Language and Groundwater: Symbolic Gradients of the Anthropocene

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This paper argues that geographers must study the power of words as integral parts of human-environment relationships, with particular attention to local meanings, in order to intervene more effectively in the Anthropocene. Words are important tools by which people come to understand environmental changes and develop plans to facilitate mitigation and adaptation, or alternatively to postpone these responses. This project considers the portion of Texas underlain by the Ogallala aquifer as a system of communication, exploring stakeholder articulations through in-depth interviews. The semiotic concepts of gradients, grading, degradation, and grace are employed to facilitate consideration of how verbal articulations intersect with resource use, conservation, anthropogenic environmental change, and action, within a highly conservative political context.

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We are tool-using animals, belatedly realizing that our tools affect the planet on which we live. This recognition entails nothing less than a protracted crisis, with political, economic, philosophical, and religious components (Callison 2014, 14). Among the tools caught up in this crisis are words, *semiotic* devices by which people understand environmental changes and develop plans to facilitate mitigation and adaptation, or alternatively to postpone these responses (Hulme 2008; Lakoff 2010; Boykoff 2019). Geographers must therefore study the power of words as integral parts of human-environment relationships, at scales from the global to the local, to intervene more effectively in the Anthropocene. This paper demonstrates a *semiotic* approach to the Anthropocene, taking words about groundwater as semiotic tools that both help and hinder sustainability.

Consider how groundwater is put into words. An informational booklet by the U.S. Geological Survey contains the following description: "On a regional scale, the configuration of the water table commonly is a subdued replica of the land-surface topography" (USGS 1999, 6). These words evoke gently rounded uplands of groundwater hidden beneath visible hills and mountains. Later in the booklet, the impact of a well on an unconfined aquifer is explained in more technical language: "dewatering of the formerly saturated space between grains or in cracks or solution holes takes place. This dewatering results in significant volumes of water being released from storage per unit volume of earth material in the cone of depression" (USGS 1999, 14). Here we find specialized terms, "dewatering" and "cone of depression," with the latter giving three-dimensional form to the anthropogenic change indicated by the former. As Tuan noted in regard to the Mississippi River (1991, 688-689), a name can in effect "be said to have

created the [hydrological] system by making the entire river, and not just the parts visible to observers on the ground, accessible to consciousness." There are also legal terms like "rule of capture," the principle whereby landowners in Texas have "a legal right to capture water beneath their property without regard to effects on other wells except in cases of waste or malice" (TAGD 2019). Another important verbal tool is "desired future conditions" (DFC), which the Texas Alliance of Groundwater Districts (TAGD) defines as a "quantifiable condition of an aquifer at a specified future time." This exemplifies a name with "the creative power to call something into being… to impart a certain character to things" (Tuan 1991, 688).

What will be explored here is how such verbal tools imply *figure-ground relations*, which in turn indicate what is taken-for-granted, and what is worthy of notice. The paper will examine the semiotics of groundwater, but the same approach could be employed with any other aspect of the environment. Of particular interest here are environmental *gradients*—significant differences (across space) or changes (through time). By examining how language embodies gradients we can better understand semiotic tools working on and in the Anthropocene.

The paper begins with an introduction to the study site followed by a discussion of theory and methodology. The body of the paper interprets the meanings of *production* and *consumption*, *conservation* and *waste* as key indications of semiotic processes in the Anthropocene.

Study Site

The study site includes the portion of Texas underlain by the Ogallala aquifer: 36,500 square miles in the northernmost part of the state (Figure 1). Much of the water in this formation was deposited thousands of years ago and replenishment of the Texas portion is less than a quarter inch (6 mm) per year (Reedy et al. 2008). It is being drawn down more than a foot (30 cm) per

year in significant portions of 20 Texas counties (George, Mace and Petrossian 2011, 15; McGuire 2017). The water table has fallen by as much as 300 feet in some areas and, at the current rate of drawdown, the region's irrigation-based economy will collapse or undergo massive transformation by the end of this century.

The region is famous as an emblem of environmental crisis. Along with portions of adjacent states, this part of Texas experienced severe drought and catastrophic agricultural failure in the 1930s "Dust Bowl." Today, much of the same region is covered by circles of corn, wheat, sorghum, and cotton a half mile or mile in diameter. A local narrative holds that as material technology diffused into the region (center-pivot irrigation systems with affordable wells and downhole pumps, better plows, and cultivators, hybrid seeds, chemical fertilizers, herbicides and insecticides) technological change transformed this place from dustbowl to cropland. However, it is equally valid to assert that after the dustbowl people learned to read the environment differently and communicate its potentials and constraints in more productive (though not necessarily more sustainable) ways. These readings shaped the diffusion of various agricultural technologies, relations between people, and patterns on the landscape.

Such environmental readings employ *gradients*—ranges of difference with both physical and symbolic attributes, knitting together time and space. One such gradient is total annual precipitation, which ranges from 23 inches (585 mm) to 18 inches (460 mm) along an east-west transect of the study site. A more complex set of spatial gradients exists below the earth surface where an undulating layer of sand, gravel, silt and clay holds the Ogallala aquifer. This formation varies in thickness, depth and composition, creating different levels of groundwater access for farmers from neighboring counties, and even from neighboring properties. There are also temporal gradients in water, like the annual oscillation between rain and snow, dry winters and

somewhat less dry summers, or the annual cycle in which cones of depression ("drawdown cones") are deepened and broadened by pumping during the growing season, then partially recover each winter. This, in turn, leads to another temporal gradient, the overall drawdown of groundwater throughout the region.

Gradients are translated into language in many ways. According to one verbal formulation, those who extract a natural resource from a finite supply can be called *consumers* engaged in *consumption*; their actions result in eventual *depletion* of the resource. According to an alternative formulation, the same actors are *producers* engaged in *production*; the result of their actions is *development* of the resource. Farmers, ranchers, and water conservation administrators throughout Texas favor the second set of terms when talking about groundwater. This word choice can be pursued to see how semiotic processes shape resource use. Beyond this, we can explore how stakeholders charged with conserving water manage to articulate that conservation goal despite the narrow definition of waste they uphold. Doing so reveals gradients of several sorts: articulated gradients of language, experienced gradients in time, and constraining and enabling gradients in social and physical environments.

Methodology and Theory

Extended interviews were conducted in 2018 and 2019 with thirty-four stakeholders in ten counties scattered across the study site. Subjects included nineteen farmers, two ranchers, seven officials in groundwater conservation districts, four agricultural extension agents, and the director of a metropolitan water utility. The total duration of the interviews was 35 hours. Participants answered questions about groundwater, including its value, usefulness, and management in the High Plains landscape, as well as questions about weather, climate, and sense of place. Interviews were interpreted using a methodology drawing on communication

geography, place attachment research, environmental semiotics (Adams 2016; Kockelman 2016a; 2016b; 2016c; Smith 2018).

This methodology assumes that verbal constructs structure human perception and sense of place, but place has a reciprocal power over verbal meaning (Tuan 1991; Evernden 1992; Cronon 1996). Words can highlight or obscure environmental risks (Whorf 1941). Words also ascribe value to things, marking them as resources, whether human or nonhuman (Kockelman 2016c). Environmentally relevant words include general-purpose terms like "nature" (Evernden 1992) and "wilderness" (Cronon 1996), as well as terms of specific interest here: "water table," "drawdown," "right of capture," and "desired future conditions." Therefore, in an agricultural landscape, new material technologies (e.g. hybrid seeds, irrigation systems, GPS-guided combines, herbicides) do not simply alter the landscape; changes in technologies are linked both to human agency and the material environment through semiotic constructs.

Based on the writings of Ferdinand de Saussure, Charles Sanders Peirce, and others who followed in their footsteps, semiotics is the analysis of meaningful associations and distinctions. Semiotic equivalences and differences give structure to language and other aspects of culture, including human relations with natural phenomena. The Saussurian approach is most accessible, and will be presented first by way of a brief introduction. We can think of a linguistic sign as composed of a signifier and a signified, each of which treats certain things as equivalent and certain things as different: the visual shapes of the letters in "water," are treated as equivalent to the sounds of the spoken word "water," despite the manifest differences in these signifiers. Signifiers point to a signified which, in the case of water, is a chemical substance H_2O that is found on earth in solid, liquid and gaseous states, and is understood as the same thing (signified) even when bound up in living organisms or below the earth surface. Signs have *syntagmatic* and

paradigmatic relations to other signs. Syntagmatic relations are the grammar of signs, what goes with what, in what order or combination, while paradigmatic relations govern which signifiers can be substituted, and how that affects meaning (Saussure [1916] 1983). The focus of the paper can now be clarified as *a study of paradigmatic relations between production and consumption, conservation and waste in a particular place.*

Semiotic analysis problematizes the elusive, shifting and fuzzy lines between linguistic constructs as they are built into verbal expressions and mapped onto phenomena in the world. Such analysis provides a glimpse of the constructedness of relations, not only between signs (as potentially substitutable things with constructed differences) but also between distinctions operating simultaneously at levels including signification, perception, and action. To integrate semiotics with action we must turn from Saussure to Peirce (see Peirce and Hoopes 1991). For example, if one goes to fill a water bottle, then reads a sign "non-potable water" and walks away without filling the bottle, the change between intended and final actions reveals the fulfillment of the sign's function, which Peirce calls the sign's *interpretant*. Both Tuan's interest in "language and the making of place" and Cronon's concern about "the trouble with wilderness" stem from an awareness that signs are not mere labels, but also imply *interpretants*. That is to say that semiotic processes are geographical because they are place-making processes.

Signs are also place-specific. If one drives on Interstate 10 from California to Florida, one starts on a "freeway" and ends on a "highway"; the signifier for a limited-access, multi-lane road changes as one moves from place to place. Similarly, departing from California, the plural of "you" is "you," but somewhere along the way the plural of "you" becomes "y'all." Thus the sign "you" has a narrower signified in Alabama than in California. In this paper, the signifiers

"production" and "consumption" are assumed to map different signifieds depending on place and situation.

Insofar as place is generally understood by geographers in terms of location, locale, and sense of place (Agnew and Duncan 1989), then signs do not merely vary with regard to location; they also help constitute locale and sense of place. Particular uses of words engage social and psychological processes of inclusion and exclusion, self-identity, and subjectivity (Adams 2017, 5081). Saying "y'all" in the South identifies one as an insider; it signifies who and what the speaker is. Likewise, describing well water extraction as "production" in Texas signifies that the speaker adopts local terminology relating to groundwater, and is *of* the linguistic community. Insofar as place attachment has a communal dimension involving the "*expressive* (or symbolic) meaning of places to which people are attached" (Smith 2018, 5, 6), then such place-specific semiotic peculiarities are central to place attachment.

Place-based studies of semiotic processes are therefore needed to clarify place-making, place attachment, and human-environment relations. In that interest, we will move between legal terminology of the Texas Water Code and excerpts from interviews with local stakeholders, particularly the directors of groundwater conservation districts (GCD). Their attempt to grapple with environmental change will be interpreted in terms of gradients, grading, degradation and grace. *Gradients* build on Peircean analysis, and are "the way relative degrees (or quantities) of relevant dimensions (or qualities) vary over space, in time, or across individuals" (Kockelman 2016a, 406). People make active use of gradients, changing them according to perceived needs and interests, a type of action we can call *grading*. Grading involves individual human actions, as when a well owner creates a drawdown cone. It can also involve collective actions, as when

hundreds of irrigation farmers, industrial users, and municipalities across a region all contribute to the drawdown of an aquifer.

By understanding actions relative to gradients as figure-ground relations, new light is shed on human-environment relations. The "figure is that entity whose degree (along some dimension) is being graded; and the ground is that entity whose degree (along the same dimension) is being used to grade" (Kockelman 2016a, 392). Grounds of semiotic comparison include things that range through space, as well as things that change through time. Semiotically speaking, the ground is what is taken for granted:

> For example, when I say, 'the rains were heavy,' you don't just need to know that I am talking about rains (as opposed to cellphones, stars, or trains); you also need to know what counts as a heavy rain around here, for people like us, engaged in an activity like this, given recent events and future plans as much as past experiences. (Kockelman 2016a, 397)

Environmental communication therefore draws on, and perpetuates, shared understandings of what is typical or normal, while simultaneously indexing what is changing or unexpected, such as the disappearance of a useful or beneficial gradient. *Degradation* describes such a negative consequence of grading, and the attempt to preserve a valued gradient can be called *grace* (Kockelman 2016a; 2016b).

Insofar as "decline management is a primary goal of water-resource management" (Emel and Roberts 1995, 672) the community-organized resource regimes administered by groundwater conservation districts in Texas are manifestations of this sort of *grace*. As Gilbert White maintained (e.g. 1961), collective decisions about water can potentially be improved by

expanding the *range of choice* from which policies are chosen. A semiotic approach to geography in the Anthropocene suggests new choices within a particular "socially and historically structured context" (Wescoat 1987), facilitating more resilient articulations of each place's hydrosocial choices (Perramond 2016) relative to its manifestations of gradient-maintaining *grace*.

In this epistemological context, the Anthropocene can be understood as a period in which: people increasingly encounter degradation of useful gradients, grading gets out of control, and grace is in chronically short supply, environmental degradation becomes more widespread, and stakeholders search for verbal and visual language that will help them to intervene (Moser and Boykoff 2013; Wilson 2019). We now move to research findings from West Texas and the Panhandle, with attention to water consumption and production, waste and conservation.

Words and Water

Consumption or Production?

As signs, consumption and production are closely tied to grading and degradation. Generally, consumption depletes, degrades, or uses up something useful while production creates, increases, or mobilizes something useful; the former is a shift toward absence while the latter is a shift toward plenitude. However, this semiotic relationship varies geographically and historically. The Texas State Water Code (henceforth simply "the Water Code") avoids the terms "consumption," "extraction," and "depletion" when referring to human use of groundwater (Texas 2019). In Chapter 36 of the Water Code, there are 70 separate references to water involving words related to "produce," including: "production from water wells," "producing of wells," "water produced," "a well that produces the majority of its water," "groundwater that an aquifer is capable of

producing," and so on. In striking contrast, the term "consumption" appears only once in the 39,541 word document. Behind the legalese (a product of the time in which the water code was written as well as its subsequent revisions) lurks a cornucopian model of the world in which people only create or augment hydrological resources, never depleting, degrading or exhausting those resources. In Texas, an artesian well and a pumped well both "produce" water; reflecting a disenchanted, economistic worldview diametrically opposed to earlier understandings of the hydrologic cycle, where water moving through the environment was read as a sign of divine providence, supernatural power, and sacred perfection (Tuan 1968).

All of the Texas water district administrators who were interviewed employed the term "production" to refer to water extracted from the Ogallala aquifer, calling farmers and ranchers with working wells "producers." While these administrators were clearly dedicated to goal of groundwater conservation, their production-oriented language is an unrecognized obstacle to reaching their goals and objectives; it positions water use on a temporal gradient—a slope from less to more, from lack to potential—which fails to reflect drawdown. When Becky[1], the manager of a GCD east of Amarillo described challenges facing water conservation districts she said: "[T]hey have people *who can produce a lot*, and they have people who *can't produce very much*." When Patricia, the manager of a GCD west of Lubbock spoke about limits on water use she explained: "You still can *produce* the water, but you're gonna have to use maybe more than one well to get that *production* so that that smaller capacity pump is in the hole." When Jacob, the general manager of a large, centrally located GCD pointed to a model of the aquifer he said: "[A] well here versus a well where there's larger gravel, those two wells are going to have a different *production capability*." Through such spontaneous verbal articulations, the terms "produce," "producer," and "production" are drawn from the water code and transformed into

practice. The term "produce" indeed serves as a general word to describe water sourced from a well, even if it flows on its own, as from an artesian well. The term is applied whether one is obtaining water from a well that replenishes or from a well that does not. This broad semiotic mapping implies that wells generally participate in a gradient (or gradients) tending towards abundance, potency, and value. Officially sanctioned words are missing if one wants to talk about groundwater degradation and exhaustion in Texas.

Beyond the normative question of how we should speak and write in order to better manage scarce resources lies a broader semiotic question: how can we articulate reality to better reflect increasing scarcity in the Anthropocene? Water districts in the study area have been innovative communicators. They have developed physical and digital models of the aquifer, technical reports, maps and manuals (Emel and Roberts 1995, 670), lessons for local schools, and even trailers outfitted with interactive displays of hydrological processes. However, the weight of linguistic habit continues to obstruct their communications about groundwater.

Conservation, Waste, and the Law

We turn now to another word with an interesting career in the Panhandle and West Texas. In the study region, responses to the term "conservation" range from neutral to positive, despite the region's conservative politics. This is due in part to the fact that when Texas added the "Conservation Amendment" to the State Constitution in 1917, "conservation" had a distinctly different meaning that it does today. It included the capture of surface water and the drilling of wells (Green 1973; Mace 2016). "Conservation" evolved after the Dust Bowl, when relatively erodible land was taken out of production by the federal Soil Bank program, which was renamed the Conservation Reserve Program (CRP) in the 1980s. This program sends over $74 million in federal funds to this part of Texas each year to support fallowing some 2 million acres (USDA

2019), linking "conservation" not only to soil preservation but also to household financial security. Meanwhile, the state has enabled and encouraged the creation of "groundwater conservation districts" (GCDs) at the local level. Approximately 100 of these GCDs are now recognized by the state, each guided by a locally elected board of directors for the purpose of managing groundwater. It is not surprising, therefore, that Panhandle conservatives support "conservation." Conservation has been performed and articulated here in terms of resource capture, federal subsidies (CRP payments), and local governance (GCDs), all animated by a reigning logic of efficient resource capitalization (Opie, Miller and Archer 2019; Trigilio 2016).

The CRP and GCDs can slow groundwater depletion. The latter often enforce setbacks from property lines when drilling wells, limit water extraction to a certain number of gallons per minute or acre-feet per year, and set the minimum distance allowed between adjacent wells. GCD planning tools also include DFCs, for example 50/50 (50 percent of groundwater left after 50 years): a temporal gradient (drawdown) in the form of a policy objective linked to spatial gradients (varying groundwater availability across the GCD) and determined through public debate. Unfortunately, in many cases such conservation efforts are sufficiently lenient to accommodate the current rates of depletion.

One of the main functions of a GCD is nonetheless to prevent the waste of groundwater. So one might expect conservation and waste to be articulated as opposing philosophies. Oddly, conservation and waste are not coded semiotically as opposites in the study site. "Waste" is defined in the state's Water Code, as "the flowing or producing of wells from a groundwater reservoir if the water produced is not used for a beneficial purpose," or "willfully or negligently causing, suffering, or allowing groundwater to escape into any river, creek, natural watercourse, depression, lake, reservoir, drain, sewer, street, highway, road, or road ditch, or onto any land

other than that of the owner of the well…" (Texas Water Code § 36.001). Under Texas water law, then, waste does not mean consuming water too quickly. In Jacob's words: "In Texas the legislature has stated that allowing water to escape your property, that constitutes waste. OK, so you need to keep it on your property." Well water crossing a property line in a ditch then sinking into the ground is waste, but well water moving across the same property line in a bottle for sale as drinking water, or in a tanker truck for use in *fracking,*[2] is not considered waste. One can also allow well water to flow in an existing waterway, but this requires a "bed and banks permit." State law in effect condones two related forms of "capture"—territorial capture and capitalist capture—as the opposite of "waste," though neither necessarily involves using less water. The determining factor is whether groundwater is being used for some "beneficial" purpose on the user's property or elsewhere, or alternatively if the water is flowing without regard to human objectives.

The closely related "rule of capture" dates to 1904 (Houston & T.C. Ry. Co. v East, 81 S.W. 279) and depends on the common law principle that every landowner in the state has a right to take, for use or sale, all of the water that he or she can capture; the state "recognizes that a landowner owns the groundwater below the surface of the landowner's land as real property" (Texas Water Code 2019 § 36.002). This official recognition implies that a subterranean flow of water from Property A to Property B is *not recognized* as seizure of Owner A's property by Owner B even though a well on Property B, operated by Owner B, may be causing or accelerating that flow. This legal territorialization of water (Perramond 2016) has the odd effect that the water one owns is constantly changing, since the Ogallala aquifer flows at a rate of about a foot (30 cm) per day (122 yards (109 meters) per year), and local flows across (under) property lines can be much faster in response to drawdown cones (Quinn and Woodward 2015, 551). This

territorial definition of water rights creates profound contradictions, causing water to appear as a "badly behaved substance" (Emel, Roberts and Sauri 1992, 38). Those whose job it is to manage water manifest these contradictions between territorialized property and material property as part of their place-based subjectification as environmental actors (Emel, Roberts and Sauri 1992, 51).

Playing by the rules

Speaking with Troy, the General Manager at a GCD that has implemented unusually comprehensive water use regulations, I asked if he received any resistance from landowners. He replied:

> Oh yes. All the time! Let's, let's be straight about this: the water under your land is coming from somebody else's land. And somebody else owned it at one time. The rule of capture allows you to continue to pump and not really have to worry about the guys around you, except for the groundwater conservation district. So if you're telling me that you should be able to just pump whatever, and the hell with everybody else around you, that doesn't… that is not groundwater management. And yeah, I've heard that before!

This answer expressed personal commitment to groundwater management but left open the question of how Troy managed to defend the need for regulation. After further prompting, he explained:

> We hold everyone to the same account. If you go look at our rules in that book you won't see any difference in public water supply water rules compared to irrigators or industrial users. We treat everyone the same. And the reason is that we do want to have something left in fifty years or forty years.

Equal treatment is one way of dealing with differences among stakeholders, although owners of more land can extract more water, so equality does not necessarily mean equity. Troy's next comment invoked gradients in a different way, pointing out that some of the oldest landowners in the area were following the rules, so others should be able to adapt at least as well. He then followed up with:

> Something else about this area I really like: we're real conservative. … I've used that as one of the things to say [to people who argue against regulation]: look, everybody else out there is playing by the rules and seems it's not bothering them, so what's your problem?

Here, interestingly, the region's extreme conservatism (on the far right of political gradients) is taken as a sign that resource users desire equal application of rules. While the association between conservatism and commitment to equality is debatable, Troy's comments indicate the discursive opportunity to link conservation to a conservative sense of place. Not only is sense of place "deeply politicized as people defend a sense of place rooted in one narrative and dismiss countervailing narratives as distortions and delusions" (Adams 2017, 5081), but narratives employ signs, and signs are interpreted in place-specific ways. Where regulation is rejected, conservation can be presented in other terms, such as protecting private property or preserving fairness.

Who you're gonna sit at church with

As previously explained, in Texas "waste" is not necessarily the opposite of "conservation." GCD administrators frame their role primarily around the preservation of peace and order, which can be thought of in Kockelman's terms as a kind of *grace*, in this case an effort to preserve

valued social (as opposed to geophysical) gradients. Patricia, the general manager of a one-county conservation district says:

> A lot of people think water districts are out preventing you from getting to your private property rights, and that's such a misconception because we're actually protecting you from the people who are producing next to you… By our spacing regulations, [your neighbor's wells] aren't interfering with what's going on under your land. And so if you choose not to irrigate your property for so many years, um—of course, with gravity and the way the aquifer flows there is some [loss of water to one's neighbors], with the rule of capture with Texas—but, for the most part the way we're spacing out [wells] so that that cone of depression doesn't go underneath your property, you're protected from that [loss of water to one's neighbors].

Patricia further articulates a perspective on water that reflects the GCD's role in terms of community and morality:

> I know my producers and they know me. They know our office and that one-on-one communication. They know they can call me if they have a question. They know our board because it's who you're gonna sit at church with on Sunday morning and have those real conversations if they have an issue.

Conservation is articulated in these place-based terms as caring, neighboring, and leading a moral life. This place-based discourse engages the local value placed on community order, thus securing cooperation and buy-in from local stakeholders.

Conclusion

What people say does not reveal its full meaning until we drill down into the underlying semiotic gradients. In West Texas and the Panhandle, tensions between "production" and "consumption," "conservation" and "waste," point to stakeholders' locally coded understandings of resource management. These words are ways of interpreting evolving human-environment relationships. They reflect gradients of groundwater in space, grading and degradation of hydrological resources through time, and the "grace" of achieving conservation goals through local commitment to the ideal of a peaceful, fair, stable, and moral community.

Like an aquifer, the currents of a linguistic underworld can be charted and its flows can be followed. Semiotic analysis helps to map the human-environment relations in a place. It reveals how the powerful text of a law circulates through environmental agents like conservation administrators and local water users, crossing boundaries, defying capture. The questions implied by this approach are not just about the human power to shape the environment but also about meaningful differences, and differences in meaning, and local forms of grace flowing below the surface, slowing degradation and hastening acceptance of place-based understandings of conservation. If the Anthropocene is a time when people's role in shaping the environment has come to the fore, then we must be aware that people are themselves shaped by an environment of language that channels their thoughts and actions.

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Figure Captions

Figure 1: The Texas portion of the Ogallala aquifer (shaded) with highlighted boundaries around the ten counties where interviews were conducted. Base map redrawn by Danielle A. Ruffe, after George, Mace and Petrossian 2011, p.51.

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[1] Names of interview respondents have been changed. University of Texas IRB Exempt Protocol Number 2018-05-0099.

[2] Fracking is a common term for hydraulic fracturing, a technique in which water and various "proppants" are injected into the oil-bearing formation under high pressure to facilitate the extraction of oil and gas.