



## Article

# The Driving Federal Interest in Environmental Hazards: Weather Disaster as Global Security Threat

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**Abstract:** The U.S. federal government manages many domestic and global operations, including environmental disasters. With the need to both mitigate and adapt to climate change, legislative and executive branches have spurred research efforts as the impacts of the Anthropocene accelerate around the country. The Army Corps of Engineers' overlapping interest in security and providing technological answers to mitigate weather disasters has led to recent research and development, including facilitating the federal mandate to convert military fleets to electric vehicles by 2027 while also building a hydrogen fuel cell emergency operations vehicle. The emergency vehicle, H2Rescue, has recently been tested in the field, and further refinements in the technology are leading towards a transition out of development and into production. However, the engineered solution must also attend to the social dimensions of disaster relief. This paper examines past environmental disasters in one location, the Navajo Nation, to describe how the vehicle could provide a combination of technological and societal future research possibilities for environmental anthropology.

**Keywords:** climate change; disaster relief; hydrogen fuel cell vehicle; mitigation



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## 1. Introduction

Research and development of technology created for mitigating climate change is booming. Within this paper, the authors describe the current program for building and testing a hydrogen fuel cell emergency response vehicle, H2Rescue. Using examples of two disasters occurring approximately a decade ago on the Navajo Nation, the researchers outline how further development of the vehicle could have been mobilized if it had existed at the time. An extensive government response to climate change has been demonstrated in many situations such as the destruction of installations abroad and domestically.

As an example, an Air Force team clustered inside a two-story cinder block building as driving winds shook the walls in early October 2018. This group was tasked to ride out the storm on the Tyndall Air Force Base so they could immediately assess the damage after the Category 5 hurricane had moved on (Price 2022). Following the unexpectedly stronger storm's passing, the team discovered that Hurricane Michael left damage resulting in 484 installation buildings being destroyed or beyond repair, with the other half of the structures stable enough for fixing (Reeves 2019). As Tyndall began to dig through the remains, the Department of Defense planned to rebuild stronger, using the latest technology and integration of the natural environment as a defense against the effects of future hurricanes (L. Thompson 2022).

The federal government manages many domestic and global operations such as environmental disasters. Before the founding of the United States, General Washington recognized the necessity of securing infrastructure by creating the precursor to the Army Corps of Engineers. Two hundred and fifty years later, as weather disaster impacts accelerate around the country, the federal government has become the largest landowner

in the nation. Overlapping interests in security and providing technological answers to mitigate weather disasters have resulted in research that not only documents the effects of climate change from a security perspective (Miller 2019) but also ranks the threats by military installation, as some bases can be impacted by multiple environmental factors (Glass 2019). The Secretary of the Army, Christine Wormuth, emphasized that “Climate change threatens America’s security and is altering the geostrategic landscape as we know it. For today’s soldiers operating in extreme temperature environments, fighting wildfires, and supporting hurricane recovery, climate change is not a distant future, it is a reality” (Department of the Army 2022).

This paper will demonstrate the government’s concern with climate change due to immediate effects and describe how such governmental concern is being enacted through executive orders, resulting in climate change mitigation and adaptation. The U.S. federal government is a broad, multi-headed conglomeration of agencies and departments, which makes the separation of political rhetoric and sensationalist popular culture articles difficult (as reported in government publications or in the news media, magazines, etc.). Therefore, observing texts produced by government policy and then empirically documenting their affects through participant observation is difficult to say the least. An applied social scientist working within the government is uniquely qualified to both observe the dynamic between these large scales (e.g., governmental policy and work being carried out on the ground) and analyze the changes in governmental policy with actual experience on the ground.

The U.S. Army Corps of Engineers (USACE) leads research and development efforts at seven different laboratories while also assisting in climate adaptation efforts on the ground. Recent interventions by the corps include facilitating a mandate to convert federal fleets to electric vehicles by 2027 as well as research and development (R&D) solutions for a prototype hydrogen fuel cell emergency operations vehicle, H2Rescue. This paper provides an overview of both these long- and short-term efforts as an outline to future research possibilities for environmental anthropology. After describing these R&D efforts, the authors outline an argument for further specific development of the H2Rescue vehicle using examples of two disasters occurring on the Navajo Nation in 2013 and 2015, in which it could have been mobilized if it had been created a decade ago. Grounding future research in an applied anthropological methodology will allow sharper understanding of whether these currently unfolding efforts meet the needs of the government, people, and the environment.

## 2. Climate Change and Government Mitigation Methods

The USACE laboratory system, the Engineering Research and Development Center, supports a range of efforts, research, and physical interventions both domestic and abroad. These Army laboratories are only part of a much wider governmental effort to mitigate and adapt to climate change. Each laboratory focuses on a specific domain of interest, with many of their names providing a clear differentiation between their foci. The seven labs include the Cold Regions Research and Engineering Laboratory, Geospatial Research Laboratory, Coastal and Hydraulics Laboratory, Environmental Laboratory, Geotechnical and Structures Laboratory, Information Technology Laboratory, and the Construction Engineering Research Laboratory (CERL). The last lab, CERL, has been instrumental in the two examples of government mitigation provided in this article; meanwhile, other governmental institutions lead research programs and mitigation efforts within their realms of interest.

Many research projects at the USACE are driven by broader governmental interest and often focus on solving environmental issues. From managing flooding along the Mississippi River in New Orleans to erecting electrified fish barriers for stopping invasive species from entering Lake Michigan (Kolbert 2021), the USACE uses its laboratories to research solutions to current problems and then implement those developments. Often, these programs are driven by federal mandate, but solutions are fueled by the scientific method and provide many approaches as varied as the USACE laboratories.

Although management of flooding and invasive species indicate the corps' commitment in adapting to environmental quandaries, these projects represent medium-term solutions to climate challenges. Since 1990, when the U.S. Global Change Research Program was mandated to deliver a climate change report to Congress and the President every four years, a vast and varied conglomeration of scientists have briefed numerous administrations on the state of the world. The recently released Fifth National Climate Assessment (NCA5) delivers alarming news for both the nation and the world (Crimmins et al. 2023).

As described in the NCA5 report, with the planet warming (as a result of greenhouse gases in the atmosphere) at a higher rate than any time in the past 800,000 years, increasing temperatures have led to cascading environmental impacts. For example, climate-related shocks to food supply chains have spurred global migration patterns that in turn threaten U.S. economic and security interests (c.f., Koubi 2019). Compound events, meaning the combination of two or more extreme incidents occurring at the same time or shortly after each other, are increasing in frequency (Jay et al. 2023). These findings indicate that the growing incidence of weather disasters and the rapidly escalating effects of a warming globe must prompt greater short-term adaptation and long-term mitigation.

The Department of Defense (DoD) acknowledges several significant security threats to the military. Installations around the world are endangered by rising sea levels and increasing extreme weather events. The health of troops and civilians are threatened by a rise in infectious diseases as changing environmental conditions increase the vectors of transmission. The escalating melting of polar ice caps expands zones of nationalist competition, while stresses to other ecosystems and resource scarcity will likely lead to mass migrations. As all these instabilities are regional but have a global impact; the DoD has highlighted that these security concerns have much greater implications beyond the U.S. and military installations abroad (Miller 2019). Researchers have shown that in some high-income countries, there is a correlation between a rise in military spending and larger expenditure on green capital investment (Das and Hussain 2023), demonstrating that increasingly common environmental disasters are seen as a security threat to many nations.

The increasing impacts of greenhouse gases have spurred a proliferation of research across disciplines and spanning broad periods of time. From marine biologists to global change scientists, the compilation of climate documentation over time and across scientific fields has resulted in the proposal of a new geologic epoch, the Anthropocene. Defined as the period during which human influence has become the major force upon the globe, this label carries significance in that humans move more soil, rock, and sediment each year than all other natural processes combined (Lewis and Maslin 2018). However, the impact of humanity on the world reaches much farther back than the Industrial Revolution.

Some authors rightfully assert that "nature" has been used in a variety of ways, both political and apolitical, to shape ecology and economies over time. For example, during the first one hundred years of the U.S., "laws shaped Americans into forest-clearers and farmers, forests and grasslands into fields" (Purdy 2015, p. 9). The critique of this new geological epoch as "an effort to expand homogenized European historical experiences, frameworks and chronologies onto the rest of the world" (Morrison 2018) certainly hearkens to the politicizing of "nature".

Many debates about the Anthropocene focus on recent climate change since the Industrial Revolution and the expanded use of internal combustion engines. Some authors describe how the periodization of this relatively recent era uses the language of progress and modernity that shows consistency with those ideologies used for the colonization of the world (Simpson 2020). However, the comparison of texts during the last 300 years does not attend to the longer-ranging effects that humanity has had upon the globe (Davies 2016). Here, the term Anthropocene is used to refer to more long-term perspectives on human intervention that include widespread extinction events that corresponded with early humanity's spread around the globe (50,000 years ago) and the domestication of crops and animals (starting approximately 10,500 years ago). Looking at these examples, the global scale of humans' activities has affected the trajectory of geological processes,

affecting other species and the planet, which will necessitate a similarly broad approach for mitigation (Lewis and Maslin 2018).

Solutions should be locally specific, as adaptation depends on dealing with place-based environmental impacts like rising sea levels and weather disasters, while mitigation attends to the broader forces driving climate change (e.g., lowering carbon dioxide emissions). To address and adapt to events such as hurricanes, wildfires, flooding, and typhoons, the USACE assists with domestic emergencies under the Civil Works program. USACE Emergency Management operations overlap with the Federal Emergency Management Agency (FEMA), and each year, these agencies meet to discuss the previous year's operations and update the Emergency Management Continuous Improvement Program (USACE 2023).

From these yearly disaster adaptation efforts and the NCA5's acknowledgment that greenhouse gases must be curbed to slow climate change, there is positive news in that carbon dioxide emissions dropped by 12% in the U.S. between 2005 and 2019 (Jay et al. 2023, p. 8). Despite this, projections about reaching zero CO<sub>2</sub> emissions show that the rate of decline is not enough to reach current governmental goals. To temper this positive news, "Faster and more widespread deployment of renewable energy and other zero- and low-carbon energy options can accelerate the transition to a decarbonized economy and increase the chances of meeting a 2050 national net-zero greenhouse gas emissions target for the US. However, to reach the US net-zero emissions target, additional mitigation options need to be explored and advanced" (Crimmins et al. 2023, p. 34).

Therefore, significantly altering the equation means that society must change its culture of response, both in terms of adaptation and mitigation. Traditionally embedded resilience, or the ability to quickly adapt, mitigate, and rebuild after disaster—the culture of response—includes (1) prior social memory of disasters, (2) available social-economic response and recovery resources, and (3) the local political economy of disaster aid (or who is given aid and who is not (Dyer 2009, p. 313)). Situating broader governmental action within the culture of a response framework allows researchers to compare the scale of national responses to local consequences.

Intensifying environmental threats, such as the hurricane that destroyed much of Tyndall Air Force Base, led to an Executive Order in 2021 calling for a broad governmental approach for combating climate change (Executive Office 2021). Although the Army had previously provided guidance on how to assess, plan for, and adapt to the projected impacts of changing climate and extreme weather (Secretary of the Army 2020), the president's directive for implementation included a mandate to transition all Federal Government light-duty vehicle fleets to being fully electric by 2027 (Executive Office 2022).

This goal was included within the much broader plan for the Federal Government to lead by example towards a carbon pollution-free electricity sector by 2035 and economy-wide net-zero emissions by 2050, using its scale and procurement power to achieve this objective (Executive Office 2022). The level of action this will take can be demonstrated by looking at efforts to convert a light-duty fleet of vehicles at just one Army installation, Fort Carson in Colorado Springs.

Considering both the long-term mandate for a massive transition to zero-emissions vehicular fleets and the need to aid in extreme weather disasters, CERL has been providing research and development solutions to address these challenges. Laws and Executive Orders provide the impetus for R&D funds for mitigation, and research projects are the outcomes (with specific methods varying by program). The Federal Government has provided both an extended memory of previous disasters and a broader social-economic response—the first and second tenets of a strong culture of response. Examining broader methods and a case study allows for an analysis of the local political economy, underscoring the importance of an anthropologically situated culture of response.

### 3. Results from Mitigation Legislation

Examined from the perspective of mitigation and adaptation, the government's adoption of electric vehicles (EV) and carbon-free building processes outlines efforts that are

currently unfolding. The process of carbon-free building is still in the early stages of development (c.f., [Huyhn et al. 2023](#)), while a transition to electric vehicles has already begun. These approaches must be continuously monitored, especially since they create a broad culture of response that can be confounded or encouraged very differently depending on local contexts. The authors have participated in many discussions and planning meetings about how to mitigate climate change on military installations as USACE provides engineering support along with the research and development of new technology. After describing general approaches to government mitigation, a more specific research program, H2Rescue, will be described, with implications for an anthropological approach outlined for future research.

### *3.1. Zero Emissions Driving Long-Term Mitigation*

The rise in global temperature due to greenhouse gases has led to an unprecedented push for a transition to clean energy across all sectors. In demonstrating the results of governmental efforts towards climate change mitigation, it is important to show how the private sector has responded and the limitations of those actions. Initially, the auto industry ramped up electric vehicle production, but many CEOs in the U.S. currently complain about slow sales ([Krietzberg 2023](#)). As inventory grows, producers are marking down prices, while consumers explain that the lack of charging stations and lifestyle barriers dissuade them from purchasing; therefore, there is a glut of unsold electric vehicles ([St. John and Naughton 2023](#)). However, any transition from internal combustion engines will necessarily include a cultural shift as consumers discover new ways to interact with vehicles and infrastructure.

Despite cooling consumer interest, companies such as Mercedes-Benz are not just producing electric vehicles but are also attempting to create that change in lifestyle. Recently, the company has unveiled a futuristic charging hub at its U.S. headquarters in Sandy Springs, Georgia. The station includes the fastest charging technology available, which also works on any brand of vehicle, and a charging lounge with comfortable seating and vending machines ([Poultney 2023](#)). The drive to change attitudes about how people “refuel” might convince some skeptical consumers.

Other companies, such as Toyota, have scaled back the immediate transition to EVs and instead completely converted one of their most popular brands of sedan, the Camry, to hybrid. This production change addresses consumer concerns about lack of range and convenient charging stations, while simultaneously cutting down on emissions ([Valdes-Dapena 2023](#)); meanwhile, Mercedes-Benz has embraced a business plan that includes altering the culture of response to climate change based on consumers’ uptake of these vehicles. However, a larger factor in spurring innovation will be the government’s push to electrify, creating a massive production boost for electric vehicles, which could lead to broader adoption in commercial markets.

Following the President’s order for a transition to electric vehicles and the Army Climate Strategy Guide for converting to carbon-free installations ([Executive Office 2022](#); [Evans 2022](#), respectively), many government agencies have produced guides for implementation (c.f., [Hodge et al. 2022](#)). Some installations have begun planning for fleet renovation, while others have already started that transition. Army leadership at Fort Carson, who have encouraged environmental sustainment efforts in the past ([Procter et al. 2016](#)), began procuring both vehicles and a variety of chargers by the end of 2022.

Masterplans for the conversion of fleets are currently gathering speed, with assessments of current light-duty vehicles, immediate implementation of charging stations, and how the future transition might impact base operations. Analysis regarding the number of new vehicles and chargers will lead to the amount of additional electrical load that will be added to existing distribution systems. Future infrastructure upgrades include microgrids to lessen the draw on nearby municipalities, with the production of new solar arrays and the use of other forms of renewable energy. New EV chargers will be strategically located near existing utility transformers to minimize distance and cost for electrical connection.



Metering for all new EV chargers would be at the existing utility transformer and would be metered separately from the existing loads so that private vehicles can be charged through a plug-and-pay system.

Although Fort Carson is proceeding with plans to transition away from light-duty vehicles (with 200 trucks currently existing on the installation; [Shinn 2023](#)), early efforts have only covered the Department of Public Works lighting trucks, with other departments also switching their light-duty, medium-duty, heavy-duty, and off-post vehicles at a later date. The differences between types of chargers and where they would need to be located provide a critical foundation that would lead to complete acquisition and installation. EV chargers must be mapped out by building, including how many vehicles are stationed at various parking lots. Considerations for down range and training land locations, where electrical infrastructure are lacking, opens opportunities to explore the strengths and drawbacks of standalone solar-powered charging stations (see Figure 1). R&D technology such as these off-grid chargers will mean less of a drain on current electrical infrastructure, but the location of this equipment must be carefully chosen to maximize the convenient use of alternative energy sources—an important human factor that will confirm the success of the program. Additionally, hydrogen as a clean alternative fuel complements electricity generation while also mitigating pressure on the grid (as will be shown below). Using hydrogen reduces the burden on the electric grid, generating off-peak energy to be stored and used during critical power timeframes.



**Figure 1.** An off-grid, solar-powered charging station with an autonomous shuttle parked to the side and a motorcycle plugged in underneath the solar panel roof.

Fort Carson will be taking hundreds of internal combustion vehicles off the roads, switching to electric vehicles, and acquiring chargers to power those machines. Between this

and the other 58 Army installations (listed on [Military.com 2023](#)), the impact of demand on supply will drive a significant U.S. public and private sector culture of response regarding climate change mitigation.

The significant effect on local and international markets will certainly create problems related to how demand increases tension on supply chains. Considerations in relation to electrification on military bases due to added charging costs also have critical human dimensions. As an example, planning for new vehicles and the energy to be used by them can be carried out according to mileage per vehicle. However, this does not account for the specific use of said vehicles. Light-duty trucks that carry a heavier load due to necessary tools and equipment, and vehicle use during periods of high heat will have a greater electrical impact on battery usage.

Applied anthropologists can ask questions before and during the development of new technology to implement its use more effectively (c.f. [Aiken 2016](#)). Their participation in the building of objects and tools ([Keller and Keller 1996](#)) and the iterative process of technology production ([Suchman and Trigg 1993](#)) has long placed them in spaces to evaluate the effective creating and implanting of innovations. The authors' participation in the government's broader mitigation efforts informed research in a specific R&D program that led to successful demonstration of an alternative energy solution that both mitigates and adapts to climate change.

### 3.2. Short-Term Mitigation and Adaptation: H2Rescue

In 2020, CERL led efforts to create a zero-emission fuel cell-powered emergency vehicle. The launch of the truck for two field tests later that year was the culmination of work from a consortium of federal agencies and industry partners, including the U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office and Vehicle Technologies Office, the U.S. Army Ground Vehicle Systems Center, the U.S. Department of Homeland Security's Science and Technology Directorate, the U.S. Naval Research Laboratory, and Accelerate™ by Cummins. Following the production and initial testing of this prototype vehicle, the engineering team brought an anthropologist onto the program to provide the lens of social sciences in the continuing development and research of this project. The foundational information provided on this vehicle was taken from the initial contractor's report and the field test briefs.

H2Rescue is a Department of Transportation roadworthy class 7 medium duty boxed truck weighing approximately 33,000 pounds (see [Figure 2](#)). The polymer electrolyte membrane fuel cell battery-powered truck carries a maximum of 176 kg of hydrogen at 700 bar, which is enough fuel for H2Rescue to travel approximately 1500 miles on a single fueling. The boxed bed of the vehicle is climate-controlled and can act as a mobile command center during an emergency. It provides load-following microgrid-capable exportable power. Instead of polluting exhaust from a diesel engine, the hydrogen fuel cell produces deionized water as waste, which could be used as an asset during an emergency.

The vehicle's ability to provide a microgrid for energy, a climate-controlled environment, and water will allow it to drive into austere situations and immediately begin operations as a command center. Regions lacking services and shelter due to a hurricane, flooding, or wildfire could all benefit from H2Rescue's ability to set up and begin assessing the recovery of an area provided the roads are accessible. To understand the physical capabilities of the vehicle, two demonstrations were given after its construction.

The objective of the two field tests in April and May of 2023 was to confirm the emergency relief truck was capable of a 180-mile round-trip driving range to relief destinations. Additionally, H2Rescue should be capable of providing up to 25 kW of load-following exportable power for a sustained period of up to 72 h once on site. The first field test on 11 April was a drive from the Cummins Electrified Power facility in West Sacramento to the FEMA headquarters in Oakland and back to the facility, with a mix of on-highway and street driving.



**Figure 2.** The H2Rescue hydrogen-powered emergency vehicle.

The second field test on 8 May started at the National Renewable Energy Laboratory in Golden, Colorado with a round-trip drive to FEMA Regional 8 in Agate, Colorado. Both 180-mile trips were completed, and the power export tests were successful, although the Colorado field test was cut short after 28.4 h due to harsh weather conditions. The functional capacity evaluation of both startup and power delivered during the export portion of the test indicated air blower limitations at higher elevations, but this did not impact regular operations.

These field results highlight the importance of testing new R&D equipment, such as H2Rescue, before producing the technology for consumers and sending it out into emergency situations. The addition of an anthropologist to the team led to a reevaluation of the water producing abilities of the vehicle, and how they could be refined and used in real world disaster contexts. Other considerations regarding the technical properties of the relief vehicle and how those overlap with the social–economic challenges of specific environmental disasters will be explored below. The importance of an early national culture of response underscores the long-term success of resilience, as seen during two disasters on the Navajo Nation.

#### 4. Discussion

The reception of governmental aid by local people during a disaster can vary depending on the level and speed of response. Past environmental calamities have been exacerbated by slow responses, especially in locations with a lack of robust infrastructure. Examining these disasters, such as the Navajo Nation’s 2013 deep freeze and the 2015 Gold King mine disaster, can provide a focus for our adaptation efforts. The local culture of response can be seriously impacted during future events depending on initial federal reactions to disaster.

To demonstrate how a national culture of response, encompassed in objects such as the H2Rescue vehicle, can adapt to local emergencies, we turn to two disasters that occurred in the same regions, one shortly after the other. As described by the Director of the Navajo Nation’s Department of Emergency Management at the time, Rosalita Whitehair, these disparate crises could have both benefitted from H2Rescue ([Whitehair 2023](#)). The first



calamity resulted when the Southwest U.S. was hit by a cold snap lasting three weeks in January 2013.

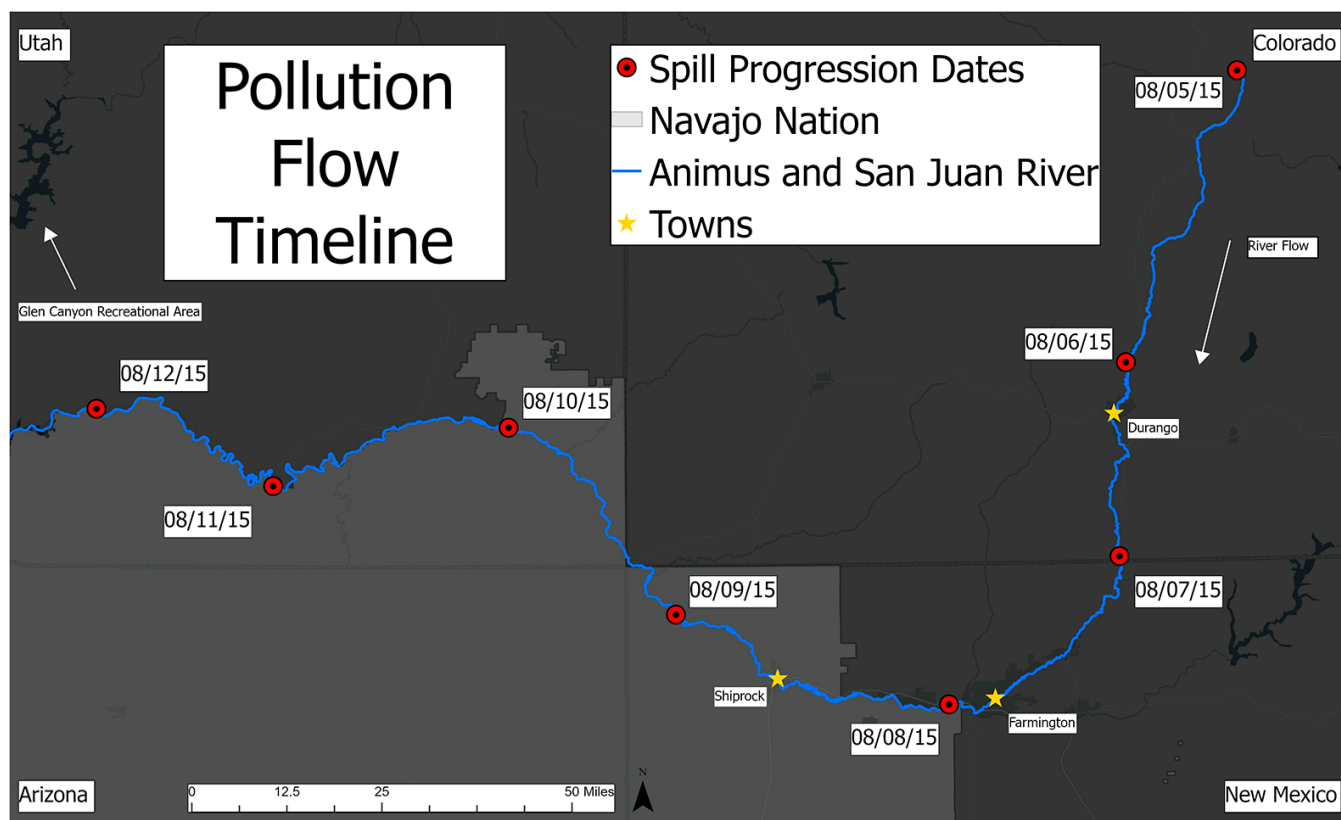
The long freeze shattered pipes, leaving thousands of Navajo tribal members without drinking water. State and federal emergency departments had registered 1729 reported water outages by February 7 (N. L. Smith 2013). The Navajo Nation spans an expansive area of 27,000 square miles, with most of its population dispersed in small settlements or scattered houses (Davis et al. 2021). After the state of Arizona issued a declaration of emergency, tanks of water were delivered to communities—something that H2Rescue could have provided—along with a more mobile operations center. With up to 400 gallons of water being generated as the byproduct of operations during one full tank usage, both the 110 chapter communities and smaller widespread settlements would have water for drinking and cleaning.

When analyzing the political economy of aid, the structural limitation of a large vehicle needing accessible roads is the first factor that is confounded by frozen roads. The anthropological field method of participant observation would be critical to assess the access of locals to the vehicle's heated cab, water, and any administrative functions taking place in the command center. The type of emergency and how quickly H2Rescue allows resumption of living in the area could provide a starting point for measuring resilience, with quickly accessible communications between widespread communities.

Perceptions of a national culture of response must be gauged in the context of providing immediate relief where local supplies are compromised, as was the case with the 2015 Gold King mine disaster on Navajo Nation. On 5 August, a spillage of mine waste-rock from the Gold King Mine released approximately three million gallons of toxic metals into the Animas River, which flowed through Durango, Colorado and onto the Navajo Nation via the San Juan River. The Southern Ute Tribe acted quickly to notify other tribes downstream, begin its own water sampling, and start providing water for livestock (G.P.O. 2016). As one Navajo farmer described, the pollution of their water occurred when all crops needed moisture during the desert environment's growing season (J. P. Thompson 2018, p. 9).

Over the next eight days, the sludge made its way downriver, resulting in a forced separation from the river as the Navajo people closed their irrigation channels (see Figure 3). The challenge of access to water was reemphasized in this desert environment as Native Americans were cut off from their main source for both crops and livestock. Unlike the deep freeze of two years previous, this affected a non-piped water source that runs along 250 miles of the Navajo Nation. The people living along the river mistrusted the delivery of large tanks of water that clearly had oily residue within them (Whitehair 2024). The mobility of H2Rescue and its water creation potential as a byproduct of operations would, again, provide critical post-disaster relief. The importance of crop and livestock water generation is underscored by the H2Rescue vehicle's volume compared to the small average household usage of five gallons of water per day. These normally low levels of personal water consumption are driven by the lack of running water outside large communities (Whitehair 2016). The water production of H2Rescue would clearly go a long way in this context.

With the minimal water requirements of households that are further away from larger communities (which have piped water), H2Rescue's water production could be focused on livestock and crops. Households that raise cattle or sheep need different levels of water, as the average cow requires 12–15 gallons per day (Ward et al. 2017), while a sheep can subsist on three gallons a day in similarly arid environments (G. Smith 2023). Without accounting for water used by their human caretakers, the emergency vehicle could provide water for thirty head of cattle or for 133 sheep in a day using one full tank of hydrogen.



**Figure 3.** The dates of the Mine King Disaster pollution spill and its spread (map by Bradley Crissman 2024).

Whether sitting at rest to generate export power and acting as a communications center or driving to the next location, the hydrogen fuel cells generate water. The challenge is capturing that liquid so it can be used while at each stop, as the current overflow tank is only 10 gallons. H2Rescue's water storage capacity would need to be expanded to a 300-gallon capacity for successful short-term mitigation at a scale useful for watering livestock or crops. Removable water tanks could be employed, which would make it easier for the vehicle to travel the West's open-range environment, leaving potable water for communities and then moving on. The flexibility of mobile water generation during a disaster could assist in immediate adaptation, but building more permanent water storage in centralized locations might provide easier long-term mitigation.

However, just rebuilding infrastructure and monitoring immediate impacts are not the primary factors in determining resilience. To gather an accurate measure of recovery, longitudinal data on the community response should be obtained. Depending on both the nature of the disaster and the community, this could be achieved with follow-up participant observation and surveys. More importantly, this long-term research should be governed by participants within the affected region (Beans et al. 2019). The effectiveness of H2Rescue must be based on its actual performance in destabilized environments and a measure of culturally situated long-term resilience in the communities it services as a true measure of operational efficacy.

## 5. Conclusions: Research Implications

The Anthropocene must be mitigated using technology, but the best way to both adapt and mitigate is by focusing on human activity. Technology itself will not do the job. Research and development must occur in concert with a focus on the social-economic factors of resilience within affected communities. Technological mitigation and adaptation will be best served by looking beyond the laboratory to see how these solutions are used

by affected communities. R&D projects such as H2Rescue will ideally be placed in mass production and then act as response vehicles in emergencies after the robust development process anticipates a variety of situations and adaptations. Version two of the prototype will need more hardening for use in disasters. However, the use of the equipment is best evaluated by those who it purports to help. Do locals actively integrate the national culture of response that builds resilience? Do technological R&D solutions such as H2Rescue provide usable on-the-ground solutions for a variety of disasters? More importantly, collaborations with indigenous communities for inspiration as to how they have adapted to and mitigated climate change will lead to more robust planning and policy initiatives (Crimmins et al. 2023, p. 49). A combination of technology testing alongside social science to provide applied, time-constrained research is only the beginning of longer-term strategies for mitigating climate change.

The importance of access to an insider group is critical, though the time constraints of applied anthropology can be a limiting factor when gathering data in the field. Rapid appraisal techniques for collecting information during a disaster will assist in gathering evidence as to whether technology fills the needs highlighted by the Navajo Nation case studies (Beebe 2002). Quality control can and must be maintained through interactive methods such as observing local sociocultural idioms during emergency deployments, gathering important contact information from perspective participants, and then following up at a later time with surveys or more formal interviews (Finan and van Willigen 2002).

As environmental disasters persist, emergency deployments of vehicles such as H2Rescue—after the R&D period is over and the hydrogen fuel cell emergency response has become routine—will necessitate applied methods for building resilience. Interactive research could include documentation of rural contacts for follow up to both discover the acquired social knowledge and facilitate surveys for a systematic comparison of effectiveness (Finan and van Willigen 2002). The progress of technological and socially led efforts will produce the strongest adaptation and mitigation programs.

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