multiple parties and the prospect of litigation can substantially complicate the recovery of funds.[123] In cases where adequate resources cannot be obtained from private entities, the “Superfund” -- a trust containing government revenues dedicated to CERCLA purposes -- is used.[124] DoD cleanups, however, are funded by a specific military environmental account, as will be discussed in Chapter VI.

The toxic waste historiography exhibits a strong emphasis on citizen activism, and not without good reason. In addition to lobbying by national environmental groups, localized hazardous waste disasters -- including the infamous Love Canal affair and lesser-known catastrophes at the Stringfellow Acid Pits and other sites -- spawned well-organized grassroots opposition movements which earned substantial news coverage. In the *Columbia Guide to American Environmental History*, Merchant’s section on the anti-toxics movement tells the Love

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122. “Monday, May 19, 1980,” *Federal Register* 45, no. 98 (May 19, 1980): 33127.

123. In addition, the polluting entity often becomes defunct through bankruptcy or the death of its main proprietor(s). When the polluter is a small business like a dry cleaner or a salvage yard, it may simply lack the requisite funds to address the site. Cost recovery is most feasible when the culprits are large, profitable corporations.

124. J. Alfredo Gomez et al., “Trends in Federal Funding and Cleanup of EPA’s Nonfederal National Priorities List Sites” (Government Accountability Office, September 2015), 7.

Canal story with a focus on the role of Lois Gibbs and other local activists, who helped pressure the government to seriously investigate the dangers of Love Canal's wastes and buy out the affected residents.[125] Gibbs' association of concerned residents has since become something of an archetype for resistance to hazardous waste contamination and polluting industries.

Around the same time, a notable episode of TCE-related judicial activism occurred in Woburn, Massachusetts, where local industry polluted an aquifer used by two municipal wells. The TCE contamination was discovered incidentally by a state environmental official who ordered tests after chemical drums were illegally dumped near the wells.[126] Subsequently, a cluster of childhood leukemias in the area prompted a lawsuit against the polluters, with the young, ambitious attorney Jan Schlichtmann leading the effort. The groundbreaking case attracted media coverage from the outset, but ultimately yielded a disappointing settlement of $8 million.[127] However, the groundwork laid by Schlichtmann helped the EPA win a settlement obligating the polluters to fund the $69 million dollar cleanup.[128] The saga eventually spawned a nonfiction bestseller -- *A Civil Action* -- which was adapted into an eponymous movie starring John Travolta. The book and movie depicted Schlichtmann and the Woburn residents as crusaders -- albeit flawed ones, in the former's case -- against nefarious corporations and a byzantine legal system.

The prominence of such narratives belies the fact that many cases of toxic contamination attract no such public activism or scrutiny. The remainder of this essay will examine how TCE

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125. Carolyn Merchant, *The Columbia Guide to American Environmental History*, 185.

126. Jonathan Harr, *A Civil Action*, Reprint edition (Random House, 1995), 36-37.

127. Jonathan Harr, *A Civil Action*, 81.

128. Jonathan Harr, *A Civil Action*, 490-1.

contamination was uncovered and remediated at DoD installations, seeking to highlight the perhaps unglamorous investigatory and oversight role played by government agencies.

Chapter V: Drinking Water Regulations and the Failure at Camp Lejeune

> Surface pollution is usually open and notorious, whereas underground contamination is hidden, insidious, and difficult to get at.
>
> - S. Wilson at the US Public Health Service's 1961 Symposium on Ground Water Contamination[129]

Whereas many authors and activists have emphasized the military's negligence at Camp Lejeune, I focus on the parallel development of an EPA maximum contaminant level regulation for TCE. Notably, this regulation did not enter force until well after the military shuttered the affected wells itself, which suggests that belated rulemaking contributed to the exposures. More broadly, the saga demonstrates how difficult-to-detect groundwater contaminants like TCE create a reliance on government agencies to uncover and address pollution.

In the wells examined by Lyne and McLachlan, TCE contamination was perceptible by smell due to its extremity. But, in the vast majority of cases, concentrations were far lower and the presence of TCE could only be discovered using laboratory tests.[130] This created a chicken-and-egg problem; nobody would conduct tests for TCE unless they had a reason to suspect its presence, and nobody had a reason to suspect its presence because nobody had conducted tests. It was not until the 1970s that a confluence of factors helped raise awareness of the issue.

In 1973, the EPA published a study on New Orleans' drinking water, which included alarming findings of pollution and inspired follow-up research by non-agency scientists. These

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129. S. Wilson in "Ground Water Contamination: Proceedings of the 1961 Symposium," 131.

130. John C. Petura, "Trichloroethylene and Methyl Chloroform in Groundwater: A Problem Assessment," *Journal (American Water Works Association)* 73, no. 4 (1981): 205.

included the University of New Orleans researchers Dowty, Carlisle, and Laseter, who published a series of papers in 1975 on chlorinated organics in the Mississippi river. Crucially, their work employed cutting-edge gas chromatography to determine the organic contaminants, which allowed the researchers to identify TCE without ordering a specific analytic test for the chemical.[131] Sure enough, TCE was present in the Mississippi River's water at the highest relative concentration of any substance identified.[132]

On December 29, 1975, the EPA promulgated the National Interim Primary Drinking Water Standard, the first regulation issued under Safe Drinking Water Act authority. It was a monumental achievement, incorporating thousands of public comments and regulating a variety of harmful substances through the usage of maximum contaminant levels (MCLs), which are legally enforceable limits on harmful substances in drinking water. The MCLs in this regulation reflected the state of water pollution knowledge and medical research at the time. First, the rule targeted a variety of inorganic compounds (such as lead, selenium, and arsenic) which had been recognized as industrial groundwater pollutants for decades. The rule also addressed organic pesticides and herbicides, including endrin and fenoprop -- the sorts of highly toxic chemicals discussed extensively in Carson's *Silent Spring*. The last type of contaminants regulated were disease-causing microorganisms.[133]

Unsurprisingly, TCE and other chlorinated solvents did not receive MCLs in this standard, as research into their carcinogenicity and their presence in the environment was just

131. Richard E. Jackson, "Recognizing Emerging Environmental Problems: The Case of Chlorinated Solvents in Groundwater," *Technology and Culture* 45, no. 1 (2004): 66.

132. Betty J. Dowty, Douglas R. Carlisle, and John L. Laseter, "New Orleans Drinking Water Sources Tested by Gas Chromatography-Mass Spectrometry. Occurrence and Origin of Aromatics and Halogenated Aliphatic Hydrocarbons," *Environmental Science & Technology* 9, no. 8 (August 1, 1975): 763.

133. "Wednesday, December 24, 1975," *Federal Register* 40, no. 248 (December 24, 1975): 59566-70.

beginning. But, tucked into Subpart E of the rule was a section titled "Special Monitoring Regulations for Organic Chemicals." This contained "sampling, monitoring, and other testing requirements" intended to provide the EPA with initial data on the prevalence and concentration of various organic chemicals, including TCE, by sampling around 100 water systems nationwide.[134] No justification was provided for including TCE specifically, but the rule noted that chemicals "considered to be liver toxins and/or potential carcinogens" were singled out, and TCE certainly fit this description.[135] It seems the NIOSH intelligence bulletin on TCE carcinogenicity -- released just prior to this regulation -- likely piqued the EPA's interest, especially given the findings of Dowty et al.

The study established by the Interim Drinking Water Standard was known as the National Organics Monitoring Survey (NOMS) and ran from 1976-1977. Of the water systems included, less than a quarter tested positive for TCE. Among those which did contain some TCE, all but one were below 5 ppb. The only samples exceeding 5 ppb were from Des Moines, Iowa. Testing there discovered 32 ppb; 49 ppb; and 15 and 14 ppb during phases I, II, and III respectively.[136]

Because NOMS was the first nationwide survey of organic chemicals in drinking water, many local news outlets ran stories on the discovery of novel chemicals like TCE in their cities' water systems. This coverage illustrates just how little information was available in the mid-1970s regarding the health effects of TCE contamination. None of the reporters offered descriptions of the severity of contamination, such as "low" or "high." Tampa's water had .19 ppb of TCE in one sample, a low and relatively unremarkable finding by modern standards. Even so, a local reporter wrote, "two known carcinogens . . . -- chloroform and trichloroethylene --

134. "Wednesday, December 24, 1975," 59587.

135. "Wednesday, December 24, 1975," 59588.

136. "The National Organic Monitoring Survey," 44.

[were discovered] in Tampa's drinking water," with no qualitative description of the TCE concentration.[137] The city's water resources coordinator said that he was not familiar with the chemicals described in the report, but since they were unregulated, the city's water was perfectly safe.[138] In fact, chloroform levels in Tampa's water exceeded the proposed MCL by three times. The coordinator's assertion that unregulated substances were harmless reflected the prevailing compliance-oriented approach to water safety, one in which meeting legal obligations was the primary concern. Perhaps this water administrator genuinely believed that existing EPA and state regulations encompassed all dangerous chemicals that might be in water, but this was certainly not the case at the time. In Des Moines, where the NOMS TCE concentration was highest, newspapers picked up on the survey's findings as well. Maurice King, the general manager of the city's water works, "quoted EPA officials as saying no techniques exist[ed] to identify a safe or unsafe level" of TCE. King stated that the 32 ppb result was "very infinitesimal" and should not pose a danger.[139] It seems that King was, in the absence of regulations or strong signals from environmental authorities, relying on his own judgement of contaminant levels.

Around the same time, some local environmental departments were beginning to act on TCE pollution. In 1977, Pennsylvania's Department of Environmental Resources told 35 families to cease using their well water because it contained 35,000 ppb of TCE. The reason for initial testing of this well was not stated, but such extreme contamination was likely offensive to the senses. Intriguingly, a state official remarked that "any [TCE] in the water would be dangerous" when interviewed about the finding. This contrasts strongly with the aforementioned

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137. Sara Schwieder, "Cancer-Causing Agents Found in City Water," *The Tampa Times*, November 8, 1976, 1.

138. Sara Schwieder, "Cancer-Causing Agents Found in City Water," 1.

139. Diane Graham, "EPA Questions Quality of D.M.'s Drinking Water," *Des Moines Register*, January 26, 1978, 1.

statements by other utility officials, highlighting the discrepancies in water administrators' views of TCE safety.[140]

The EPA released its own assessment of TCE's health effects in drinking water two years after the NOMS was published. This report included two separate analyses. First was a "Suggested No Adverse Response Level" (SNARL), calculated to be protective against non-carcinogenic effects such as hepatotoxicity. The one-day and ten-day figures for the SNARL were 2,000 ppb and 200 ppb, respectively, and the long-term SNARL was 75 ppb.[141] Second, the EPA provided a rough assessment of TCE's carcinogenicity in water based on research by the National Academy of Science. The EPA concluded that 4.5 ppb and 45 ppb would lead to 1 in 1,000,000 and 1 in 100,00 excess cancers, respectively. The EPA typically established its regulatory thresholds somewhere within this range.[142] As such, the report implicitly suggested that 45 ppb should be the upper limit of sustained contamination in drinking water. However, these figures were not MCLs; they had no legal force and mandated no action when exceeded.

Though TCE would not find its way into regulations for almost a decade, another class of organic chemical -- trihalomethanes -- were thoroughly incriminated by the EPA's research and were subjected to MCLs in 1979. As a result, total trihalomethane (TTHM) testing became mandatory for water systems serving more than 10,000 users. At this point, drinking water regulations and Lejeune's TCE contamination finally begin to intersect.

Some DoD installations produced their own water, often using wells. Camp Lejeune was one such facility -- its tens of thousands of residents were served by aquifers below the base. In

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140. Eileen Canzian, "DER Finds No Contamination of Ironton School Water," *The Morning Call*, April 14, 1977, 12.

141. "SNARL for Trichloroethylene" (EPA, 1979), 3-4.

142. "SNARL for Trichloroethylene," 5.

total, Lejeune had eight water systems, each serving a separate resident population.[143] Though TTHM regulations would not enter force until 1982, testing was initiated in 1980. According to EPA regulations, TTHM tests were only required for systems with over 10,000 users. Notably, Lejeune only evaluated the two water systems which exceeded this threshold, indicative of a compliance-oriented approach to meeting water quality regulations.[144] One was the Hadnot Point water system, which was contaminated by the TCE disposal and handling practices discussed in Chapter II.

What occurred next was a series of missteps that have been closely scrutinized ever since. The TTHM samples were analyzed by a US Army Environmental Hygiene Agency laboratory, which reported its findings to LANTDIV, the Atlantic division of the Naval Facilities Engineering Command. At the bottom of a TTHM result form dated October 1980, the Army scientist wrote, "Water is highly contaminated with low molecular weight halogenated hydrocarbons. Strong interference in the region of $CHCl_2Br$."[145] Two months later, the second TTHM surveillance result was sent, with a note stating, "Heavy organic interference at $CHCl_2Br$. You need to analyze for chlorinated organics by GC/MS [gas chromatography/mass spectrometry]."[146] One month later, another plea: "You need to analyze for chlorinated organics

143. "Drinking Water Fact Finding Panel Report for Camp Lejeune" (US Marine Corps, 2004), 11.

144. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 29.

145. "TTHM Surveillance Report Form Camp Lejeune -- Hadnot Point, Collected 10/21/1980" (US Army Environmental Hygiene Agency, 1980).

146. "TTHM Surveillance Report Form Camp Lejeune -- Hadnot Point, Collected 12/18/1980" (US Army Environmental Hygiene Agency, 1980).

by GC/MS."[147] And finally, "Water highly contaminated with other chlorinated hydrocarbons (solvents)!"[148]

The Navy's fact-finding commission on Lejeune's water contamination has since concluded, "It is likely that someone at LANTDIV reviewed [the TTHM result sheets] but did not act."[149] Efforts to determine who exactly would have read and interpreted the documents have proven unsuccessful, and LANTDIV did not mention the interference in the TTHM findings report sent to Lejeune staff.[150] Since no VOC regulations existed at the time, the presence of chlorinated solvents was of lesser relevance to LANTDIV's main objective: ensuring base utilities were not shut down for non-compliance. Correspondingly, LANTDIV employees could ignore the written protestations of the Army scientist without serious repercussions.

In 1982, Camp Lejeune contracted Grainger Laboratories, a private company in North Carolina, to conduct further TTHM analysis. Unsurprisingly, Grainger also noticed chlorinated solvent interference when analyzing the samples. Because there was a direct relationship between Grainger and Lejeune personnel, a company scientist called the base and described the issue to Ms. Betz, a civilian chemist with the installation's environmental division. Ms. Betz met with base leadership shortly after receiving word of the interference but did not mention the finding, as the meeting was focused on TTHM compliance.[151] After noticing continued interference, Grainger tested for TCE and PCE (another solvent) on its own dime, and scientists

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147. "TTHM Surveillance Report Form Camp Lejeune -- Hadnot Point, Collected 1/29/1981" (US Army Environmental Hygiene Agency, 1981).

148. "TTHM Surveillance Report Form Camp Lejeune -- Hadnot Point, Collected 2/26/1981" (US Army Environmental Hygiene Agency, 1981).

149. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 31.

150. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 31.

151. Mike Magner, *A Trust Betrayed: The Untold Story of Camp Lejeune and the Poisoning of Generations of Marines and Their Families* (Da Capo Press, 2014), 50.

from the company discussed the findings with Ms. Betz.[152] However, numerous wells were rotated at Hadnot Point, and only some were severely contaminated. As a result, the extent of TCE contamination in the water varied drastically, and the test results were highly inconsistent, with findings of 19, 21, and 1,400 ppb. Notably, the first two samples were taken on the same date, whereas the 1,400 ppb sample was gathered two months prior.[153] Still convinced that the base had a chlorinated solvent problem, a Grainger scientist named Mike Hargett visited Lejeune and spoke with a lieutenant colonel, who brushed aside his concerns with an idle promise to investigate the issue.[154]

Unfortunately, the base's environmental division concluded that the 1,400 ppb sample was anomalous and assumed the true average was around 20 ppb. Environmental personnel reviewed the SNARL report and noted that 20 ppb was within the acceptable range for both toxic and carcinogenic effects, so they decided the water was safe to drink.[155] Recent interviews and testimony from those involved suggest the Lejeune water utility had the same compliance-oriented approach as many civilian utility administrators, with little desire to investigate contaminants not subject to an MCL. Ms. Betz has since described Lejeune's water lab and environmental division as over-taxed and under-resourced, which limited their ability to understand the issue and their inclination to further pursue it.[156]

Ultimately, it was not SDWA testing that definitively established the severe contamination levels at Hadnot Point but rather an environmental investigation. Lejeune was not

152. Michael C. Hargett, "Testimony of Michael C. Hargett for the US House of Representatives Committee on Science and Technology," § Committee on Science and Technology (2010), 3-4.

153. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 41.

154. Michael C. Hargett, "Testimony of Michael C. Hargett for the US House of Representatives Committee on Science and Technology," § Committee on Science and Technology (2010), 4.

155. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 33-35.

156. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 42.

yet listed on the NPL, but the Navy had begun surveying bases for contamination as part of its Navy Assessment and Control of Installation Pollutants (NACIP) program, which roughly followed CERCLA guidelines. Initial studies identified a number of concerning sites, including the rifle range chemical dump and the Hadnot Point Industrial Area (HPIA), both discussed in Chapter II. As part of their follow-up investigation, Navy contractors sampled drinking wells near the HPIA to determine whether the suspected pollutants had reached the groundwater.[157]

It was these samples, taken directly from individual wells, that definitively identified severe TCE contamination at Hadnot Point. The highest concentration detected in this first batch of tests was 1,600 ppb, similar to the result dismissed during the TTHM saga. This time, the findings could not be overlooked -- LANTDIV phoned the head of Lejeune's NACIP program, Robert Alexander, who informed base leadership.[158] After this conversation, Alexander took wells 601 and 608 offline due to TCE, and well 602 was shut down for high levels of benzene. The findings prompted NACIP investigators to order tests of all the other Hadnot Point wells. These indicated that wells 634 and 637, and 651 were also contaminated, the latter with 18,900 ppb of TCE. Well 651 also exhibited high levels of PCE and DCE, two other chlorinated chemicals.[159] In addition to the issues at Hadnot Point, the water system for the base's "Tarawa Terrace" area was found to be heavily contaminated by PCE from an off-base dry cleaner.

In the decades since, Lejeune's environmental issues have been scrutinized heavily, with allegations of a cover-up or gross negligence on behalf of the water system's operators. Undoubtedly, the military bears responsibility for its lack of initiative in the face of mounting

157. "Chronology of Identification of Potential Water Contamination Sources MCB Camp Lejeune, NC" (US Navy, February 26, 1985), 2.

158. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 36.

159. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 67.

evidence that Lejeune's wells were contaminated. However, it is noteworthy that Lejeune's water never violated drinking water regulations, and the Marines' carelessness was thus fully legal. In fact, the TCE MCL would not enter into force until roughly five years after the wells at Hadnot Point were taken offline.

The historical record indicates that water utility operators were careful about meeting federal MCLs and state regulations but generally ignored unregulated contaminants and were not interested in conducting tests perceived to be unnecessary. The military's Lejeune investigation panel, which included experienced waterworks professionals, concluded that "the water supply industry, by and large . . . did not monitor or treat for unregulated compounds [like TCE]" in the early 1980s.[160] Similarly, Grainger scientist Hargett described the base's lack of action as "conventional water utility operations" in recent congressional testimony.[161]

This begs the question: why was there no MCL until 1989? As early as 1980, TCE was being considered for an MCL.[162] In 1982, the EPA issued a request for public commentary on the prospect of VOC regulations, including TCE. At this point, the agency was not wedded to MCLs and wished to explore all avenues.[163] After three years of gathering comments and continued surveying and research, proposed MCLs were circulated in 1985. Finally, in 1987, the MCL for TCE was established at 5 ppb, in line with the proposed MCL and earlier carcinogenicity estimates.[164] However, there was a two-year grace period between the MCL's promulgation and its entry into force in 1989.

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160. "Drinking Water Fact Finding Panel Report for Camp Lejeune," 19.

161. Michael C. Hargett, "Testimony of Michael C. Hargett for the US House of Representatives Committee on Science and Technology," Committee on Science and Technology (2010), 5.

162. William A. Coniglio, Kittibel Miller, and Duncan MacKeever, "The Occurrence of Volatile Organics in Drinking Water" (EPA: Exposure Assessment Project, March 6, 1980), 4, 48.

163. "Thursday, March 4, 1982," *Federal Register* 47, no. 43 (March 4, 1982): 9352-3.

164. "Wednesday, October 28, 1987," *Federal Register* 47, no. 43 (October 28, 1987): 9353.

The lack of apparent TCE contamination in the initial drinking water surveys almost certainly contributed to this sluggishness. An account of the SDWA's early years, written by high-ranking former EPA employees, notes that "standard-setting activities had to begin with national monitoring surveys" due to a lack of reliable nationwide data on water contamination.[165] To any rational observer, NOMS would have suggested that a TCE MCL was not of pressing importance. Even in Des Moines, the contamination level fell within the implicitly permissible concentration outlined in the EPA's SNARL carcinogenicity analysis. Apparently, NOMS failed to detect more extensive TCE contamination in part because it focused on utilities which used surface water sources rather than groundwater.[166] Surface water, though testing positive for TCE at similar rates to groundwater, typically had lower concentrations -- a logical phenomenon given that TCE evaporates quickly when exposed to air.[167] Of course, the EPA knew that TCE was an issue in some wells because local authorities reported TCE at thousands of ppb or more. But the EPA's guidelines dictated that contamination had to occur in a "sufficient number of locations" for regulations to be enacted.[168] Given the inconclusive findings of the late 1970s, the agency sought to investigate the issue further. This required additional data gathering, including the Community Water System Surveys, the 1982 Groundwater Surveillance Survey, and reviews of state testing results.[169] It was only after these efforts that the EPA issued its request for commentary on prospective VOC regulations in 1982.

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165. Victor J. Kimm et al., "The Safe Drinking Water Act: The First 10 Years," *Journal (American Water Works Association)* 106, no. 8 (2014): 87.

166. Victor J. Kimm et al., "The Safe Drinking Water Act: The First 10 Years," *Journal (American Water Works Association)* 106, no. 8 (2014): 89.

167. O. Thomas Love et al., "Treatment of Volatile Organic Compounds in Drinking Water" (Environmental Protection Agency, May 1983), 2.

168. "Drinking Water Research Strategy" (Environmental Protection Agency, March 1979), 4.

169. William A. Coniglio, Kittibel Miller, and Duncan MacKeever, "The Occurrence of Volatile Organics in Drinking Water" (EPA: Exposure Assessment Project, March 6, 1980), 26.

Moreover, the EPA faced a challenging situation in which potentially life-saving regulations were balanced against financial and feasibility concerns. After all, water is the lifeblood of human activity, and excessively stringent rules could shutter utilities and drastically increase prices. On these grounds, water industry officials lodged strong opposition to certain EPA initiatives. For instance, a proposal to require granular activated carbon filtration alongside the TTHM rules was scuttled after intense backlash.[170] Testing for TCE and other chlorinated solvents would have raised the costs of compliance, even for the majority of systems with no contamination. To ensure the water industry could voice its concerns, the EPA conducted lengthy comment periods, extensive surveys, and other time-consuming activities prior to rulemaking. These mechanisms certainly increased the transparency and feasibility of regulations, but Lejeune's contamination hints at the downsides of this meticulous approach. Whether or not the EPA's VOC regulation process was the "correct" one is a complicated question, one far beyond the scope of this paper. But it does seem that an earlier TCE MCL could have prevented tens of thousands of exposures at Lejeune.

Notably absent from this saga are the voices of base residents, who were unwittingly exposed until federal investigators stumbled into the contamination. In this respect, the episode at Lejeune's Hadnot Point stands in sharp contrast with Love Canal and other instances of grassroots resistance to contamination. Whereas Love Canal residents were acutely aware of the chemicals in their backyards -- they could see the exposed drums and smell the oppressive odors -- the drinking water contamination at Hadnot Point was not detectable to base inhabitants, who thus possessed no real agency over their own exposure.

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170. Victor J. Kimm et al., "The Safe Drinking Water Act: The First 10 Years," *Journal (American Water Works Association)* 106, no. 8 (2014): 90-91.

Some pollutants, such as oils and fuels, tend to leave stains or discoloration, providing a visual indicator of their presence. Many hazardous landfills accepted mixed industrial refuse, including some visible wastes like oily sludges and chemical drums. But TCE contamination is not visible, is not detectable by scent or taste in moderate quantities, and often occurs independently of known landfills or dump sites. Moreover, TCE does not rapidly produce injury or death in organisms exposed; instead, its carcinogenic mechanisms act slowly but steadily.[171] As a result, expensive test instruments and procedures are required to definitively evaluate whether dangerous levels of solvent are present, leaving citizens reliant on the state. The Lejeune episode is but one of many instances where pollution remained undetected (and thus un-protested) until a government agency happened to order the necessary procedures. At the Navy's Treasure Island facility, for example, decades-old radioactive materials with innocuous appearances -- including buttons and scraps of metal -- littered the soil until the early 2000s, when environmental contractors swept the island for radiation.[172] In response to hazards of this nature, a proactive approach is necessary. Rather than waiting for complaints and pushback, regulators must determine likely sites of contamination and conduct the necessary assessments. Anticipating a problem is more difficult than reacting to complaints, which makes chemicals like TCE especially challenging. Luckily, the Navy's proactive NACIP program filled the gap left by slow EPA rulemaking, but an earlier MCL could have nonetheless prevented exposures at Lejeune.

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171. As discussed, TCE can be lethal, but the exposure levels necessary for perceptible acute health effects only occur in an industrial or medical setting. Concentrations present in the soil, water, and ambient air are almost never high enough to produce readily identifiable illness, although higher rates of cancer, miscarriage, and birth defects may be detectable in a large population over time.

172. Robin Respaut Levinson Reade, "Special Report: The Toxic Legacy of a California Naval Base," *Reuters*, January 31, 2019.

Chapter VI: DoD TCE Remediation and Regulatory Oversight

> A barber, a baker, a candlestick maker, they don't have to know pollution. You can't ask them [what they] think [about remediation]. They don't think in those terms. They have no cause to think in those terms. They'd like to think they're safe.
>
> - Brent Poll, leader of South Weber Community Coalition at Hill AFB[173]

This chapter aims to show that -- by and large -- the DoD, the EPA, and state regulatory agencies have driven TCE remediation at military bases, an intriguing contrast with the toxics historiography's emphasis on citizen protest and oversight. The relationship between the DoD and the EPA under CERCLA was, and remains, somewhat convoluted. In addition to CERCLA itself, the DoD's NPL cleanups are governed by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and by the Superfund Amendment and Reauthorization Act (SARA) of 1986. Pursuant to SARA, the DoD is required to conduct preliminary investigations of all facilities that have interacted with hazardous wastes, which includes virtually all major bases.[174] Many such assessments were executed before the SARA mandate by the Navy's NACIP and the Army and Air Force's Installation Restoration Programs (IRPs).

Once preliminary studies are complete, the EPA reviews the findings to determine whether bases should be added to the NPL.[175] Per NCP and SARA, the DoD is the lead agency for CERCLA implementation, with the responsibility to fund and execute the necessary activities, usually by contracting private engineering firms. Once the CERCLA process reaches

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173. "Draft Fifth Five-Year Review Report: Operable Units 1 through 15 and Sites SS030 and OT106, Hill Air Force Base, Utah (With EPA Comments and Enclosures)" (Tetra Tech, EPA Region 8, July 2018), 465. Note: Pagination for this document is provided for the PDF, as the letters, report itself, and enclosures all have varying pagination.

174. "An Act To Extend and Amend the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, and for Other Purposes," Pub. L. No. 99–499, 42 U.S.C. 9601 (1986), 107.

175. John B Stephenson et al., "Superfund: Greater EPA Enforcement and Reporting Are Needed to Enhance Cleanup at DOD Sites" (Government Accountability Office, April 16, 2009), 17-18.

the remedial investigation and feasibility study phase, the DoD is required by law to enter into a federal facilities agreement (FFA)[176] within 180 days. The FFA is a legally binding agreement between the DoD, EPA, and state environmental agencies that has certain mandatory stipulations. One is a requirement that major documents be subject to commentary by the parties.[177] Disputes between the agencies are subject to an arbitration process, over which the head of the EPA has the final say. According to Joe Healy, who oversaw CERCLA implementation at two military bases, EPA and DoD personnel were instructed not to escalate disputes to this level unless absolutely necessary.[178] In addition, the parties could (and frequently did) sue each other, which could prompt the involvement of the state's attorney general's office.[179]

SARA, the NCP, and federal guidelines dictate that local community input be considered in the execution of DoD CERCLA cleanups. This takes the form of information dissemination, advisory boards, and the solicitation of public comments -- especially at the record of decision (ROD) stage.[180] However, advocacy groups and community members do not have a formal oversight role. As I will attempt to show, there was relatively little citizen input at the TCE-contaminated sites examined, and it does not appear local sentiment was a driving factor in the remediation process. This was due, at least in part, to the complexity of the regulatory and technical issues involved with CERCLA activities.

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176. Also known as an inter-agency agreement (IAG).

177. John B Stephenson et al., "Superfund: Greater EPA Enforcement and Reporting Are Needed to Enhance Cleanup at DOD Sites," 5-6.

178. Joe Healy, interview with author, March 19, 2021.

179. Ken Alex, interview with author, March 17, 2021.

180. "Community Relations Plan Final For Remedial Investigation/Feasibility Study at Hadnot Point Industrial Area and Limited Scope Investigations at Sites 6, 48, and 69" (Environmental Science & Engineering, Inc, September 1990), 13. An ROD is a document which outlines the lead agency's choice of remediation method. Decisions on the means of addressing contamination are one of the most important stages of any CERCLA cleanup.

Hill AFB's "Chemical Disposal Pit #3," discussed in Chapter 2, is an ideal case study for describing the more technical aspects of CERCLA TCE remediation. Phase 1 of Hill's environmental program was initiated in 1982, about two years after CERCLA had been signed into law, and consisted of an initial assessment and records search. At this point, the base was not yet listed on the NPL, but the Air Force's Installation Restoration Program (IRP) at Hill largely followed CERCLA guidelines. For instance, the IRP's "Phase I: Initial Assessment and Records Search" was similar to CERCLA's "Remedial Investigation Level 1 - Problem Identification and Scoping."[181] This step identified areas of concern based on interviews and records searches, assigning severity scores using standardized criteria.[182] "Phase II: Problem Confirmation/Quantification" was roughly equivalent to CERCLA's "Level II - Problem Quantification" and entailed collecting "specific site data . . . through sampling and field studies in order to characterize the extent of the problems at [each] site."[183]

At Hill, Phase II was split into two parts. For Part I, an "IRP Survey" was completed in 1984. The IRP Survey included the identification of four especially suspect areas and some preliminary testing. The IRP Survey results for Chemical Disposal Pit 3 indicated beyond a doubt that TCE pollution was extensive -- levels of up to 1,400,000 ppb were detected in groundwater near the pit.[184]

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181. "Installation Restoration Program Remedial Investigation and Feasibility Study (RI/FS) Work Plan Chemical Disposal Pit 3" (Radian Corporation, May 1988), 1-3.

182. "Installation Restoration Program Phase I - Records Search, Hill AFB, Utah" (Engineering Science, January 1982), 3-4.

183. "Installation Restoration Program Phase I - Records Search, Hill AFB, Utah," 3-4.

184. "Installation Restoration Program Phase IIB - IRP Survey Final Report" (UBTL, September 1984), 181.

After the Hill IRP Survey, the program entered Phase II Part 2,[185] which entailed further testing and the completion of a more thorough "Quantification and Confirmation" study. For unspecified reasons, work did not begin until 1986, so Hill's Quantification and Confirmation study was not completed until 1988. Totalling over 500 pages, not including appendices, the Quantification and Confirmation study provided an accounting of the contamination profiles and geological attributes of 18 different sites, a considerable expansion in scope.[186] As early as 1986, Air Force personnel attended meetings of the South Weber City Council to report findings from the Phase II Part 1 investigation that TCE had migrated off-site from Chemical Disposal Pit #3. Thereafter, new findings were reported to nearby residents once a year.[187]

Though far more detailed than the IRP survey, the Quantification and Confirmation study was still merely a starting point. Upon its completion, the Hill IRP effort advanced to site-specific remedial investigations (RIs) and feasibility studies (FSes), the stage in CERCLA which immediately precedes the start of remedial work.[188] The RIs aimed to more fully characterize the contamination, geology, and offsite migration potential at each location -- information necessary for carrying out work. The FSes would consider appropriate remediation technologies based on the RI findings, weighing the benefits and drawbacks of each.

Once Hill was added to the NPL based on the severity of its contamination, Chemical Disposal Pit #3 and its TCE plume received the CERCLA designation "Operable Unit 2," or OU2. The OU2 RI results were published in 1990 and included over 200 pages of detailed

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185. Official documents exhibit this inconsistent usage of Arabic and Roman numerals.

186. "Site Characterization Summary for Operable Unit 2" (Radian Corporation, August 1990), "1-18."

187. Edward Heyse, W. Robert James, and Jo Anne Summers, "Record of Decision for Interim Action at Operable Unit 2" (Hill AFB Environmental Management Directorate, August 1991), 9.

188. "Installation Restoration Program Remedial Investigation and Feasibility Study (RI/FS) Work Plan Chemical Disposal Pit 3" (Radian Corporation, May 1988), 2-8.

information on the site's geology and hydrology. The RI also identified a mass of particularly concentrated TCE immediately below the dump site.[189]

Officials considered various means of remediating the site. Their priority was addressing the large volume of TCE right under the pit, which would leach into the surrounding groundwater and soil until removed. In 1990, IRP officials released a conceptual design report for a solvent recovery system to remove groundwater from the highly contaminated area. The recovered water would be stripped of TCE by an aeration system, which would volatilize and separate the TCE for storage in a tank and, ultimately, removal by a qualified hazardous waste contractor.[190]

The base accepted written public comments from February 1991 to March 1991 in advance of an interim ROD on the air stripping system. Feedback solicitation notices were published in local newspapers and sent to property owners on the IRP's mailing list, and the Air Force informed local radio and television stations of the opportunity via press release. An in-person comments session was also held on March 5, 1991, at a local elementary school; 25 community members attended.[191]

At the March 5 meeting, many of the inquiries were straightforward attempts by residents to determine whether their families, property, or livestock were in danger. For instance, one attendee asked if his cows (which grazed in the plume area) would be affected by the contamination. IRP officials responded that above-ground springs contaminated with TCE had been identified and remediated, and that TCE's volatility would prevent it from accumulating in

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189. "Site Characterization Summary for Operable Unit 2" (Radian Corporation, August 1990), "4-42."

190. "Final Conceptual Design Report: Source Recovery and Groundwater Pre-Treatment System at Operable Unit 2" (Radian Corporation, June 1990), "3-1 to 3-3."

191. Edward Heyse, W. Robert James, and Jo Anne Summers, "Record of Decision for Interim Action at Operable Unit 2" (Hill AFB Environmental Management Directorate, August 1991), 9-10.

plants, so the cattle should not be at risk.[192] Another attendee remarked on the difficulty of understanding the remediation process, especially given the technical language and the sheer quantity of documentation involved.[193] Complaints of this sort are present in the administrative record at all three bases. The Air Force spokesperson acknowledged this concern and stated that the EPA permitted communities to hire an expert to serve as a liaison between the IRP and the local community. They also stated that the Utah Department of Environmental Quality, the EPA, and Hill AFB had phone numbers listed and could offer some assistance in explaining facets of the program.[194]

Overall, the transcript indicates that some residents had a modest understanding of the Hill IRP's activities. For instance, one commenter asked if capping technologies, which encased and immobilized contaminants, could be employed at OU2. It seems they were aware of this approach because it had been employed at Hill's OU1.[195] And the same resident who mentioned the complexity of the remediation process asked whose standards -- the Air Force's, the EPA's, or Utah's -- would be used in establishing acceptable contaminant levels.[196] These questions demonstrate a certain level of familiarity with Hill's contamination and CERCLA processes; in order to know that capping technologies were relevant or that various agencies might have conflicting standards, the commenters must have done some research or attended earlier meetings and presentations. Yet, none of the comments criticized or suggested improvements to

192. "Record of Decision for Interim Action at Operable Unit 2," 30.

193. "Record of Decision for Interim Action at Operable Unit 2," 31.

194. "Record of Decision for Interim Action at Operable Unit 2," 32.

195. "Record of Decision for Interim Action at Operable Unit 2," 32.

196. "Record of Decision for Interim Action at Operable Unit 2," 32-33.

the Air Force's OU2 proposal. The participants were not providing technical oversight or grassroots pressure but rather inquiring for the sake of their own health and understanding.

Moreover, it appears that only a handful of individuals spoke at the public meeting, even though 25 people were in attendance. And the Air Force received no written comments on the ROD from community members, despite publishing solicitations in various local media outlets. It seems that engagement with Hill's TCE remediation at OU2 was fairly minimal.[197]

A more comprehensive 1993 feasibility study projected that remediating OU2's contamination would cost $30 million (FY93 dollars, not including inflation) over the course of 30 years.[198] The small, inconspicuous Chemical Disposal Pit #3 -- two earth trenches with no visible pollution -- was destined to become a multi-decade fiasco.

Since potable wells were not installed in the plume area, human health was a lesser concern at Hill's OU2, but was nonetheless considered in the remediation effort. As seen in the map above, OU2's plume was encroaching upon nearby residences, raising the prospect that TCE in the plume would evaporate and be inhaled by individuals nearby.[199] Ultimately, the investigation calculated the risk of TCE-induced cancer from vapors at 2×10^{-10} to 6×10^{-13}. The EPA's threshold for remediation was a risk of between 1×10^{-4} and 1×10^{-6}, so ambient vapor carcinogenicity was not seen as concerning.[200]

The interim solvent recovery system was ultimately completed, and 34,000 gallons of solvents (mostly TCE) were removed from 1993 to 1996, a volume equivalent to 630 55-gallon

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197. "Record of Decision for Interim Action at Operable Unit 2," 33.

198. "Final Feasibility Study Report for Operable Unit 2: Sites WP07, SS21" (Radian Corporation, April 1993), "ES-5."

199. "Final Feasibility Study Report for Operable Unit 2: Sites WP07, SS21," "2-21."

200. "Final Feasibility Study Report for Operable Unit 2: Sites WP07, SS21," "2-31 to 2-47."

chemical drums. An interceptor trench was constructed in 1997 between the plume and South Weber Drive to extract contaminated groundwater that was slowly moving northward and pump it to the treatment building.[201] Other pilot studies and experimental techniques were employed, including the injection of steam into the groundwater to volatilize hard-to-reach TCE pools for extraction. By 2000, 40,750 gallons of solvents had been removed from the area.[202] In 2009, a soil vapor extraction (SVE) system was constructed -- SVE works by inserting perforated pipes into dry ground and creating a vacuum, which promotes evaporation.[203] By this time, the volume of solvent recovered per year had decreased drastically, as the concentrated mass had already been removed. Although over a million gallons of groundwater were extracted in 2009, treatment only yielded 25 gallons of contaminants. As of 2020, remedial efforts at OU2 are ongoing; the Air Force and EPA estimate that TCE remediation will not be complete until about 2100, or 120 years since the Hill IRP began.[204] This timeline reflects the severity of the contamination and other site-specific geological features which make operations at Hill's OU2 especially difficult.

Broadly speaking, the technical and procedural contours of TCE remediation at Lejeune and Ft. Ord were similar to Hill's OU2, so the remainder of this chapter will focus on the relationship between the DoD, environmental agencies, and citizens in directing cleanup operations.

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201. "Final Treatment Systems Operations Report 1999 Operation and Performance Report Repository Operable Unit 2, Hill AFB, Utah" (Radian International, December 1999), "1-8."

202. "Final Treatment Systems Operations Report 1999 Operation and Performance Report Repository Operable Unit 2, Hill AFB, Utah," "1-9."

203. "Operable Unit 2: Annual Treatment System Cost and Performance Report for April 2009 through March 2010" (CH2M HILL, July 2010), "ES-1."

204. "Draft Fifth Five-Year Review Report: Operable Units 1 through 15 and Sites SS030 and OT106, Hill Air Force Base, Utah (With EPA Comments and Enclosures)," 10-11.

The CERCLA process at Ft. Ord helps demonstrate how state regulatory agencies and the EPA exerted influence over remediation decisions involving TCE. As discussed earlier, inter-agency relations at federal NPL sites are governed by Federal Facility Agreements (FFAs), which commit the lead agency -- in this case, the DoD -- to submit major documentation for review and comment by the other parties. The DoD, EPA, California Department of Health Services (DHS),[205] and California Regional Water Quality Control Board (CRWQB), Central Coast Region were parties to the Fort Ord FFA.[206]

Exchanges between Ft. Ord and the other FFA parties suggest the military received substantive, critical feedback, pushing the Fort Ord IRP in a more comprehensive (and costly) direction. For instance, the DHS held a 1990 meeting with the other FFA parties and the NOAA to discuss Fort Ord's RI/FS plans. All the agencies objected to the fragmented nature of the proposed RI, which broke the base into study zones for discrete analysis rather than assessing the facility as an integrated system where contaminants like TCE could migrate and impact multiple sites.[207] In addition, the EPA took exception to the DoD's plan to cease investigating certain sites that were included in earlier assessments and requested that extensive documentation be provided for each site which was to be "screened out."[208] With regards to risk assessments, the NOAA stated that Ord's proposal to consider only on-base hazards in the risk evaluation was improper given the potential for off-base contaminant migration.[209] These are only a sampling of

205. Later supplanted by the Department of Toxic Substances Control (DTSC).

206. "Federal Facility Agreement Under CERCLA Section 120" (EPA Region 9, State of California, US Army, November 19, 1990), 2.

207. "Issues and Resolutions Discussed at the Remedial Investigation and Feasibility Study (RI/FS) Scoping Meeting" (EPA Region 9, December 6, 1990), 1.

208. "Issues and Resolutions Discussed at the Remedial Investigation and Feasibility Study (RI/FS) Scoping Meeting," 2-3.

209. "Issues and Resolutions Discussed at the Remedial Investigation and Feasibility Study (RI/FS) Scoping Meeting," 3-4.

the issues raised, but they reflect a general theme: environmental agencies generally pushed for the expansion of IRP activities. And these were not mere suggestions or comments; the letter began with a warning that addressing the concerns would be necessary if the Army wished to "minimize unwanted future disputes and delays," implying the EPA was prepared to exercise its oversight authority.[210]

When the Army's contractor submitted a new draft RI/FS work plan in early 1991, the agencies were dismayed by the neglect of many suggestions. The EPA was unhappy with the Army's continued unwillingness to analyze the "big picture" at Ft. Ord, writing that a proposal "must be offered" to consider the base as an integrated system.[211] In addition, the Army continued its plans to restrict access to contaminated areas rather than executing a full remediation, which the EPA had previously identified as unacceptable.[212] In total, the EPA's comments on the RI/FS work plan totaled 25 pages of single-spaced type. The CRWQB's feedback was almost irate in tone; the agency's executive officer was "encouraged [that] the editorial quality of the report [had] improved" but noted that the document still "contain[ed] inaccurate and erroneous information" including "mislabeled figures" and maps which lacked scales.[213] Additionally, the CRWQB echoed the EPA's demands for a big-picture site conceptual model and reiterated some other concerns; this document totaled 17 pages. It appears that continued issues with the RI/FS work plan may have caused the Army to release its original

210. "Issues and Resolutions Discussed at the Remedial Investigation and Feasibility Study (RI/FS) Scoping Meeting," 1.

211. "EPA Comments on the Fort Ord Base-Wide RI/FS Workplan Documents (Feb 91) Volumes 1, 2, and 3" (EPA Region 9, February 1991), 2-3.

212. "EPA Comments on the Fort Ord Base-Wide RI/FS Workplan Documents (Feb 91) Volumes 1, 2, and 3," 6.

213. William Leonard, "Fort Ord: Workplan Review - Volumes 2 and 3 Base Wide Remedial Investigation / Feasibility Report" (EPA Region 9, May 16, 1991), 1-2.

contractor, EA Associates, and switch to a new firm, Harding Lawson Associates.[214] The commentary on subsequent drafts was more favorable, and -- after further revisions -- the work plan was finally approved. Needless to say, the EPA and California environmental agencies were not merely rubber stamping the Army's plans.

With regards to community involvement, the administrative record suggests that Ft. Ord's efforts attracted more engagement than at Hill or Lejeune. SARA stipulated that each installation should establish a Technical Review Committee (TRC) to review its handling of hazardous wastes and that the TRC should include at least one representative from the local community.[215] In 1990, Ft. Ord established its TRC, but only one citizen representative was sought. However, a 1993 DoD memorandum directed installations to transition their TRCs to Restoration Advisory Boards, or RABs. The RABs featured increased community involvement and adopted a more formal structure, with set mechanisms for reviewing and commenting on installation documents.[216]

At a February 7, 1994 meeting held to explain the RAB's functions and solicit participation, one member -- Winston Elstois -- remarked that the military's presentation on CERCLA issues was "almost incomprehensible" and included "sort of a machine gun rattle-tattle of acronyms."[217] As with Hill, community members at Ft. Ord faced substantial technical barriers to fully understanding the military's decisions. But Ft. Ord's administrators did have a well-informed opponent: the Fort Ord Toxics Project, a local branch of the national Military

214. The administrative record does not provide an explanation for the contractor change, so this is merely speculation.

215. "Notice of Environmental Restoration Activities," Pub. L. No. 99–499, 10 USC 2705 (1986).

216. Vicki Card, "Fort Ord Technical Review Committee Restoration Advisory Board Reporter's Transcript of Proceedings" (Vicki Card, CSR, February 7, 1994), 64.

217. Vicki Card, "Fort Ord Technical Review Committee Restoration Advisory Board Reporter's Transcript of Proceedings," 67.

Toxics Project. Both entities were active during the 1990s and early 2000s but appear to have ceased operations since. The Fort Ord Toxics Project was run by Curt Gandy and consisted of "roughly two dozen area residents," according to a mid-1990s newspaper article.[218] Gandy was present at the February 7 meeting and lodged compelling objections to the military's cleanup efforts and the proposed operations of the RAB; for instance, he mentioned that Ord's administrators neglected to assign the RAB some functions called for by the DoD's memorandum.[219] At the first official RAB meeting with citizen attendees, the Ord Toxics Project sent two members, Gandy and Valerio Biondo.[220] Both were active in questioning the Army's presentation and had clearly prepared in advance. When an Army administrator could not remember the concentration of a blistering agent in a chemical weapons kit purportedly buried at Ord, Gandy stepped in to remind her.[221]

In fact, the two were so assertive that another citizen RAB member -- Chris Parent -- complained, "I thought we were going to be able to hear a quality presentation without the agendas coming out."[222] It seems that Gandy and Biondo's view of the RAB as a citizen oversight body did not align with many other participants, who desired a more collaborative approach. This tension between activist members of the RAB and residents more sympathetic to the military and regulatory agencies persisted. In one late 1994 meeting, Gandy expressed a

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218. Marty Burleson, "Fort Ord Toxics Study: Report to Assess Public Health Risks," *The Californian*, May 15, 1996, Newspapers.com.

219. Vicki Card, "Fort Ord Technical Review Committee Restoration Advisory Board Reporter's Transcript of Proceedings," 64-65.

220. Vicki Card, "Fort Ord Restoration Advisory Board Reporter's Transcript of Proceedings" (Vicki Card, CSR, May 11, 1994), 5-6.

221. Vicki Card, "Fort Ord Restoration Advisory Board Reporter's Transcript of Proceedings," 76.

222. Vicki Card, "Fort Ord Restoration Advisory Board Reporter's Transcript of Proceedings," 37-38.

desire to reduce the RAB's size by expelling many government participants, but other community members vigorously opposed this suggestion.[223]

By 1996, relations had become even more contentious. Scott Allen, another RAB member and an attorney, sent a letter asserting that the Army was violating CERCLA and NCP stipulations in altering its remedy for the TCE-contaminated landfill without adequate documentation and feedback on the revised plan.[224] A few other citizens drafted notes expressing similar concerns.[225] The RAB soon became so procedurally dysfunctional that the military and the EPA took the extraordinary step of ordering its dissolution in favor of a format more akin to a town hall.[226] This did not discourage Gandy and Allen from continuing to attend meetings, where they almost invariably objected to the Army's proposals.

Evidently, there was sustained community involvement in TCE remediation efforts at Ft. Ord. However, the activism was limited to a small but vocal minority, unlike the broad-based movements at Love Canal and the Stringfellow Acid Pits. Moreover, the DoD and regulatory agencies considered many of the objections to be technically invalid, and the small activist cohort did not have enough political or scientific sway to convince decisionmakers otherwise. Thus, the overall impact of resident complaints on TCE remediation appears to have been low. In contrast, EPA and state regulatory comments were perceived to have technical merit and often prompted changes.

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223. Vicki Card, "Fort Ord Restoration Advisory Board Reporter's Transcript of Proceedings" (Vicki Card, CSR, October 20, 1994), 50-56.

224. Scott Allen, "Comments on OU-2 ESD," October 29, 1996.

225. Lida Tan, "EPA Letter to Lorna Moffatt" (EPA Region 9, December 6, 1996), 1-3.

226. Daniel D. Devlin, "Letter from Army to Restoration Advisory Board Members Stating Army's Decision to Disband the RAB at Fort Ord" (US Army, May 12, 1999).

Community involvement at Camp Lejeune was more similar to Hill's OU2 than Ft. Ord. Lejeune's public affairs program was unusually ambitious, and its TRC minutes are consistently digitized in the base's administrative record. Lejeune went beyond the one-community-member requirement and ran its TRC with a focus on soliciting local involvement.

At first, the TRC included six citizen members, in addition to the city manager of nearby Jacksonville and an array of state, EPA, and DoD officials. The initial meeting -- held on August 9, 1988 -- was something of an introductory affair, with government officials presenting overviews of the remediation efforts, especially at Hadnot Point, to the community members. Some citizen attendees were ex-military, including Tom Caulfield, who informed base personnel of sites he suspected might be contaminated due to activities he observed while stationed at Lejeune.[227] According to Healy, such informal tips from veterans and base employees were a useful source of information given the sparsity of records.[228] Like at Hill's OU2 ROD meeting, the community members primarily asked questions about procedural and technical aspects of the program to strengthen their own understanding.

As time went on, the TRC's role shifted. Of the six original community members, only two -- John Mader and Ray Humphries -- chose to attend the second meeting on July 25, 1990. However, the number of government attendees grew substantially, and so this meeting featured less exposition for the community attendees and more inter-agency sparring.[229] The FFA was still in negotiation at this point, and the EPA was not happy with Lejeune officials' contention that underground fuel tanks near Hadnot Point were outside of its jurisdiction unless explicitly

227. "Meeting Summary: Technical Review Committee, August 9, 1988" (Lejeune IRP, August 9, 1988), 15-16.

228. Joe Healy, interview with author.

229. "Technical Review Committee July 25th, 1990" (Lejeune IRP, July 25, 1990), 1.

added to OU1 in the FFA. Victor Weeks, an EPA administrator, stated irately that his agency's authority to comment was ensured "by statute" and remarked that the Navy conducted unapproved work at its "own risk."[230] Threats of this nature appear relatively often in the administrative records of NPL bases. According to Healy, the prospect of a dispute could help bring the military into compliance, so aggressive posturing was a valuable tool.[231] This particular exchange became so tense that Lejeune's IRP director remarked "we certainly did not mean to slight EPA" and offered to send documentation related to the storage tanks.[232] As in the previous meeting, the citizen members asked questions on legal and technical matters, such as the funding source for cleanup activities.[233]

The committee's third meeting, held on March 21, 1991, included no citizen attendees. Thus, the TRC ultimately became a forum for inter-agency politics, despite Lejeune's efforts to include the community. Difficulties understanding the arcane subject matter almost certainly contributed to the attrition; because citizen members found themselves constantly asking questions and seldom making substantive contributions, the meetings likely felt unproductive. In addition, the administrative record suggests there was a general lack of concern about Lejeune's cleanup efforts in the community.

As part of their public affairs program, Lejeune officials conducted a series of interviews with local leaders. One document summarized the reception of Lejeune's environmental efforts as "overwhelmingly positive," a conclusion which appears justified given the interview

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230. "Technical Review Committee July 25th, 1990," 7-8.

231. Joe Healy, interview with author.

232. "Technical Review Committee July 25th, 1990," 8.

233. "Technical Review Committee July 25th, 1990," 16.

summaries.[234] A city council woman was reportedly "surprised at how little concern the off-base community [had]" about the hazardous waste issues, and many of the interviewees commended Lejeune for its relative openness in dealing with the cleanup.[235] Multiple subjects who were themselves retired Marines expressed confidence in the base's efforts because they believed Lejeune's leaders would perform their environmental duties faithfully.[236] And some interviewees expressed more confidence in Lejeune's cleanup efforts than the city of Jacksonville's attempts to address its own wastes.[237] Overall, the interviews suggest that local figures were satisfied with Lejeune's implementation of the cleanup and with the base's outreach attempts. Other details in the administrative record further support the conclusion that interest was minimal -- for instance, the comment period for the OU1 ROD yielded no written community responses.[238]

The EPA and the North Carolina Department of Environmental Health and Natural Resources (NCDEHNR), however, did provide critical feedback. In one noteworthy episode, the NCDEHNR repeatedly asserted that the deep aquifer below the TCE plume required additional monitoring and possibly remediation.[239] [240] The Marines' contractor addressed the NCDEHNR's

234. "Community Relations Plan Final For Remedial Investigation/Feasibility Study at Hadnot Point Industrial Area and Limited Scope Investigations at Sites 6, 48, and 69" (Environmental Science & Engineering, Inc, September 1990), 11.

235. "Community Relations Plan Final For Remedial Investigation/Feasibility Study at Hadnot Point Industrial Area and Limited Scope Investigations at Sites 6, 48, and 69," 100.

236. "Community Relations Plan Final For Remedial Investigation/Feasibility Study at Hadnot Point Industrial Area and Limited Scope Investigations at Sites 6, 48, and 69," 104-6.

237. "Community Relations Plan Final For Remedial Investigation/Feasibility Study at Hadnot Point Industrial Area and Limited Scope Investigations at Sites 6, 48, and 69," 99, 105. Ultimately, these residents' sentiments would prove justified. The Marine Corps has devoted considerable resources to its cleanup, whereas a Superfund site in the city of Jacksonville (ABC One Hour Cleaners) is currently in limbo due to funding shortfalls.

238. "Final Record of Decision for Operable Unit 1 (Sites 21, 23, and 78)" (Baker Environmental, September 8, 1994), 70.

239. Patrick Watters, "Letter and Comments on the Draft Remedial Investigation Report for Operable Unit No. 1" (NCDEHNR, March 23, 1994), 1-3.

240. Patrick Watters, "Letter and Comments on the Draft Remedial Investigation Report for Operable Unit No. 1" (NCDEHNR, June 10, 1994), 2.

feedback by arguing that additional deep wells would be unnecessary for characterizing the plume and might actually facilitate the spread of contaminants between aquifers.[241] The NCDEHNR was satisfied with this reasoning and ultimately concurred with the Marines' ROD, provided that the deep groundwater would be closely monitored using existing wells. Furthermore, the NCDEHNR stated that any worsening of the deep aquifer's condition would void the agreement.[242]

The EPA did not share this concern and instead focused on technical issues with the ROD, such as incorrect exposure calculations and typographical errors. The contractor moved swiftly to implement the majority of these suggestions.[243] Healy related that military leaders often appreciated the regulators' commentary -- even when critical -- because the feedback helped to identify problems with plans and documentation.[244] Unrecognized errors could result in serious and costly issues down the road, giving the DoD an incentive to seek and heed the advice.

To conclude, the type of grassroots political engagement seen at Love Canal and other prominent toxic sites was largely absent at TCE-contaminated military installations. Even at Ft. Ord, where the historical record indicates that a handful of community members critiqued military practices, the resistance was quite limited in numbers. It seems the EPA and state environmental agencies were able to fill the adversarial role, using their subject-matter expertise to provide substantive critiques of the approaches set forth by DoD officials and contractors.

241. "Final Record of Decision for Operable Unit 1 (Sites 21, 23, and 78)," 48, 73.

242. Jack Butler, "Letter and Comments on the Final Record of Decision for Operable Unit 1, Sites 21, 24, and 78" (NC DEHNR, October 27, 1994).

243. Tammi A. Halapin, "Response to Comments on the Draft Final Feasibility Study, Proposed Remedial Action Plan and Record of Decision for Operable Unit 1" (Baker Environmental, April 29, 1994).

244. Joe Healy, interview with author.

Broadly speaking, comments by the EPA and other state agencies pushed the DoD to study and address its contamination in a more thorough and costly fashion. And environmental agencies backed up their recommendations with regulatory authority, frequently achieving the desired changes in policy.

Conclusion

To be sure, a relative lack of interest in the DoD's remediation efforts does not mean the contamination has been ignored by the public. On the contrary, there has been an increase in military TCE-related activism since the mid-1990s -- the Newspapers.com archive returns 602 hits for the query "Camp Lejeune trichloroethylene," of which 571 articles were published after 1995. This reflects a heightened focus on the health effects of historical exposures. Questions of TCE-induced cancers and other ailments have spawned a book,[245] government reports and post-mortem analyses,[246] epidemiological studies,[247] [248] [249] websites and online support groups,[250] [251] and legislation. In 2012, after years of lobbying, the "Honoring America's Veterans and Caring for Camp Lejeune Families Act" was passed. Among numerous other provisions, the act gives veterans who lived at Lejeune for more than 30 days -- and their families -- access to free Veterans Affairs (VA) medical care for 15 conditions potentially related to their exposure. The law does not require that a connection between the exposure and the condition itself be

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245. Mike Magner, *A Trust Betrayed: The Untold Story of Camp Lejeune and the Poisoning of Generations of Marines and Their Families* (Da Capo Press, 2014).

246. "Drinking Water Fact Finding Panel Report for Camp Lejeune" (U.S. Marine Corps, 2004). Among others.

247. "Morbidity Study of Former Marines, Employees, and Dependents Potentially Exposed to Contaminated Drinking Water at U.S. Marine Corps Base Camp Lejeune" (ATSDR, April 2018).

248. Frank J. Bove et al., "Evaluation of Mortality among Marines and Navy Personnel Exposed to Contaminated Drinking Water at USMC Base Camp Lejeune: A Retrospective Cohort Study," *Environmental Health: A Global Access Science Source* 13, no. 1 (February 19, 2014): 10.

249. Perri Zeitz Ruckart, Frank J. Bove, and Morris Maslia, "Evaluation of Exposure to Contaminated Drinking Water and Specific Birth Defects and Childhood Cancers at Marine Corps Base Camp Lejeune, North Carolina: A Case–Control Study," *Environmental Health* 12, no. 1 (December 4, 2013): 102.

250. "Camp Lejeune Water Contamination (CLWC)," Facebook, accessed March 25, 2021, https://www.facebook.com/groups/150177337803. This Facebook support and advocacy group has over 3,100 members as of March 2021. There are many similar groups, for Lejeune and other contaminated installations.

251. Jerry Ensminger and Mike Partain, "The Few, The Proud, The Forgotten," accessed March 25, 2021, http://tftptf.com/.

definitively proven. This is crucial because, although studies have shown elevated mortality among those exposed, establishing a causal relationship between any specific case of illness and toxic contamination is often difficult, especially for carcinogens like TCE.[252] Efforts to secure compensation continue, including a bill by Sen. Thom Tillis which seeks to allow lawsuits against the military by former Lejeune residents.[253]

Nonetheless, TCE cleanup remains fairly low-profile. At Hill AFB, a small grassroots organization -- the "South Weber Coalition" -- is active, but the group is concerned primarily with a former landfill and not the OU2 TCE plume. A recent community survey found that 60% of community members were satisfied with the Air Force's efforts at Hill, with 15% having mixed opinions and 25% disapproving.[254] At Ft. Ord, engagement has decreased markedly since the mid and late 1990s. In 2017, the Army mailed and emailed a survey to more than 65,000 nearby residents. One item asked if anyone wished to participate in a re-established RAB; there were no takers.[255] Lejeune's RAB continues to operate, and questions about the base's water quality occasionally crop up, which is unsurprising given the context. Nonetheless, meeting minutes suggest the RAB is a largely congenial affair, and there is no indication of cleanup-related activism.[256] In addition to CERCLA initiatives, the Agency for Toxic Substances and

252. Frank J. Bove et al., "Evaluation of Mortality among Marines and Navy Personnel Exposed to Contaminated Drinking Water at USMC Base Camp Lejeune: A Retrospective Cohort Study," 10.

253. Calvin Shomaker, "Sen. Tillis Introduces Camp Lejeune Justice Act for Water Contamination Victims," *Jacksonville Daily News*, September 29, 2020.

254. "Draft Fifth Five-Year Review Report: Operable Units 1 through 15 and Sites SS030 and OT106, Hill Air Force Base, Utah (With EPA Comments and Enclosures)" (Tetra Tech, EPA Region 8, July 2018), 651-3.

255. Thomas E. Lederle, "Memorandum for Record Documenting No Community Interest to Reestablish a Fort Ord Restoration Advisory Board (RAB) and Documenting the Community Assessment Procedures" (US Army, August 20, 2020), 2.

256. "Restoration Advisory Board Meeting Minutes from Meeting Held 19 February 2020 At Coastal Community College" (CH2M HILL, February 27, 2020).

Disease Registry (ATSDR) has formed a panel at Lejeune to facilitate outreach and receive community feedback on health-related issues.[257]

The heyday of TCE pollution and remediation may have passed, but groundwater contamination by carcinogenic organic chemicals remains a salient issue. There are rising concerns about a class of synthetic groundwater contaminants -- per- and polyfluoroalkyl substances (PFAS) -- which have been linked to kidney, breast, and liver cancer. Indeed, authors have begun comparing PFAS to chlorinated solvents in their search for a precedent to guide future cleanup and regulation efforts.[258] Like TCE, PFAS have been widely used by the military, and aspects of PFAS remediation will probably mirror TCE -- including a relative lack of popular awareness and interest.[259]

Amidst a toxics literature flush with accounts of brave and resourceful activists dragging contamination into the spotlight and confronting powerful interests, the history of TCE at military bases offers an alternative sort of narrative, one where scientists and regulatory agencies are the main actors. This framing helps shed light on the crucial role of government research, rulemaking, and oversight in the recognition and remediation of pollutants like TCE, which inflict harm on unwitting victims and can cause widespread pollution virtually undetected. A reliance on government initiative can have pitfalls, as the Lejeune drinking water contamination episode demonstrates. However, TCE remediation at military bases should offer hope that -- when empowered by robust legislation such as CERCLA -- regulatory agencies can offer

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257. "Camp Lejeune Community Assistance Panel and Agency for Toxic Substances and Disease Registry: General Charter Procedures" (ATSDR, March 23, 2016).

258. Charles J. Newell et al., "Comparing PFAS to Other Groundwater Contaminants: Implications for Remediation," *Remediation Journal* 30, no. 3 (2020): 7-26.

259. "Suspected and Confirmed PFAS Pollution at U.S. Military Bases," Environmental Working Group, accessed March 14, 2021, https://www.ewg.org/news-and-analysis/2020/04/updated-map-suspected-and-confirmed-pfas-pollution-us-military-bases.

rigorous oversight in the absence of substantial public pressures. Ultimately, scrutinizing the history and materiality of a specific pollutant, at a specific type of site, can reveal insights -- in this case, the value of robust research efforts, active screening for imperceptible substances, prompt rulemaking, and strong regulatory authorities -- which help us better understand environmental history and better confront the future's challenges.

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