Title

Does It Hold Water?: Drought in California from 1959 — 2017

Permalink

https://escholarship.org/uc/item/37p1v27w

Author

McInnis, Haley

Publication Date

2022

UNIVERSITY OF CALIFORNIA SAN DIEGO

Does It Hold Water?: Drought in California from 1959 – 2017

A Dissertation submitted in partial satisfaction of the requirements
for the degree Doctor of Philosophy

in

Sociology

by

Haley McInnis

Committee in charge:

Jeffrey Haydu, Chair
Daniel Cayan
John Evans
Thad Kousser
Martha Lampland
Daniel Navon

2022

The Dissertation of Haley McInnis is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2022

DEDICATION

This dissertation is dedicated to my family – the one I was born into and the one I’ve made along the way.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

Bay-Delta	San Francisco Bay and Sacramento-San Joaquin Delta Region
CCSS	California Cooperative Snow Survey
CMI	Crop Moisture Index
CSUC	College System
CVP	Central Valley Project
DEWS	Drought Early Warning Systems
DWR	California Department of Water Resources
ENSO	El Niño-Southern Oscillation
NOAA	National Oceanic and Atmospheric Administration
PDSI	Palmer Drought Severity Index
SWC	State Water Contractors
SWRCB	State Water Resources Control Board
SWP	State Water Project
USDM	United States Drought Monitor
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
WY	Water Year

ACKNOWLEDGEMENTS

It is impossible to acknowledge all of the people who have helped me research and write this dissertation – let alone helped me get to this point in the first place. But it is also a task that I savor because I am overwhelmed by the gratitude I have for the individual and collective support I have received during this process.

The Department of Sociology at UCSD has been a source of support and growth, particularly during the early years of my graduate school career. The engagement and kindness of professors and my fellow graduate students exposed me to new ideas, challenged my thinking, and helped me grow into a more thoughtful sociologist and person. Jeff Haydu – my chair – was central to this process. Beginning in my first year, I benefitted from his advising on comparative historical methods, study design, archival research, argumentation, and writing in an authentic yet academic voice. His feedback has made my work and writing better, and any weaknesses in this dissertation are certainly my own. I am also thankful for his generosity of feedback and time. Thank you, Jeff, for your constant and invaluable support.

To my other committee members, thank you for your comments and support during this process and beyond. Dan Navon, thank you for your insightful comments, your willingness to collaborate, and showing me that it's possible to write clearly but academically even about complicated ideas. I will be striving for that level of clarity for the rest of my days. Martha Lampland, thank you for showing me how much history matters, that the good stuff is in the details, and how productive anger can be. Dan Cayan, thank you for making sure I was grounded in the science and pushing me to do sociology for a wider audience. My time with you and everyone else at CNAP was wonderful. John Evans, thank you for always being practical, interested, and encouraging. And Thad Kousser, thank you for your willingness to roll with things and share your knowledge of all things California politics. You have all shaped my approach to research and writing in large and small ways, and I will be eternally grateful.

I am also thankful to the funding sources I received to conduct this research. The UCSD Department of Sociology's Graduate Summer Research Grant, The Chancellor's Research Excellence Scholarship, and the Judith and Neil Morgan Fellowship made it possible for me to reach the archives I needed and helped make this dissertation possible. I am also thankful for the support I received at the UCSD Writing Hub, particularly during 2020 – 2022 when it was hard to find community.

The friendships forged in graduate school are possibly the part of this experience that I am most grateful for. I will miss each and every one of you desperately as we move on to the next big thing, but hopefully we never lose touch. Kayleigh Setoda, there is not enough space for me to tell you how important you are in my life and how much I value your kindness, encouragement, and time over the last six years. If nothing else had worked out at UCSD, I would still be grateful to have found you – our hangouts were crucial for keeping me sane. Erica Bender, you are my friend and my mentor. You taught me so much about sociology, grad school, and life in general. And you continue to do so – thank you! Cat Crowder, when I think about meeting my people in graduate school, I think of you (and your lovely family). Thank you for the tea, cookies, and game nights. Matt Wills, your humor and quiet rage were sources of joy and camaraderie over the last three years. I am so sad you are on the other side of the world now, but I cherish our coffee calls and snarky text threads even more for the distance. Lauren Olsen, thank you for cheering me on and guiding me through the hard points of graduate school – our check ins and emoting sessions were invaluable. Lindsay DePalma, thank you for being clear eyed and asking hard questions when they needed to be asked. I learned so much listening to you and working with you at the Writing Hub. Harrison Carter, thank you for being my first friend in graduate school and helping me feel at home in a new city and state. I can't wait to be back in the same place as you. And finally, thank you to my dissertation writing friends, Tapan Goel and Viona Deconinck. This process was lonely and painful at some points, and I am so thankful to have had you both to go through it with.

My friends outside of academia were equally meaningful and reminded me that there is more to life than graduate school. To some of my oldest friends, the D&D squad – Justine, Tara, Chelsea, and Nicky – thank you for our Thursday nights; they are everything to me. Your jokes, encouragement, and buckwild gameplay were critical to my survival. I hope we get to keep playing for years to come, and I can't wait to be properly at the table again. Susan Madsen, thank you for being the best roommate a person could ask for and a wonderful friend. You showed me what emotional health looks like, and you have the best taste in medical dramas and in restaurants. Alli Carlisle, thank you for being the best mentor and organizer someone could know, and for being warm and funny all the while but especially when the going was tough. And Sofia Fransson, you deserve your own paragraph for how important you are to me and how much I have relied on you these long nine years. Thank you for being a constant source of love and support even when I was difficult to love and support. There are not words for how much I love you and how grateful I am to have you in my life.

My family deserves special acknowledgement because they have supported my education and training my entire life. Thank you, Mum, for making sure that I was fed and taking care of myself and for encouraging me to protect my time. Dad, thank you for checking in on me and my progress and for making sure I had what I needed to make it over the finish line. Thank you both for your endless support over these last nine years, and particularly during this final one. I will never be able to repay you or express how much it means to me to have such understanding and generous parents who knew I was capable of finishing even when I didn't think so. Thank you, Grampa, for the ice cream money and calling on the weekends to see how I'm doing. I miss you tremendously, and I hope you would have been proud that I finally finished. And Riley, my sibling and my best friend, thank you for showing me that the hard work is worth it to get better, and that happiness is worth taking risks to find. You are my favorite person, and I am so lucky to have been born into the same family as you. I love you all so much, and I could not have done this without you.

Portions of Chapters 1, 2, 3, 4, and 5 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

VITA

2013	Bachelor of Science in Sociology, Arizona State University Bachelor of Science in Psychology, Arizona State University
2022	Doctor of Philosophy in Sociology, University of California San Diego

FIELD OF STUDY

Comparative Historical Sociology, Sociology of Knowledge, Environmental Sociology

ABSTRACT OF THE DISSERTATION

Does It Hold Water?: Drought in California from 1959 – 2017

by

Haley McInnis

Doctor of Philosophy in Sociology

University of California San Diego, 2022

Professor Jeffrey Haydu, Chair

Drawing upon in-depth archival research from California state bodies, scientific publications, stakeholder organizations, and newspaper articles, I present findings on how drought has been made and remade as a fact in California from 1959 - 2017. I study drought as a fact that is shaped by institutions, infrastructures, scientific research, water distribution, and other

practices. I use the framework reiterated fact making to analyze the conditions of possibility, path dependencies, and networks of expertise that explain the continuities and changes between four officially declared droughts in California: 1976 – 1977, 1987 – 1992, 2007 – 2009, and 2012 – 2017.

Three conditions of possibility laid the foundations for drought to emerge as a fact in California. First, the structure of California's water rights system led to a hierarchy of water access that shaped where water was delivered and whose shortages constituted a drought. The second was state government's commitment to water management through large infrastructure projects, making it possible for local water conditions to be disconnected from water supplies. Finally, the emergence of a meteorological interest in drought's physical indicators would transform drought from a socio-economic disaster to a complex but scientific phenomenon.

Material path dependencies like the State Water Project shaped drought by altering the relationship between place and water, making it possible for drought to become a statewide problem by connecting Central and Southern California to Northern California's water conditions. The infrastructure project made it possible for further population and agricultural growth that altered drought again. Finally, definitions of drought in the 1920s - 1930s continue to shape drought today through runoff calculations and water year classification systems.

Networks of expertise built up around drought changed over the last sixty years, changing drought itself. Climate scientists, environmental scientists, environmental activists, and Native American tribes entered a network already comprised of engineers, agricultural stakeholders, and water managers. Drought changed from a question of having enough water for agricultural and urban development in the 1960s to a complex, meteorological phenomenon that impacts farmers, cities, fish, ecosystems, and traditional cultures.

CHAPTER 1: INTRODUCTION

In 1965, Helmut Enrich Landsberg, a German climatologist working in American government, wrote that “Drought has been cited as a scourge of mankind since biblical times. It is still a major menace to world food supplies. Insect plagues, with which it ranks as a crop thread, can be fought by modern means. Drought remains an unconquered ill” (Palmer 1965:ii). Landsberg refers to the prominence of drought as a social problem, but also the inability of government and science to “conquer” or mitigate this problem. At the time, drought occurred when “water supplies deviate from average expectancy” (California Department of Water Resources 1961:4) and disrupted the rhythm of agricultural production – a critical economic sector. Taken together, drought in the 1960s was a well-known disaster to human beings that occurred when water supplies fell short of water demand, and it was an understudied and open scientific question in terms of its causes and how to prevent it.

Nearly thirty years later, drought was better understood scientifically, and progress was made to mitigate drought’s impacts with infrastructure. Even so, there was still a surprising amount of openness when attempting to define the thing itself. By 1988, California had a “panoply” of reservoirs, aqueducts, canals, and pumps that could insulate much of the state from the negative effects of dry conditions, but only for two years until those many reservoirs ran dry (Staff Writer 1988:B6). When the reservoirs are dry, ranchers are forced to sell off cattle to devastating financial losses (Williamson 1988:E1); and residents of suburbs outside of Sacramento are surveilled and policed for water wasting with the possibility of jail time if they are caught doing it more than once (Staff Writer 1988:A1). Surely, these water and social conditions must be a drought. Although conditions were dire, the chief deputy of California’s Department of Water Resources (DWR) can still muse “‘Well, I'm not sure if `drought' is the term, but we're still in a situation where we have to worry about carrying over enough water for next year,' [DWR director] Kennedy's chief deputy, Bob Whiting, said Wednesday" (Malnic 1988:no page). In the face of lowering reservoir stores, economic impacts to ranchers, and increased surveillance of water use – it is still unclear whether or not California was experiencing a drought.

Drought would continue to be both very real and very hard to define into the 21st century. New methods of studying drought never imagined in the 1960s, like tree-ring data and atmospheric modeling techniques, led to a deeper understanding of drought as a meteorological phenomenon and contextualized these climate events within centuries of data. However, the openness of when a dry period becomes a drought persists. In May of 2013, snowpack – the amount of snow in the Sierra Nevada Mountains during the winter months – might be well below average, but reservoirs storage from the previous year close to 100% average forestalls defining the conditions as a drought via a declaration (Grossi 2013:A3). In the following November, a chief hydrologist with the DWR muses that "it has been dry across the state, and it has been remarkably dry where the population centers are and where the bulk of the water storage is… Most operators plan on multiyear dry years, but nobody plans on as dry as we've seen" (Fimrite 2013:C1). It can be "remarkably" dry into a second year, but still be unclear that a drought is occurring.

We can see this contrast – very real but hard to define – formalized on the DWR's website. When looking for a definition on their website, a searcher will find this on the "Drought" page under a header labeled "Defining Drought":

> Defining drought is based on impacts to water users. California is a big state and impacts vary with location. Hydrologic conditions causing impacts for water users in one location may not represent drought for water users in a different part of California, or for users with a different water supply. Individual water agencies

> may use criteria such as rainfall/runoff, amount of water in storage, or expected supply from a water wholesaler to define their water supply conditions.
>
> Drought is a gradual phenomenon, occurring slowly over a period of time. Storage, whether in surface water reservoirs or in groundwater basins, buffers drought impacts and influences the timing of when drought impacts occur. A single dry year isn’t a drought for most Californians because of the state’s extensive system of water infrastructure and groundwater resources buffer impacts. (California 2022)

This definition – or lack of one – demonstrates the complexity of drought in general, but also the specific complexities represented by California. With its sprawling water projects, surface water in California is closely monitored and managed with daily updates on runoff, reservoir levels, and snowpack fed into the DWR databases. Water is expensive and precious – central to California’s agricultural sector and urban areas in the North, Central, and South. Like the quotes from 1965 and 1988 demonstrate, drought operates at the intersection of meteorology and economy, atmosphere and agriculture. Drought is gradual. It creeps up on the state over two years, manifesting through dwindling reservoir levels and snowpack measurements. Before any of us know it, water agencies have enacted conservation measures and agriculture stakeholders are reporting millions of dollars of losses. What is the tipping point? When is a dry period a drought?

I approach drought as a scientific fact that articulates an environmental problem. To do so, I draw on work from Environmental Sociology, the Sociology of Knowledge, and from Science and Technology Studies. Debates in environmental sociology have gone back and forth on how to understand environmental problems like drought: as constructed through our definitions and politics or real via the interactions between built and natural environments. I provide one possible answer on the side of realism with my examination of drought. I also draw on actor network theory, infrastructure studies, and studies on measurements and standards to examine how drought is rendered as a scientific fact over a fifty-five year period (1959 – 2016). To understand the changes over time, I make use of reiterated fact making – a comparative historical framework meant for studying the emergence of a scientific fact and how it is subject to radical change while maintaining a deep continuity.

In this introduction, I begin by laying out empirical and theoretical puzzles that grow out of the central research question: "When is a drought a drought?" I then describe current explanations and studies on drought in both physical and social sciences to lay out dominant understandings of drought as a fact and object of study. Next, I review the literatures that this study is built on in environmental sociology and sociology of science, knowledge, and technology. Specifically, I lay out frameworks for studying environmental problems and the emergence of scientific facts grounded in material relations and networks of human and non-human actors. Then, I build on a framework for studying the emergence of scientific facts through a comparative historical project: reiterated fact making (Navon 2019). I end the chapter with a discussion of each chapter's structure and how the empirical and theoretical findings contribute to discussions of California drought and the construction of facts and environmental problems - points which I elaborate more fully in the dissertation's conclusion.

Research agenda

This dissertation is about the deceptively simple question: "When is a drought a drought?" This is an important question to ask because defining and declaring a drought and involves many actors, and it leads to very real consequences for life in the state. Answering this question requires a bold grappling with both the social elements and physical elements of drought. In California, drought declarations are made by the Governor's office. The California

DWR measures and monitors surface water storage and determines how much water will flow to water districts and agencies. Farmers demand financial relief to keep this critical sector of the state's economy afloat. Meteorologists, climatologists, and hydrologists working in state agencies and in research institutes use a plethora of historical and atmospheric data to develop models, maps, and predictions for drought's severity, cause, and possible end. Drought is at once a social concern and a meteorological phenomenon. It is, in short, a very complicated process. To answer the question "when is a drought a drought?", I examine drought as both a social problem and a scientific fact, and how it changes over time.

It is necessary to define and differentiate among three related yet distinct terms that will be used throughout the dissertation. They are representations, definitions, and declarations of drought. "Representations"[1] depict a particular fact, and they can appear in different configurations. Sometimes they are a bar graph describing the runoff levels of a particular basin. Other times they are maps with areas demarcated by the severity of drought in a given geographic space. Representations also work to construct the fact they depict, and they exert real influence over how the fact is researched further (Callon 1984; Derksen 2000). They are crucial parts of networks because they work as a visual representation of water conditions, atmospheric patterns, or even drought itself. I borrow from the literature on social problems for my understanding of definitions of drought. Rather than an objective assessment, "definitions" are operationalized thresholds and attempts to draw a line around what is a "drought" and what is "not a drought", in a sometimes contentious, but always social process (Blumer 1971; Hilgartner and Bosk 1988). Definitions can differ, such as the distinctions between a meteorological,

---

[1] I do not mean to advocate for the philosophical position of "representationalism". I am not arguing that representations of drought as they appear in reports, papers, and other documents are "merely" representations of an objective reality that exists out in the world.

hydrological, and agricultural drought. Yet they all articulate a point at which conditions move from "dry" to "drought". They can be formal and encoded in water management practices, or they can be informal and circulated through newspaper reports and stakeholder statements. "Declarations" of drought are similar to definitions, but declarations are political. A drought declaration requires branches of government to confirm and label the current dry conditions as a drought. A declaration triggers coordinated responses and mitigation strategies. Water conditions might be defined as a "drought" by various indices for months before a drought is officially declared. A drought declaration is a moment of significant consequence because it means that regardless of what definition is in use or what organization is discussing the conditions – the state's social world now exists in the context of a drought. This is when a drought becomes a Drought – when the representations and definitions are all too overwhelming to ignore any longer.

The question “when is a drought a drought?” is primarily focused on definitions and declarations. I use it as an entry point to interrogate when different experts and stakeholders define drought, and how those definitions matter for official declarations – the ultimate designation of drought's existence in California. Representations are critical for explaining definitions and for understanding how definitions are formalized and depicted visually in reports. However, as I attempt to answer this question throughout the dissertation, I will focus on how representations depict definitions of drought, while focusing more closely on how drought is defined and eventually declared over the last sixty years.

I divide my investigation into sets of research questions that attend to the major components of drought declarations via a comparative-historical framework. The four focuses are as follows: a chronological historical overview; physical and legal infrastructure; water measurements; and networks of actors built up around drought. Each theme offers a different site for interrogating the complicated relationships between state agencies, measurements, actors, and water that characterize drought in California. These four themes were the most prominent analytically, although separating them from each other may disguise how interconnected they are. The sets of empirical questions within each "bucket" are as follows:

> How have the timing and reasons for drought declaration in California changed over time? What does this tell us about the implicit definitions of drought?
>
> How have water rights laws shaped the construction of physical infrastructure? How do water rights and physical infrastructure interact to shape water distribution across the state? How do these interactions shape drought declarations?
>
> How is water measured across the state? How are those measurements used to define and declare drought in California? What values are embedded in them?
>
> Which experts define and study drought? How do different experts represent drought? What stakeholders are invested in defining and declaring drought? How do each of these groups shape definitions and declarations both in terms of their own interests and through their interactions? How are these different – and sometimes conflicting – interests worked out in the process of drought declaration?

Each set of questions will be the focus of their own empirical chapter. Each chapter examines a particular component of what makes a drought a drought and tries to make sense of how it has been shaped over the last sixty years.

Additionally, this dissertation contributes to the fields of sociology and science and technology studies by providing an original empirical study and a new case analyzed through the framework of "reiterated fact making" (Navon 2019). Drought is a compelling case due to its complexity yet the strong consensus around its status as a fact. Experts across diverse scientific fields and actors within state and federal government all acknowledge the existence of drought as a meteorological phenomenon, and it is often defined as a lack of water to serve specific purposes, such as farming or gardening. As demonstrated in the opening of this introduction, this “lack” of water is ambiguous. The ambiguity leaves ample room for discussions over a meteorological fact that can be articulated through concrete thresholds of percent of average or reservoir storage. Also, there is ambiguity around “whose” purposes are at the heart of the working definition of drought. As such, drought is both a scientific fact and a social problem, and a site rich for examination.

The four sets of empirical questions raise larger theoretical questions that will be interesting to environmental and comparative historical sociologists, and those interested in science, knowledge, and technologies. This dissertation contributes to the ongoing discussions around these kinds of questions, but it does not settle them. The four sets of theoretical questions are as follows:

> How does a scientific and social fact change and remain the same over time?
>
> How does infrastructure shape environmental problems? How does infrastructure lock in certain definitions of environmental problems over time? How does infrastructure mediate the experiences of those problems and contribute to structural inequality?
>
> How are values are incorporated into seemingly neutral measurements? What was deemed important enough to include in the monitoring of infrastructure? How do these values, in turn, shape social problems and environmental problems?
>
> How do experts and stakeholders shape facts through representations, definitions, and advocacy? How does the relationship between different groups of actors change when the fact at the center is already well established as a lay category?

To answer these questions, I undertake a sociological and comparative historical study of drought and drought declarations to trace its development as a fact over time and offer insights into how and why we got here. Of course, many other disciplines have investigated and studied drought over the last few decades, and they have important insights to offer. Yet, few appreciate the intersection of drought as a social and scientific problem – messy and “creeping” in ways that make it challenging to study.

Drought studies

In this section, I offer an overview of different explanations of drought from outside sociology to contrast with a sociological approach. The work in these fields – particularly in climate science – will be encountered throughout the dissertation. I start by reviewing explanations of drought from climate science, then review explanations from the social scientific fields of economics, political science, and psychology. The critical insights from climate science map the physical indicators of drought onto social consequences. The studies from climate science – often meteorology, climatology, and environmental engineering – most often focus on different types of drought, like meteorological (Hayes et al. 2011; Heim 2002; Oladipo 1985; Zargar et al. 2011), agricultural (Sheffield et al. 2004), hydrological (Cayan et al. 2010; Mishra and Singh 2010) . Each type of drought centers on a lack of water for a particular purpose or particular region. Often, explanations of drought involve quantifying precipitation, soil moisture, water runoff, and groundwater recharge, among many other physical indicators. This work also includes developing drought indices, which render these complex processes into usable numbers or maps (Guttman 1998; Meko, Stockton, and Boggess 1995; Palmer 1965). While important, these explanations do not attend to the social repercussions embedded in the definition itself, preferring to black box those effects as "socioeconomic drought." Instead, digging into the social and economic impacts of water shortages is the purview of other social sciences[2].

These approaches are valuable and interrogate critical aspects drought's physical elements that underly the socioeconomic impacts. However, the question of "when is a drought

---

[2] In economics, political science, and psychology, drought is treated as an exogenous factor that shapes markets (O'Brien and Leichenko 2000), leads to regional conflict (Ide et al. 2021), new policies and responses (Mullin and Rubado 2017; Taenzler, Carius, and Maas 2008) and stressors that individuals must endure (Alcamo et al. 2008; Ternes 2019).

a drought" requires taking drought as an ongoing negotiation; as an intra-action between humans, structures, and water that produce a specific fact. It is important to bring in some sociological framework to better answer this question. The fields of sociology and science and technology studies are well situated to attend to the social processes that underpin drought as a scientific fact and social problem. A sociological explanation of drought could address many aspects: governance, success/failure of legislation, activism around declaration, history of water law, unequal access to water, crisis responses, and much more.

Sociology and explanations of drought

When sociologists engage with drought, it is most often as one of the many markers of climate change. It is utilized as a concrete example of environmental change that society must respond to, which provides ample opportunity for sociologists a range of opportunities to engage with drought through questions of climate change. This framing has led to interesting research on the modest impacts on out-migration and return patterns in Northeast Thailand (Entwisle et al. 2020). It has also created a specific policy thread to follow when examining political responses to climate change. Caniglia et al. (2016) trace the heterogenous water governance structures in Oklahoma and show how water governance can be both fragmented and adaptive in the face of climate change. Others have examined how understandings of vulnerability due to climate change are changing for rural communities, specifically agricultural workers (Greene 2018). In each example, drought is taken for granted as an environmental problem. It is an outcome of climate change, and it provides rich ground for analyzing responses to those changes.

Studies that focus drought impacts and strategies for developing drought resilience are crucial for understanding impacts of climate change and disaster, but they fall into the same patterns as other social scientific fields. Sociological researchers tend to treat drought as a pre-existing, obvious category or phenomenon. Drought is an indicator of climate change, and its impact can be assessed through models, policy analysis, and interviews with those impacted. They do not engage with drought itself as an object of study, and they more often discuss it as one of many environmental impacts of climate change. Questions about the definition or production of drought is mostly absent and left to environmental sociologists – a sociological subfield that is still peripheral to mainstream sociology[3].

Environmental sociology and the nature of environmental problems

Environmental sociology is a rich and dynamic subfield of sociology that examines the "inseparability of human society from nonhuman natures and the centrality of inequality that shapes both" (Pellow and Nyseth Brehm 2013:232). Three major approaches in this subfield include analyses of political economy (Rudel, Roberts, and Carmin 2011; Schnaiberg 1980), environmental justice (Auyero and Swistun 2009; Brown and Gibbs 2007; Chiro 2008; Hooks and Smith 2004), and risks/disasters/hazards (Brown 2013; Higgins 2001; Tierney 2007). All three approaches are committed to examining the deep links between society and nature, and how inequalities on a local or global scale shape and are shaped by the environmental as well.

Central to each of these discussions is the debate about the nature of environmental problems themselves. Answering the question of "when is a drought a drought" requires engaging with theoretical debates about whether environmental problems are "real" or

---

[3] The American Journal of Sociology has published one article on environmental sociology (Foster 1999), and never published an article about drought. The American Sociological Review does slightly better with two articles about environmental sociology topics (Longhofer and Schofer 2010; Vasi and King 2012), but still no articles about drought. However, it should be noted that both journals more regularly publish on the subject of environmental injustice and inequality, which is critical.

"constructed". A now classic debate between "realis[4]" or "constructivism"[5] grapples with whether to prioritize the "social" or "natural" worlds. Often, the entry point for an analysis will prioritize one over the other – even unintentionally. Over the decades, environmental sociology has arrived at something of a middle ground that holds both as important, and it has gained prominence for the balance it attempts to strike.

A more materially aware approach views environmental science as the result of both "social action" and "natural dynamics", a more nuanced, hybrid framework. The core of this framework is a commitment to the idea that nature and society inform one another, giving agency and space to nature that is equal to society. This framework, proposed by researchers like Murphy (2002) and Freudenburg, Frickel, and Gramling (1995), argues for an approach that contextualizes research in its material relations, understands that nature can be socially encompassed, and recognizes that nature can affect social processes. One outcome of this approach is the utility of comparing cases or time periods. If we argue that social and natural (or biophysical) forces interact and influence each other in taken-for-granted ways, then sufficient comparison across time and space becomes necessary. It is through comparison over time or between locations that these interactions become clearer.

Ecological realism makes it possible to draw compelling conclusions about the relationship between nature and society by attending to both meaning and materials. In an exemplar of the framework, Freudenberg et al. (1995) demonstrate how a comparative approach

---

[4] Constructivists interrogate how politics and values influenced what scientific questions are funded and investigated and what meanings are embedded in the language and statements that come of it (Buttel and Taylor 1992). A constructivist approach also draws attention to how definitions of terms or concepts like "landscape" vary across groups and over time, which results in shifts of the landscape itself to align with shifts in meanings assigned to it (Greider and Garkovich 1994). The classic critique of a strong constructivist approach is that if everything is constructed, then what allows sociology to make claims about the world. Additionally, a constructivist approach frames nature as the by-product of human activity (Dunlap and Catton 1994; Murphy 1994).

over time reveals how meanings assigned to environments change on different scales. The environment's physical properties change very little, but the meanings associated with the environment range from a living space to a resource for exploitation, underscoring how changes in definitions do not always correspond to changes in the environment itself. In disaster studies, an ecological realist approach makes it possible to examine how social inequalities embedded in infrastructure can exacerbate natural disasters (Klinenberg 2003) revealing how slow-moving disasters can interact with and by shaped by society itself. More recent studies have expanded on this work, reveal the complex interactions between environmental disasters, capitalism, and built environments and how cities develop a "disaster industrial complex" in the face of persistent environmental bad (Fu 2016; Haney 2021). Framing environmental problems in this way makes it possible to move beyond laboratory or policy spaces that dominate sociological research on environmental problems. Instead, an ecological realist framework makes it possible to center to center the environmental problem within a delimited social space.

The question is no longer whether a realist or constructivist approach is more appropriate, but instead what middle ground approach to take. An ecological realist approach provides a partial foundation to how this dissertation frames environmental problems. The approach explicitly attends to the ways in which meanings and materials change and shape each other over time. This framing of environmental problems is well suited for studying drought given the expansive infrastructure and intensive monitoring of water in California. It would be impossible to understand drought as an environmental problem without considering the way that water, natural environments, and built environments interact and shape each other. Additionally, a comparative study lends itself to examining changes in meaning and materials to better understand how drought both changes and stays the same across decades. I describe the formation of drought as a scientific fact over time and interrogate the ways in which it has changed in the last sixty years. I strive to hold the material reality of water in equal importance with the work of scientists, water managers, and governors in my analysis. And I draw on work from the sociology of knowledge and science and technology studies to do so.

The sociology of knowledge & Science and technology studies

Science studies and the sociology of knowledge have a long history of examining scientific facts – how they emerge, their politics, their adoption and circulation, and even their demise. In fact, the ecological realist approach in environmental sociology is indebted to STS, and the efforts in this discipline to bring the material "back in" to accounts of social processes (Barad 2003; Murphy 2006:200; Smith 1990; Swyngedouw 1999, 2006). The approaches outlined below interrogate the politics behind research and the formation of scientific knowledge, the materials that are necessary for that work to be done, and how it circulates between different groups of actors and social worlds. I build on the approach referred to as Actor-Network Theory (ANT) most famously pioneered by Latour and Woolgar (2013) in their studies of laboratory work. I also build on studies of infrastructure and measurements. First, I discuss the utility of ANT before moving on to discuss infrastructure studies.

ANT and other Network Theories

Actor-Network Theory and other theories of "doing" science are critical for understanding the emergence of scientific facts. Alongside human actors, network theories give equal importance to the tools and material arrangements that make it possible for the social work of research to be completed. In line with the realist critiques of strong constructivism, network theories call attention to the non-human actors (Anderson et al. 2012; Bennett 2005; Jasanoff 1995; Lakoff 2016; Latour 2007; Swyngedouw 2006). In STS and the sociology of knowledge, these theories are used to take seriously material reality and the heterogeneous, complex, and fluid composition of networks (Bakker 2012; Latour 2007; Latour and Woolgar 2013; Marcus and Saka 2016; Murphy 2012; Shapin 2016). The sociological adaptation developed by Eyal (2013) argues that sociologists should also attend to the process of assembling the networks of "objects, actors, techniques, devices, and institutional and special arrangements" (2013: 864) that make expertise possible. A rigorous study of drought requires centering complex systems with a variety of actors and material components that work to produce drought as an environmental problem and scientific fact.

The network approach to understanding the development of facts, expertise, and collaboration is important to this project because it centers the tools, representations, and collaborations across the networks built up around drought. Networks are useful because it requires attention to more than just the people and provides clear structure for including the material conditions in the analysis. Because drought is informed by materials, committing to this analytic approach encourages me to center water and the material elements of infrastructure. It also affirms the importance of shared understandings and definitions among actors (both human and nonhuman) to the network's stability, and how changes in the network might put the entire thing in danger. As such, I use the insights from ANT and networks of expertise to identify the actors and materials built up around drought, and I build on these approaches using reiterated fact-making. In this dissertation, I attend to the most prominent components of the network around drought in California, beginning with infrastructure. Infrastructure is a subject of dynamic and fascinating investigation, specifically research into the standards and measurements that go along with it.

Infrastructure studies: Big and small

Big infrastructures: Dams and other hydraulic technologies

Infrastructure is an invisible yet dominant force in our lived experiences. Much work at the intersection of infrastructure studies and sociology of knowledge focuses on how the infrastructures and the measurements that support them organize huge portions of social life yet vanish almost entirely when performing their functions (Lakoff 2016; Lakoff and Collier 2010; Star 1999; Star and Ruhleder 1996). Not only do they organize life “behind the scenes”, but they do so in part by incorporating and reproducing the social values and material relationships. In the following section, I discuss two branches of studies – ones that focus on large infrastructure projects and those that focus on the “smaller” infrastructures of standards, classifications, and measurements that support and often communicate elements of the larger infrastructures.

Large infrastructure projects are much more than efforts to improve human lives. They are also often state building projects and sources of national pride. Infrastructure projects are critical nexuses for studying where and how the social and the natural are pulled together and intertwined (Star and Ruhleder 1996). They are at once material, political, and natural. They often serve a modernizing purpose, and those politics inform their very construction (Edwards 2004; Laet and Mol 2000). Most relevant to this dissertation, infrastructure studies emphasize what problems are solved through large infrastructure projects, what the framing of those problems communicate about a region’s ideologies at that time, and how those ideologies are embedded in the infrastructures themselves as the proposed solution (Carroll 2006; Pritchard

2011, 2012). Infrastructure studies offers analytic and methodological approaches for investigating these sprawling projects and how to better understand the intersection of nature and society.

Infrastructure studies at the intersection of nature and society demonstrate the intricate links between the material and the ideological and how rare a purely engineering or logical approach is to either. The studies demonstrate how infrastructures do not bridge the nature/society divide, but how they destroy it. This approach has recently been applied to singular instances of drought to show how infrastructure shapes patterns of drought (Carse 2017) and can even lead to a drought crisis independent of precipitation (Cohen 2016; Millington 2018). These studies of infrastructure build on the framework proposed by environmental sociology. Rather than segmenting the social from the natural, infrastructure studies demonstrate how it is futile to differentiate between the two. Infrastructure projects are built by regimes of power to shape nature; nature changes in response and in turn requires new or changed infrastructure. In California, twin large infrastructure projects have dramatically altered relationships between people, water, landscapes, and even the seasons themselves. Examining how infrastructures respond to drought and change drought in turn is central to this dissertation.

Small infrastructures: Standards and measurements

The measurements and representations connected to large, sprawling infrastructures are also powerful for enacting the goals of the projects and holding the network together. Studies on measurements, standards, and classifications offer methodological and analytic tools for bringing to the forefront how politics become embedded into these representations and how they exert power within the networks of people, places, and things[6]. Studies of "small" infrastructures explore the specific histories of standards (Noble 1979; Tanaka and Busch 2003); the social processes involved in their creation (Clarke 1991); and the role of technical and scientific expertise particularly in their formation (Jordan and Lynch 1998; Webster and Eriksson 2008). The development of standards can be complex and messy, yet they often sink beneath the surface of our social lives (Lampland and Star 2008) even as they organize our visits to the doctor (Armstrong and Ogden 2006; Casper and Clarke 1998) and in what time zone we find ourselves (Zerubavel 1982). Standards are expressions of power and authority. They can make life difficult when we do not conform to them, such as when certain identities are unavailable on medical forms or when food allergies require constant surveillance (Star 1990). In short, standards play a significant yet quiet role in daily life, and they have an important place in water governance. And the power of infrastructure studies is attending not to the deviations from the standard or the individual user, but to the creation of the standard and measurements themselves.

For a dissertation project focused on drought, attending to these smaller infrastructures is critical. There is an abundance of smaller infrastructures across the state that shape drought, like low-flush toilets or low-pressure showerheads. I am interested in a different set of infrastructures: the standards, measurements, and classifications are central to depicting water stores. They form the basis of governance decisions about water usage during water years. Also, they form the basis for understanding drought as a scientific fact. Standards and classifications order access to water across the state with implications for social life built on sustained and reliable access to water.

---

[6] As Timmermans and Epstein astutely note in their 2010 American Sociological Review article, sociology has a broad interest in "standards" – whether that be labor standards, institutional standards, or other formalized norms. However, far fewer studies focus explicitly on standards themselves and the process of establishing them. The body of literature I discuss here is part of the latter category.

The work done in the sociology of knowledge and STS using ANT, infrastructure studies, and studies of standards and measurement offer useful insights. They each call attention to the non-human components of the network. These insights compliment the call in environmental sociology to interrogate the ways in which nature and society produce each other. By attending to the measurements, infrastructure, representations, and people developing and using them, it is possible to examine carefully where each intersects with nature - in this case, water or the lack of it. Each of these approaches offers a path for interrogating the mutual constitution of nature and society through investigating components of natural disasters and environmental problems. However, these frameworks on their own are not ideally suited to a comparative historical project about drought.

The focus of this dissertation is drought itself, not the network, infrastructure, or measurements associated with drought. Yet, each theoretical approach is necessary for understanding the complexity of drought. How then, does one make use of the insights of each theory, while keeping the focus on the fact that changes and persists over time? Rather than attempting to apply each theory separately to drought, I *build* on the insights from Environmental Sociology, the Sociology of Knowledge, and Science Studies. I do this by expanding a comparative historical approach – reiterated fact-making (Navon 2019). Reiterated fact making is an extension and retooling of the reiterative problem-solving approach proposed by Haydu (1998, 2009).

Reiterated fact making

Reiterated fact making has its roots in a different comparative historical framework: reiterative problem solving. The reiterative problem-solving approach developed by Haydu

(1998; 2009) presents a method for utilizing sequential time periods during which similar groups of actors wrestle with problems that they would recognize as the same thing. This approach is wonderful in how it deals very much in reality. Solutions to a problem in a previous time will inform solutions to the problem as it crops up again. Simply, history matters, and Haydu offers a method for understanding *how* while also explaining different outcomes. However, as previously argued by Navon (2019), reiterative problem solving provides a starting point, but is not the complete answer to the questions proposed by this project. Central to drought's emergence as a scientific fact and its declaration is a shifting group of actors who may not always agree on what constitutes capital D "Drought". So, I rely on the "reiterated fact-making" framework developed by Navon (2019) and expanded on in Navon and McInnis (under review). The approach incorporates elements of reiterative problem solving as well as insights from Ludwik Fleck to develop a framework for comparing time periods where the fact is held constant.

Ludwick Fleck's philosophical work focused on the life course of a fact. Specifically, he described how facts move from something discussed in specialty journals – esoteric knowledge – to commonly circulated ideas in the wider public – exoteric knowledge (Fleck 1981[1935]). Fleck identifies the networks of experts and non-experts built up around the fact as critical for this movement, noting how the fact itself is reshaped by the changes in networks. Reiterated fact-making builds on this critical insight of a dynamic life course of facts by adding a comparative historical element to the framework. The networks include human and nonhuman actors engaged directly with the fact itself – the frames, tools, and representations of the fact too. However, drought and its directionality present a departure from Fleck's work that reiterated fact making must grapple with. Drought moves from a salient lay category to a scientific fact, rather than scientific fact to well-circulated lay category. Reiterated fact making calls attention to the radical changes and deep continuities when analyzing the emergence of scientific facts. To make sense of the changes and continuities that characterize a fact, reiterated fact making looks at the conditions of possibility, path dependencies, and networks of expertise.

Radical change and deep continuity

There are two central, yet conflicting elements to a scientific fact that must be grappled with. Scientific facts do not show up fully formed and unchanged as it moves from the lab to popular knowledge. In fact, they live very dynamic lives as they are investigated in labs and then picked up by different groups of actors within and outside the research communities where they are first articulated. Reiterated fact making offers a framework for tracing a fact as it moves between and among communities of experts and lay actors and the changes that accompany that movement over time. The changes can be dramatic disruptions or more subtle alterations to the fact. However, the attention to deep continuity of scientific facts sets this approach apart from many classic works on scientific facts. Few previous studies take an explicitly comparative approach – instead focusing on the scientific communities and laboratories in which facts emerge and are stabilized. So, by attending to the deep continuities that undergird facts, reiterated fact making provides a grounding for comparisons between time periods. This is necessary when the actors and materials around a fact shift during the duration of the study. How do we attend to these changes and continuities analytically? Grappling with both change and continuity demands analytic guidance to draw a researcher's attention to spaces where evidence of both qualities might be found. Reiterated fact making identifies conditions of possibility, path dependencies, and networks of expertise the three key mechanisms.

Conditions of possibility, path dependency, and networks of expertise

Conditions of possibility calls attention to what has changed and examine their implications for the development of a fact (Foucault 1994[1970]; Swidler and Arditi 1994). The conditions of possibility point to changes to the broader social context that sets the stage for a scientific fact to be thinkable. Conditions of possibility do not refer to mundane pre-conditions such as gravity that allows water to flow down from mountains to fill reservoirs. We must carefully examine a fact's history to determine the consequential arrangement of interests, development of tools, and so on that make it possible for a scientific fact to develop and then facilitate action. This pillar underscores the necessity of focusing on the scientific history of a fact to figure out those impactful conditions that make the fact possible. This pillar calls attention to background conditions that are important but may be overlooked when examining how facts are taken up and represented.

Path dependency calls attention to how decisions made at one time period enable and constrain decisions in future time periods (Arthur 1989; David 1985). Examining path dependency leverages the comparisons over time to determine how changes to material arrangements and social meanings conjointly construct the fact over time (Freudenberg et al. 1995). Reiterated fact making goes a step further and separates path dependencies into epistemic and material. Epistemic path dependencies focus on how facts are understood; how prior definitions continue to impact subsequent ones. This includes both formalized and informal thresholds that are used to determine when a fact is a fact and how it might apply to different circumstances. Understandings developed and shared by multiple actors and encoded into governance and responses continue to shape them into the future. On the other hand, material path dependencies call attention to conditions that enable and constrain understanding and acting on facts, such as infrastructure, tools, databases, responses, and so on. Together, these twin dependencies can enable and constrain the development of a fact. Attending to path dependencies is necessary for understanding what underpins their “stickiness” over time.

Networks of expertise and mobilization shape how a fact is understood and the impact it has on the social world. Networks offer a framework for tracing actors who are directly engaged with a fact from discovery to mobilization. Building on Eyal’s characterization of expertise as a network (2010; 2013), reiterated fact making examines not expertise but the fact itself at the network’s center. A fact will change in many ways as it moves through different networks of people and *things*. The materials, tools, and representations of the fact are key to the networks too. By attending to who is studying, mobilizing, measuring, and representing a fact, we attend to the ways in which a fact can maintain core elements while changing radically as it moves throughout the network.

Drought is an intriguing scientific fact to study using reiterated fact making due to the complexity of the network built up around it. Drought was not “discovered” when the first scientific measurements of drought were developed. Instead, it moved from a salient and widely accepted lay category to a scientific fact. This reversal of direction for many other facts studied by sociology of science demonstrates reiterated fact making’s utility, but also offers an opportunity to refine this framework further by examining how scientific experts contend with a pre-existing network of stakeholders already built up around a fact.

The analytic payoff of reiterated fact making is a flexible framework that helps sociologists explain how facts are made and remade according the three axes. It allows for a comparative historical framework that makes space for causal explanations even when some conditions (like networks of actors) shift over time. By keeping a tight focus on a fact, we can make a clear argument about the fact itself amidst a sea of changes. This is an excellent framework for studying drought in California because it casts drought as a consistent problem, one that can be defined as a scientific fact. Even though the stakeholders who work with questions of drought, the tools used by meteorologists to represent drought, and many other things change – reiterated fact making makes it possible to compare drought over time by holding it at the center. The direction of drought's movement from social problem to scientific fact demonstrates the utility of reiterated fact making for studying all kinds of scientific facts.

Drought in California – A comparative historical project

California is a strong case study for interrogating the construction of drought as a scientific fact for three reasons. First, although California is a state rather than a nation, it is one of the largest economies in the world[7]. California's larger economy presents a balance between complexity and manageability. The economic sector is diverse with numerous competing interests, which provide space for conflict as well as alliance building over drought definitions and representations. However, it is not so complex as to be unwieldy. It is still possible to identify and analyze sets of actors meaningfully. By studying drought declaration in California, we can grapple with the complexities that "calling" a drought entails for a large geographic and highly populous region yet on a somewhat manageable scale for a research project.

Second, California is also complex infrastructurally, making it a strong case for examining how "modern" states grapple with water shortages and define drought. A vast network of dams and canals provides at least one year of surface water storage, meaning that

---

[7] According to a 2018 report from the US Department of Commerce, California's economy was 2.747 trillion dollars – the fifth largest in the world, outranking the UK.

California can persist through prolonged dry periods without too much economic damage until a second dry year. This one year of cushion is analytically useful because it makes some thresholds more explicit, even if they are not official. The thresholds are more explicit because stakeholders, scientists, and water managers need to make arguments about why or why not a drought exists in newspaper articles, water reports, publications, and other kinds of statements.

Finally, California has experienced multiple declared droughts over several decades, which provide a strong temporal comparison. The almost sixty year time frame of this study provides ample room to demonstrate the utility of reiterated fact making by showing the depth of continuity over several decades as well as the radical change that takes place over the sixty years. I make use of four distinct droughts declared in California: 1976 – 1977, 1986 – 1992, 2007 – 2009, and 2012 – 2016[8]. The four cases demonstrate a strong continuity underlying the change, making them appropriate for a comparative historical project. Each included a declaration of a drought emergency from the Governor's office; included reduced water deliveries and allocations; disruptions to the agricultural sector; and some level of water conservation. Additionally, these four drought periods are regularly used as comparative cases in various reports and by different government bodies connected to weather or water management. I also include a fifth case from 1959 – 1961, but it does not feature as much in certain chapters because it occurred prior to the construction of the State Water Project. This drought was felt predominantly in Southern California. It does not compare as easily to the others because a significant portion of infrastructure did not exist at this time. After the completion of the State Water Project, dry conditions in predominantly Southern California were not enough to result in

---

[8] The official months and years of the drought declarations that comprise these cases are as follows: January 1977, April 1988, June 2008, and January 2014.

an official declaration. But the case is included in some chapters because it was critical for creating certain conditions that shaped drought across the other four periods.

Data and methods

The majority of evidence and data for this dissertation is historical and archival. Answering my research questions required me to know about a wide range of people and structures in connection to California's water. The actors and materials are connected to water through governance, economics, and research to varying degrees. I needed to know what the water conditions were at each drought declaration and how those measurements were discussed by government insiders, stakeholders, and in public discourse to understand how definitions of drought changed over time. It was necessary to understand the logic behind California water law, how laws were enshrined, and subsequent changes over time. I would need to research how infrastructure projects were planned, proposed, and passed; then, how those projects were discussed in later time periods in connection to drought. I had to learn the debates about water measurement practices and their connection to water governance. Finally, I needed to know how different scientific and stakeholder communities defined and represented drought at different points in time. I relied on archival material focused on state government, water management, public discourse, and developments in climate science to build this repository of knowledge.

I made regular visits to the California State Archives in Sacramento and the Water Resources Collections and Archives at UC Riverside[9]. These two archives house documents from California's governing bodies, such as the correspondence and meeting minutes for groups

---

[9] I made three trips to Sacramento over three summers in 2017, 2018, and 2019 for a total of eight weeks at the California State Archives. I made dozens of day trips to UC Riverside between 2017 and 2019 for a total of four weeks at the Water Resources Collections and Archives.

like the Drought Emergency Task Force and other temporary groups that come together to mitigate drought's impacts. They also house documents on water measurement development, measuring practices, and various reports that are not yet digitized. From these archives I drew official reports, conference proceedings, meeting minutes, internal group correspondence, letters from individual citizens as well as group and corporate letters from the four different drought periods. Many reports were connected to the California DWR, the State Water Resources Control Board (SWRCB)[10], the US Geological Survey, and the US Bureau of Reclamation. In total, the documents amounted to multiple hundreds of pages. These materials provided insights into debates about measurements, infrastructure, water governance during dry years, responses to drought, and other topics at the time of their writing, as well as reflections on the same topics at different time periods.

I also made use of various online and digitized archives. These archives include the California DWR online data archive; the Online Archive of California; the News Bank Archive of historical California newspapers; San Francisco Law Library online archives; and website archives of interest groups like the California Cattlemen's Association, California Grape Growers Association, and others. From these archives I examined further legal writings, including court decisions, law reviews, and reports from state, private, and activist groups. Additionally, I analyzed 1,008 newspaper articles from four California newspapers published in the buildup to a declaration. The four publications were The Los Angeles Times, The Fresno Bee, The Sacramento Bee, and the San Francisco chronicle. These papers were selected to capture different regional concerns and characters that shape their reporting. They were also comparable in terms of circulation and publications history. Additionally, I examined scientific

---

[10] This also includes documents from the Department of Public Works, which was later reformed as the DWR and SWRCB.

publications in meteorology and climatology on drought to trace the development of tools and methods for studying it as a scientific fact. I selected these publications from article databases, such as Meteorological & Geoastrophysical Abstracts and Earth, Atmospheric & Aquatic Science Database. Finally, I examined stakeholder organizations reports and publications on droughts through the website archives of interest groups like California Cattlemen's Association and Wine Growers Association of California. These reports, statements, and biographies provided important insights into the representations and definitions of drought from non-government sources.

I relied primarily on text and discourse analysis and close readings. For the archival materials, I read first to understand the broader history of drought in California. Then, I examined patterns of actors, measurements, representations, and responses to drought, noting how they changed over time. I coded which actors were featured most often; the measurements cited to articulate droughts existence; and the reports on responses to the drought. This careful examination of reporting was critical for understanding who the primary actors were, who had power in shaping public discourses, and seeing how public discourses around drought changed and stayed the same over the years. Further information on the sources relevant to different parts of the research project will be offered in each chapter that follows.

Over the last four years, I have also been a member of an interdisciplinary group of researchers focused on California and Nevada climate programs, and I have worked with other researchers on questions of drought. While not a data source, this experience has informed my research in other ways. Being a member of this interdisciplinary research group provided a critical opportunity to work with a range of experts studying drought, and it was a vital context for better understanding current drought research and the complexity of the models and tools available. It was also a source of support and encouragement for the last four years.

Chapter structures and contributions

Chapter 2 – Historical Overview

Chapter Two offers important historical background on California's water rights system and infrastructure. It also chronologically recounts the four different declared droughts. This chronological account examines the water conditions that were defined as a drought; the coordinated responses to mitigate dryness; and the various stakeholder groups exerting influence over the declaration. The purpose of this chapter is fairly simple: I want to offer important context from pre-1914 that shapes California's water landscape today, and I want to underscore the continuities and disruptions that will be examined in depth in the following chapters.

In this chapter, I draw primarily on state documents written during the droughts or immediately after, as well as newspaper coverage of the drought periods. I compare the definitions of drought encoded in reports and formalized declarations across the four time periods. The timing and logic of declarations are always tied to a shortage of water, but the causes for those shortages shift from period to period. This reveals that drought constitutes a shortage of water for the "normal" functioning of California's economy, but what is considered normal and for which economic sectors do not stay consistent. These findings show how drought as a fact is reshaped over time while remaining the same. A drought is *always* due to a lack of water – regardless of what number is being used to represent that lack. However, changing social contexts and networks of stakeholders can change what constitutes "normal" or "average" across time periods, leading to changes in definitions of scientific facts. It also serves as a jumping off point for the following empirical chapters that dig deeper on the central themes in each time period: major water projects; water standards, measurements, and classifications; and the role of representations, climate science, and stakeholders in shaping declarations.

Chapter 3 – Big Infrastructures

Chapter Three focuses on the two large infrastructure projects in California and examines how their history and their operation shape drought as a fact in California. In this chapter, I find that water laws developed in the late 19th and early 20th centuries shaped the development of infrastructure by providing certain stakeholders and regions access to more water than others. I also find that infrastructure quite literally reconfigured the state's water resources and became the dominant method of water management during the 20th century. I find that infrastructure – specifically reservoir levels – plays a central role in defining drought conditions and often leads to an official declaration. Over time, its popularity as a solution to water problems has waxed and waned, but the relationships between region, water, and people persist across the four called drought periods.

Theoretically, Chapter Three shows how infrastructure works as both a condition of possibility and as a material path dependency for drought's emergence as a scientific fact. Infrastructure was created to solve a generalized water problem (Carroll 2012), and its creation made it possible to conceive of drought as a solvable problem. The expansion of infrastructure with the State Water Project to solve "drought" as a problem in the 1960s also locked in certain responses to drought and created formal thresholds for its definition in the state. These findings also reiterate other findings that infrastructure is unequal. California's water system privileges those who are in the agricultural sector (farm owners) and those in big cities who can lay claim to priority rights – even though they were certainly not the first people here. To grapple with water equity in California means to grapple with California's colonialist past and strategies that led to uneven development across the state.

Chapter 4 – Little Infrastructures

Chapter Four digs deeper into the standards, classifications, and measurements that are integrated into water projects and governance decisions in California. In this chapter, I examine how a large variety of water measurements are used across the State to determine how much water is present in stores and to predict how much water may (or may not) be on its way via winter storms. These measurements are not incorporated into official drought thresholds that immediately trigger a declaration. However, they are still used to develop technical definitions of drought, and they serve as the basis of declarations, particularly runoff and precipitation. Water year classification systems also serve as the basis of water management practices and determine which water quality standards are in place for any given water year. The values embedded in these measurements are very much those of modernist state building. The priority is always economic functioning and consumption by people, even at the cost of long-term sustainability and health.

Studying the standards, classifications, and measurements reveals how definitions of drought developed as far back as 1924 continue to shape definitions today. As with other studies on the expansion of technical knowledge and engineering (Noble 1979; Shapin and Schaffer 2011), I show that the plethora of water measurements exist to serve a social purpose, namely for economic development and stability across California. Additionally, I show how the networks of experts and stakeholders worked together to maintain a specific definition of drought through the development of standards and classifications at various points in the sixty year period. These definitions of drought once again are not legally encoded thresholds. Instead, they are formalized in cutoffs between different kinds of water years and the water standards "triggered" by certain levels of availability. These values shape drought by prioritizing some social needs over others, and by prioritizing human consumption over environmental sustainability.

Chapter 5 – Networks

Chapter Five explores how drought's journey from lay category to scientific fact can be seen most clearly in changes to the network built up around it. In this final empirical chapter, I interrogate the groups of researchers, managers, and stakeholders engaging with drought as a scientific fact shift over time. Drought became an object of meteorological study in the 1960s, bringing scientific experts other than engineers into the picture for the first time. This group of researchers wrangled drought into an objective fact through the development of indices and representations that linked drought to the atmosphere. However, these scientists had to contend with the pre-existing network of engineers, water managers, and agricultural stakeholders already mobilized around drought as a fact. I find that climate scientists had to persist for decades before the representations and tools were fully integrated into the network, when stakeholders begin to take up climate explanations of drought.

This chapter reveals how networks of experts and stakeholders shape drought as a fact through the development of tools for understanding drought and by advocating for certain definitions over others. Over the last sixty years, drought shifted from a lay category to a scientific category, prompting the development of expanded monitoring networks and an explosion of data. Representations of drought and explanations that locate it in the atmosphere were not initially integrated into the state-centric network put in place by the 1960s. Instead, climate scientists worked with and responded to the needs of stakeholders already connected to drought. This demonstrates the analytic utility of reiterated fact making, but also indicates that some caution is warranted. When historicizing a scientific fact that was already an established lay category, it is necessary to begin with the non-scientists who are already defining and studying drought from a different perspective.

Notably, when groups initially excluded from that network like environmentalists and Native American tribes take their seat at the table, the questions of "normal" amounts of water and for "who" are altered by forcing the network of water consumers to expand and push back against many of the taken-for-granted fundamentals of water in California. Environmentalist groups like the Sierra Club and the Environmental Defense Fund slowly enter the network over decades by positioning "the environment" as a stakeholder that should share in water allocations on the same level as agriculture and urban spaces. Perhaps the most unjust, Native American tribes should have the oldest water rights in the state, but it took decades of litigation for those rights to be apportioned officially.

Chapter 6 – Conclusion

In Chapter Six, I offer some concluding remarks on how this study contributes to research programs in environmental sociology and the sociology of science, knowledge, and technology. I begin by briefly examining the drought we currently find ourselves enduring – another record setting dry period contextualized by the worsening effects of climate change. Then, I summarize my findings and address their contributions to questions in environmental sociology and the sociology of knowledge. In addition, I review the limitations of the study and possible future research directions. I end with a discussion of potential policy and governance implications for water and drought in California that are contextualized by this history of a scientific fact. These implications are humble yet grounded in the reality of a warming climate and limited access to water structured by historical inequalities.

Portions of Chapter 1 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

CHAPTER 2: HISTORICAL BACKGROUND AND DROUGHT OVERVIEWS

Introduction

I offer this historical overview to provide important background context for the droughts in California during the 20th and 21st centuries. Additionally, it serves as a chronological anchor, providing an account of drought from the 1960s to the 2010s. In this overview, I introduce the major themes of the dissertation – infrastructure, measurements, and networks of expertise. This historical overview also serves to emphasize the radical change and deep continuities that characterize drought over time. The four time periods that make up the bulk of this dissertation – 1976 – 1977; 1987 – 1992; 2007 – 2009; and 2012 – 2016 – are independent droughts but also rely on the decisions and definitions at work in the previous time periods.

This chapter takes a chronological approach to exploring the definitions of drought in each of the time periods to emphasize the changes and continuities at work across the decades. First, I lay out historical context that is foundational to the analysis of the four time periods. I review the pre-history of modern drought by examining different forms of water rights and the infrastructure projects that mediate water access across the state before the 1930s. Then, I examine a drought in Southern California that took place during the 1950s to 1960s as the starting point for the deeper comparative historical project at the heart of the dissertation. The 1950s – 1960s drought was the last "localized" drought the state experienced that required statewide response before the completion of the state water project, marking the period of modern drought. Finally, I examine the four declared droughts in succession, highlighting the changes and continuities that characterize each of the droughts. In each examination, I highlight the water conditions present at each declaration; the tensions created by the lack of water; state responses to the drought and strategies of mitigation; and changes to California between the drought periods. The characterization provided in this historical overview is the foundation of the deeper analysis in the following empirical chapters.

“Pre-history” of drought: Water rights and infrastructure

In this section, I provide a brief overview of California’s water laws and the emergence of infrastructure as a solution to many of the “problems” facing California at the turn of the 20th century. The discussion provides background information for the following chapter that analyzes legal and physical infrastructures in relation to specific declared droughts. I draw on secondary sources for portions of this overview. The typologies of water rights and the construction of physical infrastructure form the basis for water access, and they shape governance decisions around water during dry periods. Rather than focusing on the state bodies that make the decisions, like the State Water Resources Control Board or the Department of Water Resources, I focus on the laws and material infrastructure that enable and constrain those decisions. During dry periods, laws determine who has primary access to water, and they limit or enable water transfer, which are decisions fundamental to shaping drought.

California’s water rights system

California’s water rights system is complex and serves as a foundation for much of the infrastructure and governance decisions made during the four declared droughts examined by this dissertation. California’s water rights system was developed slowly and over many decades. The important foundations for California’s water rights system were laid during Spanish colonization and during the nineteenth century Gold Rush. The typologies and hierarchies of water rights in California are legacies that predate California’s statehood, but like other relics of settler-colonialism, they still exert influence over law and governance today. The three important forms of water rights that emerged from these eras were "pueblo" rights, "riparian" rights, and "appropriative" rights. These different sets of rights order access to water in specific ways. These historical orderings matter for how water is allocated every day in California, but especially during dry seasons.

Many large coastal cities in California draw their water rights from colonial-era water rights referred to as "pueblo rights". During the era of Spanish colonialism (1768 – 1821), settlements or "pueblos" had the right to surface and subsurface waters within the settlement area (Hutchins 1959). During California's early days of statehood, these laws were encoded and honored in California's water rights system, naming the American city as successor to these settlement rights. Pueblo rights form the foundation of many cities' water supplies that were critical for building and expansion in the 19th and 20th century (Rodrigue and Rovai 1996) and they are still in place today. Pueblo rights guarantee a city the right to access all water within the modern city limits, offering opportunities for a city to expand its water access by expanding its city limits. For example, Los Angeles began as a Spanish settlement, and its development depended on asserting these Pueblo rights as the city expanded management of local water sources. Before 1913 and the construction of major dams, Los Angeles had to rely on an aggressive assertion of its pueblo rights in the San Fernando Valley to ensure access to enough water. These historical water rights form an important foundation because it gives coastal cities in Northern and Southern California very clear and very foundational access to water to support large urban centers even in regions like Southern California.

"Riparian" water rights were established in the earliest years of California's statehood, and they are the last set of rights that tightly link water and land. During early years of statehood, California established that ownership of water would be tied to ownership of land (Attwater and Markle 1987). This system, also used in the Eastern United States, meant that a landowner had the right to the surface water and groundwater within the area of land that he (since landowners were almost exclusively men) owned. As more land was purchased along rivers and other watersheds, the simplicity of "first in right" became much less simple as sales of land "upstream" could deplete water resources for users downstream. This led to the development of "primary" and "secondary" riparian water rights. The primary rights holders had the older rights and therefore could not have the amount of water drastically reduced due to "upstream" uses by secondary rights holders. The system of primary and secondary rights established a hierarchy within the water rights system that is consequential for who has their water access reduced or cut off and when during a period of dry seasons.

"Appropriative water rights" – the last type of water rights – were crafted during the Gold Rush (1848 – 1855), and they decoupled water ownership from land ownership. During the Gold Rush[11], miners and mining companies would use water flows for hydraulic or placer mining[12]. Of course, the water was not necessarily located where it was needed for the mining operations, so a system for managing water rights separate from landownership had to be developed (Kanazawa 2015). To stake their claim to the water, miners or mining companies would use the same "posting" system to declare appropriative water rights as they did to claim land for gold. The miner or companies would literally post signs at the point of diversion, and these rights were generally respected by other miners. Appropriative rights dictate how much

---

[11] For a more detailed history on California's Gold Rush Era please see H.W. Brand's *The Age of Gold: The California Gold Rush and the New American Dream* (2003) and J.J. Rawls and R.J. Orsi's *A Golden State: Mining and Economic Development in Gold Rush California* (1999).

[12] Hydraulic mining involves using high pressure blasts of water to dislodge rock materials and move sediment; placer mining involves sifting through sediment and stream beds for gold – the common image of "panning for gold".

water can be accessed by a particular individual or association without needing to own all of the land on which the water is located (Attwater and Markle 1987) . These rights were formalized in 1914 in the Water Commission Act, and they are differentiated as “pre-1914” and “post-1914” to differentiate senior and junior water rights (Archibald 1977). This system of water rights made it possible to move water across large distances completely separate from landownership. Senior water rights cannot be lost by non-usage, but junior water rights must be utilized regularly or lost.

California’s water rights system forms the legal infrastructure that forms the basis for the physical infrastructure in the 20th century, and it constrains governance decisions during times of scarcity. Although water rights have changed over the last sixty years, these early laws entrench a hierarchy of access reaching back to the settler-colonial era. Spanish settlements, early landowners, and early economic developers were best positioned to benefit from access to water early in the state’s history. And to this day, those rights maintain primary access to water with important consequences for drought as a social and scientific fact. These dynamics play out in terms of how water is moved across the state during times of scarcity; which communities are first impacted by drought; and whose interests are central when considering what constitutes a disruption.

Infrastructure and state growth

Early droughts in and outside of California shaped infrastructure projects by framing them as a solution to local water problems. In California, dry conditions plagued the state from 1929 – 1934[13]. This six year drought was the first major drought on record in California’s time a

---

[13] There is not perfect agreement on the exact years included in this drought. The decade from 1924 to 1934 was characterized overall by “dry” conditions, so sometimes this longer time period is used. However, other times the

state. In 1930, California's population was still relatively small; it was only estimated at 5.7 million and the sixth most populous state (U.S. Census Bureau 2000). It is difficult to find details on the impacts to the economy due to the localized effects and lack of state development at this point in time (Jones 2020:12). Due to a lack of storage capacity, the lower precipitation levels some years were more harmful than they would be today. The impact of the drought is described less as a widespread disaster and more often as the impetus for the development of infrastructure. This six year dry period would act as a model for the kind of drought that infrastructure was meant to mitigate. But this was not the only drought that shaped California's large infrastructure projects. Another significant drought outside of the state boundaries overshadowed California's own dry period and also spurred the development of the large infrastructure projects in the 20th century.

The Dust Bowl drought in the Midwestern United States led to a population explosion during the 1930s that directly precipitated the development of the Central Valley Project. The twin disasters of the Great Depression and the Dustbowl in the Midwest are immortalized in Steinbeck novels and Woodie Guthrie songs, and they dramatically reshaped the United States. Demographers estimate that approximately one million people resettled in California from states like Oklahoma and Arkansas during the devastating drought (Gregory 1991). Many of the migrants settled in the San Joaquin and Imperial Valleys looking for farm work. The influx of migrants from the Midwest strained the state's already troubled infrastructure. However, California did not prove to be the "promised land" that many migrants hoped to find, instead

---

period is referred to as 1929 – 1934. This drought occurred before the construction of major water projects, so the year-to-year water conditions were much more powerful than they are today. I will use the time period 1929 – 1934 in this dissertation because the six year drought period is used more frequently in USBR and DWR reports. Those years also formed the foundation for dry year thresholds in future droughts, although 1924 is often referenced as a single, critical dry year that also informed thresholds that define drought.

living in extremely difficult conditions as farmers in California were also struggling during the Depression. The Central Valley Project (CVP) was eventually funded through the US Federal Government as a public works program to solve the combination of problems related to water and farming in the Central Valley (United States Congress House Committee on Interior and Insular Affairs 1956).

The development of infrastructure to control water resources was an important component of California's state government formation (Carroll 2012). During this period of drought abroad and "at home" from 1929 – 1934 large scale infrastructure projects were built by the state and private groups. The first barrel of the Los Angeles Aqueduct and the Mokelumne River Aqueduct in the Bay Area were completed by the beginning of the 1920s drought by local utility groups (Jones 2020); and the Hetch Hetchy Aqueduct was completed in 1934. These early infrastructure projects successfully brought stable water supplies to large urban areas in Northern and Southern California. During the 1930s, the state of California focused intensely on developing water supplies to support continued economic and urban development. This can be seen in the State Water Plan authored in 1930 and adopted by the California Legislature in 1931 (California Department of Public Works 1930). Although unable to finance the project due to the Great Depression, some of this plan was executed through the building of the Central Valley Project in 1933.

Access to water – both legally and infrastructurally – has been at the heart of California since early in its statehood. California's water laws and the early stages of infrastructural development create conditions of possibility in two important ways. First, California water law has deep continuity between time periods. It means that some water users - both individuals and groups - will *always* have access to water until the situation is extremely dire. Second, sprawling infrastructures like the Central Valley Project and the State Water Project dramatically alter the relationship between location and water. The storage and conveyance the projects provide act as a buffer from the effects of dryness. The formalization of a legal hierarchy and the development of large infrastructure projects provides a foundation for the time periods I will compare in the next section and the following chapters that informs every state and stakeholder decision made historically. It sets the stage or the playing field that the rest of the action takes place. It is within these confines that drought emerges as a scientific and social fact over the course of the next three-quarters of a century.

Drought periods

1950s – 1960s

During the 1959-1961 drought, infrastructure was viewed as a successful solution to the ongoing drought and future droughts. By the 1950s, the majority of the CVP had been completed by the United States Bureau of Reclamation (USBR). The new infrastructure project carried over thirteen million acre-feet[14] of water through the Central Valley (Stern, Sheikh, and Ward 2022), making it possible to expand the amount of irrigated farmland from 5 million acres to 8.5 million (Giannini Foundation of Agriculture Economics, University of California 2018; Johnson and Cody 2015) It was widely viewed as a success, and when another water crisis hit the Southern region of the state, politicians and engineers once again turned to infrastructure to solve the problem.

---

[14] For context, one acre-foot is approximately 326,000 gallons; an average California household uses one half to one acre-foot of water in a year for both indoors and outdoors according to the Water Education Foundation (a non-profit founded in 1977 during the first drought).

Water – once viewed as unruly and threatening to development – had been partially tamed through the CVP. Now, water was seen by politicians and state engineers as plentiful in Northern California and controllable through careful water plans and management (Brown 1961; Udall 1961). The persistent drought in the more arid and more populous Southern California presented a problem of mismatched resources and need. According to state actors, ample water existed in Northern California, but the need was concentrated in counties like Los Angeles and San Diego (California Department of Water Resources 1961). The agricultural sector in Central California was also growing, leading to an increased water need that could not be met entirely by the CVP. The proposed solution built on the original 1930 State Water Plan, and it involved an expansion of infrastructure throughout the state. The proposal was the "State Water Project", and it would share some of the same material infrastructures with the CVP. But it would move further south, storing and delivering more than five million additional acre-feet of water (California Department of Water Resources 2017). The State Water Project was contentious due to competing interests that mapped onto the North, Central, and South regions of the state (Nie 1998). However, it did pass when put to a ballot vote as the Burns-Porter Act in 1960.

The State Water Project was built to end drought by solving the "mismatch" between water supply and water demand. During this time period, drought was viewed as a problem that could be solved by engineering, so the root of drought itself was the mismatch between supply and demand. Water plans to develop water supplies promised to eradicate all but the most persistent droughts. At the outset of the 1970s, dryness was understood by government actors and powerful stakeholders as an element of California's hydrology that could be managed and carefully monitored. All it requires is the construction of expansive water projects to build carry-over storage between years and careful regulation of water allocations based on water rights.

The State Water Project was meant to remove much of the concerns around drought – certainly the ones that were most prominent at the end of the 1930s before infrastructure was widely developed.

1976 – 1977

The 1976 – 1977 drought tested the expansive state and federal infrastructure projects. The 1976 and 1977 water years were record-setting dry years. The 1977 water year[15] was the single driest year on record since 1924 when little infrastructure existed until 2021[16]. The infrastructure projects had been built to buffer against a series of dry years, but water managers and state engineers were not prepared for the two critically dry years that hit Northern California particularly hard. The CVP and SWP are only able to capture and convey water when Northern California receives regular rainfall. The lack of precipitation in the North impacted the rest of the state when reservoirs were not refilled after a dry 1976. In 1976 and 1977, statewide precipitation was only 60% and 30% of average respectively (Santos and Godwin 1978)with reservoir storage dipping as low as 50% of average in May of 1977 (California Cooperative Snow Survey 1977). The SWP and the CVP cut water allocations to both urban and agricultural users for the first time in history. Unlike previous droughts, the 1976 – 1977 drought was not felt locally but statewide due to the construction of statewide infrastructure.

As a statewide drought, the tensions amongst governments, different regions, and stakeholder interests were also felt statewide. The state and federal governments disagreed over

---

[15] A "water year" is based on California's hydrological cycle rather than the calendar year. The water year runs from October 1 – September 30th of the following year. For instance, the 2022 water year began on October 1, 2021, and will run through September 30th, 2022.

[16] The ongoing drought in California and the Southwest more broadly began after data analysis for this dissertation was well underway. I will discuss the ongoing drought briefly in the conclusion of the dissertation.

which level of government had a final say in water quality and allocations, and they would proceed to fight it out in court (State Water Resources Control Board 1978). Northern California and Southern California's already well-known hostility grew to a breaking point when regions of Northern California that still relied on local supplies were forced to tightly rationed water while Southern California did not experience the same need for conservation (Governor's Drought Emergency Task Force 1977). Finally, the need for environmental protections began to emerge as well, adding more demands to the state's strained water conditions. Water quality in the Sacramento-San Joaquin Delta and the San Francisco Bay (Bay-Delta) region deteriorated significantly during this drought – far beyond what was expected based on pre-infrastructural levels[17] (Santos and Godwin 1978). The different interests and competing uses for water represented in this series of tensions would shape drought in future declarations.

The dire circumstances of the 1976 – 1977 drought created a need for a coordinated response to drought emergencies. Infrastructure was not able to completely mitigate drought, and the statewide conditions required a statewide response. I want to note that the SWP and the CVP were not failures. The existence of infrastructure and carryover storage during 1976 mitigated nearly all impacts to irrigated land (California Department of Food and Agriculture 1976). But they did fall short of their original goal of removing drought as a source of strife and emergency. To handle the emergency conditions, Governor Jerry Brown Jr. formed a Drought

---

[17] Salinity would increase in the Bay-Delta during dry years before infrastructure was built. In fact, infrastructure was meant to help control salinity intrusion (State Water Resources Control Board 1978). However, as growers and urban dwellers came to rely more on the water delivered through the CVP and SWP, pumping water out of the Bay-Delta to meet demand began to erode water quality further than would be expected from dry years with no infrastructure.

Emergency Task[18] force that coordinated communications and responses[19] across the state. The "emergency" status of this drought required the mobilization of the National Guard to provide support to communities in Northern and Central California experiencing critical water shortages (Governor's Drought Emergency Task Force 1977). The response was coordinated through the Department of Water Resources – this department would play a central role in future drought responses. This particular drought also led to collaboration between government agencies and the California state university and colleges system (CSUC) in order to study drought impacts, potential mitigation strategies, and development of other measurements (Governor's Drought Emergency Task Force 1977). These mitigation strategies set expectations for state-level coordination, broad allocation reductions, and individual conservation practices for future droughts.

During 1976 – 1977, a definition of drought was solidified, but it was also reshaped in meaningful ways. Drought's status as a state of emergency was solidified, and it was clear that drought would persist even with costly and far-reaching infrastructure projects. Drought continued to be a disruption to typical economic functioning due to a lack of precipitation. And, critically dry years like 1976 – 1977 defined the water conditions that qualified as a drought. However, drought shifted dramatically from a localized event to a statewide emergency. Water supplies in Northern California had been physically connected to the rest of the state, so the water conditions of Northern California determined the conditions for the rest of the state –

---

[18] Executive Order No. B-27-77 (1977)required that the task force be comprised of representatives from the following state agencies and departments: Agriculture and Services Agency, Business and Transportation Agency, Health and Welfare Agency, Department of Finance, Department of Fish and Game, Department of Food and Agriculture, Department of General Services, Department of Health, Department of Housing and Community Development, Department of Navigation and Ocean Development, Department of Parks and Recreation, Department of Transportation, Department of Water Resources, Division of Forestry, Employment Development Department, Military Department, and Offices of Emergency Services

almost entirely independent from the amount of precipitation falling on Central and Southern counties. The statewide status of drought persists in the future declarations, but new interests and new mitigation strategies alter drought as a fact and a problem.

1987 – 1992

By the 1980s, California had undergone significant changes in population, and the change demonstrated the limits to the "bountiful" water in Northern California. Between 1960 and 1980, California's population had grown from 15.7 to 23.6 million, and it made California the most populous state in the country (U.S. Census Bureau 1982). All of the new people, residences, businesses, and so on that came with the expansion require water. The new developments had to acquire junior appropriative water rights that would come second to all rights before it. With the new allocations, the state entered a "paper water" phase of development. "Paper water" describes a state where an individual, business, or community may have the rights to water, but the amount of water available during an average year cannot cover all of the water rights allocated in California (Carle 2004). California residents had also lost their taste for massive infrastructure projects as a potential solution to the state's water problems. In 1982, the Peripheral Canal which would have transported drinking water *around* the Sacramento-San Joaquin Delta instead of *through* was soundly defeated at the ballot box (California Proposition 9 1982; Kahrl 1990). New projects to expand surface storage were unlikely to be funded. Water had gone from "bountiful" to "scarce" in two decades. The consequences are a sharper tiered system of water access and a reliance on ground water to make ends meet – both of which are important for the six-year long drought of 1987 – 1992.

The 1987 – 1992 drought would test infrastructure yet again, but this time its endurance. By 1986, the vast majority of both the CVP and the SWP were completed, providing over nineteen million acre-feet of surface water storage (Dziegielewski, Garbharran, and Langowski Jr. 1993:39–40). Water conditions looked stable in 1986, after a record-setting wet year where statewide precipitation was 135% of average and reservoir storage was 115% of average (California Cooperative Snow Surveys 1985). However, the following six years would all be dry or critically dry, and it strained California's water infrastructure to the breaking point. The amount of surface water storage built by the CVP and SWP equates to two years of storage, meaning the storage capacity can buffer dry conditions for two years before needing to make cuts (Priest et al. 1993). Over the dry years that followed, reservoir storage dwindled down to 65% by May of 1991 (California Cooperative Snow Surveys 1991).

The 1987 - 1992 drought used familiar mitigation strategies, but also required new ones with the duration of the dry period. Governor Deukmejian issued Executive Order W-3-91on February 1, 1991, to form the Drought Action Team to coordinate a statewide response (Priest et al. 1993). The SWP and the CVP had to reduce water delivers to all water users. Residential water users were once again encouraged by public information campaigns on how to use less water (Figure 2.1 and 2.2), or in some counties, coerced into conserving through increased prices. Agricultural water users turned to pumping groundwater to survive the extended drought. It is estimated that the land table in the Central Valley sank by more than two feet over the six years of drought (Priest et al. 1993:25). These familiar responses were paired with new efforts to explain what causes a drought.

How to give water conservation a push.

It's easy. Just sweep your driveway instead of washing it with a hose.

Every time you do, you'll save about 300 gallons of water. And if you think about all the driveways here in Southern California—and all the patios, too—it's not hard to see why reaching for a broom is so important during the drought.

If everyone did that, we'd save billions of gallons of water this summer.

And during the drought, that's exactly what we need to do.

(YOUR LOGO HERE)

Figure 2.1: A Metropolitan Water District advertisement developed for local water agencies to encourage individual conservation as a method of mitigating drought (Spencer 1988:3).

Too many drips and we're down the drain.

It doesn't *look* bad—but even a slowly dripping faucet can waste up to 50 gallons of water a day.

So check for leaks, inside and out. If you find a leaky faucet, it's easy to fix. Usually, a washer from the hardware store will do the trick.

If every dripping faucet in all of Southern California gets fixed right away, we'll save millions—even billions—of gallons of water this summer.

And during the drought, that's exactly what we need to do.

(YOUR LOGO HERE)

Figure 2.2: A Metropolitan Water District advertisement developed for local water agencies to encourage individual conservation as a method of mitigating drought (1988:4).

Scientific explanations for drought had developed and gained a foothold by the 1987 – 1992 drought. Previously, drought was explained as a lack of precipitation to meet needs, but climate science research had begun to build a body of knowledge focused on the physical elements of drought (Heim 2002; Palmer 1965; Philander 1985; Rasmusson and Carpenter 1982;

Ropelewski and Halpert 1986). Part of this body of knowledge was an explanation of drought rooted in the atmosphere. Phenomenon like high pressure ridges and El Niño-Southern Oscillation conditions were connected to the lack of precipitation that led to drought in California (Priest et al. 1993). The duration of the drought opened up more space for non-government scientists to define drought as a scientific fact by connecting the multi-year dry conditions to atmospheric causes that moved beyond water management and water stores.

The 1987 – 1992 drought further demonstrates the continuities and changes that characterize definitions of drought. First, drought remains a lack of water to meet the needs of residents and economic sectors. Drought can be intense, felt statewide, and deeply disruptive to the functions of everyday life. However, drought can also be a multi-year statewide disaster that requires thoughtful and sustainable mitigation strategies, rather than intensive emergency responses. Not only can the SWP and CVP not protect against a six year drought like the one in 1929 – 1934, but it also cannot be used to solve every single drought. And drought is no longer the purview solely of state engineers. Climate scientific explanations of drought separate from water storage or economic impacts were incorporated into discussions and official reports. The characterization of drought as a persistent disaster would shape responses and declarations in the 21st century, and climate science would provide new context for future water shortages.

2007 – 2009

The approach to water and the "natural" world that contextualized the 2007 – 2009 drought was a significant change from the previous time periods. During the 1970s and the 1980s, the environmentalist movement emerged as a powerful political force (Dryzek et al. 2003; Dunlap and Mertig 2014; Dunlap and Michelson 2001). Organizations like Environmental

Defense Fund, Sierra Club, and other local conservation groups found success in the courts, using new policies like the Environmental Protection Act to push back against further development and infrastructure projects (Clark 1980; Racanelli 1986; Trott 2006). Using lawsuits, environmentalist organizations were able to push for water allocations for the environment itself.

As mentioned briefly, the 1976 – 1977 and 1987 – 1992 droughts contributed to environmental degradation of the Bay-Delta area due to increased pumping. Over pumping increased salinity and reduced fish and wildlife populations. In the intervening decades, more water was earmarked for environmental protections, restricting the amount of water available for human consumption (State Water Resources Control Board 1988; Trott 2006). This environmental push dovetailed with a general halt on large infrastructural projects during the 1990s and 2000s. Unchanged surface water stores and reallocations of available water changed the definition of drought. Now, more purposes needed to be served with the same amount of water. The changed in definition led to a more politicized drought declaration than in previous decades.

During this dry period, the politics of water distribution and water management came to the forefront more than the levels of precipitation. The snowpack in the Sierra Nevada mountains – California's largest "reservoir" – was far below seasonal average (California Cooperative Snow Survey 2007), but the storage levels in reservoirs like Lake Oroville were high enough to supply water through at least one dry season due to a particularly wet 2006 water year (California Cooperative Snow Surveys 2006)As a dry 2007 played out, secondary water users in Central California, specifically newer farmers and cities in San Joaquin Valley[20], were

---

[20] Westlands Water District which covers Fresno was one particularly hard hit

expected to experience water cuts. The water cuts were exacerbated by the new environmental regulations that required more water remain in the Delta than in previous droughts. Farmers and some politicians advocated for an expansion of water infrastructure to mitigate the dryness. These stakeholders argued that there was enough water available, but it was being given to "stupid little fish" (Scoville 2019). The politicized declaration revealed splitting over how to manage drought. And new research from climate science showed that prolonged dry conditions in California were going to become more frequent.

The rhythm of wet, dry, and critically dry years in California was better understood by the 2007 – 2009 drought. New methodologies like tree ring data revealed that California had experienced prolonged droughts off and on over the last thousand years (Jones and Schwitalla 2008; Stahle et al. 2000, 2007). With this new evidence drought was not just a question of managing resources, but an atmospheric phenomenon that was outside of human control. In contrast to the discourses of "mismatch" in the 1960s, water management was moving towards a different understanding of drought. Drought is seen as a part of the rhythm of a longer hydrological cycle of the state, rather than an anomaly that could be prevented through careful storage and conveyance.

In this drought we see the most radical of changes, which in turn reveal the deepest continuities. Once again, drought is a lack of water for the regular social functioning of the state. However, the "state" now included environmental protections that shifted the network of stakeholders who could claim water allocation. Also, drought is no longer attributed to the limits of infrastructure and storage as in previous time periods. Now, drought is part of the regular rhythm of California's hydrology and tied to broader atmospheric patterns. Instead of two- or six-year disruptions that are outside the norm, drought is a regularly occurring emergency that requires more consistent planning to maintain balance among human actors, wildlife, ecosystems, etc. even with the existence of infrastructure. In the final declared drought, the new context of climate change would alter drought once again.

2012 – 2016

The 2012 – 2016 drought demonstrates deep continuity between all three previous periods. Tensions between environmentalism and development persist. Climate change presents an ongoing concern. In fact, some meteorologists and hydrologists view this drought as an extension of the 2007 – 2009 drought (Berner et al. 2017; Diffenbaugh, Swain, and Touma 2015; Dong et al. 2019). In terms of water conditions, the 2007 – 2016 water years were all classified as below normal, dry, or critically dry; only 2011 is classified as a wet year (California Department of Water Resources 2021). The 2012 – 2016 drought is both meteorologically and sociologically an extension of the previous declaration. Additionally, there are some striking continuities from the 1976 – 1977 drought. Governor Jerry Brown Jr. was back in office, giving him the dubious honor of having declared half of California's official droughts during the era of large water infrastructure. Similar to the three previous droughts, water storage levels were critically low at the end of a second dry winter, with statewide reservoir storage reaching 65% of average by February 1, 2014 (California Cooperative Snow Survey 2014). Mitigation strategies included the usual suspects: reduced water allocations, individual conservation, groundwater pumping, and state-coordinated responses (Jones 2020, 2021). But these mitigation strategies were limited, particularly with the looming impacts of climate change.

The new context of a looming permanent shift in California's climate also shaped this drought's character and response. Climate change was and continues to be an unfortunately politicized topic, but in 2014 it had become an important context for discussing water issues in California. Climatology and meteorology models predicted that climate change would dramatically alter how water fell on California by the year 2050 (Griffin and Anchukaitis 2014; Mann and Gleick 2015; Swain et al. 2018). There would be more frequent droughts, particularly in Southern California, and precipitation would fall more frequently as rain than snow, and it would fall earlier in the year (Pagán et al. 2016). This shift in hydrology has deeply important ramifications for California's water governance system.

California's water management systems – both physical and legal - were built based on a particular understanding of the hydrological cycle. It assumed that there would be wet months from October through April, and those wet months would include precipitation that fell as both rain and snow. The snowfall was concentrated in the Sierra Nevada Mountains, making the mountain range California's largest reservoir. Since 1930, snowpack was carefully and ritualistically measured on the first of every month beginning in November and ending in May (California Department of Public Works 1930). That snowpack would slowly melt from the Sierras and flow through rivers like the Sacramento, San Joaquin, and American Rivers, filling reservoirs throughout the state. The water could then be carefully meted out during the dry months. Now, climate scientists predict that with more precipitation falling as rain, the infrastructure will be less able to prevent flooding and capture water. Scientists are even working on creating new "precipitation" indicators to disentangle rain and snow as these new weather patterns emerge (California Nevada Climate Applications Program 2017).

The 2012 – 2016 drought is the final case that illustrates the continuities and changes that underscore drought as a fact in California. Just as it was in the 1920s, drought is defined by a lack of water for social purposes – typically economic development. The declaration entailed conservation measures from both urban and agricultural water users. However, drought had also changed substantially from the 1970s. Rather than an intermittent problem or "abnormal" emergency that could be mastered through engineering, drought is now defined as a permanent feature of the California hydrological cycle and likely to become even more frequent with climate change, challenging the assumptions of California water management. Rather than a period of multi-year dryness that can be controlled and mitigated with careful governance before a return to "business as usual", drought is now a problem that is here to stay. The definition of drought in 2012 – 2016 creates the possibility for a future drought to be declared for reasons other than a disruption to agriculture or lower water allocations as these also become more frequent.

Conclusion

I offer this historical overview as a snapshot of the complexity of each case that I analyze in the dissertation. In each period, there are infrastructures, measurements, and networks of expertise shaping drought definitions. In the coming chapters, I explore each of these themes across the different droughts. First, I start with an interrogation of "big" infrastructure, analyzing it both as a condition of possibility and path dependency for drought to emerge in a particular formation in California. Then, I interrogate the "small" infrastructures of drought indices and water measurements, and how they function as the basis for thresholds for defining drought across time periods. I examine how they work as epistemic path dependencies, defining drought based on water levels in the 1930s that continue to shape what qualifies as a "dry" year. Finally, I discuss the networks of expertise that grew and changed around drought as a scientific fact. Drought was already an established lay category with stakeholders, engineers, and depictions already established. I examine how representations and definitions of drought change as new forms of expertise – like climate science and environmentalists – join the network. Then, I demonstrate how the changes to the network led to changes in drought itself.

Portions of Chapter 2 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

CHAPTER 3: INFRASTRUCTURES

Introduction

In front of a crowded conference room in Los Angeles in the Summer of 1961, Governor Pat Brown articulates his vision for California's future – one that is built on the control of water. He tells the attendees – including state and federal engineers, water district directors, agricultural stakeholders, and the Secretary for the US Department of the Interior – that after years of bickering between Northern and Southern California there is finally movement towards action: "We boiled the problem down to three simple facts. The counties of origin deserve and must have flood control and protection of their water rights. The deficient areas deserve and must have benefit of California's surplus water. This is <u>one</u> state and must have <u>one</u> unified water plan" (emphasis original) (Brown 1961:4). This one unified water plan was the State Water Project – a massive infrastructure comprised of dams, canals, and pumps that would capture "surplus" water in Northern California and transport that water to the arid Southern region. It would eventually be passed as a ballot measure in the same year with the glowing promise that there was enough water in the state for everyone – it just needed to be used more wisely. Fifty years later, it was clear that those promises were not true.

In June of 2008 – two months after a drought declaration, a writer at the Fresno Bee questioned the conditions of the declaration. The writer urged then-Governor Schwarzenegger:

> Demand an explanation from the state Water Resources Control Board why current water rights permits and contract allocations exceed available supplies by several times. This phantom supply, known as "paper water," is being used to justify more urban sprawl throughout the state. The State Water Project promises contractors 4.2 million acre-feet annually (an acre-foot is 325,851 gallons), but can safely deliver only 1.2 million acre-feet. (Carter 2008:J1)

Over the last 60 years, infrastructure – both legal and physical – has shaped our understandings of drought as a fact. It has both made it possible for drought to emerge as a problem, and it has shaped our understandings of drought over time. In California, a drought is not a single dry season, and that is entirely due to the large infrastructure projects that capture, conserve, and convey water across the state.

In this chapter, I focus on the big infrastructures – legal and physical – interrogating how they create the conditions for drought to emerge and shape drought across the four cases that comprise this dissertation. The central questions of this chapter are as follows: How have water rights laws shaped the construction of physical infrastructure? How do water rights and physical infrastructure interact to distribute across the state? How do these interactions shape drought declarations?

To answer these questions, I make use of reiterated fact making to build on the insights of infrastructure studies and environmental sociology. With this framework, I briefly trace the legal foundations of water rights in the 20th century, showing how their structure underpins access to and benefit from the physical infrastructures built by the United States Bureau of Reclamation (USBR). Then, I argue that the building of the Central Valley Project (CVP) constitutes a condition of possibility given *when* it was built and *the purpose* it was built for. In the second half of the chapter, I show that the State Water Project (SWP) is a material path dependency that enables and constrains certain understandings of drought over the four declared droughts from the 1970s into the 2010s. Finally, I demonstrate how this plays out over the course of the four declared droughts by examining reservoir levels in two key dams – Oroville and Shasta – and how infrastructure was debated during these periods of dryness while simultaneously shaping them as well.

Literature

There is a rich academic history that interrogates the notions of the “environment” as well as environmental problems. Much like in other areas of sociology, this work breaks down into two prominent strands: constructivists who emphasize the openness of science and importance of politics and power (Buttel and Taylor 1992; Greider and Garkovich 1994; Taylor and Buttel 1992); and a second turn who argue that a strong constructivist approach is too uncertain and leaves no room for nature/nonhumans to have an effect on the world (Dunlap and Catton 1994; Goldman and A. Schurman 2000; Murphy 1994; Murphy and Dunlap 2012). This second approach has been incredibly fruitful in discussing the relationships between humans and nature, and how these two sets of actors (as much as they can even really be separated) mutually constitute each other. This critical approach offers a useful starting point for interrogating the relationships between law, materials, and the environment to determine exactly how they shape each other. The study of infrastructure - or "built" environments - offers a good case for interrogating where the social, material, and nature intersect.

Infrastructure studies are interested in how governance and nature become intertwined through the building of large networks of irrigation, dams, and other materials. Historically, control of natural resources – and water in particular – has been a central component of governance and even state-formation (Carroll 1996, 2012; Scott 1998). The historical development of large infrastructure projects and the kinds of knowledge that support them provide states with the power necessary to set standards of practice related to resources like water. Today, water resource management remains a political project. Even with well-established governments and built infrastructure, water management still rests on the control of a contested resource (Mollinga 2008), and there is often conflict over jurisdiction and goals for water use that make it yet more complex (Caniglia et al. 2016). Drought is certainly a time when these conflicts will be on full display. To understand how drought is shaped by water management practices, we must interrogate the intersection of state governance and infrastructure.

Two studies of infrastructure provide the groundwork for interrogating the intersection of drought and water projects. They both demonstrate how the built environment is shaped by material relationships and political ideologies, and how those infrastructures reciprocally shape relationships in turn. Sara Pritchard (2011, 2012) develops the framework of "enviro-technical analysis" in her examination of hydrology and technologies of dam-making in France on the Rhône beginning in 1945. She highlights the connections between the material and the discursive in building these technical systems and demonstrates the centrality of environmental management and technological development to culture and politics in the twentieth century. Additionally, Patrick Carroll (1996, 2006) demonstrates how the elevation of engineering within governance led to experimentation in Ireland that focused on engineering not just machines, but people, land, and sprawling infrastructures. He further developed this argument by examining how engineers in California were a central process of state-formation through water and land management (2012). Engineers and managers addressed California's "water problem" through irrigation systems, canals, dams, and pumps. In doing so, they built state authority. California's state government became the arbiter of water rights, water standards, irrigated farmland, and inspectors of infrastructure. California as a state was made by technologies and sciences that made water management possible.

These works at the intersection of management, states, and water provides a strong foundation for studying drought in California. Both researchers take a historical approach to analyzing a particular piece of infrastructure over time and show how geographic regions, electricity, and technologies were shaped by the goals of engineers and shaped the region itself. The technologies break down the distinction between “nature” and “society” by showing how infrastructure reshapes rivers and watersheds, altering the very landscape they were built to manage. In turn, the infrastructures must change in response. These research projects are invaluable for demonstrating how dominant ideologies and inequality shape water management practices and “natural” disasters themselves. I am deeply in their debt as exemplars of how to examine large scale infrastructure projects over a period of decades to understand how the projects and politics shape each other. However, they are less helpful for uncovering how these interactions do or do not change over time to shape our understandings and experiences of a disaster like drought.

The studies discussed above put state power and governance at the center of their analysis, not disasters themselves. The focus is firmly placed on how solving problems allows a state to accumulate power, rather than how state power and infrastructure shape “natural” disasters like drought. Other studies have looked at how water infrastructures and the discourses governing it can create drought independent from levels of precipitation (Kaika 2003, 2004) and shape how water scarcity is experienced (Carse 2012, 2017). These projects also fall short even with their focus on drought. They do not offer an analytic framework that lends itself to a comparative historical project. Rather than analyzing a single instance of drought to understand how infrastructures shape that particular experience, I want to understand how these forces work across different droughts. The outcomes in one drought period are among the influences on later ones. This allows me to attend to how infrastructure shapes drought not just in one time period, but how infrastructure settles definitions of drought over time. Making use of multiple droughts allows us to make stronger causal arguments about why some aspects change between time periods and why some elements – declarations, responses, arguments – remain the same. I utilize the first two axes of reiterated fact making – conditions of possibility and path dependencies - to examine why drought emerged in California.

Using reiterated fact making to examine physical and legal infrastructure raises the following theoretical questions: How does infrastructure shape environmental problems? How does infrastructure lock in certain definitions of environmental problems over time? How does infrastructure mediate who experiences the problems and to what extent? To answer these questions and their empirical counterparts, I need to examine the history of California's major infrastructure projects; the intended and unintended goals of their construction; and how water rights and physical infrastructure are discussed in lead ups to a drought declaration.

The data and materials used for this chapter were an array of government reports about water conditions, publications on California's water rights, statues and reports on infrastructure, and other archival materials. I began with documents from the Department of Water Resources, so I could understand how infrastructure was managed and underpinned discussion of dry conditions. These documents include Department of Water Resources drought reports and bulletins regarding water conditions across the state. After learning more about how the infrastructure projects function in these reports, I examined state documents covering the construction of the Central Valley and State Water Projects, using statutes, conference proceedings, and water allocations and deliveries. These documents provided insights into the purposes of their construction which could be contrasted with the drought reports from across time periods. Finally, I relied on legal writings from the last one-hundred years to understand California's water rights system, how they were tied to water deliveries, and how they were altered or honored during droughts. These historical documents provided rich data on legal and physical infrastructure and how they shaped drought definitions and declarations over time.

In this chapter, I show how decisions to mitigate drought in the 1960s – even in light of resistance from various groups – locked in some features of drought in the following periods. Conditions of possibility and material path dependency ground my analysis for a strong comparison between the four droughts in California. In this chapter I show how California's water rights system works as a necessary background condition for drought to emerge as a scientific fact in addition to the construction of the CVP to help the state control water flows in the Central Valley. Then, I trace the construction of the State Water Project as a material path dependency to show how decisions about infrastructure lock in key definitions of drought that persist across the four cases.

Conditions of possibility: Legal and physical infrastructures

Water rights

Reiterated fact-making calls attention to the necessary conditions that must be in place for a fact to emerge. In the case of drought, one such condition of possibility is the legal infrastructure of California's water rights. I touched on this briefly in Chapter 2's historical overview. Water rights in California are hierarchical, and they either tie water to land or disconnect them. In this section, I look closely at how California as a state developed the intensive monitoring of surface water rights, the absence of groundwater within the system, and how they intersect with the construction of physical infrastructure as a form of state power. California's water rights system shapes drought by dictating who receives water during times of scarcity and what kinds of water regions and communities can access during a drought.

Additionally, the water rights system provides the foundation for the two major water projects that connect watersheds across the state.

The structure of water rights provides a legal infrastructure, which enables and constrains certain water projects. The decisions about the structure of water rights made in the 19th and early 20th century prove to be deeply consequential for how access to water was regulated. The water rights established through the pueblo and riparian systems mediated water projects during the end of the 1800s and into the early 1900s. Any water project built in California needs to acquire water that is not already held by another community or group and could not reduce the amount of water already claimed farther downstream (Attwater and Markle 1987; Wiel 1911). Proposals for new dams had to follow the same rules, and water could not be impounded and stored if it reduced the water someone already claimed (California Department of Public Works 1940). The legal infrastructure of these water rights resulted in some regions of California obtaining rights to large portions of water through pueblo and riparian rights. These regions are familiar to many of us: Sacramento, San Francisco, Los Angeles, and the Central Valley. With primary water rights secured, water districts or individual landowners were positioned to benefit from infrastructure projects that could make accessing "their" water much easier. The legal infrastructure also led to a ground water supplies being unmonitored for a long period of time.

Before the 21st century, California water law was mostly silent about groundwater usage. Prior to 2001[21], groundwater was not monitored or controlled by the state or other body beyond the doling out of property rights. Groundwater refers to water that is underground, often in aquifers. Groundwater is crucial to California's water supply – acting as the source for as much

---

[21] The Groundwater Monitoring Act was passed in 2001. The Act was established to improve comprehensive groundwater monitoring and increase the availability of information about groundwater quality to the public (Liu 2001).

as 30% of all water used in the state during normal years and 60% in dry years (Carle 2004). In the first half of the 20th century, groundwater was treated as an extension of riparian rights (Grantham and Viers 2014). It was seen as water on a landowner's property, and therefore completely within their rights to use if they were able to access it. This meant that farmers and other landowners in the Central Valley – which sits on top of the large Central Valley Aquifer system – would be able to pump groundwater with no oversight during dry years, offering them a more expensive but reasonably accessible backup source of water.

The water rights system works as a condition of possibility by shaping which areas of the state can reliably access water. Beginning in the 1800s, water users were stratified based not just by the amount of water they had a right to, but how "old" those rights were. Landowners, growers, and private companies like the Metropolitan Water District that operated in the early years of the state secured their rights through this system (Hanak 2011; Hundley 2001). It positioned these sectors and users at the heart of water in California. With reliable access to water, the metropolitan regions of Southern California and became population and business centers for the state. The Central Valley became one of the most productive agricultural regions in the country. Other regions with less secure water rights experience dry seasons and disruptions more frequently and before growers in the Central Valley or residents in San Diego. However, dry periods in those areas rarely come to define a drought. Instead, "drought" happens when water allocations to the more prominent users are cut. The system of rights makes it possible for a specific configuration of drought to emerge because it governs and prioritizes access to a natural resource.

Legal infrastructure also delineates which bodies could build physical infrastructure to move and store water. At first, many private companies built dams and reservoirs across the state. Many of the dams built between 1850 and 1928 were developed by private companies and had very minimal formal supervision or evaluation (Hutchins 1956, 1959). Many dams were smaller. The dams diverted water for mining projects or to irrigate private lands. State actors had not managed to position themselves as the legitimate managers of water in the region. However, a major shift occurred in 1928 with the failure of the St. Francis Reservoir. This reservoir was built on the Los Angeles-Owen's Valley Aqueduct under the supervision of William Mulholland (Nunis 1995). According to the investigation conducted in the ensuing months, the dam reached its full capacity in the middle of the night in March 1928, and a week later it failed catastrophically (Bowers 1928). The failure led to flooding four towns and drowning hundreds of people.

After the failure of St. Francis Reservoir, the state intervened to counteract the damage done to the image of dams and residents' confidence in them as a structure. The State of California consolidated power over water under itself and the United States Bureau of Reclamation in 1929. The 1929 legislative session passed the Dam Supervision Act, which stipulated that any dams over a certain – relatively small – size would need to be examined, reviewed, and regularly inspected by state engineers to ensure that no other failures happened (California Department of Public Works 1940, 1941). Additionally, the act put the "maintenance and operation" of larger dams under the purview of the Public Works Department. The state body was the ultimate authority over the building, expansion, repair, and operation of large dams across California. State actors had a vested interest in rehabilitating the image of dams because California's growth was already predicated on their construction and expansion. Governor Clement C. Young in his forward to the report on the St. Francis Reservoir stated, "As the future of California depends in a large measure upon the storage of water, and the construction of dams, it is gratifying to note that this report finds that such structures can be built with entire safety when due regard is paid to suitability of foundations and correctness of design" (Wiley et al. 1928:i). Private companies and local water authorities were allowed to construct new dams, but they were small comparatively. The state and federal governments by building and operating major dams and reservoirs consolidated power over a majority of California's water through this act.

This Act is important for understanding physical infrastructure because it sets the stage for state control over water resources and drought declarations. Local communities and private groups still built and maintained dams over the last 100 years, but these dams contain a minority of surface water storage[22]. State and federally run dams contain 60% of the surface water stored in California, meaning that the state and federal government controls most of the water used on farms, in businesses, and at homes. This is in addition to the power California's state government has to inspect and audit any non-federally operated dam in the state. With such far reaching power to shape dams and water storage across the state, California's government is well positioned to determine what projects are necessary; how they should be built; and when water storage levels constitute a drought. These are important conditions of possibility for droughts emergence. Water rights – both in terms of access and ability to build infrastructure – lay the groundwork for the construction of massive infrastructure problems to address water as a problem. In the next section, we will examine how the construction of the federally run Central Valley Project is also a critical condition of possibility for understanding how drought emerged in California in the 1960s.

---

[22] Privately owned dams account for 40% of the surface water storage in California (Escriva-Bou, Mount, and Jezdimirovic 2019). According to the National Inventory of Dams, approximately 63% of all in the USA dams are privately owned and operated, but in California only 44% of dams are privately owned and operated (US Army Corps of Engineers 2020).

Physical infrastructure: The Central Valley Project

Now let's consider physical infrastructure as a condition of possibility. I want to start with one of the two major water projects in California. For this analysis, I place the Central Valley Project (CVP) in the conceptual category of condition of possibility rather than a material path dependency because the project was not built to address drought or even dryness. Earlier in California's statehood, "water" was seen to be a singular - albeit complicated - problem (Carroll 2012). Flooding, dryness, irrigation, and inland navigation were all seen as part of one issue rather than separate problems requiring unique attention. In the late 19th and early 20th century, a primary concern of state government was land reclamation in the Central Valley, and flood control was the focus of early infrastructure projects (O'Neill 2006). The CVP built on flood control projects by capturing water to prevent flooding and conveying it to reclaimed farmland during the dryer summer and fall months. Its success and impact on the state made it possible for a specific configuration of drought to emerge and to envision an infrastructural solution to drought further down the road.

The CVP was proposed as a solution to California's many-layered water problem, and it set California on a modernizing path. California engineers and politicians concentrated on the Central Valley where large-scale farming projects were planned. However, the Valley would routinely flood during the spring as water melted from snowcaps in the Sierra Nevada mountains, making it hazardous to grow and develop the region further. The project was initially proposed in the 1800s by private builders with the aim of controlling flooding and improving farming conditions in the Central Valley.(United States Congress House Committee on Interior and Insular Affairs 1956). After the passage of the Dam Supervision Act, the state and federal governments stepped in. The CVP was a system of interconnected dams and canals that could be used to capture the water melting from the mountains to prevent flooding and provide a consistent water supply during the summer and fall months. The project was initially funded in 1933 by the California state legislature. However, it was eventually undertaken as a public works project during the Great Depression, so it would be built and managed by the US Bureau of Reclamation. The project was started in October 1937 and major components completed by 1945 by the US Army Corps of Engineers and the US Bureau of Reclamation (US Bureau of Reclamation 2011)[23].

The CVP changed the flow of water across the state and the relationship between the economy and the "natural" world. California's climate is characterized as "Mediterranean" – it has mild but wet winters with dryer and warmer summer and fall seasons. Spring was a time for snowmelts and potential flooding, and summer could be quite arid – especially in the areas of the Central Valley and the Southern region. But the CVP altered the impact of these climate rhythms. The project made it possible to support a large agricultural sector in more arid regions of the Central Valley, but it would require a huge proportion of the surface water available across the state. Two-thirds of California became deeply reliant on the snow that falls in Northern California in the Sierra Nevada mountains. From the perspective of infrastructure studies, this is not surprising. Infrastructure is often researched as networks of technologies that remake relationships to the natural world, and certainly as projects of state building (Barnes 2014; Harvey and Knox 2015; Mukerji 2021). But more than changing relationships, the CVP set the

---

[23] Construction began October 1937 with the Contra Costa Canal, which is the main canal of the project. It was completed in 1948. Construction on Shasta dam (the keystone dam of the project) began in 1938 and was completed in 1945. The project continued to expand in the 1950s and 1960s, but the central components of the projects were completed by the end of the 1940s.

stage for drought to emerge as a very specific fact because dryness was so decoupled from an area's actual water resources and what constituted dryness changed dramatically.

The CVP set the stage for drought to be more than a regional experience. The CVP decoupled many economic sectors and communities from local water resources, which set the stage for drought to emerge as a statewide problem and be addressed as such. Wealthy landowners with primary water rights were able to access the stores provided by the CVP, stabilizing their agricultural production with irrigation systems fed by the project. Additionally, the CVP provided *more* water for consumption by preventing flooding, which created opportunity for further development without the worry of over drawing rivers – at that time. Physical and legal infrastructures came together to produce a state reliant on such projects first for growth, and eventually for stability and survival by 1960. Drought would not be regional – it would be statewide and entirely focused on Northern California.

The success of the CVP put infrastructure first when it came to solving water problems, including drought. In the 1960s, when *drought* specifically became a problem for the state to solve, it would turn once again to dams, canals, irrigators, pumps, and meters to make things right. In the next section, I will argue that the second large water project – the State Water Projects – is a hugely consequential material path dependency for understanding drought in the state.

Material path dependency: sprawling infrastructure

In this section, I argue that the State Water Project must be analyzed as a material path dependency because it was constructed as a solution to localized drought in Southern California. It is distinct from the CVP not just for when and who built it, but what problem it was trying to solve. The legal infrastructure of water rights and the physical infrastructure of the CVP created the possibility for the SWP to emerge and shape drought. The SWP was built on the same legal infrastructure, and it was also literally built out of the CVP – the two water projects share elements of their physical infrastructure in the Central Valley. In this section, I start by examining the context of the SWP's construction and how it was framed by California politicians and managers as a solution to drought as a problem. Then, I will compare the role of infrastructure in each of the declared drought periods. The comparison between the dry periods shows how the decisions during the 1960s led to specific understandings of drought that enable and constrain declarations and responses in these later dry periods.

Development of the State Water Project, 1960s

In the decades after WWII, Southern California's population grew from just under seven million to nearly sixteen million in 1960, increasing the demand on the region's water resources (U.S. Census Bureau 1961). The demand on water was felt both on local resources moved through the Owens Valley, mostly by the MWD, as well as resources brought in from Northern California and Colorado through the CVP. The CVP contributed to this population expansion by stabilizing access to some amount of water. However, the primary users of the CVP were always and continue to be agricultural producers in the Central Valley (Stern and Sheikh 2017). Southern California was never the first priority in water deliveries from that project. Southern California entered a dry period in 1947 that persisted through to the 1960s, while Northern California had "normal" water conditions (California Department of Water Resources 1961:viii). The dry conditions in Southern California and normal conditions in Northern California led to a reframing of California's water problem in the 1960s.

In the 1960s, the "water problem" shifted from its original inception in the late 19th and early 20th centuries. Rather than issues of reclamation and irrigation, it was now seen as a "mismatch" between where water existed and where it was needed (Beerman 1961; Berry 1961). The CVP went a very long way of solving the problems of reclamation and irrigation. With those problems solved to some extent, the water problem shifted. According to water managers, there was still water in Northern California that was not being captured, and it was not being effectively used. However, there were fewer local water resources in Southern California. With a fifteen-year dry period persistently leaving those stores short, the uncaptured water in the North was seen as a solution to Southern California's drought problem. To address this problem, state leaders proposed another infrastructure project: The State Water Projects.

The State Water Project was proposed as a solution to this "mismatch" between resource and population location. The SWP was developed during the 1950s as a plan to develop the state's water resources to meet the growing demands in large metropolitan areas like Los Angeles (Shelton 1959). The plan was based on an investigation of state water resources, and the project grew from project on the Feather River to a much larger project with a series of reservoirs and aqueducts that would bring water from Northern California down to the Central and Southern areas. The project was large and complicated, and its passage was difficult.

This framing for California's water problem and drought can be seen quite clearly in the speeches at the Governor's Dry Year Conference that took place on July 12 – 13, 1961. The framing of the mismatch problem required engineers and politicians to navigate tensions and conflicting interests among California's three major regions. As part of the campaign to support the infrastructure expansion, Governor Pat Brown held the Conference to highlight California's water concerns and frame the SWP as a solution (California Department of Water Resources

1961). One day of the conference was held in Los Angeles, and the second was held in Sacramento. The conference dates catered to two different audiences, but across both dates and sets of speakers, the message remained the same: "There is enough water in the state, but it doesn't fall where it is needed." The State Water Project was proposed as the solution – after all, large infrastructure had worked in the past, why not now? But it was not a simple matter to get a state water project approved.

Northern Californians were very resistant to sending more water to Southern California, and Central Valley users were concerned that new infrastructure would degrade or interrupt their own water stores (Nie 1998). Northern California voters were resistant to the new projects, disagreeing with one of the core ideas of the "mismatch framing" – *need*. Voters in Northern California certainly did not think that security for Southern California should come at the expense of their own access to water. The calls for generosity and a single California failed to mollify the voters in the North, but Governor Pat Brown was determined to see the State Water Project constructed. In part, he wanted to mitigate against future droughts in Southern California by moving "plentiful" water down to the south. But he also wanted to cement California's capacity for growth and prosperity, and he saw the passage of the state water project as central to that vision (Dowall and Whittington 2003; Pawel 2018; Sribnick 2008). The State Water Project was eventually approved by a 3%[24] margin in a 1961 referendum, held at the end of a second drought year (Hanak 2011; Nie 1998). There was only support from one Northern California county – Butte County where Oroville dam was planned.

The passage of the State Water Project changed what drought looked like in California in subsequent time periods by tying the entire state to Northern California's water conditions. As

---

[24] The Burns-Porter Act passed by a margin of 173,944 votes; 5,800,000 votes were counted (Nie 1998).

evidenced by this particular time period, it was still possible in the 1960s for Southern California to experience a drought separately from Northern California. The CVP was concerned with development in the Central Valley, so most of the water it conveyed went to agricultural users in the area. Southern California did not have access to the same amount of water from Northern California. The SWP changed this dramatically. The SWP connected the Southern region of the state much more fully to the Northern region. The result is that Northern California's water conditions became the *only* conditions that mattered. If the South was dry, but the North was normal – nothing would be amiss again. But if the North was dry, everywhere would suffer[25]. The SWP reshaped watersheds and the environment itself; with the completion of the SWP, drought conditions became truly statewide.

The following comparisons grapple with the consequences of this reconfiguration. When regional precipitation is no longer driving drought within that region, what does? The short answer is reservoir storage. Reservoirs that capture, conserve, and convey water across hundreds of miles became central indicators of when dry conditions tip into "drought". The increased storage capacity not only decouples place from water resources, but it also decouples water and time to a certain extent by creating a buffer against a single dry year.

In the following section, I will trace the role these infrastructure systems played during drought declarations. I will use two specific reservoirs – Oroville and Shasta – to help focus the exploration. These are appropriate locations to compare for two reasons. First, they are the two largest and most cited reservoirs when it comes to discussions of dryness. Second, they are

---

[25] In April of 1988, The Northern California coastal, Sacramento and Northern Lahontan (that encompasses portions of the Cascade Range and the Sierra Nevada) received 75%, 65%, and 55% of their seasonal precipitation respectively. However, Southern Coastal and Southern interior portions fed by the Colorado River were at 90% and 180% respectively (California Cooperative Snow Survey 1988). This was the month when a drought was officially declared. The conditions of Northern California and to some extent the Central region of San Joaquin are driving the definition of a drought.

connected to different infrastructure projects. Oroville is run by the California Department of Water Resources (DWR), and Shasta is run by the United States Bureau of Reclamation (USBR). This allows me to give weight to the importance of each water project for California's water supply. As the two largest reservoirs, they are relied on by multiple stakeholders and offer a window into how legal and physical infrastructures interact on the ground. Finally, these reservoirs are in the same hydrological region/basin. They are both located in Sacramento River Basin in the Sacramento Valley, although they are fed by different rivers.

I rely on a variety of archival sources for the comparison between time periods. The most important are published government reports, mostly from the Department of Water Resources (DWR); materials from the California State Archives, such as meeting minutes and correspondence between actors; and numerous newspaper publications documenting the lead up to droughts. In each period, I begin with a snapshot of the reservoir levels at the beginning, middle, and end of the drought period to illustrate how reservoir levels articulate dryness. Then, I outline the responses to the droughts as articulated by reservoir levels, examining how the infrastructure works to shape drought across time periods.

Changes over time: Comparing four historical droughts

The Big Test, 1976 – 1977

The 1976 – 1977 drought was the first real test of the massive infrastructure projects, and reservoir levels were a driving concern in defining drought. In the first dry year of 1976, the infrastructure projects worked as the politicians and engineers hoped – the reservoir storage helped minimize negative impacts for the first dry year[26]. In February 1976, the statewide reservoir storage levels were 95% of average (California Cooperative Snow Survey 1976:5)[27]. However, the following year would also be extremely dry, leaving reservoirs at 60% of average storage by February 1977 (California Cooperative Snow Survey 1977:5). By the fall of 1977, the storage levels had fallen to 37% of average (Santos and Godwin 1978:10). This was a low point – the reservoir storage levels would never reach such a low point so quickly again. These low storage levels were deeply concerning to engineers and stakeholders who needed to determine mitigation strategies and emergency responses.

The "downstream" impacts of these low levels of reservoir storage were reduced water deliveries, and they shaped the experiences of drought. Both water projects make estimations in the winter regarding how much water will be delivered to their contractors based on available stores. The ability to deliver water at times of the year when water would typically be scarce is striking in and of itself. During drought years, these allocations fall dramatically in proportion with the drop in water supplies and restrictions about water that must be used to protect the environment and primary water users. The amount of water a user could claim was tied to their water rights. So, when there is far less water being captured and stored, there is less water to be conveyed to downstream users. Downstream users that exist because infrastructure makes it possible. By January of 1977, water deliveries from the SWP were cut by 10% for residential users and 60% for agricultural users (Santos and Godwin 1978:39). CVP deliveries were cut by

---

[26] The areas most impacted were ranchers, orchard growers, and winter recreation (McCullough and Peters 1976). Ranchers cannot rely on irrigation to grow feed; orchards require greater amounts of irrigated water; and winter recreation like skiing cannot be bolstered by water deliveries.

[27] In water condition reports, government bodies and nongovernment bodies typically report any metric in "percent of average" for a given month. In the case of this figure from February 1976, this does not mean that reservoirs are "90% full" it means that there is 90% of the amount of water expected to be stored in this reservoir by February in a typical year. Storage is sometimes represented in percent capacity, but percent of average is far more frequent because it denotes the "natural" rise and fall of storage levels over the course of a year. A reservoir may only have 30% of its capacity in the fall, but that might be 100% of average for that year.

50% for municipal and industrial users and 25 – 75% for agricultural users, depending on the kind of water rights contractors claimed (41). The water conditions of the state were so poor that mitigation strategies not seen in any other drought were undertaken.

By Executive Order, the Governor formed the Drought Emergency Task Force in order to coordinate communications and directives between state, federal, and local governments. The Executive Order was signed by Jerry Brown Jr. on March 4, 1977, and it required a number of state and federal government agencies to send representatives to serve on the task force (Brown, Jr. 1977). The order designated Major General Frank J. Schober as the Director – referred to as "the General" throughout the life of the task force. Alex Cunningham, a manager from the Department of Water Resources, was appointed as the task force's Deputy Director (Governor's Drought Emergency Task Force 1977). Eighteen departments and agencies were required to send representatives, and another twenty-three were invited to send representatives if they desired. The departments and agencies varied in their scope and focus with some expected (the Department of Water Resources) and others perhaps less so (Regents of the University of California). Over the next calendar year, a varying number of representatives met monthly to coordinate a response plan to the drought emergency.

The formation of the Drought Emergency Task Force (DETF) was the first time California formed a coordinated body to mitigate a drought emergency. It would serve as a template moving forward, although some elements of this task force would remain unique to 1976 – 1977. It was the first – and last – time conditions were poor enough that it required spearheading by the National Guard and military. In the future, state agency leaders would take the position of Director. The response did create its own kind of path dependency, setting expectations for coordinated and meaningful state response in future drought situations. The response would never be created by executive order again because it quickly became just the way that it was done. The executive order and formation of the DETF was another example of state power over water issues in California and a further concretizing of the state as the central body for responding to and mitigating drought conditions. The DETF was responsible for devising plans to mitigate drought but left it up to various governing bodies at the state and local level to carry them out (Drought Emergency Task Force 1977). These plans can be divided into "urban" and "agricultural" responses[28].

Urban water users were encouraged to reduce consumption in their homes and businesses for the duration of the drought. One of the most stringent mitigation strategies undertaken were blanket mandatory conservation orders across the state. For residents and communities connected to the major projects, this meant cutting back on water use a minimum of 20% (Staats 1977:53–57). This was enforced through a combination of public pressure and fees. To create public pressure, the DWR developed a massive public awareness campaign encouraging the conservation efforts to use less water (Governor's Drought Emergency Task Force 1977). The campaign seemed to work to some extent with statewide savings reaching 13%[29] by summer of 1977. To leverage fees, whichever body provided water to a neighborhood or community, increased water rates and included painful monetary penalties when a water user did not meet the conservation goal. Generally, this two-prong strategy for conservation worked. In some districts, water users reduced water usage by more than 50% (Staats 1977), and statewide the average was above 20% by the end of the drought.

---

[28] According to DWR reports, urban water users account for approximately 15% of water use in the state, and agricultural users account for approximately 85% of water use. The precise numbers fluctuate minutely from year to year, but these proportions are regularly cited in multiple reports.

[29] The savings were uneven. According to the June 7, (1977), meeting minutes of the DETF, the savings could be broken down as follows: 6% in the Northern most regions of the states, 20% in the Northern portion of the Central Valley, 13% in the Southern portion of the Central Valley, and only 5% in Southern California.

For farmers, it was less about short showers and more about taking a season off. Agricultural users were encouraged to find ways to avoid using as much water as possible – conserving even the water they could get through their contracts with the SWP and CVP. Many made use of US federal grant programs or state relief through the DWR, and they fallowed their growing fields for a season (California Department of Food and Agriculture 1976; Santos and Godwin 1978:50–56). Many farmers still planted seasonal crops, so skipping one year was a loss but not a one so devastating that recovery was impossible. Ranchers had fewer choices. Many California ranchers chose to sell off large numbers of their cattle, keeping only what was necessary to hope for a rebuilding year. This was also shaped by the SWP. Farmers could irrigate fields with water deliveries or choose to sell that water back while leaving their fields empty. Ranchers could not irrigate grazing lands for cattle and needed to purchase feed to avoid losing their herds. The SWP made it possible for some stakeholders - like farmers - to experience a very different emergency than others who were disconnected from the project, altering the distribution of pain during a drought. The communities who were *unconnected* to the major infrastructure projects suffered the most.

Smaller communities throughout California experienced some of the hardest impacts during the drought because they were not connected to major water projects. It would be impossible to connect every town in the state to the SWP or the CVP. It would not be practical, and it would also violate water rights in some cases. Many of the smaller communities still relied on local water sources, meaning smaller reservoirs or groundwater wells (Santos 1977). These communities had no buffer against the single critical year; they could not rely on the larger infrastructure projects to cushion them like other water users. The water conditions in some of these communities were so dire by 1977 that the National Guard was called in to transport trucks of water into the communities to alleviate the drought conditions (Governor's Drought Emergency Task Force 1977). Dozens of water trucks were called in from across the Western states to drive water into these disconnected communities. While everyone in the state was experiencing a lack of water in comparison to other years, the shape and intensity of that deprivation was certainly influenced by the connection or lack of to the SWP.

This first test of major infrastructures and their ability to mitigate drought conditions led to a particular understanding of drought. First, the SWP was built on the assumption that Northern California would always have a certain amount of water, and there was enough water in the state to support its growth and development. This drought demonstrated the limitations of the assumption and the consequences of a statewide water system. Northern California experienced two record-setting dry years back-to-back, and it resulted in the first wide-spread drought since the 1930s. The lack of water was felt across the state, so the SWP and the CVP were not able to deliver on promises that there was enough capacity built to mitigate dry seasons. However, it was clear that these projects had not outright failed. Many towns, business, farms, and ranches were able to get through what would have otherwise been a disastrous two years. The emergency measures taken to alleviate the suffering in non-connected communities is also evidence of that.

The decision to build the SWP to address drought shaped how this drought was experienced across the state. The SWP was built to resolve the "mismatch" between water location and water need, on the premise that there was enough water to meet all needs in the state. The drought of 1976 – 1977 showed that it was far more complicated than that. The projects changed California's water landscape, so drought became statewide rather than local. However, the SWP was lauded for mitigating outright disaster and providing enough water stores for the economy to make it through to 1978 mostly intact. The low levels of reservoir storage that characterized this drought shaped definitions of drought for managers, stakeholders, and citizens alike. Additionally, the responses to drought like cutting water deliveries and emphasizing individual mitigation strategies would persist into future declarations. These strategies focused on conserving water in reservoirs for as long as possible. If the infrastructure project could not fulfill its promise and deliver water, then people began to entertain the idea that a drought might be occurring. This shapes the character of the much longer drought that stretched from 1987 – 1993.

The Marathon, 1987 – 1993

The 1987 – 1993 drought would be a test of endurance for the SWP, where 1976 – 1977 was a test of intensity. On September 30, 1987, the storage levels in Oroville and Shasta were 81% and 70% respectively (California Cooperative Snow Surveys 1987). By April 1988, the month of the drought declaration - the storage levels in Oroville and Shasta were 85% and 78% of average respectively (California Cooperative Snow Surveys 1988). The increase was due to a "normal" rainy season of December through February, which added to the storage available, but was not enough to pull the state water supplies out of a "dry" status. As the drought went on, the levels dwindled. At the end of the 1992 water year – the sixth consecutive drought year – reservoir storage was 55% and 57% of average (California Cooperative Snow Survey 1992). The storage levels never reached the low points of the 1976 – 1977 drought in part because water managers were wary of releasing too much water in the first few dry years. Still, the stores were well below average, which meant impacts for downstream users that are very similar to the patterns established in 1976 – 1977.

The low levels of reservoir storage led to reduced water deliveries to downstream users, and the duration led to an increased reliance on groundwater. These consistently lowering levels translated into very, very low water deliveries for SWP, with some agricultural users and urban water districts receiving 0% of the water allocated to them from the water project (Priest et al. 1993:31, 35). Deep reductions during the 1987 – 1993 drought led to increased drilling and use of groundwater to make ends meet for farmers and other stakeholders (Butterfield 1991:4–6). Groundwater continued to be extremely difficult to measure, so it was also extremely difficult to manage and regulate.

The riparian water rights ensured access to these large stores, even as aquifers were over pumped, and the water table was reduced by up to 100 feet in the Central Valley. Some portions of the San Joaquin Valley sank by up to eight feet, in a phenomenon known as "land subsistence" – when changes underground lead to changes in land surface elevation (Jones 2000:8–9). The structure of water rights in California interacted with the physical infrastructure to shape drought across the state. Water users with riparian rights had more flexible water access than others who did not, changing the strategies of mitigation depending on what a water user could access. For some landowners in the Central Valley, they could rely on groundwater because it was still out of reach for the state (Butterfield 1991:12–14). This too shapes definitions of drought by emphasizing surface water and deemphasizing groundwater. Drought occurs when water managed by the state or federal government and is stored in canals cannot be delivered.

Here, infrastructure was put to a different kind of test. Rather than two excruciatingly dry years[30], the infrastructure buckled under a prolonged drought, revealing the limits of the "two

---

[30] 1976 and 1977 maintained the record for driest years until 2020.

years" worth of water storage created by the state. However, these limits served to further concretize one important definition of drought. Because of the infrastructure, drought came to be defined as a two-year period of dryness (Jones 2000:14; Jones and Nguyen 2010:7) State engineers and scientists do not specify a timeframe that constitute a drought. Instead, drought is informally defined as the second consecutive dry year when water storage in reservoirs begins to run low. And that definition is derived from the mitigation capacity built by the SWP and the CVP. Through the end of the 1976 – 1977 drought, increased storage capacity was often seen as a solution. But during the 1987 – 1993 drought, that was no longer the case.

Changes to California's context challenged the status of infrastructure as the favorite solution to water problems. A booming environmentalist movement and reduced investment in public projects came together to defeat large scale infrastructure projects proposed as solutions to the lack of water in California. The Peripheral Canal is a strong example of this. Originally proposed in the 1940s, a version of it was sponsored by Governor Brown Jr. in 1978 (Anthrop 1982; Carle 2004; Gwynn, Thompson, and L'Ecluse 1983). The Peripheral Canal was a plan to build underground canals that would divert water around the Sacramento-San Joaquin Delta to deliver more water to Central and Southern California with the hope of reducing disruption to the ecosystem of the Delta. However, unlike in 1960 when his father was able to pull together support for the SWP, the Peripheral canal did not garner the same support. It was defeated in 1982 at the ballot box, and infrastructure projects fell mostly out of favor as a solution to drought after this as concerns over water quality and protecting the Delta took priority.

The SWP continued to shape definitions of drought, and decisions made in the 1970s persisted into the next dry period. Again, the refrain that there is enough water to go around was proven false, and the limits of infrastructure as a solution to regular dry periods and droughts becomes clearer. With this six-year drought, the two-year limits of these massive infrastructural projects are put on display, but their capacity still went a long way in shaping definitions of drought even as pushback against infrastructure became more prominent. Drought is focused on the surface water that is captured and stored in these infrastructures, and lowered deliveries signal an impending declaration. The loss of interest in new infrastructure projects signals an era of interesting new tensions, many focused on the negative outcomes of the projects themselves. These tensions indicate the limits of infrastructure, but they also demonstrate just how strong they are in shaping definitions.

The Political, 2007 – 2009

The drought declaration of 2007 – 2009 departed from previous patterns for how quickly the drought was declared in relation to reservoir storage. In the year preceding the drought declaration in April 2008, the storage levels in Oroville and Shasta dropped from 113% to 61% of average and 107% to 80% of average respectively (California Cooperative Snow Survey 2007, 2008). In contrast with the preceding droughts, this was a not a spectacularly low number, although it was certainly concerning for water managers. The numbers would continue to dwindle until September 2009, when the levels for Oroville and Shasta were 59% and 63% of average respectively (California Department of Water Resources 2010). Reservoir storage never hit the lowest points that they did in the 1976 – 1977 and 1987 – 1993 droughts. This is of course partially due to the differences in intensity (two record-setting critical years versus three mixed critical or dry years) and difference in duration (six years versus three years). However, for the first time, the reservoir storage levels were not a driving force for a declaration. Instead, managers weighed the needs of human and nonhuman water users against how much reservoir storage there *would be* in the coming months.

During this drought, snowpack is framed as the central concern in relation to future reservoir storage, rather than the storage itself. Snowpack was always a core component of water management. It was included in the drought reports all the way back in 1930 when regular and formalized measurements began (California Department of Public Works 1930). The difference between this drought and the two previous droughts is how snowpack was discussed as a harbinger of trouble to come. In 2007 – 2009, the Sierra Nevada snowpack drove discussions of drought. The snowpack in April of 2007 was about 39% of average (California Cooperative Snow Survey 2007). Snowpack levels predict how much water will flow into reservoirs over the warmer spring and summer, and this measurement indicated that the water already in the reservoirs would be most of water available for the rest of the summer. Snowpack would improve in 2008, but it would not be enough to compensate for the dry 2007 that preceded it (California Cooperative Snow Survey 2008). The explicit treatment of snowpack as part of this material infrastructure is very clear in this drought. Rather than the man-made reservoirs being central to the declaration, it was the "natural" reservoir in the Sierra Nevada mountains that was worrying due to the low reservoir storage it signaled[31]. The concern over snowpack as "future reservoir storage" was partly driven by tension over where the water would be sent and how it would be used.

---

[31] The phenomenon of low snowpack with average reservoir storage and how it interacts with climate change is now referred to as a "snow drought". Snow drought occurs when precipitation only comes early in the water year or when snow accumulation is slow during regular precipitation years (Harpold, Dettinger, and Rajagopal 2017). Climate science predicts that increased frequency of snow drought could be one impact of climate change (Harpold et al. 2012; Hatchett and McEvoy 2017; Pierce and Cayan 2013).

The politics of the intertwined legal and physical infrastructures were put on display in the 2008 drought declaration. By the 2007 – 2009 drought, the SWP was not capable of delivering all of the water in its contracts even under normal circumstances. More water has been allocated out than actually exists in the state, a phenomenon called "paper water" (Carle 2004). The overcommitment was exacerbated by the dry conditions in 2007 and 2008 in a way that was very distinct from the two previous droughts. By the 21st century, the SWP supports millions of residents in Southern California and the Bay Area[32]. Water was a scarcer resource, so many new communities could only secure secondary water rights. In above normal or wet years, this was not a typically problem. During dryer years, these communities were the first to have their allocations cut, their rights being considered "paper water" rather than real-world "wet" water. Additionally, human uses were no longer the only primary consideration. So, secondary water rights were also truncated by increased environmental regulation over the last thirty years (California Department of Water Resources 2008).

In 2007 and 2008 water delivery cuts were announced like in all previous droughts, but they were met with greater overt hostility. In 2007, the SWP estimated deliveries at 60%, and the CVP project estimated deliveries between 100% and 50% depending on the rights of the contract holder (California Cooperative Snow Survey 2007). By 2008, at the time of the drought declaration these numbers had fallen to 35% for SWP contractors and 75% to 45% for CVP contractors (California Cooperative Snow Survey 2008). In relation to previous droughts, these allocations were higher. The reductions would certainly lead to mitigation strategies for water users, but it was not as severe as in previous droughts. However, these reductions were met with

---

[32] California's population continued to grow from 1980 until 2008, increasing by 12.25 million people (U.S. Census Bureau 1982, 2010). As more people moved into the state, new buildings and communities needed to acquire water. However, with new water saving technologies, the increase in population is not proportionate to the increase in water needed.

greater hostility by the water contractors due to shifts in environmental regulations and water management practices.

Over the last 25 years, California water management practices had changed to accommodate environmental protections. The infrastructures had worn away at the environmental integrity of the Sacramento-San Joaquin Bay Delta, resulting in degradation and decrease in water quality (State Water Resources Control Board 1978). To protect ecosystems and species new regulation had been put in place that increased the amount of water allocated for environmental protections, which meant less water for secondary water rights users during dry years. Beginning in 1986[33], the SWRCB began placing greater emphasis on improving water quality and protecting the delicate ecosystem in the Sacrament-San Joaquin Delta (Brandt 1987). This region is considered the "heart" of California's water system. The Bay-Delta is where crucial pieces of the SWP and the CVP are located. In fact, the canals and pumps that convey water from Oroville and Shasta are located in this region (Figure 3.1). The built infrastructure created water flow disruptions that needed to be reversed, which meant leaving more water in the Bay-Delta during dry years to prevent further degradation of water quality and the ecosystem. These environmental regulations were reinforced and upheld in various court decisions at both the state and federal levels (State Water Resources Control Board 1988; Trott 2006). The expanded population and environmental protections interacted to produce water precarity for certain regions in 2008, which facilitated a drought declaration. The water districts represented by the State Water Contractors provides an illuminating example of how it all played out.

---

[33] United States vs. California State Water Resources Control Board will be discussed in more detail in the next chapter.

Major rivers and facilities

Figure 3.1: Map of Central Valley and State Water Projects (California Department of Water Resources 2015:3)

In the 1980s, contractors with the SWP formed an interest group to advocate for their rights and interests. The organization is the State Water Contractors (SWC), and the lack of access to water during 2008 shows how the legal infrastructures intersected with the physical infrastructures to produce a more politicized drought (California Department of Water Resources 2022; State Water Contractors 2022). The SWC is an organization comprised of 27 public water agencies[34] that contract with the SWP. The SWC was founded in 1982, and it "represents the legal, policy and regulatory interests" of their members. When the DWR reported the critically low snowpack measurements in 2007 and 2008, the SWP announced cuts in water allocations to districts across the state. The cuts were necessary to meet the demands of primary water rights holders and the environmental regulations put in place. But the members of SWC were vocal that the environmental regulations were too stringent, and that they manufactured drought conditions.

The water managers affiliated with SWC were vocal about the regulations' negative impact on their members and the communities they served. The Sacramento Bee and other state papers covered the tensions throughout 2007 and 2008. When discussing slightly improved snowpack numbers in 2008, managers did not mince words: "'That water's not going to be available to us,' said Laura King-Moon, assistant general manager of the State Water Contractors… 'We have an artificial drought this year because of the regulatory restrictions on pumping'" (Weiser 2008:B1). This water manager is articulating a different notion of drought – one that is "artificial" or manmade due to environmental regulations. The water exists within the State Water Project, but it is not available to the managers who want to send it to farmers and residential communities.

---

[34] The following agencies are members of the State Water Contractors: Alameda County Flood Control District Zone 7; Alameda County Water District; Antelope Valley – East Kern Water Agency; Central Coast Water Authority; Coachella Valley Water District; Crestline – Lake Arrowhead Water Agency; Desert Water Agency; Dudley Ridge Water District; Empire West Side Irrigation District; Kern County Water Agency; Kings County; Littlerock Creek Irrigation District; Metropolitan Water District of Southern California; Mojave Water Agency; Napa County Flood Control and Water Conservation District; Oak Flat Water District; Palmdale Water District; San Bernardino Valley Municipal Water District; San Gabriel Valley Municipal Water District; San Gorgonio Pass Water Agency; San Luis Obispo County Flood Control and Water Conservation District; Santa Clara Valley Water District; Solano County Water Agency; Tulare Lake Basin Water Storage District; Ventura County Watershed Protection District; Yuba City

The tension in the Bay-Delta between water contractors and environmentalists is painfully clear. The competing commitments of water managers and environmentalists are heightened as water stores become scarcer. One editorial said the following about a possible drought declaration: “Farmers would complain about a ‘regulatory’ drought, meaning that the Endangered Species Act is forcing too much river water to flow into the ocean. The environmentalists would complain about a ‘paper’ drought, meaning that there is ample water in the system (most reservoirs began the year quite full, thanks to last year's rains), but that the system is overcommitted” (Editorial 2007:B6). The quote lays out the interests and commitments of water managers and farmers against those of environmentalists. The 2007 – 2009 drought is something different than the previous two droughts. In the past, interest groups and stakeholders generally agreed that water supplies were too scarce. But in 2007 – 2009, the drought was “political”.

It is tempting to attribute the dry conditions to regulatory changes and environmental activism. However, I argue the drought was shaped by the material path dependencies formed by the State Water Project in two ways. First, the environmental degradation is the direct result of the SWP’s construction and consistent use. The SWP made it possible to pump more water out of the Delta during dry periods, which accelerated salinity intrusion and deteriorating environmental conditions in the region. These were the conditions that environmental regulations were developed to address. Additionally, the communities that the State Water Contractors support only exist because the SWP does. The SWP made it possible for more communities to build and grow because of the deliveries it made possible. The SWP shaped the ongoing drought by creating the need for stronger environmental regulations as a result of over-pumping, and the SWP also led to the existence of communities that are not able to receive water deliveries. The drought conditions seen in 2007 - 2009 are in large part built on the SWP.

Infrastructure reemerged as a solution to drought, which is a break in the previous 20 – 30 years of governing. Schwarzenegger's plan was certainly a departure from previous Republican Governors. Infrastructure in general had fallen out of favor with voters and politicians. First, as discussed in the previous paragraph, infrastructure had taken a toll on California's ecosystem, and new laws had been put in place. Both of these changes worked together to make building new infrastructure more difficult and required far more environmental considerations than in the 1940s and 1960s when the CVP and the SWP were built. Additionally, large government spending fell out of favor in the 1980s across the United States, and California was no exception (Berry 2014; Birch and Siemiatycki 2016; Fieldman 2011). Neoliberal policies reduced investment in public infrastructure, which meant less interest in spending millions of dollars on water infrastructure as well. However, even in this context, Governor Schwarzenegger saw new infrastructure as the solution to the problem (Governor's Office 2008). In theory, it would provide more storage capacity, and it would update the now-aging infrastructure built in the previous century. He proposed and supported a new version of the Peripheral Canal project that was defeated in 1982. The proposal in 2008 was met with mixed reactions from various corners of California's political and managerial spheres.

Pushback on the plan to increase infrastructure came from two different groups: environmentalists and water scientists. Environmental organizations questioned the sustainability of more infrastructure, especially more in the Bay-Delta region. Instead, environmental groups pushed for alternate solutions like increased water conservation in households, updates to irrigation equipment, and desalination plants (Schultz 2007; Vogel 2007;

Zito 2008). A variety of groups also questioned the usefulness of more infrastructure, but for different reasons. Voters and other experts were not convinced that there were any good locations remaining for more infrastructure projects or much water to capture (Escriva-Bou, Mount, and Jezdimirovic 2019; Skelton 2019). Ideal reservoir sites are located on rivers, where water can be impounded into a man-made lake without the need to pump or move water against gravity, and the locations where that was most easily done had already been used during the building of the CVP and the SWP. The remaining sites would be far more expensive, and they would capture far less water, making them inefficient for the purposes of creating more water storage. Additionally, scientists were not convinced that there was any more water to capture. The current infrastructure was already storing and delivering over 13 million acre-feet of water on a yearly basis. It was only in very wet years that water went uncaptured and perceived as wasted. For all of these reasons, increased infrastructure was not taken up as a response to the 2007-2009 drought.

The stickiness of infrastructure is put on display during this drought through the increased tensions between human need for water and environmental protections. We can see that infrastructure and water storage are still central to the definitions of drought, but water rights have gone beyond the reality of water resources. The SWP also needed to serve an additional purpose. The physical infrastructure of the SWP still stores water, but it no longer stores water just for flood control and irrigation. It stores water to protect habitats and animal species as well[35]. The SWP must also work to mitigate its own negative consequences by acting as a buffer for further environmental degradation. The material path dependencies result in a contradiction of uses and tensions throughout the state.

---

[35] We will see more in Chapter 5 how the networks of actors (human and nonhuman) shape definitions of drought.

However, we can see that the ideas and decisions from 1960 are still operating in 2007 – 2009 both in terms of interests of water districts *and* the definitions of drought. Drought continues to be a two-year dry period where infrastructure is not capable of delivering water to the various districts that contract with the project. Now, they are bumping up against changing priorities, a degrading landscape, and a shifting climate, but the infrastructure that allowed for population growth and economic prosperity hold practices in place. The economic sectors and cities that were built with the expectation of reliable access to water are not going anywhere in response to the new environmental constraints. The canals, dams, and pumps of the SWP are still there. These tensions between the material path dependencies of infrastructure and the world it was built to modify become clearer and more pressing in the next drought declaration.

The Perennial, 2012 – 2016

The 2012 – 2016 drought resulted in questions about the very hydrology that the SWP was founded on. At the end of the 2013 water year, the storage levels for Oroville and Shasta were at 75% and 70% of average respectfully[36], after a dry and critical year (California Department of Water Resources 2013). Midway through the next wet season when no relief was in sight, Governor Jerry Brown Jr. declared his second statewide drought (Governor's Office 2014). 2014 and 2015 would be critically dry years, and by September 2015 storage in Oroville and Shasta had reached 48% and 59% respectively (California Department of Conservation 2015). These are the lowest levels these bellwether reservoirs reached since the end of the 6-year drought in 1992. The 2016 water year saw small improvements over critical conditions,

---

[36] Percent of average is the more meaningful measurement for reservoir storage when comparing different points of time. The percent of average incorporates the seasonal rise and fall of reservoir storage across the months as water flows into reservoirs as snowmelt, then leaves the reservoirs as water deliveries during the summer and fall.

but it took a massive storm in winter of 2017 to end the drought (California Department of Water Resources 2017). This drought was very dry, and it came after only a couple of years of normal conditions. Infrastructure again played a central role in carrying the state through the dry period without total collapse, but the assumptions the CVP and SWP were built on were thrown into question by this five-year drought.

The dry conditions of this drought were severe and resulted in some of the most intense water delivery cuts in both the SWP and the CVP's history. In 2013, the SWP announced 35% allocations, and the CVP announced between 100% and 20% to users in the north and south of the Delta (Jones 2021:49). In 2015, these allocations would drop 20% for the SWP, and 0% for all CVP agricultural contractors and 25% for urban. It was the first drought in the CVP's nearly 100-year history where 0% water allocations were announced (i). The conditions were so critically dry that it was impossible for the SWP or the CVP to operate at a basic level while also maintaining the environmental standards developed to protect the Bay-Delta. These allocations were some of the most severe in the state's history, more similar to the 1970s than other droughts. As such, some responses were similar. Conservation for urban users was either mandated or encouraged depending on their water district. However, the agricultural sector could not rely on the same repertoire of responses as in the 1970s drought.

California agriculture moved away from seasonal crops and on to perennial crops. The shift was made possible by the SWP and CVP, and these new crops constrained mitigation strategies for dry seasons. Between 1977 and 2007, the number of acres of cropland dedicated to water-intensive crops like fruit and nuts in California steadily increased until it accounted for the most acres of cropland (Alston, Lapsley, and Sambucci 2020; Goodhue, Martin, and Simon 2020). This trend began as far back as 1888, and others have grappled with the causes elsewhere

(Olmstead and Rhode 2017). I am concerned with the consequences for shaping drought. In previous droughts, farmers could choose to not plant seasonal crops, reducing the amount of water their farms required. However, the dominance of intensive crops meant this was no longer an option. A farmer cannot simply not water orange or almond trees – it would lead to a multi-year devastating loss. The reliable water delivers from the CVP and the SWP led to a lack of flexibility in the agricultural sector. To address this need, an emergency working group was pulled together.

The Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) (the bodies that operate the two water projects) requested that water quality standards be suspended in 2015 (Jones 2021:17–18). The bodies argue that the water quality standards set in Water Quality Decision 1641 in 1999 were made without the dire conditions of 2014 and 2015 in mind. The dry conditions put on display the multiple competing interests for water in California (agriculture, salinity intrusion, salmon health, urban health, and other environmental protections for endangered species). In the end, the SWRCB decided to ease up on some standards but not others. A nearly real-time team gathered for weekly meetings to ensure that multiple, competing needs were balanced as best as could be managed given the dry water conditions. During this drought, scientists, managers, and water users grappled with the possibility of a new normal for California's hydrology due to climate change; one that could mean increased numbers of dry years and a disruption to the SWP's operation.

Climate change threatened to alter California's hydrology and disrupt the underlying assumptions of the SWP. California's hydrology was shifting in crucial ways. Today, more water falls on the state as rain than as snow, which undercuts the entire water system (Miller, Bashford, and Strem 2003; Vicuna and Dracup 2007). The SWP and the CVP were built based on observations form the late 1800s and early 1900s. They were constructed to work with the water flows engineers and meteorologists observed during those decades. The central component of this system was that about 15 million acre-feet of water fell as snow in the Sierra Nevada mountains during a typical year. The snowpack acted as the largest reservoir in the state, storing millions of acre-feet through the winter, which would melt and flow into the built reservoirs during the spring and summer. Precipitation falling as rain upended the assumptions built into the system. Now, water would fall faster in the winter and flow into reservoirs quickly rather than slowly over a longer period of time. Risks of flooding increased, and the reliable snowmelt is lower than it was in decades past. These changes will undermine the very assumptions that the infrastructure was built on.

The 2012 – 2016 drought was the first drought where long-term questions were asked about California's hydrology and how it may change in the coming decades. The decade of 2007 – 2017 was predominantly dry (Jones 2020:i). Only two out of the eight years were above normal or wet. If the new baseline for water in California becomes dryer, then California's water users will consistently be operating on a water deficit. The ways that the SWP shapes definitions of drought become will more obvious because the SWP will not be able to function the same way it did in previous decades. Treating snowpack like a reservoir – an extension of the SWP and the CVP – is limited as climate change alters the snowpack itself. The SWP cannot mitigate climate change the way it can mitigate two years of dryness.

The SWP and its storage capacity are still shaping definitions of drought. In fact, the SWP is not only shaping what constitutes drought, but it is shaping ideas of how climate change is going to impact California as a state. In the 1960s and 1970s, drought was seen as a "mismatch" or two critical dry years – both problems that the SWP was built to address. This definition is still clearly functioning in 2012 – 2016 in shaping understandings of what constitutes a drought. This represents a deep continuity of drought over the last 60 years, even as California itself underwent radical changes to its population and hydrology. Yet, the SWP is still central to how managers, stakeholders, and others understand drought. We have yet to see how these radical changes and deep continuity play out in the coming decades.

Conclusion

In this chapter, I examined the physical and legal infrastructure of California. I used reiterated fact making to trace the changes and continuities across the four different declared droughts and the role infrastructure played in their characterization. Water rights shaped the construction of physical infrastructures by dictating a hierarchy of water access and providing state control over a majority of surface water. Together, water rights and infrastructure reconfigured the relationship between place, water, and use. Over time, drought definitions of drought are tied to material infrastructure. I do this by examining how California's water rights system and the Central Valley Project operate as important conditions of possibility for drought to emerge as a statewide condition. I also show how the material path dependencies built in by the SWP in the 1960s persist over time, shaping how infrastructure projects produce drought as a scientific fact and environmental problem.

For drought to emerge as a lack of water for productive purposes in California, certain relationships had to be enacted through water rights. Drought is always determined to be a lack of water due to dry conditions, but who experiences those dry conditions and whose experiences matter are mediated by the legal infrastructure in California. California's water rights are not equal. Cities and landowners with primary water rights are guaranteed deeper and more sustained access to water even during dry years. Other communities with secondary water rights are much more vulnerable to dry seasons. We know from work from at the intersection of sociology and the law that legal systems not only reflect values but are important for reproducing them (López 1996). With reiterated fact making, we can show how water law enshrines and reproduces certain inequalities, and how those laws make it possible for a specific experience of drought to emerge.

The presence of physical infrastructure is also critical for the emergence of drought as a fact statewide. The development of the CVP in the 1930s to control flood waters and make Central California agriculturally productive was hugely influential in drought's configuration. The development of the CVP stabilized water access across seasons and reduced flood risks in the Central Valley region. The reduced risk meant a strong agricultural sector and infrastructure for the southern urban regions to build off of, allowing for population growth. The Central Valley project functions as a condition of possibility by growing the economic sectors and populated areas for drought to impact. Without the CVP, dry seasons would not have been shaped in the same way. It set the precedent that watersheds could be reworked to the benefit of the economy and the ever-growing state, upending relationships between geography and resources in a striking way. The CVP made it possible for infrastructure to be seen as a solution for drought specifically.

Material path dependencies in California are many, but few as consequential as the construction of the State Water Project in the 1960s. The water project was proposed in response to the long-endured drought in Southern California. The more arid region was the most populated in the state, and water was seen as plentiful in the Northern area. The water project was built to solve the "mismatch" between water need and water availability across the state. A reiterated fact making approach reveals how the development of the SWP constrained future decisions. Water stored behind dams and in The Sierra Nevada's snowpack became central to the definition of drought not just in the 1960s but over the next half century. In all four drought declarations, the storage levels of the SWP (and CVP) are integral to drought conditions and responses.

Infrastructure shapes drought by creating material path dependencies that characterize each declaration. The SWP was built to eliminate drought, so drought exists when the SWP (and the CVP) cannot supply adequate water to water rights holders. The projects restructure water flows across the state, making it possible for a lack of water in Redding, California to impact Los Angeles, California over five hundred miles away. Across every declaration, the disfunction of the water projects is exactly what defines drought and shapes mitigation strategies. The persistence is strong, and the comparison across time periods shows how infrastructure shapes declarations. The comparison also shows how unintended outcomes of infrastructure like environmental degradation can also shape drought declarations. The material path dependencies shape what drought *is* by constituting the relationships between water and people and plants and cattle.

By using reiterated fact-making to understand drought, we are able to see points of interaction between nature and society in a new light and understand the emergence of drought as a fact in a different way. This approach verifies previous research on how infrastructures shape drought (Carse 2017; Kaika 2003), emphasizing how the reordering of relationships can change the environmental problem in itself. However, it also reveals possible limits to these pathways. As California's climate warms and hydrological patterns shift, the constraints of infrastructure will only become more obvious and perhaps more contentious. We are in some ways locked into the reservoirs, canals, and pumps because most of California was built on those very same structures. Reiterated fact making helps us make sense of what those conditions are and how those constraints play out over time.

Thus far, I have been silent about the water measurements and numerical representations lurking throughout this project. The representations of how much water is available are the basis for many of the decisions around water governance and drought declarations. These smaller infrastructures bolster the water systems and makes their conditions "usable" to state actors and stakeholders alike. The percentage of average and allocation fulfillments used to discuss reservoir levels communicate something important about dryness. Of course, they are not neutral either. In the next chapter, we will examine how those measurements render drought into a fact and why California's measurements look the way they do.

Portions of Chapter 3 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

CHAPTER 4: MEASURING DROUGHT

Introduction

In the winter of 1988, Jack Pardee, a senior engineer with the California Cooperative Snow Surveys (CCSS) of the state Department of Water Resources, hiked to a survey spot in the Sierra Nevada mountains to determine how much water the snowpack is storing. However, this time "the snowpack was so scant that surveyors collected several samples and measured once but there was not enough water to measure a single core with their hand-held scale. Pardee said, 'I've got more ice in my refrigerator'" (Staff Writer 1988:A1). The dreary measurement foreshadowed the drought declaration that came three weeks later. Twenty years later, nearly to the day, another drought was on the horizon, but this one was different. Unlike the survey in 1988, the CCSS team found an average amount of snowpack at the end of their hike. A Sacramento Bee reporter reflected on the complex relationship between water conditions and water users when they outlined that "average" snowpack is not enough in times of trouble. This time around, "trouble" is a preceding dry year and a court order to reduce exports from the Sacramento-San Joaquin Delta to "protect the fragile Delta smelt, a threatened species that may be near extinction" (Weiser 2008:B1). These two quotes nominally describe the same phenomenon: a drought.

However, one features snow levels so low they cannot be measured, while the second involves the presence of water but constrained access. Both are defined as dry periods and eventually declared droughts due to these measurements but absent clear criteria. How then, do each of these different measurements articulate the same thing through very different means? How are water measurements used to define and declare that a dry period is a drought?

In this chapter, I focus on the little infrastructures, examining how water measurements, their calculation, and their implementation define and shape drought as a fact. The central empirical questions of this chapter are tied to water measurements themselves. How is water measured across the state? How are those measurements used to define and declare drought in California? What values are embedded in them? In answering these questions, I show how the formation of the first drought index required compromises and assumptions that persist in future measurements, which shape drought as a scientific fact. I also show how California's water measurements and water year classification system are based on pre-infrastructural definitions of drought that define drought today and influence when a drought is declared.

In developing these answers, I draw again on reiterated fact making to build on the analytic commitments of research into standards and classifications (Bowker and Star 2000; Lampland and Star 2008). With reiterated fact making, I examine the development of drought indices and water measurement tools in California. The chapter is divided into two sections. The first half focuses on the development of the first drought index as climate science took an interest in drought. The second half examines water measurements and management practices in California.

In the first portion of the chapter, I examine how a meteorological interest in drought's physical properties was a necessary condition for drought to emerge as an "objective" scientific fact tied to indices and numerical representations. Then, I examine two tools central to California's water system – runoff measurements and water year classification systems. During this examination, I draw out how prior definitions of drought become embedded in the measurements over time, even surviving periods of disruption and redefinition, which leads to a specific understanding of drought as both a scientific and social phenomenon.

Literature

Studies on standards, classifications, and measurements are perhaps some of the most underrated subareas in the Sociology of Knowledge. Those of us who are interested in these materials want to know what exists in the margins and the footnotes. Studies interrogate what is abstracted or incorporated into numerical representations and forms that have shocking amounts of power over our day-to-day lives, all while being mostly taken for granted and dismissed as "boring" (Timmermans and Epstein 2010). Much like infrastructure studies, scholars concerned with these informational infrastructures are interested in revealing the complex work done by technologies that are mostly invisible in daily life, even though they are ubiquitous (Star 1990). Scholars in this field argue that standards and measurements constitute the complex informational and technical systems that support modern medical practices, trade agreements, and agricultural production to name a few (Bowker and Star 2000; Lampland and Star 2008). The purpose of standards is to construct uniformity across time and place. Therefore, studies of standards – as well as of classification systems and measurement systems – require a close attention to precisely the things that lurk in the background and quietly organize our social lives. These studies and their methods are invaluable to studying a topic like drought.

Two seminal works demonstrate how deeply consequential standards, classifications, and measurements are for our world. They show how standards are everywhere yet nowhere all at once. Bowker and Star in *Sorting Things Out* (2000) argue that standards and classifications are constitutive of the systems that they support, and understanding those standards is fundamental to understanding the politics at play in these systems. The classification systems found in diagnostic manuals, census forms, and tire pressure requires form their own "ecology" as they layer and entangle with each other in our day-to-day lives (38). For example, the authors use the

International Classification of Disease (ICD) to explore how classification systems are historically contingent[37], and how continues to be shaped by interests like insurance companies, industrial firms, and pharmaceutical companies. The data gathered by these systems shapes the policies available to individuals, and other classifications like age, gender, and race layer on top to further shape experiences. Understanding classification systems requires fine-grained reading of reports, documents, and other dry materials to bring narratives back in and understand how politics become embedded and then reproduced through these systems. The book demonstrates how to read a classification system to "uncover" the politics operating beneath the dry, informational system.

In the edited volume *Standards and Their Stories* (2008), Star and Lampland outline a similar approach and commitment to interrogating taken-for-granted standards. In the opening section of the book, they argue that standards are nested withing each other and unevenly distributed across people and places. Standards also codify, embody, and prescribe values with deep consequences for individuals to whom they are applied. Lampland's examination of the field of work science and how it was applied to Hungarian agricultural workers in the 1950s shows how standards are tied to political regimes and the values that regime holds. Worker's motivations and capabilities were carefully studied and classified in order to assign them to standardized jobs. The process was not one of deskilling the work but instead a process of careful differentiation that reproduced race, class, and gender inequalities in the standardization of work and classification of the workers. Much like classification systems, the implications of standards are excavated through careful readings of documents that use standards and set them forward.

---

[37] An early version of the ICD had 200 categories because that was the number of lines available on census forms.

To ask the question, “how do measurements and standards define drought” requires an ethnography of infrastructure (Star 1999), a way of studying texts and materials that have little narrative and disappear when they are used properly by their communities of practice. It also requires making decisions about which threads of standards and measurements to follow and how to grapple with large quantities of data. This methodological advice is invaluable. Drought as a category is tied to multiple types of standards. Definitions of drought are underpinned by indices, classifications, and all manner of water measurements that work to standardize water conditions across the state at various moments in time. Drought itself is a category meant to describe a deviation from some unarticulated standard of water need present in the state of California. An entire chapter on measurement is already in debt to this literature just by existing.

I draw on the insights and methodologies used to study standards and classifications, but I shift the analytic framework slightly to accommodate my interest in drought as a fact. Classic works in standards and classifications attend to the messiness at the local level when the systems are implemented on the ground. Rather than a detailed exploration of a set of standards and classifications, I am interested in how water standards and measurements shape and make drought legible. I attempt to build on the commitments and insights of the research into standards and classifications by pulling this analytic thread into the reiterated fact making framework. I uncover the textures and politics of measurement practices in California's water management system using the methodological insights of this field. But I analyze them as an epistemic path dependency that shapes a scientific fact – not an infrastructural system – over time.

The axes of reiterated fact making that guide my analysis are path dependency and conditions of possibility once again. However, the scale of these conditions and paths will be much “smaller”. Rather than large, state-spanning infrastructures, I am concerned with the smaller tools and measurements embedded in this system of water governance. Also, I only briefly touch on the necessary condition of meteorology's interest for drought to emerge as a scientific fact. Rather than the networks of expertise, I examine the development of the first drought index and how it shaped measurements in use today.

Paired with this framework, my theoretical questions for this chapter are: How are values are incorporated into seemingly neutral measurements? What was deemed important enough to include in the monitoring of infrastructure? How do these values, in turn, shape social problems and environmental problems? To answer these questions and their empirical counterparts, I need to understand what water measurements are central to drought studies and California's water management practices. I also need to know how these measurements work; how they were developed; and how they have changed over time. Finally, I need to evaluate how any thresholds or definitions tied to those measurements are applied at moments of drought declaration across the four time periods that are the center of this dissertation.

The data and materials used for this chapter were specific sets of government reports, scientific publications on drought indices, legal decisions, and archival meeting minutes for a consequential workgroup. I began with documents from the California Department of Water Resources, particularly official drought reports where retroactive definitions and thresholds were applied. This allowed to me to assess which measurements were prioritized and used to define drought conditions across the four cases, so I could identify which measurements and classifications to examine historically. This chapter also relies on close readings of two consequential documents. The first is Wayne C. Palmer's 1965 paper *Meteorological Drought*. It is the first attempt at creating a drought index, and it is hugely consequential for the indices that followed and how drought is defined in California and across the United States. The second is a set of documents from a workgroup that was charged with reformulating a central California water measurement – the Water Year Classification. In these two documents, as well as the array of others I relied on, I found surprising epistemic path dependencies that shape definitions of drought today.

In this chapter, I argue that definitions of drought are shaped by goals related to water management and water quality control. These definitions are also based in a California landscape that has not existed since the 1930s. I also argue that the development of the Palmer Drought Severity Index in 1965 shaped scientific measurements of drought that are used across scientific research and reporting bodies today. In this chapter, I begin with an examination of the index Palmer developed to create an objective measure of drought with careful attention to the challenges of standardizing drought across time and place. Then, I examine two central tools in California water management: runoff and water year classifications. Both of these tools were developed for purposes other than measuring and defining drought, and they each incorporate values associated with development and expansion. I interrogate how these measurements are calculated; how they are used to define drought; and the important changes to those practices over time. Finally, I apply the thresholds articulated by the Department of Water Resources to water conditions of actual drought declarations to illustrate how the definitions are and are not applied to actual dry periods.

A meteorological interest in drought: The first drought index

In this first section, I briefly outline the historical context which opened the possibility for climate science to take an interest in drought. Then, I breakdown the first effort to transform drought into a scientific fact through the development of the first drought index[38]. Drought has been a social concern thousands of years as a source of human suffering. However, drought has only recently become the object of scientific investigation – a phenomenon that can be understood and conceptualized through hard numbers and observations. In 1965, Wayne C. Palmer – a meteorologist with the US Weather Bureau, Office of Climatology – was the first to attempt to wrangle drought into an objective measurement that could assess drought in clear, more concise terms (1965). The indicator developed by Palmer was the first attempt at studying drought as an objective scientific fact. The indicator is still widely used today, and it served as a model for many of the other drought indices developed in the following decades.

After World War II, meteorology and climatology were poised to take advantage of the increased computing power and the field's expertise to solve complex problems tied to weather patterns. Drought was of particular interest. World War II and the early Cold War Era were consequential for many forms of scientific expertise, generating funding sources and relationships between the US government and research centers. Others have detailed how WWII impacted scientific disciplines, (Devorkin 1992; Kaiser 2002; Mukerji 2014; Thorpe 2006), funding structures (Kleinman and Solovey 1995), and the very relationship between the government and science itself (Lowen 1997; Solovey 2001). Similarly, the emerging disciplines of meteorology and climatology were not left untouched. The US government required more data and research on weather patterns – particularly tools to predict weather patterns – to increase successful aviation and naval operations during the war, and the military retained control over these operations after the war ended (Harper 2003). During this post-war period,

---

[38] The following chapter will focus more explicitly on climate science expertise and how it shaped drought in California over time, alongside stakeholder networks. The focus of this chapter is on the development of the measurement itself and what it can tell us about definitions of drought.

numerical weather prediction advanced significantly as meteorologists pushed to replace the "art" of predicting with the "science" of meteorology in the 1950s. As part of this larger project of rationalizing and better understanding the weather, climate impacts were also studied more thoroughly. Drought cost the United States and other countries millions of dollars a year, so meteorologists sought a more scientific understanding of this phenomenon.

Development of Drought Indices

The first and most important attempt at understanding drought as a scientific fact came from Wayne C. Palmer and his seminal paper "Meteorological Drought", where he developed the first drought index. This first attempt was published as a government research paper – a testament to how successful the military and federal government were at exerting influence over these newly developing fields. The importance of this paper cannot be overstated. It is one of the most cited publications in the field, and it continues to be foundational for the development of new drought indices[39]. In this section, I break down drought's status as a fact at the time of Palmer's writing; what the goal was for a useful index; the challenges Palmer faced in its development; and the index's ensuing success and limitations.

The forward and introduction to this paper are quite revealing of the status quo and the challenge drought presented to meteorologists. The foreword, written by H.E. Landsberg – a fellow meteorologist – notes that "drought remains an unconquered ill" and meteorologists have not even "described the phenomenon adequately" (ii). He refers to Palmer's paper as the first step towards prediction and limited control by permitting "an objective evaluation of the climatological events" (ibid). Palmer goes on to devote a great deal of space and attention in his paper to the persistence of multiple definitions and the strength of non-scientific of drought. He

---

[39] This paper has been cited approximately 6655 times since its publication, and its importance is unparalleled among the early scientific works on drought in the American West (Heim 2002).

opens the paper by acknowledging that while it is possible to describe drought as a purely meteorological phenomena, it still means “various things to various people, depending on their specific interests… To the farmer drought means a shortage of moisture in the root zone of his crops. To the hydrologist it suggests below average water levels in streams, lakes, reservoirs, and the like. To the economist it means a water shortage which adversely affects the established economy" (1). Palmer highlights the difficulty of defining drought given the various stakeholders and general disagreements on not only the meaning of the word, but also “its spelling and pronunciation” (ibid). From the opening lines of the introduction, Palmer and other meteorologists have their work cut out for them when it comes to developing an objective approach to understanding drought.

A useful index is one that can be used in any location for any amount of time, and a drought index would be no different. Each of these components is necessary to create an index that could render drought in different places and at different times commensurable. The efforts hinged on Palmer’s ability to determine how much moisture should have fallen in a region in a given time period and compare it to how much moisture actually fell. By doing this, it would be possible to determine mathematically how far the departure would be. Of course, “expected” precipitation would vary from month to month and place to place. Palmer needed to strike a balance between capturing the specifics of a place while maintaining a generalizable framework to make a useable index. To do so, Palmer would need to outline a basic definition of drought, choose which physical indicators are most important when determining dryness, and systematizing their measurement and analysis to capture variability.

Palmer’s first attempt at setting a generalized definition of drought set conditions for the formalizing the connections between climate and social life. He set out the following definition of drought: “A drought period may now be defined as an interval of time, generally on the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply” (3). The verbosity of this definition looks like the writing of anyone who is grappling with something new or challenging and needs space to get their point across. But in this long definition, we find the first articulation of drought as “below average moisture.” And the term “climatically appropriate” provides some leverage for wrangling geographic variability. “Appropriate” indicates that there is some level of moisture that is *inappropriate*, which is what would actually constitute a drought. Based on this definition, Palmer would need to determine what constitutes a disruption to a region’s climate. However, he was limited in two important ways at this point: data availability and methodological disagreements.

Palmer’s index was shaped by what tools he had to work with more than anything else. Palmer needed massive amounts of readings and data to make determinations about when precipitation levels become inappropriate. Therefore, he was only able to use regions and measurements that had been taken regularly over multiple decades, but ones that also offered climate contrasts to demonstrate the utility of the index. The formation of this index was constrained by that availability, so he relied on the measurements generated by engineers who were building water management systems or citizen-led weather monitoring projects (1965:4 – 5). The measurements with the longest and most robust data sets were precipitation and runoff, which Palmer used to construct an index that could approximate both the amount of water falling onto the earth and how much would not be absorbed by dry soil. It also meant that this index was originally developed using data from the Midwestern portion of the United States where there was at minimum 25 years’ worth of monthly measurements available.

Palmer also required data that had climatic variability to prove his index would work across different contexts. For his research, Palmer used a western region of Kansas described as "semi-arid to subhumid climate" – cold winters with warm summers – with data reaching back to 1887. He contrasted it with a portion of Iowa characterized as "moist subhumid" – colder winters and cooler summers. What would be considered "normal" for Kansas would be considered recognizably dry in Iowa. He used these contrasting locations: "to develop a method for computing the amount of precipitation that should have occurred in a given area during a given period of time in order for the 'weather' during the period to have been normal - normal in the sense that the moisture supply during the period satisfied the average or climatically expected percentage of the absolute moisture requirements during the period" (4). Both areas used in this study were different when contrasted to each other but did not encompass the variability of other regions – particularly the Mediterranean climate of California.

Additionally, there was no settled method in meteorology and climatology for measuring and predicting evapotranspiration and moisture interactions with the soil. In 1960, there had only been one serious effort at determining how to "rationally" classify climates. The approach was outlined by C.W. Thornthwaite, and it was the first systematic approach to measuring and incorporating the evaporation of water out of soil and plants back into the atmosphere as a key element of the water cycle (Thornthwaite 1948; Thornthwaite and Mather 1951). This element too was limited by data availability, so evapotranspiration was estimated by the more widely available temperature and precipitation data (Palmer 1965: 6). Thornthwaite's approach was criticized in the field for being "too empirical" rather than addressing the basic, theoretical questions of how the process worked. Palmer decided to utilize this method, but he worked to construct an indicator where other methods could be swapped in as they became available. With these issues settled as best they could be, Palmer attempted to create the first drought index, which would set the state for a scientific and meteorological approach to drought in the coming decades.

Palmer created a mathematical model that relied on measurements of precipitation and evaporation, combining them into different time scales that could be applied to different areas. Palmer constructed this measurement so that the index – the Palmer Drought Severity Index (PDSI) – could be used to measure drought on a three-, six-, or year-long time scale. I want to emphasize that this was quite the feat. Palmer relied on several statistical and mathematical formulas to determine how to account for variability between regions, so that the formula could be applied to a variety of places. He was also able to use variations in yearly rainfall to create an index that was not a simple "yes" or "no" outcome (drought "does" or "does not" exist), but one that was able to determine the relative severity of drought as the index becomes more negative (and therefore how much precipitation would be needed to end the drought). It was also relatively simple and empirical, which made it easier for other scientists and managers to adapt it.

Palmer was able to achieve his goal of developing an index that could function well in different locations[40] and over different time scales. Rather than speaking to the amount of moisture falling (one inch or more), Palmer's index would speak to how much that singular inch of moisture could impact the region. The PDSI was adopted by government agencies like NOAA, as well as journalists, hydrologists, and private consultants and more (Heddinghaus and Sabol 1991); and it encouraged the development of several other drought indices that use similar approaches for standardizing data but might incorporate different physical indicators of drought

---

[40] A meaningful or useful level of granularity would be a particular watershed, or a "climatic" region of a given state.

(Carrão et al. 2016; Eslamian et al. 2017; Heim 2002; Keyantash and Dracup 2002). As of October 2021, there are upwards of twelve drought indices in regular use across the United States – including two developed by Palmer, and dozens more available to scientists, planners, stakeholders, and others (Mizzell et al. 2021). The PDSI is still used by the National Oceanic and Atmospheric Administration in their regular monthly drought updates (National Weather Service 2022). It has also been used to standardize drought reporting globally, even informing the development of dendrochronology where thousands of years of drought are studied through tree ring data (Liang et al. 2007; Meko, Stockton, and Boggess 1995; Stahle et al. 2000).

The attempt to scientize drought could not sever its definition entirely from the social. Palmer in his conclusion recognizes this. He states that drought has been and will continue to be a meteorological phenomenon that occurs "at the intersection of nature and society". The social will always be embedded in "averages" and the "climatically expected" or "climatically appropriate" (1965:50). What is average, expected, appropriate, and severe are all definitions based on human observations and human needs. These first scientific attempts at quantifying "appropriate" were foundational for the emergence of drought as a scientific fact that is often represented by two- or three-digit numbers that are always attempting to determine what is appropriate based on weather data that is often separate from human use and meddling in the landscape. It is an approach that would show up in future indices and in California's own calculations.

The development of this first drought index was a critical move towards conceptualizing drought as a scientific fact, and it shaped future indices and conceptualizations of drought. Of course, the monitoring of water was not new by any means. Prior to these efforts, water could be measured and meted out according to need; water storage could be calculated and determined to be lacking or plentiful. However, the connection between water conditions, weather patterns, soil moisture, and the interactions between them absolutely *was*. Additionally, the utilization of standard water measurements like runoff to articulate drought through a single numerical representation was novel. The interest of meteorology and climatology in rendering drought a scientific fact was necessary for the scientization of drought and the prominence of numbers in defining drought in California. Now, I return to California more specifically once again and examine the central measurements in water management.

Epistemic path dependencies

Runoff measurements

In this section, I focus on how decisions regarding drought measurement and definition in California at certain points have implications for how drought is defined going forward. I focus specifically on two measurements used for monitoring and planning in all years and which carry significant weight during dry years: Runoff and water year classification. First, I provide some background context on "runoff" as a measurement before delving further into its use today and its importance for drought declarations in California. Then, I outline the history of California's water classification system before discussing an important reorganization that occurred in the 1980s with ramifications today. Finally, I step back to examine water measurements in drought reports over time, illustrating how definitions from before the 1970s impact definitions moving forward.

Runoff[41] was a relatively long-standing measurement used regularly by federal and state engineers. Engineers and hydrologists developed this measurement in the early 20th century to understand the flow of water, so experts could store and convey it during summer and fall seasons when precipitation would be less frequent but more needed by agriculture. The practices used in the Midwest and other southern states were implemented in California to develop the Central Valley into the agricultural powerhouse that it is today (Boyt 1941; Hoyt 1936; Langbein 1949). These practices helped the US government determine which areas would be ideal points for dams and conveyance systems, and it remains central to determining water availability during the drier summer and fall months. This measurement is central to solving the "mismatch problem" presented by regions with water and regions where people live discussed in the previous chapter. Runoff measurements exist explicitly to determine which regions of land are "suited" to projects that capture, conserve, and convey water across a region. The measurements accomplish this by collecting data about a region's water flow patterns with the goal of building infrastructure. Water managers utilize two methods of calculating runoff in their work: "unimpaired" and "impaired" runoff.

Both impaired and unimpaired runoff measure water flow, but they capture two different relationships between water and the land. "Unimpaired runoff" calculates water flow without the interference of dams and other diversions, constructing a "natural" watershed separate from any interference (California Cooperative Snow Survey 2022). "Impaired runoff" accounts for the interference of impoundments or diversions from dams and other human interventions. The data

---

[41] Runoff calculates water flows from an area referred to as a "watershed" or another body of water over the course of a given water year. It is often measured in acre-feet, which is the amount of water needed to cover an acre of land in a foot of water (over 325,000 gallons).

for these calculations are gathered by gauges placed along California's major rivers[42,43]. However, there is more calculating to be done. The initial readings calculate impaired runoff. The gauge readings are influenced by how the land surface has been changed by dams, buildings, roads, and so on over the last one hundred years. Once a month, hydrologists working for the Department of Water Resources (DWR) use historical data to determine the impacts of those developments and remove them by computing various coefficients of different surfaces (California Water Boards 2011), which leaves the "unimpaired" runoff calculation that is used for decision making.

Today, runoff is used frequently and faithfully by management bodies in written reports and in decision-making. Given California's water landscape and the level of interference, impoundments, and diversions across the state, it seems reasonable to expect impaired runoff to play a larger role. Impaired runoff offers a more accurate picture of what is happening "on the ground" during a given time by incorporating the current conditions of watersheds and all of the infrastructure, farming, living, and monitoring that have been built up across the state. But in fact, unimpaired runoff is far more central.

Unimpaired runoff is used more often because it relates more closely to the natural water cycle and landscapes, which water managers consider more neutral. Water managers calculate impairments through one measurement, so they can be subtracted – explicitly removing the impacts of development from the unimpaired runoff numbers used in decision-making, particularly when classifying what "kind" of water year it is. Unimpaired runoff offers a fixed picture of water flows over time, which is useful for understanding the relationships between

---

[42] Today these readings are provided automatically, but historically they were done manually once a month and preset locations.

[43] Both forms of runoff are most often reported in acre-feet (AF) or thousands of acre-feet (TAF), which communicates volume of water available for consumption or conservation.

precipitation, runoff, and reservoir storage (California Cooperative Snow Survey 2022). Today, unimpaired runoff is also used to understand long-term climate impacts by subtracting the impacts of water management to discover other evidence of human influence. Runoff is a helpful illusion for governing water even if it assumes processes that are only useful for small water sheds or longer period averages. California's understandings of runoff are deeply rooted in and shaped by the pre-infrastructural landscape. This definition of runoff and what counts as "adequate" runoff are still very deeply embedded in water measurements and standards today. In fact, runoff is used as a threshold for defining drought conditions in California.

Runoff is the core measurement for determining water stores and deliveries and therefore for defining drought. Again, according to the Governor's office, the US Bureau of Reclamation, and the California Department of Water Resources, there is no *official* definition or threshold for a drought declaration (Jones 2000:12, 2020:2); there is no amount of runoff that will automatically trigger a declaration of emergency and drought emergency operations by the Governor's office. However, it is clear from drought reports that when thresholds are articulated, runoff is at the center. A DWR report from 2000 analyzing the 1987 – 1993 drought, articulates such a threshold for that particular drought period. On the same page where the report state there is no definition, a reader also finds: "A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range, and reservoir storage during the same time period at less than 70 percent of average. These were not hard and fast values, but guidelines for identifying drought conditions" (2000:12). Numerically, this means that reservoir storage will be below average, and runoff will be significantly lower than that – about 30—40% of average. In the final section of this chapter, I discuss runoff measurements in drought reports over time, and I test whether this threshold bears out for both runoff and reservoir storage.

Runoff is central to defining drought in California, and I argue that this is due to its ability to capture both the social and the scientific elements of drought. On the one hand, the purpose of this measurement is to aid in the very social goals of water management and planning. It was created to further development by identifying watersheds for damming, growing, and building; it can be used to remove those changes from the landscape for the purpose of management. On the other hand, it is very scientific in its representation. It provides a reasonably straightforward numerical assessment of the water present in California. It is a representation that can be used by the DWR, water districts, press briefings, and beyond to boil down a complex hydrological situation into a simple numerical representation. That representation can be used to create an informal definition of drought – a guideline more than an actual rule – that ties drought to the acre-feet of water available and moving across the surface of California. And a "reasonable" number of acre-feet will be tied to pre-1940s watersheds because unimpaired runoff is used for these thresholds. In fact, California makes use of multiple thresholds targeted to different amounts of runoff. It is called a water year classification system. This classification system utilizes runoff to determine where a water year falls on the scale of "wet" to "critically dry".

Water year classification systems – 1929-1934 persists

Water year classifications are often used for management purposes, and California makes extensive use of a unique system. Any water classification system is meant to simplify complex hydrological relationships into a single number, which can then be used for decision making

(Null and Viers 2013). Some regions use specific indices like the PDSI, the Standard Precipitation Index (McKee, Doesken, and Kleist 1993), and the Surface Water Supply (Shafer and Le. E. Dezman 1982), among others (Eslamian et al. 2017; Gibbs and Maher 1967; Weghorst 1996). California's water year classification system was devised to categorize water years based on the amount of runoff predicted and then recorded for the state. "Year" may be misleading as it does not follow the January to December calendar that many of us mark our days by. Instead, water years are based on the hydrological cycle and the observed rhythm of rainfall with the wet season at the beginning of the water year and the dry season at the end. In California, the water year runs from October 1st through September 30th of the following year. Beyond simple one- or two- word descriptors, water year classifications are a powerful governance tool used in water management with nested forms of measurement and surveillance that can be unpacked to better understand how they shape drought.

California's water year classification system is a critical intersection of "big" and "small" infrastructure. It is likely unsurprising at this point to read that the Sacramento and San Joaquin Valleys are the most important regions for this classification system, given their centrality to larger infrastructural systems too. The Bay-Delta is a deeply managed area of the state and is the heart of both the SWP and the CVP (Carroll 2012). The Sacramento and the San Joaquin Rivers drain from the west slope of the Sierra Nevada mountains, then merge and move through the Sacramento–San Joaquin Bay Delta (the Bay-Delta) before flowing out to the Pacific Ocean (Figure 4.1). These two rivers convey a great deal of water from the Sierra Nevada mountains into the Central Valley for farmers and then further to Southern California's large urban sprawls. They have been historically important for California's water management, economic prosperity, and population growth. The Bay-Delta region is the starting point for determining what kind of water year the entire state is experiencing.

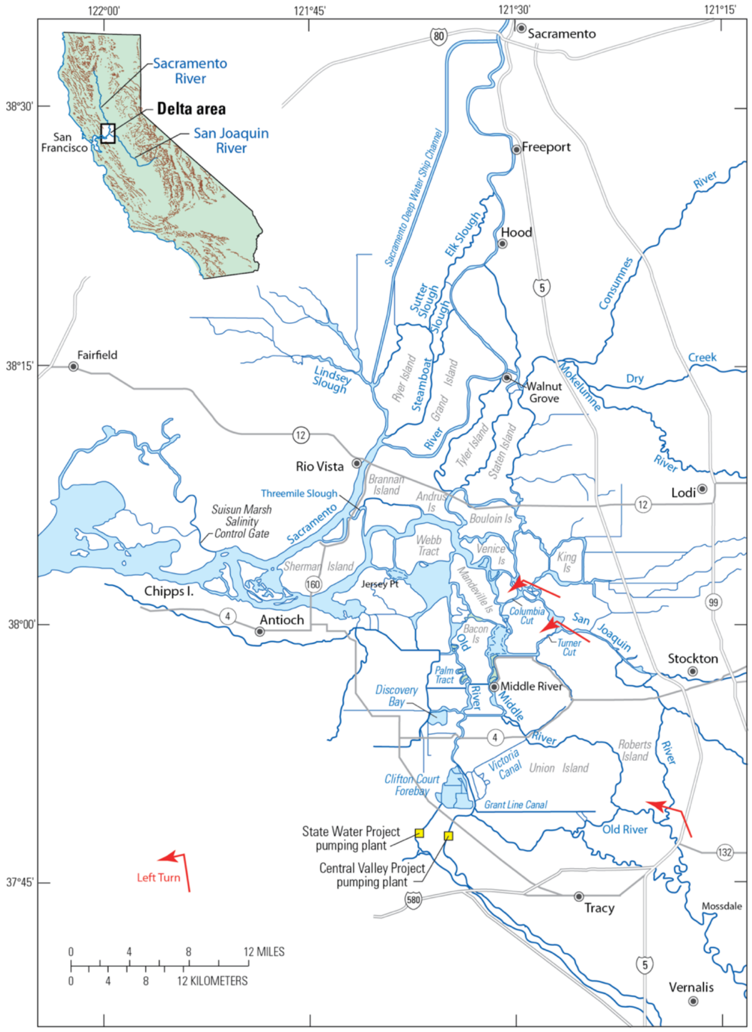


Figure 4.1: Map of the Sacramento-San Joaquin Delta by California Water Science Center (U.S. Geological Survey 2012).

Water year classifications from the Bay-Delta are used to articulate state-wide water conditions. Runoff calculations for each of these rivers are used as the foundation for an index – a numerical value that falls on a scale which can be translated into the categories of “wet,” “above normal,” “below normal,” “dry,” and “critical” for both riverbeds (California Department of Water Resources 2021). The equations are not the same for each riverbed, as each is informed by historical water data and premised on an amount of "average" runoff expected for the region in million acre-feet (MAF). The two indices for the rivers as they are utilized today are:

> Sacramento Valley Water Year Index = 0.4 * Current Apr-Jul Runoff Forecast (in maf) + 0.3 * Current Oct-Mar Runoff in (maf) + 0.3 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 10.0, then 10.0 is used)
>
> San Joaquin Valley Water Year Index = 0.6 * Current Apr-Jul Runoff Forecast (in maf) + 0.2 * Current Oct-Mar Runoff in (maf) + 0.2 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 4.5, then 4.5 is used)

The three terms in these equations emphasize different aspects of the water year. The first term, runoff forecast, is the predicted amount of water that fell as rain or snow which will flow into the various rivers during the spring and summer months. The prediction is based on precipitation measurements which can be converted into runoff[44]. The second term, current runoff, is based on present levels of runoff measured by gauges in the river basins. In each of these equations, the predicted amount of runoff during the spring and summer months carries more weight than the current runoff in winter. Finally, the third term is the previous water year's index because California's water system is built to create "carry over" storage, so that a wet year may modify impacts of a future dry year or that two dry years be taken more seriously.

It is not an accident that this hyper-managed region of California holds such sway over the classification of water years, and the governance decisions that follow from those measurements. Reservoirs are filled by the amount of runoff coming from the mountains and flowing through these rivers. In turn, the levels of reservoir storage and predicted runoff determine how much water any water district or contractor receives. Those allocations and

---

[44] From the US Geological Survey's website "California Water Science Center": "Runoff occurs as the result of precipitation (both rainfall and snowfall) that is in excess of the demands of evaporation from land surfaces, transpiration from vegetation, and infiltration into soils. The water that remains available, or runoff, is the amount of water that makes its way to streams, rivers, and, possibly, to the ocean" (United States Geological Survey 2021). A more detailed description of how land surfaces, soil, and transpiration interact is beyond the scope of this dissertation and me as a sociologist.

fulfillments determine how much water is delivered to farmers and other water users. It all trickles down from these calculations and classifications. Critical and dry water year designations can lead to journalistic discussions of drought and potential declarations – particularly if the year under discussion is preceded by a critical or dry year too. Without an official threshold that can trigger a drought declaration automatically, the cutoffs between the classifications offers insights into what a formalized definition might look like.

Of course, these categories did not manifest from nowhere. Much like Palmer in the 1960s, California water managers needed to collect data to devise numerical representations of dry conditions. California' state apparatus had begun collecting systematic data on watersheds beginning in 1928, although less systematic data had been collected for up to fifty years before. These early measurements provided a foundation for the development of the water classification that exists today. In the following section, I historicize the cutoff points within the classification system, how they have changed over time, and what they mean for definitions of drought in California.

Development of a formalized, California-specific index

Beginning in 1930, California's Department of Public Works began routinized measurements of water conditions in the Sierra Nevada mountains and at the mouth of the major rivers[45]. The survey was created at the direction of the 1928 Legislation with the purpose of developing a thorough investigation of water resources across the state (Department of Public Works 1929). The survey's findings were published in monthly reports at the beginning of the

---

[45] The Yuba River, Kings River, and Owen River had the most snow survey locations when the practice was established in 1930 (California Department of Public Works 1930a).

year[46]. Runoff predictions for the spring and summer months were included in the April and May final reports based on the snow measurements but were not given nearly as much space or discussion as precipitation and snowpack in the first decades of the formalized water condition reports. At this time, not all basins had enough data to create a "percent of normal" prediction. However, the Sacramento and San Joaquin basins were given priority even ninety years ago, although the calculations look different. Rather than integers calculated through an index equation, reports are presented as a percent of normal.

These initial reports were made during a precedent-setting drought that stretched from 1929 until 1934. As a result, bottom minimum flows were set to these early low levels, creating precedence for comparing dry years and an unofficial understanding of what constitutes drought in California based on a singular case (Santos and Godwin 1978:8). These cooperative snow surveys were crucial for developing California's own water year indices. By systematically gathering data from the Sierras, it became possible to compute and predict the runoff capacity for summer months. These runoff measurements eventually became the central indicator of what "kind" of water year California could expect to have, especially as it pertained to water deliveries during the warm summer months.

By the late 1970s, water quality in the Bay-Delta emerged as concern with the completion of much of the State Water Project. Both the CVP and the SWP pumped water out of the Bay-Delta at a rate that led to saltwater intrusion from the bay areas connected to the Pacific Ocean (State Water Resources Control Board 1971, 1978). These projects were removing so much water during dry or critical water years, that ocean water was beginning to

---

[46] At this time, the relationship between precipitation, snowmelt, runoff, and monthly distribution of said runoff had not been settled, and it was the goal of these reports to formalize that relationship (California Department of Public Works 1930b).

flow into the Bay-Delta. The inflow impacted water quality for both human and nonhuman users. During the 1976 – 1977 drought, water quality deteriorated so significantly that the state was forced to act to prevent such as poor-quality drinking water, damaging agricultural land with the salty water, and further environmental degradation (Santos and Godwin 1978:27–27).

To confront the salinity problem, the State Water Resources Control Board (SWRCB) set salinity standards pegged to what could be expected for water quality had the two projects never been constructed. We know that standards set specifications and can be leveraged to universalize practices (O'Connell 1993; Timmermans and Berg 1997; Zerubavel 1982). The SWRCB set out to do just that. The initial standards set by the Board would shift with the relative wetness and dryness (State Water Resources Control Board 1978). In wet years, water could be pumped out of the Bay-Delta to meet consumption needs without pushing salinity too high. In dry years, the CVP and the SWP would need to conserve water in the Bay-Delta to maintain water quality. The quality standards were targeted to conditions from before the two water projects were constructed. Again, the definitions and understandings of water quality from before the completion of these water projects shaped the standards of the 1970s.

The index that emerged in 1978 to tackle this issue of salinity was originally referred to as the "Four River Index" or the "Four Basin Index", and it focused on the Sacramento River. Perhaps surprisingly, the cutoff points between categories in this index were much more explicit than they are now. The categories were characterized as "wet," "above normal," "below normal," "dry," and "critical" based on the unimpaired outflows from the Sacramento River. Different standards were included for a year following a "critical" classification. In this case the standard would need to be higher to combat the increased salinity following a very dry water year (State Water Resources Control Board 1978:41). But where did this "critical" cut off come from? The drought from 1929 – 1934 was used to set the precedent for determining what the driest years can look like in California (California Department of Public Works 1930). For hydrologists, these years provided a solid foundation for two reasons. First, they were *exceptionally* dry and disrupted agricultural production in the state. Second, these years occurred before the construction of infrastructure projects, so they did not need to be reworked to compensate for the diversions and constructions that took place in the years following.

In a clear example of path dependency, these water year classifications would come to define drought, although they were not initially created to understand drought as a category. Rather, they were created to address the problem of salinity in connection with over pumping. I acknowledge that the dry conditions of 1976 – 1977 went a long way to exacerbate the problem with salinity. But these water year designations were not meant for determining whether or not a drought exists. They were set to determine how much water needed to remain in the Bay-Delta and standardize water practices in the region. The "critical" designation was based on the 1929-1934 drought, shaping definitions of drought moving forward. The standards tied to these designations were simple on paper but much harder to enforce.

Standards are rarely set without friction (Epstein 2009; Juska et al. 2000; O'Connell 1993), and water quality standards in the Bay-Delta were no exception. The creation of standards is inherently a social process that requires cooperation across fields and groups, and their creation can often be met with resistance (Clarke 1991; Timmermans and Epstein 2010). When the SWRCB set salinity standards in 1977 to curb pumping in the Bay-Delta and prevent further deterioration in water quality, the United States Bureau of Reclamation (USBR) refused to comply. They argued that as a federally operated water project, they were not beholden to state standards and would continue to deliver as much water as possible to CVP contractors (Racanelli

1986). In response, the SWRCB used its jurisdiction over water rights to alter the rights of the USBR and enforce the water quality standards by curtailing how much water the Bureau could legally access. Needless to say, the USBR and other parties protested the actions and sued the SWRCB. The plaintiffs[47] claimed that the SWRCB overreach by curtailing water rights in order to enforce the standards. Legal and physical infrastructure were now operating explicitly at the level of water quality standards.

Water rights versus water quality

The friction in the standard setting process set the stage for a showdown over state power, rights versus quality, and whose benefit needed to be considered in the creation of water standards. The case focused on how water quality laws and water rights intersected, and which would carry more weight (Brandt 1987). The court decided which governing body had the power to set and enforce water quality standards in the Bay-Delta. At the end of the day, the state of California was given the primary power to set standards – particularly for salination – for the Sacramento-San Joaquin Delta, and the federal government would be responsible for following those directives.

This ruling solidified SWRCB's power to set water standards, determine how much water could be removed from the Delta, and how the use of water should be governed. The judge ruled in favor of water quality over water rights, stating the SWRCB functioned appropriately by ensuring "the reasonable protection of beneficial uses" by setting and enforcing standards that all other parties must respect (Racanelli 1986). This ruling had consequences for water

---

[47] Other parties who filed suits against the SWRCB were the Central Valley East Side Project Association, Kern County Water Agency, San Joaquin County Flood and Water Conservation District, South Delta Water Agency, Contra Costa Water Agency, Fibreboard Corporation, and Crown Zellerbach Corporation.

management in California. Water quality would trump water rights in future rulings, which altered the legal infrastructure the physical infrastructure was built on. Riparian and pre-1914 appropriative rights were not overturned, but water quality no longer needed to come second in these considerations, an interesting reversal of previous practices. Additionally, the ruling meant that the SWRCB had the power to enforce any standards they set, easing the way for a universalization of practice with far reaching consequences for water governance today. But it was not all celebration for the SWRCB.

The court's ruling also reminded the SWRCB of its responsibility for the wellbeing of all water users, rebuking the SWRCB for under analyzing non-consumptive uses in an initial water quality plan. The court reiterated that the SWRCB is charged with ensuring "the highest reasonable water quality 'considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible'" (ibid). Until this point, human consumptive water needs had priority over others in decisions for the Bay-Delta, due to the dominance of the "capture, conserve, convey" logic in water management. Now, the ruling demanded that the needs of plant, animal, and other ecological components be included to protect the water quality. Now, water use for "widest" benefit was expanded to include the benefit of the environment and non-human users (like the little Delta Smelt Fish [Scoville 2019]). This ruling was built partially on the precedent set by environmentalists through another similar case from 1980[48]. This case successfully argued that a regional water district put development before other purposes, which was detrimental to both the environment and other economic interests. The 1986 ruling for the SWRCB was another step in that direction, and the role of environmentalists in shaping drought will be discussed more in the

---

[48] Environmental Defense Fund, Inc. v. East Bay Municipal Utility District (Clark 1980)

following chapter. Carrying out the ruling required reconfiguring the complex practices around water governance, beginning with classifying water.

The SWRCB would address all of the interrelated problems of salinity, environmental regulation, and lack of satisfying standards by putting together a workgroup to develop a new classification system. Until this time, organizations and agencies were sometimes using different methods for classifying water years, leading to a patchwork of various standards and practices. To achieve universality, The SWRCB created a "Water Classification Sub-Workgroup" comprised of stakeholders and water managers to accomplish this goal.

Changes to water year classification

In May 1989, a group of stakeholders and water managers came together to create a working group, whose purpose was to rework the water year classification equations and cutoffs to be more reflective of California's storage capacity. The workgroup was comprised of forty-one individuals representing various water stakeholders in the state. In total there were twenty-two representatives from California departments – predominantly SWRCB and DWR; two representatives from the federal USGS; nine water district representatives; and eight consultants from engineering and environmental groups. Based on this list, state interests were the largest voice given space at the table with environmental and federal voices least weighted. Together, the members of this workgroup attempted to meet the charges of the court by developing indices and classifications that offer simple, predictable forecasts of total water available (Sub-Workgroup on Water Year Classification 1989:3). The group left much of the infrastructure intact – a testament to the power of this particular material path dependency. Instead, they made two significant changes to the indices that tell us something about how definitions of drought persist across time periods.

First, they added a new variable that specified carryover storage from a previous year. The purpose of this new variable was to express the increase in storage capacity and how a large amount of carryover from the previous water year can offset a below normal year in the present. The workgroup documents indicate that this was because members wanted reliable equations to produce sound predictions. The workgroup determined that including the previous water year's runoff conditions improved prediction accuracy[49] (1989:18). This change is not inconsequential. Up to this point, the impacts of the CVP and SWP had been systematically removed from many calculations and water standards. Reservoir storage was reported, but unimpaired runoff and the water year classifications derived from runoff measurements did not formalize how carry-over between years might impact the year following it. For the first time, the standards would include clear and meaningful integrations of the large infrastructure projects. However, the workgroup disagreed on how to go about formalizing the water carried over between years.

The workgroup needed to decide whether to use the entire annual runoff or only the April-July runoff from the previous year. There were arguable reasons to include either option. The entire annual runoff would provide the most accurate assessment of a full water year, but the April-July runoff number was the most important time period in a given water year. Those warm months were when snowpack melted and filled reservoirs to be used during the arid summer months. Model studies aided the workgroup by comparing the predicted runoff of various equations against the actual historical runoff from previous water years. This allowed the workgroup to verify any changes against “observed and objective” water conditions whose

---

[49] Previously, only wildlife and forestry groups considered the conditions of the previous water year in their predictions of summer and fall water conditions.

definitions and understandings were shaped already by pre-infrastructural ideas of “appropriate” water availability. Eventually, the workgroup agreed on the following equation: .40 (current April-July runoff forecast) + .30 (current October-March runoff forecast) + .30 (previous water year index) from among the options because it was a “better representation of water available to the Delta” (1989:16). In the end, the full year was preferable because it gave the full picture of water availability.

The work group chose this possibility because it reflected the “water system capabilities” in wet and dry years. The decision formalized the built carry-over storage into a water index – a departure from previous indices. As an added benefit, it was also deemed more understandable and therefore usable by the greatest number of interests. Not only did the material path dependencies of infrastructure play out very strongly, but the close relationship between that material path dependency and epistemic path dependencies tightened by emphasizing storage capacity and system capabilities as a key component of water year classifications. Including the previous water year's runoff, extremes would have deeper ramifications across time as the consequences of wet and dry years carry forward into future water years. This is not the only example of the workgroup deciding along these lines. The decision has a profound effect on the articulation of drought as a scientific fact: it formalizes the “two dry years” pattern underlying California’s drought declarations. It literally puts into the classification calculations that it is not one dry year that makes a drought, but two do.

The workgroup took this entrenchment of built capacity a step further by adjusting the cutoff points for the classifications. Rather than hard cutoffs like in previous systems, the workgroup pushed for a sliding scale to ease potential restrictions in the wet half of a classification year (2, 16). The sliding scale meant that if a classification was on the wetter half of a “below normal” year, water users could use a little bit more water than they might have if there was no sliding scale and only hard cut offs. The argument was that this extra bit of water use in a “below normal” year would be offset by commitments to store more water during wetter years when there is plenty to go around. The cutoff points and how they are treated are consequential for allocating water during dry and critical years, so the workgroup discussed their placement at length before deciding on the ones in use today. The cutoffs for dry and critical years were given a great deal of time because those designations would mean greater reductions in water consumption. During dry and critical years, a greater proportion of available water remains in the Delta to preserve water quality for all users. Amongst all of this discussion, the group did agree on one designation: what constitutes a “critical” year.

The group made a concerted effort to keep the “critical” classification the same. The “critical” category was built on the very dry years of the 1929 – 1934 drought, and those designations were kept in place because they presented such a clear standard for what a “critical” year should look like. They discussed at length the pros and cons of six different approaches to selecting threshold points (1989:28). They appeared to fixate on the number of critical years created by each cutoff. Specifically, they desired cutoffs that avoided increasing the number of “critical” years, even if it meant decreasing them in the end. Maurice Roos, the workgroup leader and chief hydrologist for the DWR, wrote, “In my opinion, this is not unreasonable (that 1939 and 1987 come to be classified as ‘dry’ rather than ‘critical’ under the proposed 40-30-30 Sacramento River Index) as both those years would begin with above average carryover storage and are not, by themselves, among the worst of the presently labelled critical years” (1989:53). In the end, possible modifiers that were considered more accurate were dismissed in lieu of maintaining the number of years classified as “critical” years with the new index.

The workgroup focused on the number of critical years because they wanted to avoid "creating" more disasters than necessary. Here we see an interesting reversal from the workgroup's previous patterns. When it came to crafting a new water year index, infrastructure's potential carry over was formalized and incorporated into the equations themselves. However, the workgroup avoided altering the least palatable designation. The members kept the critical years from the 1929 – 1934 drought as the threshold for this negative designation, even though no major infrastructure existed at this time. In this case, the definition of critical persisted *despite* the material infrastructure that had been put in place. This is worth noting because here the epistemic path dependency proved to be noticeably powerful in decision making.

By tracing the measurements and indices, we can see how a definition of drought that emerged from the 1929 – 1934 drought – before the completion of the CVP or the SWP – persists today. This foundational understanding of drought is not reworked even in light of the tens of billions of dollars spent to rework California's watersheds and landscape through infrastructure, monitoring, and scientific study. This definition of "critical" persisted in water year classification calculations over fifty years later to address a problem created by the infrastructure that had dramatically changed California's water storage. Additionally, the persistent use of unimpaired runoff as a fundamental measurement for governing practices shows that even with incredible advances in the measurement of water and governing practices, drought remains a deeply social phenomenon, shaped by the early decades of California's statehood. Those definitions and practices are incorporated and reincorporated into modern day measurements, standards, and practices even when addressing other concerns like salinity and environmental protections. Drought remains deeply social and something to be avoided at all costs – even in our own definitions.

Drought reports – Where measurements and infrastructure come together

In this final section, I examine the central California Department of Water Resources report to show how closely actual runoff and reservoir storage levels map onto the implied thresholds meant to identify drought conditions. I do so to demonstrate how runoff plays a central role in drought declarations given how it pulls together both the material and epistemic path dependencies. Recalling the historical overview, statewide droughts were officially declared in January 1977, April 1988, June 2008, and January 2014. To "get at" the statewide water conditions during these drought years, I draw from reports published by the Department of Water Resources, specifically The California Water Conditions report, Bulletin 120.

Bulletin 120 was the report developed in 1930 with the intention of building data for water management and providing a clearer picture of water conditions to all water users across the state (California Department of Public Works 1930). The report is still published four times a year: in February, March, April, and May. I focus on the numbers published in the May bulletin because this is when predictions for summer and fall are finalized and all hope for a miraculous, drought-busting rainstorm are gone. The report lays out forecasts for seasonal runoff from major watersheds, as well as summaries of precipitation, snowpack, reservoir storage, and runoff. This snapshot of water conditions is discussed at length in publications during first and second dry years, and water managers make decisions about deliveries and the potential for emergency measures, such as voluntary water conservation based on the numbers in this report. By reviewing these reports for drought years and one dry but uncalled drought period from 2001 – 2002, I show how thresholds in runoff and reservoirs storage shape what constitutes a drought across these time periods.

The threshold[50] for a drought declaration is treated more like a guideline when actual declarations are examined. For the declared droughts, the pattern of runoff being the most weighted threshold bears out. The "lowest 10% of this historical range" really means a critical year classification alongside a dwindling reservoir storage. For all that water managers say "there is not definition of drought" – there is certainly a sense of what water conditions test the ability for society to function, although it is not always consistently applied. Three of the four drought declarations came at a time when runoff was well below 50% of normal. In 1977 it was 20%; in 1988 it was 35%; and in 2014 it was 35% (California Cooperative Snow Survey 1977, 1988, 2014)[51]. However, the 2008 declaration came when runoff was 70% of average (2008). Based on the DWR's definition, this final declaration does not qualify as a "drought" according to water stores. But when we step back to view them as a two-year build up as the notes from the sub workgroup and the indices would encourage us – the picture does clear up. For 2007, the runoff estimation was 45% of average, meaning that circumstances were dryer leading into 2008 than the single figure would indicate (2007). It is not surprising that drought declarations occur when runoff is low, but the consistency between the declarations demonstrates the centrality of runoff when determining what conditions constitute a drought.

The second half of the definition calls attention to the carry-over storage in reservoirs; but the definition does not bear as consistently as runoff. In the reports, reservoir storage falls below average for each year. But they do not fall as far as runoff, nor do they consistently reach below 70% as indicated by the threshold. In fact, only 1977 falls below that threshold at 50%

---

[50] I am referring to the threshold articulated by the DWR in 2000: "A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range, and reservoir storage during the same time period at less than 70 percent of average. These were not hard and fast values, but guidelines for identifying drought conditions."

[51] The runoff measurements closer to the drought declarations for these droughts were as follows: 20% on February 1, 1977; 20% on April 1, 1988; 15% on February 1, 2014 (California Cooperative Snow Survey 1977, 1988, 2014). These are lower measurements, but the lower levels do not substantially alter the overall pattern.

(California Cooperative Snow Survey 1977)[52], and 2014 is the only one that meets the threshold at exactly 70% (2014). 1988 and 2008 come in at 83% and 85% respectively (1988; 2008). Reservoir storage – while still important in decisions regarding what constitutes a drought declaration – are not as consistently tied to declarations. I argue that this is in part because of the persistent power of the pre-infrastructural definitions of drought rooted in the 1920s and 1930s. As argued in Chapter 3, reservoirs function as a buffer against single dry years, and they have fundamentally changed the relationship between water, time of year, and water usage. However, when California experiences a second dry year, the driving measurement is runoff. It is the root of water year classifications, which are predicated on a pre-infrastructural definition of drought. When those conditions appear again, as defined by runoff, the conditions are defined as a drought.

The 2001 – 2002 dry period was not declared a drought, and it illuminates this pattern further and suggests the persistence of pre-infrastructural definitions. Runoff levels were at 55% and 75% respectively – very close to levels seen in other declared droughts (California Cooperative Snow Survey 2001, 2002). However, reservoir storage never dipped below 100% in either year, shielding most of California's economy from the impacts of a relatively intense dry season. With reservoirs in good condition and runoff not dropping below 40%, a drought is not declared in part because the conditions of the 1929 – 1934 drought were not met.

The patterns of measurement and drought declarations show how epistemic path dependencies and material path dependencies come together to shape drought declarations in California. The material infrastructure built in the 1970s and 1980s in response to drought shaped drought as a scientific fact by reworking relationships between time, place, and

---

[52] On February 1, 1977, reservoir storage was 60% of average (California Cooperative Snow Survey 1977)

consumption. But the understandings of drought that were forged in the pre-infrastructure years persisted as well. The thresholds in place today are based on definitions of drought derived from the first half of the 20th century, and those definitions are proving to be relatively intractable.

Conclusion

In this chapter, I use reiterated fact making to examine important water measurements that define drought in California by tracing epistemic path dependencies and giving some consideration to conditions of possibility. One condition of possibility that I briefly touched on was meteorology's interest in understanding drought as a scientific fact. This interest resulted in the first effort to create a drought index that embeds certain definitions of drought into scientific measurements. In my examination of the Palmer Drought Severity Index (PDSI), I show how climate scientists attempt to separate out physical measures of drought from its social impacts, and the extent to which that process is challenging. The process was challenging in large part due to the standardization of conditions and time frames across diverse hydrological regions. The reliance on collected data limited the index's applicability, and it did not achieve the goal of predicting when droughts begin and end. But it was well received, and the PDSI shapes drought indices and definitions still today.

I also argue that definitions of drought from the pre-infrastructural period of the 1920s and 1930s function as an epistemic path dependency and still shape definitions today. These conditions inform definitions of drought through two different management tools: runoff measurements and water year classifications. The definition of drought from this dry period is embedded and re-embedded in water measurements over the last seventy years.

Runoff is a calculation that was initially developed for water planning and management, not to define drought conditions. The measurement assesses the amount of water "running off" across the state from precipitation that can be captured and stored in reservoirs. Although the amount of water actually available is measured by “impaired” runoff, it is not the measurement that is used. Instead, water managers make use of “unimpaired” runoff to construct idealized, pre-infrastructural conditions to make predictions and management decisions. Runoff is used today to calculate how much water will be available for consumption, and it is used to craft unofficial thresholds for defining what water conditions constitute a drought. The cutoff for drought conditions is based on pre-infrastructural dry periods, which define drought today.

Similarly, water year classifications categorize a given year based on how wet or dry they are. This system too is based on a drought that occurred from 1929 – 1934. The classification system was initially made to manage salinity levels in the Sacramento-San Joaquin Delta, rather than define drought. However, by articulating a cutoff for "critical" years, the system inadvertently defined drought based on the conditions from pre-infrastructural levels, while simultaneously embedding infrastructure's storage capacity in the calculations themselves.

These epistemic path dependencies form thresholds for drought declaration. These thresholds are articulated both in official reports and by reviewing the measurements at times of declaration. However, they are not uncontested nor are they formalized. For all the monitors, reports, and organizations that focus on water conditions in California, there is no level of runoff or no single water year classification that will flip a switch and automatically designate a drought status. It is surprising, but not unexpected. Drought declarations are deeply unpopular, and there is contention between different groups of experts and stakeholders over when a dry season is “really” a drought. This contention is examined in the next chapter where I focus on the networks of experts and stakeholders who have been grappling with drought for the last fifty years. These networks have shaped and will continue to shape drought as a fact and drought as a political declaration. So, I spend the last empirical chapter examining these networks and how changes to the networks shape changes in drought.

Portions of Chapter 4 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

CHAPTER 5: CHANGING NETWORKS OF EXPERTISE

Introduction

In 1976 – 1977, California experienced a record-setting drought. The drought was discussed by many people in many places – press releases, newspaper articles, government reports, water rate increases, and letters from concern citizens just to name a few. Most discussions centered on rain and snow – or lack of it – grounding the drought in a lack of precipitation. In reports assembled by the United States Bureau of Reclamation (USBR), United States Geological Survey (USGS), and the California Department of Water Resources (DWR) figures representing the drought included tables of numbers and bar graphs showing percent of average or numbers of runoff. The drought was also represented geographically, giving water users and water managers across the state a picture of what the drought "looked" like on paper (California Department of Water Resources 1978). The map laid out the hydrological regions of the state; labeled important rivers; and identified cities. Super-imposed on these geographic details is a gray area, indicating the regions state that received lower than 60% precipitation during the drought's first year. This depiction of drought is simple, but to the point. Areas of the state – concentrated in the Central Valley and Northern California –are not getting nearly the expected amount of precipitation. In 2012 – 2016, water users and managers can access a similar map of drought conditions, but with far more detailed information.

In the intervening years, climate scientists, social scientists, and stakeholders have continued to research and grapple with drought. Some things remain the same – drought is still a lack of water that impacts social life. It is still a disaster the spreads across a geographic space, impacting spaces within California differently.

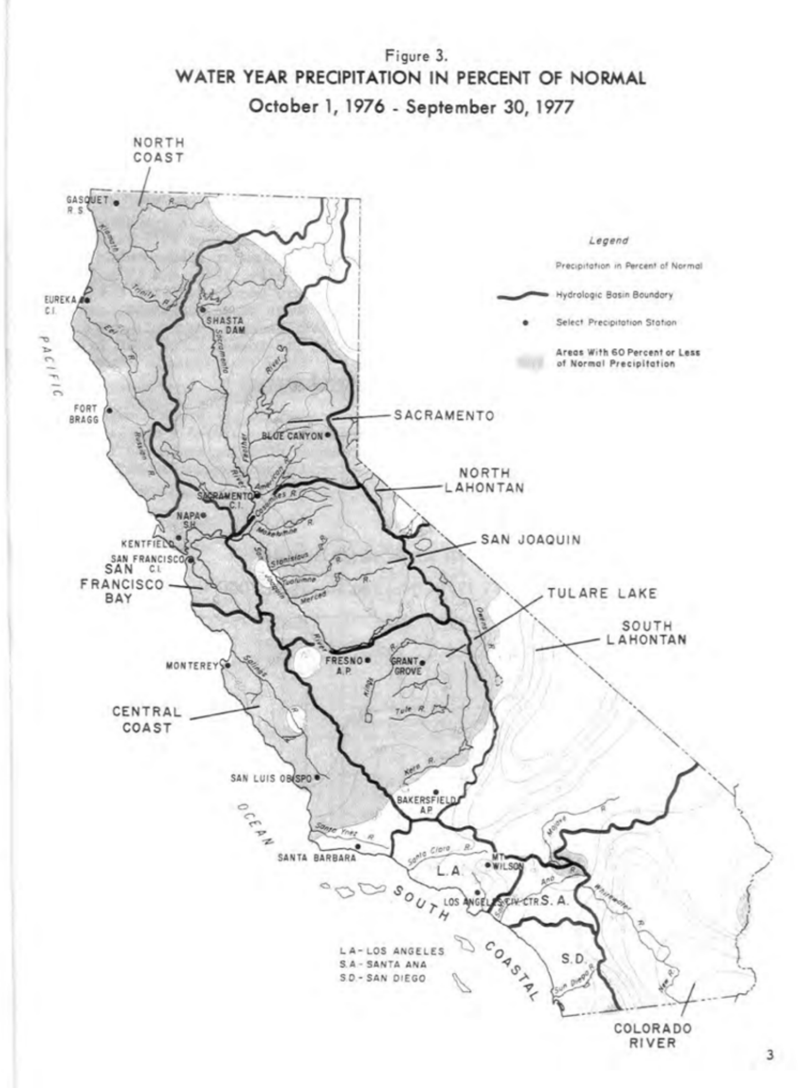
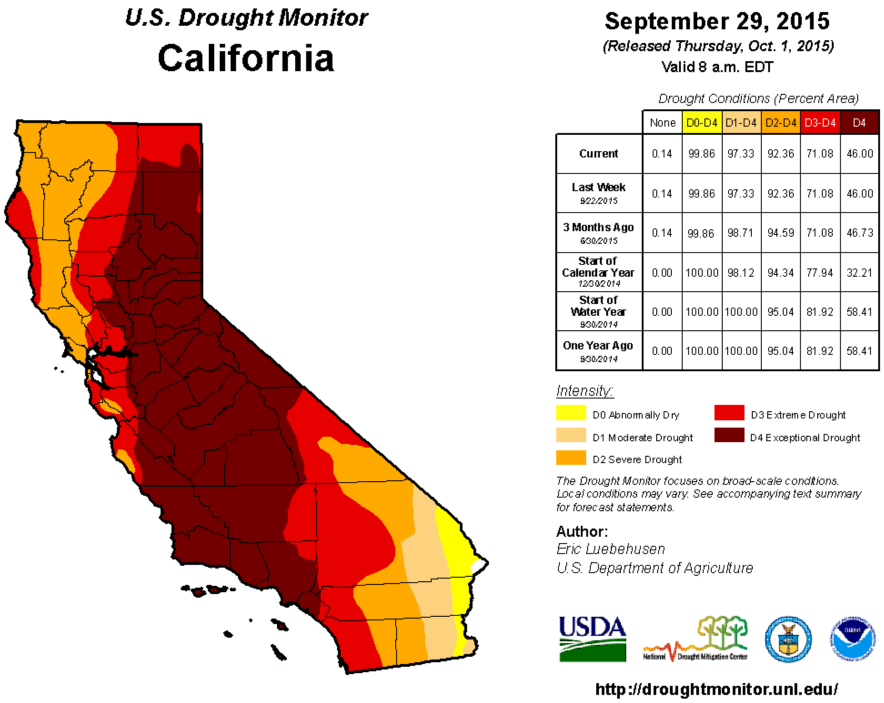


Figure 5.1: Reproduction of "Water Year Precipitation in Percent of Normal" from Department of Water Resources Special Drought Report, 1976 – 1977, p. 3

But the experts and tools involved in studying and representing drought have changed dramatically. Figure 5.2 is a snapshot from the US Drought Monitor – a tool which will be discussed in more detail later in the chapter. The state's shape is still the same, and the counties are still demarcated. Gone are the gray scale colors and the focus on percent of average. The image is from the end of the 2015 Water Year, and it shows 46% of the state as category "D4" – experiencing extreme drought conditions (Luebehusen 2015). Instead, we see drought categories designating severity mapped across the state – communicating more about the drought than in previous times.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.14	99.86	97.33	92.36	71.08	46.00
Last Week 9/22/2015	0.14	99.86	97.33	92.36	71.08	46.00
3 Months Ago 6/30/2015	0.14	99.86	98.71	94.59	71.08	46.73
Start of Calendar Year 12/30/2014	0.00	100.00	98.12	94.34	77.94	32.21
Start of Water Year 9/30/2014	0.00	100.00	100.00	95.04	81.92	58.41
One Year Ago 9/30/2014	0.00	100.00	100.00	95.04	81.92	58.41

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Eric Luebehusen
U.S. Department of Agriculture

http://droughtmonitor.unl.edu/

Figure 5.2: US Drought Monitor map of California from September 29, 2015

Over the last sixty years, drought has transformed from a lay category and social problem into a scientific fact. We can see this transformation in the emergence of climate science expert knowledge around the causes and physical impacts of drought.

In this chapter, I focus on the network of experts, stakeholders, and their tools built up around drought as a scientific fact over the last sixty years. The central empirical questions of this chapter are as follows: Which experts define and study drought? How do different experts represent drought? What stakeholders are invested in defining and declaring drought? How do each of these groups shape definitions and declarations both in terms of their own interests and through their interactions? How are these different – and sometimes conflicting – interests worked out in the process of drought declaration? In answering these questions, I show how experts and stakeholders shape facts through representations, definitions, and advocacy. I also show how the relationship between different groups of actors change when the fact at the center is already well established as a lay category.

To answer these questions, I again make use of reiterated fact making to build on the insights of actor-network theory (Latour 2007; Latour and Woolgar 2013) and networks of expertise (Eyal 2013). With this framework, I examine the networks of scientists and stakeholders built up around drought from 1960 until today. The chapter is divided into two sections. The first half focuses on the members and tools in the network built up around drought, and it traces how new groups and new tools enter into the network. The second half focuses on how the changes in the network play out across the four major California drought declarations.

In the first half of the chapter, I lay out the networks of scientific and lay experts built up around drought and it changes over the decades. I start with the pre-1960s networks of engineers, agricultural stakeholders, and water managers, and I examine their intellectual commitments, interests, and the tools and measurements that correspond. Then, I examine the new communities of scientific and lay experts enter the network as well as the changes to tools and measurements from the 1960s through the 2010s. In the chapter's second half, I examine the four drought declarations, laying out how the tools developed by climate scientists do (or do not) shape the four historical drought declarations in California and how different interests and water users shape them as well.

Literature

There is a long history of studying facts in science and technology studies and the sociology of knowledge. How do facts emerge, circulate, and even how fall out of favor with the emergence of new facts (Kuhn 1996; Merton 1938, 1942, 1973)? Central to these studies are the networks of human and nonhuman actors that make these facts discoverable, legible, and movable between spaces (Frickel and Gross 2005; Frickel and Moore 2006; Jasanoff 2004). Actor-Network Theory (ANT) is an approach that shows how the arrangement of tools, researchers, laboratories, advocacy organizing, and funding sources make it possible for a fact to be stabilized and circulate between communities (Latour and Woolgar 2013). And more recent work on expertise leverages a network arrangement to examine the actors, tools, representations, and processes that constitute expertise as an act (Eyal 2013).

Latour and Woolgar's 1986 study of laboratories and the discovery of scientific facts was a foundational study in the formation of ANT (2013). By taking an anthropological approach, Latour and Woolgar demonstrate how scientific research in labs is not about discovery, but about inscription. Measurements are inscribed into written documents, which become durable and transferable representations of a phenomenon. These representations are material and deeply important to the network of actors that make a scientific fact possible. These representations are also open to interpretation. Debate in the lab over the interpretation and representation of those measurements are key processes in stabilizing a fact as disagreements are "worked out". This use of ANT shows how the tools and material are central to scientific knowledge and the formation of a fact. Over the last thirty years, ANT has been deployed to research a wide range of practices – from critical information systems and e-government in developing countries (Doolin and Lowe 2002; Stanforth 2006) to geography (Murdoch 1997) and sickle cell traits (Carter and Dyson 2015). The expansive work utilizing this approach demonstrates the complex and heterogenous networks that make the concretization and circulation of facts in our social world possible. It is also – however – a monster of a theory (Bruni and Teli 2007; Cooper 2008) and intentionally underdetermines what is an “actor” and notions of power (Callon 1999; Law 2014), making it somewhat challenging to wield in sociological analysis.

A sociological adaptation of ANT can be found in Eyal’s conceptualization of expertise as a network (2013). Previously, sociology research on expertise had focused on professions and the processes by which certain kinds of experts were able to carve out jurisdiction over certain tasks and problems (Abbott 1988). Eyal argues that sociologists should also attend to the process of assembling the networks of “objects, actors, techniques, devices, and institutional and special arrangements” (Eyal 2013: 864) that make expertise possible. This sociological adaptation of ANT opens up examinations of “expertise” to all who can claim expertise (not just “experts”) and the material elements of a network that make expertise possible. It adds more dimensions to the historical analysis of expertise which make a more nuanced and dynamic assessment of power possible. Reiterated fact making – as explained in the introduction – utilizes Ludwik Fleck’s notion of thought communities and esoteric-to-exoteric knowledge (Fleck 1981) to build on the conceptions of networks as discussed by scholars of ANT and expertise to examine the life course of a fact.

Reiterated fact making utilizes the concept of networks of expertise as one axis of analysis to understand the continuities and changes that characterize a fact over time. Often in research on scientific facts and expertise, questions focus on how a fact emerges or falls out of use over time (Daston 2000; Foucault 1994; Kuhn 1996). Drought is quite different for two reasons. First, there is little debate about whether or not drought is important or if it exists out in the world. Second, drought did not begin its life as an esoteric fact in a laboratory – it has been cited as a social problem for millennia. I want to be clear that I am not arguing that other scientific facts articulated in labs do not map on to social groups or problems that have existed for centuries. For example, Navon's (2019) examination of genetic mutations and how they are taken up and mobilized by advocacy groups is a clear demonstration of how an esoteric fact comes to map on to pre-existing social groups, and both the fact and people are changed in the process. The discovery of a genetic mutation did not "create" mutations in human populations. However, drought remains distinct in its trajectory. It was not a process of discovering dryness in a lab and seeking out its reference in the world outside the laboratory.

The chapter's empirical questions paired with reiterated fact making's frame raise the following theoretical questions: How do experts and stakeholders shape facts through representations, definitions, and advocacy? How does the relationship between different groups of actors change when the fact at the center is already well established as a lay category? To answer these theoretical questions and their empirical counterparts, I need to understand which communities of expertise are doing research, publishing reports, and called on as "experts" in discussions of drought. I also need to know tools are utilized to produce knowledge about drought and create representations of drought.

The data and materials used for this chapter were an array of government reports, scientific publications, newspaper articles, legal decisions and reviews, and stakeholder press releases. I began with the documents from state bodies like the Department of Water Resources and State Water Resources Control Board, so I could learn which measurements and figures are prioritized when representing droughts across the periods. These documents are DWR reports, meeting minutes, and project summaries from the different drought periods - including assessment reports that covered the entirety of each dry period. These "end of drought" reports provided retrospective definitions of drought for the various periods, providing me a starting place for exploring how those definitions are formed and change over time. I also utilized the reports published throughout the drought period assessing the ongoing conditions, as well as declarations from the governor's office. I read 1,008 newspaper articles early in my research process in order to understand what kinds of actors and stakeholders were shaping public discussions on drought. Here I found rich data on competing definitions and explanations of drought, and how they changed over time.

These data sources informed my understanding of which actors were most prominent or important from 1959 to 2016. In these documents, I found more attention given to climate science than environmental science when it came to defining, representing, and declaring drought. I suspect that this can be partly attributed to environmental science's focus on impact assessment rather than studying drought itself. The prominence given to climate science in these reports and in the area of drought research led to me examine the role of meteorological and climatological scientists in the network more closely than other experts, like environmental scientists and social scientists.

In this chapter, I argue that the networks of experts and stakeholders built up around drought shift and change over time. The shifts result in changes to definitions and representations of drought and thresholds of declarations[53]. The changes in drought's status as a fact are connected to the tools, interests, and efforts of different groups – from meteorologists to environmental advocates (see Figure 5.3 for summary). In chapter 4, I briefly discussed how a meteorological interest in drought was a condition of possibility for the emergence of drought as a scientific fact that could be measured by observing surface water storage. In this chapter, I delve deeper into the tools and methods climate scientists developed over the last sixty years to

---

[53] As a reminder from the introduction, I define these three terms in the following ways. Representations are depictions of drought through charts, tables, and diagrams. Definitions are operationalized thresholds that attempt to draw a line around what is a "drought" and what is "not a drought". Declarations are political proclamations of a state of emergency that use state power to designate actors, technologies, and spaces as being in a drought.

understand drought as a scientific fact and contrast it with the engineering understanding that preceded it. I also explore the networks of stakeholders and other water users built up around drought in California that climate scientists and tools over the same sixty year period. Then, I interrogate each drought declaration in California, showing how this heterogenous network of scientists, stakeholders, and tools changes over time and alters drought as a scientific fact and a social problem.

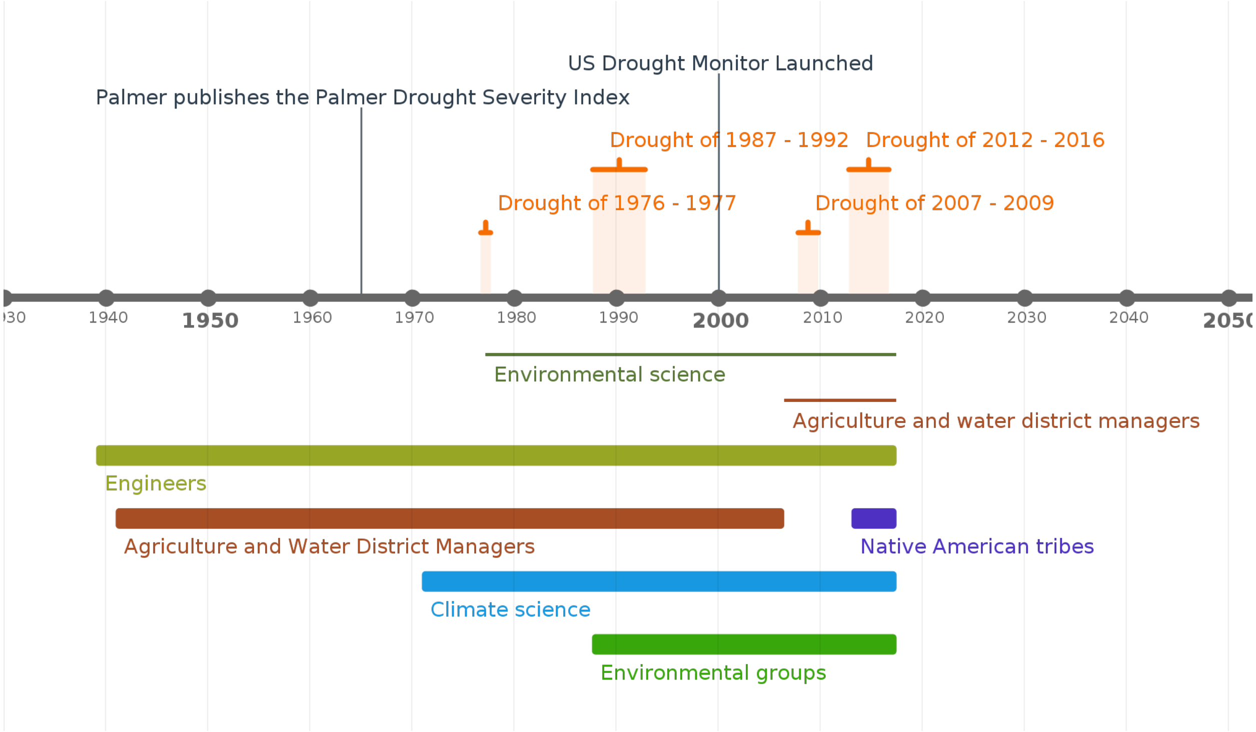


Figure 5.3: Summary timeline of communities, tools, and droughts

The changing network of scientific and stakeholder expertise around drought

As mentioned in the previous chapter, drought was a well-established lay category before it was rendered a scientific fact. Therefore, a network had already built up around drought as a social problem with experts, stakeholders, and tools in place to study and manage dryness. Scientists like meteorologists and climatologists would need to contend with this network with each innovation and new approach to drought. Additionally, new stakeholders would need to contend with the established interests of agriculture and water management. New communities of scientists and stakeholders bring with them new commitments and new tools and measurements for engaging with drought. In this section, I focus on the communities of expertise that enter into the network from the 1960s through the 2010s. I begin by describing the networks of engineers, agricultural stakeholders, and water managers that existed before the 1960s. Then, I describe when new sets of experts entered the network and changed drought as a fact through their different intellectual and social commitments and their corresponding tools and measurements.

Pre-1960s networks: Engineering, agriculture, and water management

California's network of expertise built up around drought before the 1960s is held together by water management practices. Engineers are the prominent scientific community concerned with drought, and they bring their commitment to "controlling" water through the construction of infrastructure projects. Their tools are measurements of surface water like precipitation and runoff that provide a picture of surface water conditions, so the surface water can be managed. Agricultural stakeholders and water managers in turn bring their interests in economic development and access to stable water resources throughout the year. Agriculture stakeholders and water managers make use of engineering tools to measure drought, focusing on water availability how it shapes their economic wellbeing and decisions. In turn, agricultural stakeholders and water managers shape drought definitions by emphasizing their economic interests and the broader economic wellbeing of the state.

Engineering and drought as a hybrid social and physical problem

Engineers were concerned with water management, and therefore they were connected to drought. However, studying the physical aspects of drought separately from their economic impacts was not a priority, in part because it was seen as impossible. The engineers were often hydrologists or geologists working at the USBR or state agencies. From papers written by engineers in the 1930s, we can see that engineers saw drought as an aspect of a larger water problem, mostly relating to storage (Hoyt 1936). Engineers certainly recognize that drought is tied to the weather of a region, but engineers did not view that connection as possible or worthwhile to study. John C. Hoyt[54] laid out why engineers at the time believed drought was difficult to study: "Although deficiency in precipitation is the prime cause of drought, it is not possible to set for any region an exact limit of the total annual precipitation above which a drought does not exist and below which a drought may prevail" (Hoyt 1938: 2). Below, we can see the representation of drought by Hoyt from the same report (Figure 5.4).

The maps feature maps displaying states experiencing drought conditions (colored in gray) across different drought periods. At the time, engineers with the USBR and California state government believed it was impossible to determine what an "average" amount of precipitation would be or to devise a threshold for drought's existence, which makes studying the physical elements of drought very difficult.

---

[54] John C. Hoyt was the chief surface water engineer for the Bureau of Reclamation in the 1920s and 1930s (Department of the Interior 1920; Hoyt 1944). He put together numerous reports on drought in the Western United states with a series focused on California specifically.

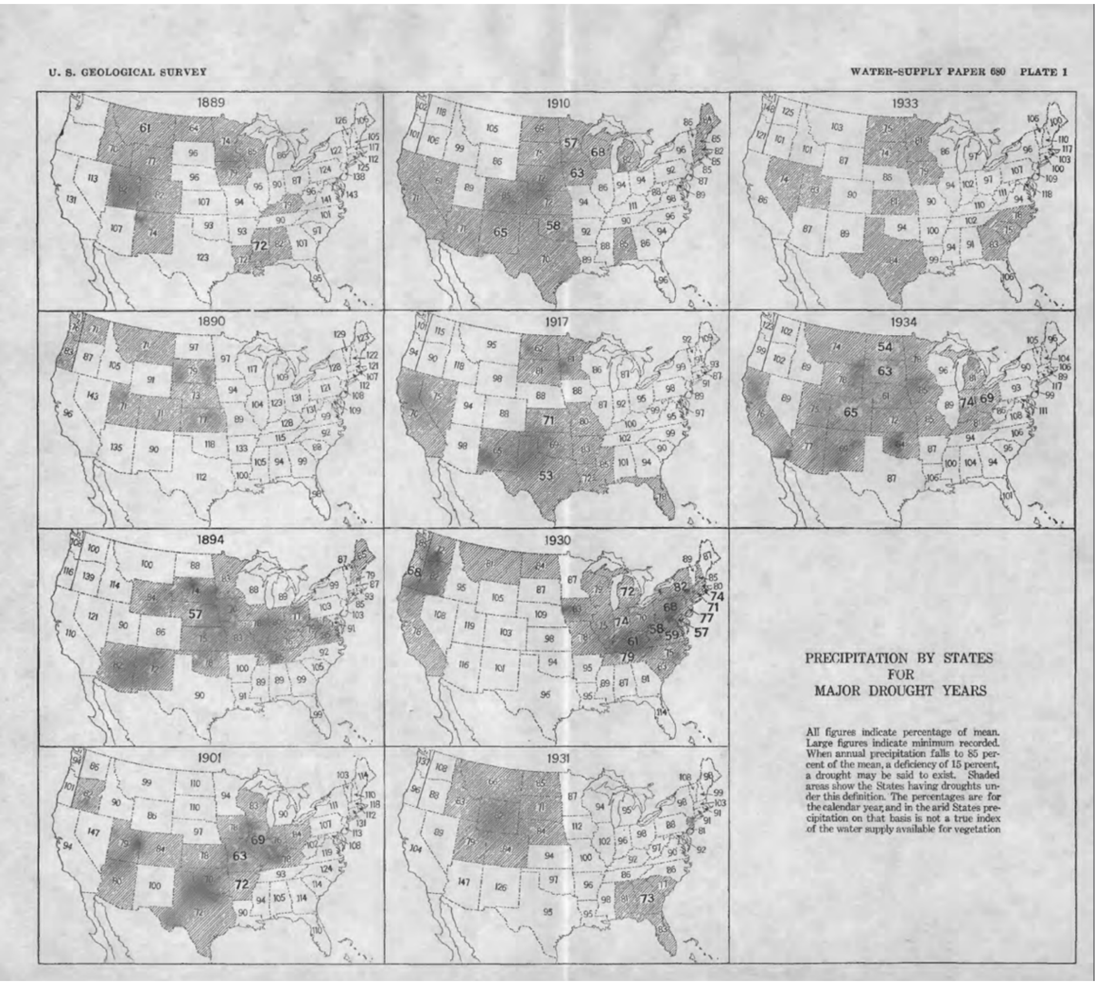


Figure 5.4: Plate 1 from "Drought of 1936, with discussion on the significance of drought in relation to climate" by John C. Hoyt (1938: 4)

In fact, the social elements of drought are still the most dominant concern. Engineers like Hoyt in the USBR or the California state government are careful to differentiate between the physical characteristics of drought and the economic effects, specifically damages. Hoyt writes that drought "may be considered either as natural phenomena or as economic phenomena – usually both – and it is therefore essential in drought studies to take into account not only physical data but also information as to the extent and nature of human activities in the area affected" (1938: 2). Before 1960, drought was seen as most importantly a social problem that caused disruption to economic functioning in civilization. Indeed, separating the physical and social elements of drought was discouraged, even seen as ineffective. The economic impacts are still centered, and a purely scientific approach to drought is openly identified as an impossibility. By 1960, climatologists and meteorologists would work to disprove this position.

Agriculture and water district stakeholders

In California, agriculture was and continues to be a dominant economic force in California. As discussed in Chapter 3, agriculture helped drive the construction of the Central Valley Project (CVP) as a public works project in the 1930s, and today agriculture still uses approximate 80-85% of surface water allocated for businesses and homes (California 2022; Hanak and Mount 2019). Pre-1960s, drought was seen as a disruption to the agricultural sector, and farmers and ranchers had a lot of power over definitions and their advocacy influenced drought declarations, in part due to the focus on the economic impacts in drought studies at the time. Growers and ranchers exert this influence through professional organizations like the Cattlemen's Association, the California Growers Association, and California Farm Bureau Federation. These advocacy groups shaped aid thresholds set by the state and federal government, determining when dry conditions switched over to droughts and opened up the possibility for financial aid (Stafford 1990). During the decades from 1960 – 2017, agricultural interests did not remain stagnant, leading to shifting needs and new advocacy organizations. Since 1993, the acreage for planting permanent crops like almonds and wine grapes has nearly doubled (Jones 2020, 2021). Crops that grow on trees or vines – like avocados, citrus, and wine grapes – led to increased reliance on regular water supplies. It also resulted in the prominence of new professional organizations like the Central California Almond Growers Association, Almond Board of California, and the California Association of Winegrape Growers, emerging to advocate for the growers' interests. The changes in crops put new strain on water managers – our final group of pre-existing stakeholders.

The second group of actors already operating around drought are water managers. Water managers is a category I use to refer to human decision-makers that work within water districts or water agencies which can be either public or private[55]. Water district managers are central to the network built up around drought pre-1960s for several reasons. Water districts financed and supported large infrastructure projects across the state; they procured water rights; and they act as "brokers" alongside the infrastructure of their districts (Daipha 2015; Giglioli and Swyngedouw 2008; Meehan 2014) by connecting water users. For these reasons, water managers are positioned to have a lot of power in defining drought. This power looks like raising costs of water, enforcing urban conservation, and deciding how to utilize the allocations received from State Water Project (SWP) or CVP. Water managers belong alongside state engineers and agriculture stakeholders in the "pre-climate science" network arrangement because they drive a huge amount of growth across the state, but especially in Southern California and the Bay Area.

Before the 1960s, the network of expertise built up around drought was centered on California's economic development and managing water resources. Rather than studying the physical elements of drought, engineers, agricultural stakeholders, and water managers were interested in measuring surface water for the sake of capturing, conserving, and conveying it to prevent negative economic impacts during dry years. The tools used by each of the different

---

[55] I do not distinguish between public and private agencies in this dissertation because the position of water managers in the network and their interests in relation to drought do not vary between public and private organizations. Additionally, research has found that the state takes a more prominent role in advocating for water conservation, so the differences between public and private to users and actions in minimal (Kallis et al. 2010; Sowby 2018).

communities reinforced drought as a lack of water for specific purposes. At this time, those purposes were primarily growing crops, watering grazing land, and expanding residential and business developments. In the 1960s, climate scientists would bring an interest in the meteorological components of drought separate from the economic impacts.

1960s and 1970s: Climate and environmental sciences

As mentioned in the previous chapter, a key force in shaping drought as a scientific fact was that a scientific field took an interest in it. Meteorology and climatology experienced increased prominence during and after WWII, creating the conditions for such an interest (Baker 2017; Edwards 2010). These scientists brought with them increased funding, computing power, and a stronger foothold in governance and basic science[56]. Additionally, climate scientists bring into the network a commitment to understanding weather and atmospheric phenomenon on their own terms, rather than the presence and management of surface water. A set of tools for studying drought from this perspective are drought indices. These indices directly confront the limitations outlined by engineers in the 1930s by determining what an "average" amount of precipitation would be for a given region by using the data accumulated over the last few decades. I start with the first and most impactful index, which you are already somewhat familiar with – the Palmer Drought Severity Index. Then, I briefly review the proliferation of drought indices as a tool for understanding drought and what that means for it as a scientific fact as meteorologists and climatologists became more secure in their expertise and jurisdiction over drought as a problem.

---

[56] Questions of *why* and *how* meteorology and climatology became positioned in academia and government to undertake basic research on subjects like drought after WWII are beyond the scope of this dissertation. See the works by sociologist Zeke Baker (Baker 2017, 2021) and historian Paul N. Edwards (2010)for deeper explorations of the development of these fields and climate science more generally.

Palmer and the proliferation of drought indices

With the creation of Palmer's Drought Severity Index (PDSI), drought became a scientific object in the fields of meteorology and climatology. Generally, drought was seen as a period of less than normal rainfall, leading to dryness that disrupted the normal functioning of an area (Blair 1942; Blumenstock 1942; Great Britain Meteorological Office 1962; White 1955). Wayne Palmer took important steps to apply parameters and values to define "normal" and to define levels of drought that is "prolonged and widespread" (Palmer 1965:5). The PDSI managed to do this by incorporating two indicators – precipitation and evapotranspiration – into a single index that represented relative dryness on a scale from -10 (dry) to +10 (wet). This first drought index was widely accepted[57]. With the creation of a meteorological representation of drought, the definition of drought changes. Drought is now more than a problem of economic disruption that can be solved with engineering. Palmer's index roots drought in measurable month- to year-long periods of abnormal weather leading to dry conditions. Because Palmer's first index was so successful, more meteorologist and climatologists begin to develop them, proliferating the measurement style. In turn, this means a build-up of databases and practices in relation to this approach to drought.

Since Palmer's publication, the number drought indices expanded as different aspects of drought were formalized through numeric representations. Drought is a complex phenomenon, so new indices could focus on different aspects of drought. Palmer utilized two indicators of dryness - precipitation and evapotranspiration, but a plethora of other indicators could be taken up and incorporated into a new index. Which is exactly what happened. As of 2011, over 110 drought indices had been proposed or put into practice (Zargar et al. 2011). Broadly, indices

---

[57] The report has been cited over 6000 times, and its importance is unrivalled among the early scientific works on drought in the American West (Heim 2002).

attune to the following three physical measurements of drought: meteorological, agricultural, and hydrological[58] (Narasimhan and Srinivasan 2005; Oladipo 1985; Sheffield et al. 2004; Shukla and Wood 2008). Additionally, they may attend to duration, magnitude, intensity, severity, geographic extent, and/frequency (Hayes et al. 2011; Mishra and Singh 2010; Svoboda et al. 2016). The proliferation of indices demonstrates how the complexity of drought makes it difficult to wrangle into a neat measurement, but it also shows how its complexity provided multiple avenues for wrangling it, utilizing a similar logic.

Although drought indices utilize different indicators and focus on different outcomes, they share a very similar structure and process. Figure 5.5 summarizes how indices are different yet similar across typology. Most indices key into one of the three "sections" of drought as seen above, using various indicators that speak to different physical variables. Different physical indicators are more tightly associated with meteorology, hydrology, and agriculture. But each index incorporates some kind of physical variables to create parameters for dryness and wetness. For example, the Crop Moisture Index (CMI) attends to agricultural drought by measuring compounding evapotranspiration (increased dryness) alongside wetness on a scale from -3.0 to +3.0 (Palmer 1968). These indices shape definitions and studies of drought because they pull attention towards specific data sets. It also shows how the pre-existing network still shapes definitions of drought. There is not simply meteorological drought in discussion but agricultural and hydrological as well. The development of indices responds to the needs of stakeholders like

---

[58] According to the National Drought Mitigation Center at University of Nebraska, meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period; agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, etc.; hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater).

growers and water managers. These actors make use of indices to make decisions about drought, demonstrating the power of this representation.

Zargar et al. 335

Fig. 1. The general sequence for the occurrence of different drought types. Modified from NDMC (2006*b*).

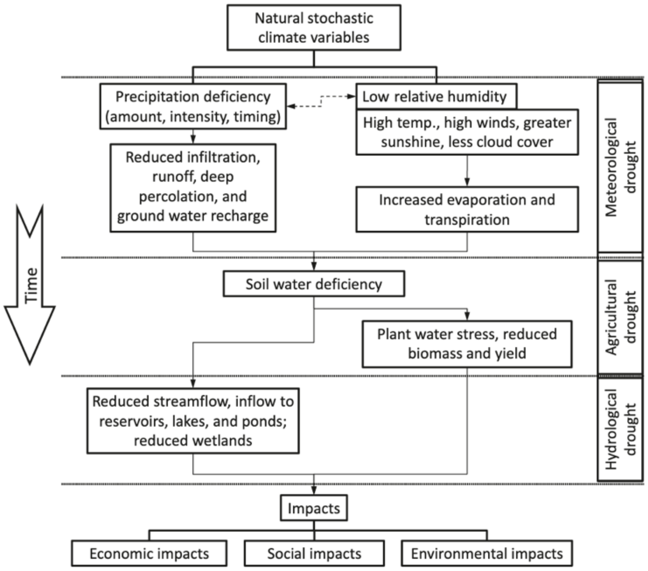


Figure 5.5: Reproduction of Figure by Zarger et al. (2011: 335), "The general sequence for the occurrence of different drought types"

Drought indices that capture complex hydrological, meteorological, and climatological phenomenon speak to the needs of stakeholders that confront the consequences of drought. Indices can be used for drought detections and real time monitoring (Niemeyer 2008); declaring the beginning or end of a drought (Tsakiris et al. 2007); managerial declarations of drought level and begin response measures; evaluation (Niemeyer 2008); representing drought in a region (Tsakiris et al. 2007); correlating with impacts over time and space; and facilitating the communication about drought conditions. There is pervasive need for clear snapshots of current water conditions, as well as communication tools that could be used by stakeholders like farmers and water agencies. Indices are critical to drought early warning systems (DEWS), although they are not infallible. These indices are seen as a solution to the "creeping" problem presented by drought. They do so by providing real time assessments of a potential problem, although they still require interpretation (Best 2012). It is still difficult to neatly quantify a complex meteorological phenomenon. And many stakeholder groups who deal directly with drought impacts often find indicators confusing and not as useful to them and their needs (Bachmair et al. 2016; Steinemann, Iacobellis, and Cayan 2015). However, they still remain the preferred tools given the limited alternatives to monitoring and tracking drought.

Environmental science and non-economic drought impacts

Alongside climate science, environmental science expanded its influence since the 1960s and became embedded in the network around drought. Environmental scientists – most within the California State University and College system (CSUC) system – operate at the intersection of water, sustainability, and ecology (Dunlap and Michelson 2001). In relation to drought, the discipline brings with it a commitment to understanding how drought years affect crops, waterways, wildlife, and more. This commitment means developing new methods and tools for tracking conservation efforts, new irrigation strategies, and methods of groundwater monitoring, to name a few. The pathway into the network was through enlistment in research projects by the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB). Environmental science existed as a discipline withing the CSUC, and the state government was able to call on the CSUC system to provide research and evidence for the degradation of places like the Bay-Delta[59] (Governor's Drought Emergency Task Force 1977; Mills 1977). Rather than developing tools to measure and represent drought as a scientific fact,

---

[59] The specific projects will be discussed more in the section concerned with the 1976 – 1977 drought.

environmental sciences studied dry season impacts, developed tools for more effective water use, and strategies for drought mitigation.

These two shifts in the network altered drought by making it possible to engage with it as a scientific fact. Drought indices were a critical step towards disentangling the social and physical elements of a drought. While indices cannot capture every element of drought in a single number, they offer a method for engaging with the physical elements of a drought on their own terms. The tools and approaches offered by climate science translate the messiness of drought into neat negative numeric representations that communicate severity and duration with greater ease than maps of precipitation averages did previously. Climate science's commitment to weather and other atmospheric research grounds drought in weather patterns rather than in surface water storage alone. Additionally, the inclusion of environmental science frames the impacts of drought in scientific as well as economic terms. Drought's affect on ecosystems - not just agricultural spaces - becomes a concern of state bodies through the enrollment of university researchers. The changes to the network opened up space for more innovations from climate scientists and new stakeholders in the form of environmental activists.

1980s and 1990s: Causal explanations of drought and the environment as a stakeholder

During the 1980s and 1990s, climate scientists develop causal explanations of drought, which fall in line with a commitment to understanding atmospheric and meteorological components of drought on their own. Rather than stopping at defining drought based on lower precipitation, causal explanations of drought attempt to uncover what causes the lack of precipitation. During this period, we also see lay communities concerned with the environment enter the network. Building on the work of environmental sciences, environmental activists were committed to expanding stakeholders to include the environment itself. They utilize legal pathways to enforce environmental protections and redistribute water resources to include the environment as a stakeholder on equal footing with agricultural stakeholders.

Causal research on drought

Drought has always been connected to weather patterns, with each definition focused on a lack of precipitation relative to the area. The growth of climate science and climate tools made it possible to move even further beyond precipitation and its relationship to the atmosphere, as we can see in indices and models. The root causes of drought are also interesting to climate science researchers. Previously, it was not possible to connect the lack of precipitation to larger atmospheric phenomena or patterns, but further improvements in satellite technology and processing abilities opened up those possibilities. These causal explanations are consequential because they move the economic and social elements of drought squarely into the "impacts" section. No longer a core element of drought itself, they are the outcomes of atmospheric phenomena. Causal explanations locate drought within more expansive and long-term weather patterns, delineating its cause further in nature rather than something that is produced through interactions. One causal explanation offered by meteorologist and climatologists that shape drought in California is the "El Niño-Southern Oscillation" phenomenon.

The El Niño-Southern Oscillation (ENSO) phenomenon[60] is linked to weather patterns in California, specifically patterns of wetness and dryness. But like all weather predictions, the connections between this larger patterns and specific droughts are not perfect. ENSO conditions

---

[60] It is reported that the term "El Niño" comes from the Spanish speaking fishermen in Ecuador and Peru to refer to the warm currents that would arrive in December. It was sometimes referred to as "El Niño de Navidad" due to its occurrence around Christmas time (Trenberth 1997; US Department of Commerce 2022). "La Niña" was later adopted to describe the opposite end of the oscillation.

describe a warming in the Pacific Ocean that brings wetter weather to the Southern portion of the United States but leaves the Northern portion dryer (Rasmusson and Carpenter 1982; Ropelewski and Halpert 1986; Wang et al. 2017). El Niño has a sister condition sometimes discussed as well: "La Niña". La Niña refers to the cooler end of the oscillation where colder water in the Pacific Ocean pushes north, which can lead to dryer weather in the southern half of the West coast and wetter weather in the North (Philander 1985). A "pressure" ridge forms near the top area of California, making it difficult for wet weather to move down from the Canada and Washington state. These two weather phenomena have led to a variety of outcomes in terms of precipitation. California's position along the West Coast also leads to mixed outcomes in terms of precipitation under either condition (Cayan, Redmond, and Riddle 1999; Patricola et al. 2020; Schonher and Nicholson 1989). But they provide observable weather patterns that can be used to target predictions for the cause of a drought, as well as the changes in atmospheric conditions necessary to end one.

The research and development of these explanations is important for understanding drought because it shows that it is possible to develop meteorological and climatological *explanations* for drought – moving beyond definitions alone. However, the explanations are not entirely satisfactory to the rest of the stakeholders connected to this social and scientific fact. The failure of research meteorologists and climatologists working on larger time scales (months and sometimes up to a year) to offer clear and understandable predictions continues to frustrate stakeholder.

Prioritizing the environment

Environmental activists engaged with drought as a scientific fact by bringing drought “out of the sky” to understand it “on the ground” (Kallis 2008). Environmental activists are committed to understanding the impact of drought and water management practices on California’s ecosystems and protecting those ecosystems through state law. Environmental activists were able to utilize the research conducted by environmental sciences to demonstrate the negative impacts on areas like the Bay-Delta.

Environmental activists entering the network dramatically changed drought as a fact by expanding the nonhuman actors considered in the network of drought. The environmentalist movement’s emergence in the 1970s is well documented (Dunlap and Mertig 2014; Gottlieb 2005; Jamison 2001; McLaughlin and Khawaja 2000), as well as its impacts on social norms (Dietz and Whitley 2018; Stern et al. 1999; Zelezny, Chua, and Aldrich 2000) and government policies (DeSombre 2000; Dietz, Dan, and Shwom 2007; Dryzek et al. 2003; Evans and Kay 2008). It is not groundbreaking to note that environmentalism had an effect on water governance in California, but it is less well understood how the movement exerted influence on drought as a fact and social problem. I will focus on how environmentalists from the social movement exerted influence through water policy and law in this section, then illustrate the impact across declarations.

Environmentalists are able to enter the network and shape drought through the legal system. This pathway is forged primarily through lawsuits that push back against a development mentality by leveraging new environmental regulations, like requiring environmental impact reports (EIPs) for new infrastructure projects. Major inroads were made in the 1970s through lawsuits filed by organizations like the Environmental Defense Fund, Sierra Club, Save Our

Shoreline, and other conservationist groups. These lawsuits[61] took the position that water districts and state counties had an obligation to perform thorough environmental impact assessments; consider reclaimed water; and account for downstream impacts and diminished water flows. It is important to note that this group of actors was also not a monolith. The environmentalists included both "classic" environmentalists who saw environmental conservation as a cause in and of itself, while others in this group were interested in preserving the environment for recreational enjoyment like fishing and boating. However, they all converged within the legal system to recodify water use and distribute water across more users. In this case, the users are non-human, like fish populations suffering from over pumping and ecosystems degrading due to salinity.

During these decades, climate scientists developed new explanations for drought, building on efforts in the 1960s and 1970s to examine the weather and atmospheric patterns associated with drought. In the 1980s, climate scientists developed causal explanations for drought, linking the ENSO conditions observed in the Pacific to weather patterns in the California region. The commitment to understanding drought scientifically, rather than socially and economically, locates drought up in the air rather than in the economy as in previous decades. At the same time, environmental activists used the legal system to gain the environment a seat at the table of water stakeholders, keeping some elements of drought "on the ground." By successfully including the environment in the network as a "water user", drought is positioned to change as a fact since the same amount of water would need to be used for more purposes.

---

[61] Some examples of such lawsuits are Environmental Defense Fund, Inc. v. East Bay Municipal Utility District; Environmental Defense Fund, Inc. v. Coastside County Water District; Environmental Defense Fund, Inc. v. Armstrong, 356 F. Supp. 131 (N.D. Cal. 1973). The Environmental Defense Fund was often a lead plaintiff on these cases as legal strategies were central to their conservation efforts.

These patterns of new tools to understand drought scientifically and new communities vying for access to limited supplies of water persists into the 2000s and 2010s.

2000s and 2010s: Drought monitors and tribal water rights

During the 2000s and 2010s, climate scientists successfully developed a new tool to represent drought - the US Drought Monitor. The monitor is a nearly-real-time map of drought conditions across the United States, and it incorporates multiple drought indices to produce its representations. It still relies on geographic representations to communicate drought, but it remains focused on physical properties of drought. During this same time period, Native American Tribes successfully use the legal system to assert water rights, bringing their interests more tightly into the statewide network around drought. Again, the introduction of more stakeholder interests changes drought as a scientific fact by reallocating a limited supply of water across wider purposes.

Drought Monitoring

The climate science approach to understanding drought is epitomized in the US Drought Monitor. The amount of data accumulated over the last sixty years and the creation of indices and models led to the development of a national “drought monitor”. The US Drought Monitor (USDM) produces a biweekly updated map of the contiguous United States, color coding dry conditions with different colors (Lawrimore et al. 2002; Svoboda et al. 2002). The amount of data available and the expanded network of climate scientists across the country makes it possible to undertake a near real-time monitoring of drought conditions across the country.

The USDM feels at once like a return to prior representations with its map-based display, but it communicates much more about drought than previous representations. The USDM is built on multiple decades of data gathered with the development of deployment of drought indices (Svoboda et al. 2002). The map generated on a weekly basis incorporates multiple measures of drought to produce a “snapshot” of drought conditions and severity across the USA. Below, you can see a snapshot of drought conditions across the United States the week I sat down to outline this chapter (Figure 5.6) contrasted with the week I completed a full draft of this chapter (Figure 5.7). Even without expertise on drought or climate science, you can likely tell what happened at a glance between these six months. Areas across the Southwestern United States went from a huge amount of scary, dark red colors to far less[62]. It is now possible to tell at a glance whether a region is experiencing drought and to what degree. Rather than a numeric representation or a harder-to-parse modeling output, dryness is now represented by color-coded drought categories mapped on to specific places.

---

[62] As of April 5, 2022, the map has once again changed – this time for the worse. Areas in California, Nevada, and Arizona have seen more severe drought conditions as a dry winter continued.

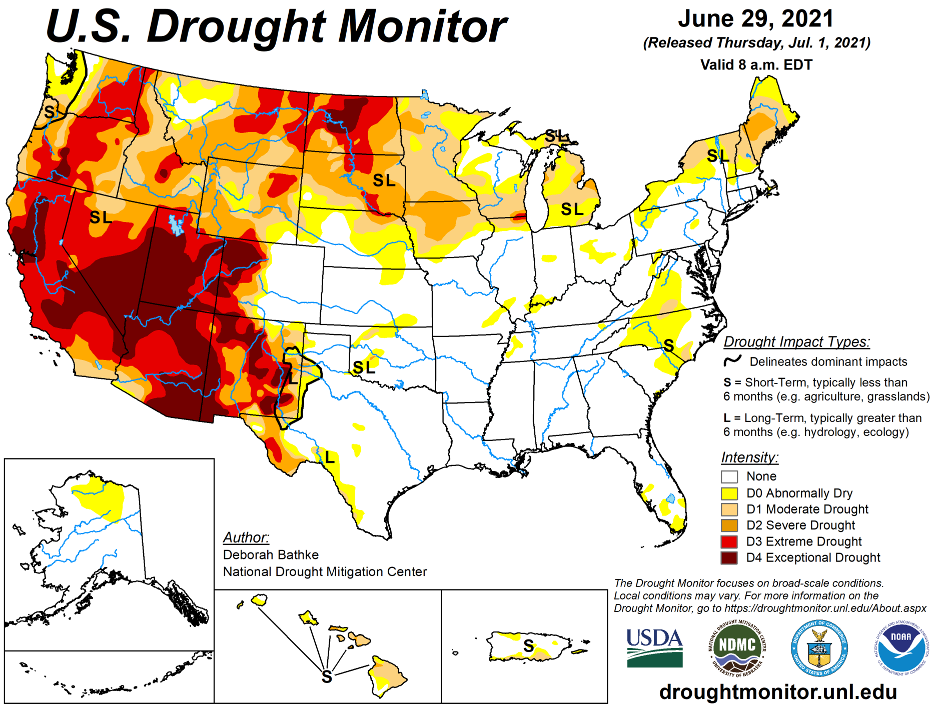


Figure 5.6: US Drought Monitor map of California from June 29, 2021

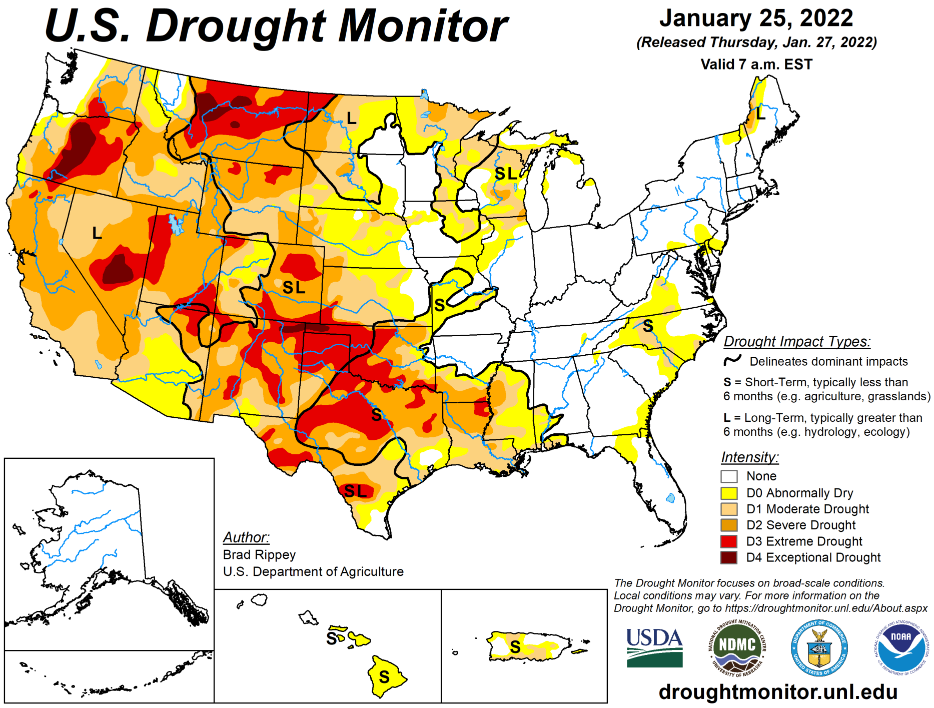


Figure 5.7: US Drought Monitor map of California from January 25, 2022

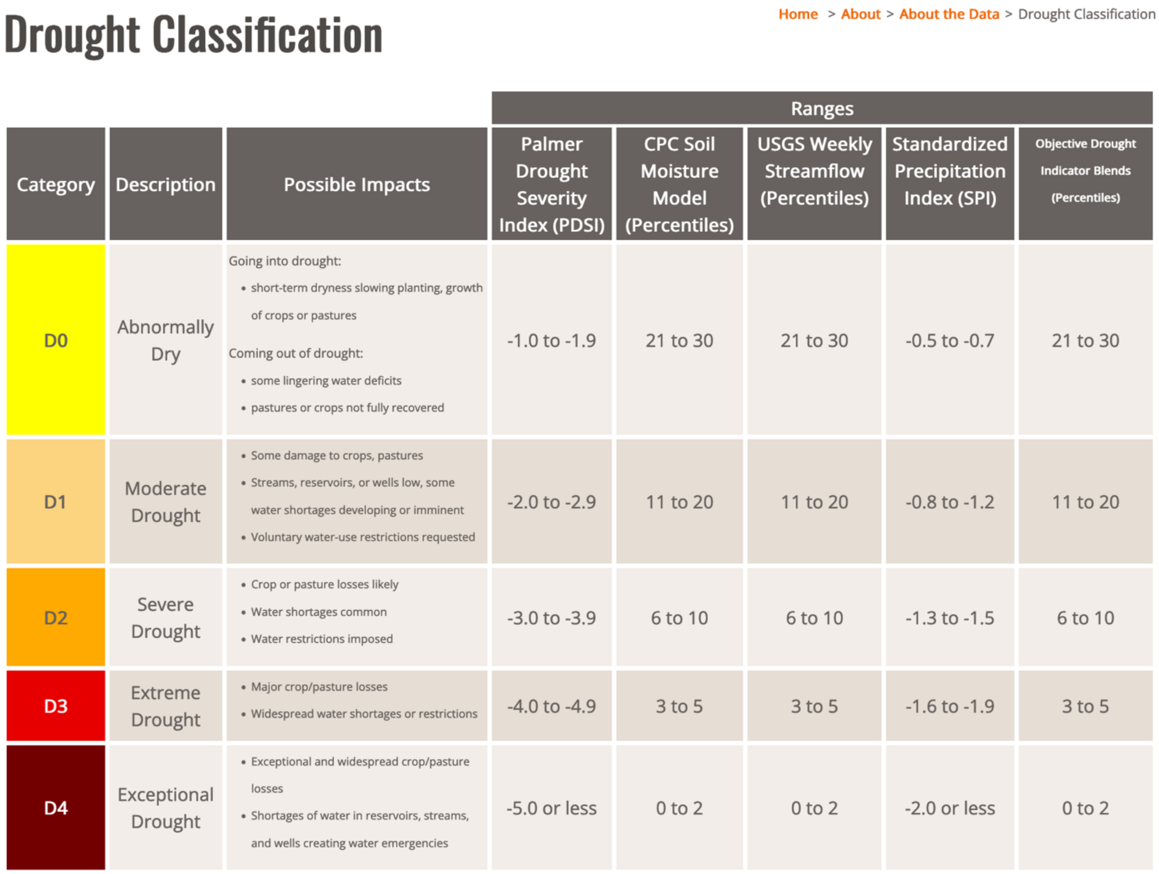
The categories are themselves complex models that incorporate a number of indices and variables. The five drought categories on the map range from an absence of drought (0) to exceptional drought (D4), making one "average" category and four levels of drought, moving from a blank white to a deep dark red (National Drought Mitigation Center 2022a). The cutoffs for these categories are determined by a blend of short- and long-term indicators with different ranges (see Figure 5.8 for full description). The "objective drought indicator blends" is a combination of other indices, and it went from an experimental option in 2018 to a validated category in 2022. The USDM also features a "impacts by state" option, where a user may choose a state from a drop-down menu (National Drought Mitigation Center 2022b). Then, the USDM maps specific outcomes onto the different categories based on historical data (see Appendix A for California's state-specific impacts). The USDM is quite spectacular, and it is only made possible by the network of experts who manage it and the citizen scientists who report impacts and improve its functioning.

The USDM relies on the work of different expertise located in government bodies and research centers at universities. The most prominent organizations responsible for managing the USDM are authors from the National Drought Mitigation Center (University of Nebraska), U.S. Department of Agriculture, National Oceanic and Atmospheric Administration, National Centers for Environmental Information, Western Regional Climate Center (Desert Research Institute in Nevada), and Climate Prediction Center (National Drought Mitigation Center 2022c). Each of these umbrella organizations have partners in other research institutes, agencies, and communities as well[63]. The expertise within the network is also wide-ranging. The USDM lists

---

[63] Take the Western Regional Climate Center (WRCC). The WRCC partners with land management agencies, fire preparedness groups, National Climatic Data Center, the Regional Integrated Sciences and Assessments branch of the Climate Program office and more.

the following subfields as necessary for the monitor's functioning: Climatologists, meteorologists, hydrologists, remote sensing specialists, agriculture scientists, biologists, natural resource scientists, and social scientists. The result of this broad collaboration is a relatively usable and impactful scientific take on drought.



Home > About > About the Data > Drought Classification

Drought Classification

			Ranges				
Category	Description	Possible Impacts	Palmer Drought Severity Index (PDSI)	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: • short-term dryness slowing planting, growth of crops or pastures Coming out of drought: • some lingering water deficits • pastures or crops not fully recovered	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7	21 to 30
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent • Voluntary water-use restrictions requested	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	• Crop or pasture losses likely • Water shortages common • Water restrictions imposed	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	• Major crop/pasture losses • Widespread water shortages or restrictions	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

Figure 5.8: US Drought Monitor Drought Classification Categories and Indicators

The irony of this complex system of measurements and experts is that it results in a simpler understanding of drought. Drought is rendered comparatively easily into a scientific fact where duration, severity, location, and variation are all incorporated into a visually gripping snapshot. Water conditions are easily communicated to stakeholders, who now have ample data to assess their region and the severity of a drought in a given moment of time, and the USDM cites a wide range of stakeholders who make use of the maps and data[64]. However, it still falls short of being incorporated fully into governance structures. Few (if any) local governments or tribes use the drought monitor as a "threshold." I have yet to find an example of a region that targets their water use and drought mitigation strategies to the USDM's color-coded map. But when placed next to Hoyt's doubts from a century ago, it is clear that experts have demonstrated that they *can* determine the physical indicators of drought.

These tools give us critical insights into how meteorologists and climatologists understand and study drought. Climate scientists entered the network with a commitment to understanding the physical properties of drought and how they connect to the weather and atmospheric patterns of a region. This commitment to discerning cutoffs and defining precisely what physical conditions constitute a drought resulted in numerous drought indices that quantify those physical conditions. The conditions of concern are precipitation, but they are also soil moisture, temperature, and the interactions between them. The US Drought Monitor brings together multiple indices, but it also makes them more intuitive and usable for stakeholders. The tension between climate scientists' commitment to understanding the underlying physical properties of drought and its atmospheric causes runs up against the pre-existing network of stakeholders. The US Drought Monitor encapsulates the drive to understand drought as a scientific fact with its many indices and calculations, while also representing drought in a legible, accessible map of varying shades of red.

---

[64] Local, state, and tribal agencies responsible for some of the following: Water & sanitation, public lands, public health, Parks, Natural resources & conservation districts, Natural hazards, Fire management, Extension, Environment, Emergency management, Fish & wildlife, Agriculture; Organizations and businesses: Water suppliers, Sports & wildlife organizations, River associations, Private businesses, Navigation industry, Intertribal associations, Irrigation associations, Forestry, Engineering companies, Dam & energy operations, Conservation groups, Agricultural trade organization; Individual water managers, agricultural producers, planners, students/academics.

Water Justice: Indigenous rights and tribal advocacy

The final group that enters the network around drought are tribes, predominantly in Northern California and the Colorado River Basin. The emergence of the Indigenous rights movements in the 1980s and 1990s is also well documented (Dean and Levi 2003; Dunbar-Ortiz 2015; Engle 2010; Healey 2014). The movement's successes and impacts are beyond the scope of this dissertation, but the intersection of indigenous rights and water rights is deeply important for understanding changes to drought in California. Indian tribes also leveraged the legal system to claim primary water rights, shaping drought as a fact by making promised allotments official and then leveraging those allotments for environmental and cultural protections.

Historically, Native American tribes have had paper water rights that they fought to have formalized and measured out. It has to be said that the "reentry" of tribes and indigenous peoples into the network around drought is the product of violent colonialism. Spanish colonizers, miners, speculators, government agencies and armies, among many others systematically denied tribes access to lands and water from the 16th through the 20th centuries (Claire and Surprise 2022; Dallman et al. 2013; Middleton-Manning, Gali, and Houck 2018; Woelfle-Erskine 2019; Yazzie and Risling-Baldy 2018). The structure of California's water rights system of land use and appropriative rights makes this exclusion is particularly egregious. The United States v. Winters Supreme Court ruling determined that tribes did in fact have prior water rights but said nothing amount or priority in relation to the rights of other, non-Indian, water users (Hundley 1982). The claims of individual tribes would need to be settled piecemeal in court proceedings.

Settlements in the Klamath River Basin and the Colorado River Basin had direct consequences for drought in California. The Klamath tribes in Oregon were determined to have primary water rights in a 1983 court decision (United States v. Adair 1983). Then, it took thirty-eight years of adjudication for the Tribes to be able to assert their water rights. In the spring of 2013[65], the tribes in Oregon and Northern California were granted the right to prevent water deliveries to farmers in order to protect the area's fishing populations and ecological integrity (Barboza 2013; Boxall 2013). Similarly, Tribes throughout Colorado and Arizona asserted their primary water rights in the Upper and Lower Colorado River basin and were allocated tens of thousands of acre-feet for reservation and other uses labeled "time immemorial" (Colorado River Research Group 2016). The assertion of these primary water rights also asserted the importance of different uses of water, detached from the development of California.

Drought's new network

Over the last sixty years, the network of experts, stakeholders, and tools built up around drought has shifted dramatically. Drought began as a salient lay category, and it was primarily the concern of engineers, agriculture stakeholders, and water managers. For this initial community of expertise, drought was one facet of a problem with water management, and it was not studied on its own terms. Since the 1960s, climate scientists have transformed drought into a scientific fact, but have had to contend with the network already in place by making their tools usable and answering to stakeholder needs. Additionally, more scientific and lay communities have entered the network with their own strategies and tools to shape both scientific definitions and water allocations. Environmental sciences, environmentalists, and Native American Tribes brought their own commitments, interests, and tools for understanding drought into the network.

---

[65] The rights of the Klamath River Basin tribes were reaffirmed again in 2021 during the ongoing drought.

In the following section, I will map out how the shifts in the network detailed above result in shifts in drought declarations and mitigation strategies over the four declared periods.

Out of the Network: Impacts of network shifts on definitions and representations across four declarations

In the second half of this chapter, I will compare the four drought declarations, highlighting the actors and tools at work in the network to define and shape drought. I will do this by examining representations of drought in reports and how scientific and stakeholder groups define and shape drought as a fact. The figures reproduced in this chapter are representative examples of patterns found in the period; they are not exceptions to the rule. This section builds on the previous chapters by showing how human actors are able to mobilize their position in the network and the tools and measurements at their disposal to characterize drought at the time of declaration. The declarations and character of a drought are nontrivial. The declaration of a drought emergency opens up the possibility of relief programs, loan programs, water transfers, suspension of payments, and humane emergency measures to name a few outcomes. The ways in which the networks of actors and tools come together during these declarations and change over time become the basis of future definitions. The definitions and representations in early time periods are reinforced or discarded in future periods, and those changes and continuities become drought in California.

1976 – 1977 Drought

Climate science is slow to be integrated

Definitions and representations of the 1976 – 1977 drought relied on measures of precipitation as an indicator of critical dryness. During this period, engineers and agricultural stakeholders defined drought through surface water storage, and precipitation was prominently featured in DWR reports both during and after the drought. Figures included maps with "percent of average" precipitation placed on top of county areas (Figure 5.1), and many others depicted drought through tables of precipitation numbers and bar graphs that compared precipitation to previous years. The opening page of a special report published by the DWR on February 1, 1976 (a year before the drought was officially declared) states, "The State of California usually has any kind of water year except a normal water year. This variability is illustrated in Figure 1, 'Seasonal Precipitation at Sacramento.' Precipitation so far this year has been far enough below normal to rank as one of the record dry periods." (McCullough and Peters 1976:1).

Figure 5.9 contextualizes the 1976 water year with a century of observed precipitation and compares it to the drought in the 1920s. In this figure, state water engineers denote the "average" based on previous observations and the low levels of precipitation provide the foundation for defining drought. Although the Palmer Drought Severity Index had been around for a decade, the measurements water managers and growers use most often hold sway over shaping definitions of drought. Across 340 news articles and government reports, almost no non-government scientists were consulted on the presence or absence of a drought. I argue this demonstrates that the relatively new ideas and methods of climate scientists remained peripheral in the network, even though Palmer's index and a handful of others had existed for nearly twenty years. However, one group of experts was looped in tightly in response to the critical levels of storage to shape future mitigation strategies.

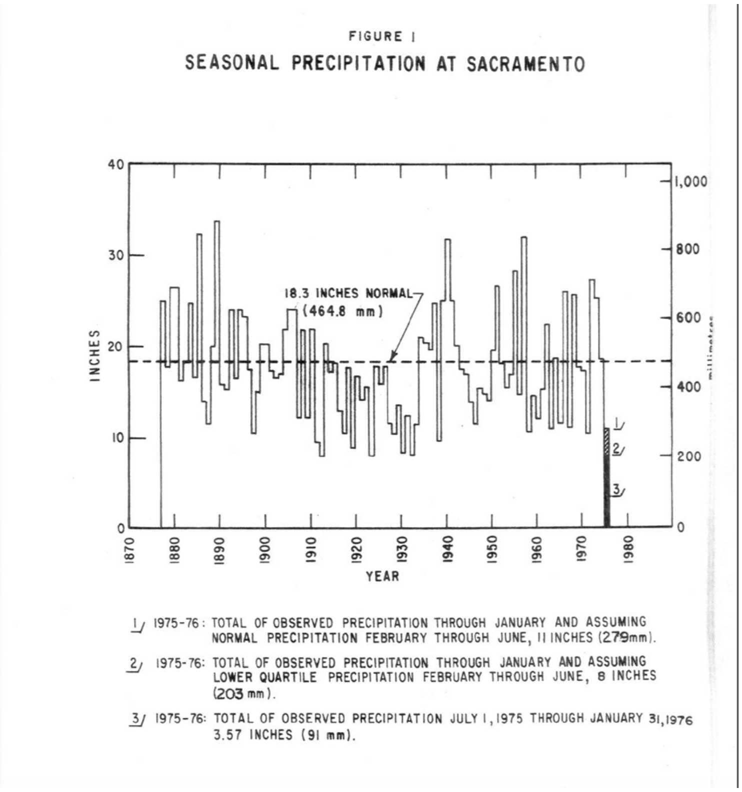


FIGURE I

SEASONAL PRECIPITATION AT SACRAMENTO

1/ 1975-76: TOTAL OF OBSERVED PRECIPITATION THROUGH JANUARY AND ASSUMING NORMAL PRECIPITATION FEBRUARY THROUGH JUNE, 11 INCHES (279mm).

2/ 1975-76: TOTAL OF OBSERVED PRECIPITATION THROUGH JANUARY AND ASSUMING LOWER QUARTILE PRECIPITATION FEBRUARY THROUGH JUNE, 8 INCHES (203 mm).

3/ 1975-76: TOTAL OF OBSERVED PRECIPITATION JULY 1, 1975 THROUGH JANUARY 31, 1976 3.57 INCHES (91 mm).

Figure 5.9: Reproduction of "Seasonal Precipitation at Sacramento" from Department of Water Resources Special Report on Dry Year Impacts, 1976

As part of the response to the critical dry years, environmental scientists within the California State University College (CSUC) system were pulled into the network to research and propose new strategies for water use. The Governor's Drought Emergency Task Force[66] (DETF)

---

[66] Collaborative organization created by Executive Order B-27-77 in January 1977 to coordinate communication and responses during the drought. The executive order required that the task force be comprised of representatives from the following state agencies and departments: Agriculture and Services Agency, Business and Transportation Agency, Health and Welfare Agency, Department of Finance, Department of Fish and Game, Department of Food and Agriculture, Department of General Services, Department of Health, Department of Housing and Community Development, Department of Navigation and Ocean Development, Department of Parks and Recreation, Department of Transportation, Department of Water Resources, Division of Forestry, Employment Development Department, Military Department, and Offices of Emergency Services.

were directed in May 1977 to "develop programs and techniques to meet the immediate and long-range effects of the drought" (Governor's Drought Emergency Task Force 1977a). The DETF elected to do this by soliciting projects from various government agencies, then passing them along to researchers at the CSUC system. Over forty projects were submitted by departments like the DWR and Department of Agriculture during the spring and summer of 1977, and twenty-seven were eventually selected by CSUC researchers for pursuit (Governor's Drought Emergency Task Force 1977b). The projects were evaluated based on the amount of information already provided to describe the project and how collaborative the proposals appeared. The DETF turned to environmental scientists to examine the impacts of drought to better understand the physical impacts and build a better, scientific understanding of drought's impacts on the ground.

The projects proposed to the CSUC researchers focused on water use and regulation, ranging from opportunities for reclaimed water use to developing new systems of irrigation targeted to specific crops based on water use (Governor's Drought Emergency Task Force 1977c). The project proposals are still framed by engineering's commitments to water management and see drought as a problem that can be solved through further management. However, the projects expand that framework slightly by seeking to produce knowledge about the physical impacts of drought on their own terms. Additionally, the DETF proposed a "Prime Project" in collaboration with the CSUC system. The Prime Project aimed at developing an environmental science curriculum for K-12 students (Mills 1977). The 1976 – 1977 drought created the space for environmental sciences to shape drought through studies on irrigation, water reclamation, and environmental impacts in the Bay-Delta region. These representations and informal definitions of drought show that the commitments to managing drought through better understanding surface water storage and how it can be used more efficiently are still the most powerful in the network.

Agriculture stakeholders dominate

During the 1976 – 1977 drought, stakeholders embedded in the network hold strong positions when articulating why this dry period is in fact a drought. During this drought ranchers and farmers are particularly vocal about the dry conditions. Ranchers hold a strong position because they are a large portion of the agricultural sector, but they are disconnected from irrigation technologies and networks. Where fields of crops could be irrigated to be watered with reservoir or ground water, pastures for cow grazing could not be. Therefore, ranchers experienced impacts of a single dry year much earlier than many other economic sectors. In reports – both official and news based – ranchers consistently point to the two dry years being disastrous. At the end of 1976, less than a month before the statewide drought declaration, the negative impact on ranchers the nonprofit advocacy organization Cattlemen's Association of California articulates the dire circumstances for ranchers. The Cattlemen's Association president used lack of precipitation as the basis for the supply and profit problems plaguing the industry, saying "It's going to be critical if we don't get a storm" (Staff Writer 1976). Ranchers were unable to maintain the level of economic productivity of the previous non-drought years. To ranchers, the dry period is a drought because the lack of rain is making it impossible for them to continue their business as usual[67]. By the end of the 1976 – 1977 drought, it was estimated that out of 566.5 million dollars in total agricultural losses, 414.5 million was attributed to livestock loses (California Department of Water Resources 1978:51). At this time, the tools and

---

[67] When the drought was officially declared by Governor Brown Jr., the emergency measures taken by the state and federal governments included millions of dollars for agricultural stakeholders specifically (Staats 1977).

definitions mobilized by these stakeholders are tightly intertwined with engineering definitions of drought because they focus on how a lack of precipitation creates disruptions to their economic sector.

Status of drought as a fact

In this declaration, drought was not debated, and the representations and stakeholder claims form a benchmark for the coming declarations. In the 1976 – 1977 drought, the definitions of drought are tied closely to state water management practices, attending to the lack of precipitation. The record dry years created a very clear problem for state engineers and agricultural stakeholders. Drought during this period was still tightly linked to the economic impacts with little discussion of the physical elements of drought on their own. The actors most closely connected to drought – as evidenced by their presence in the DETF, quotes in newspapers during the buildup to a declaration, and authorship of reports are often state or federal scientists. At this point, managers, engineers, and hydrologists are still running the show. Additionally, agricultural stakeholder definitions of drought are still central to official state declarations. They shouldered much of the suffering in the first drought period, and their suffering was given a great deal of attention in reports. Stakeholders often connect definitions of drought to the conditions that they are weathering, firmly holding the social and economic impacts of drought in place within the network. Climate scientists and the tools and representations as their disposal had not managed to shift the network of actors and representations established before 1960. Drought definitions, representations, and declarations remained tied to economic impacts and water storage.

1987 – 1992 Drought

Emergence of climate science

The definitions and representations of drought established in the 1976 – 1977 period persisted into the 1987 – 1992 period. Drought continued to be defined in part by its impact on local communities and economies, most prominently the agricultural sectors. Reports published by the Department of Water Resources (DWR) during the drought emphasized precipitation, reservoir storage, and runoff in their figures to communicate drought conditions. These representations begin with a 1989 document titled "Contingency Planning Guidelines for 1989" (Butterfield 1989) and end with a 2000 document focused on "lessons learned" for future droughts (Jones 2000). At the drought's start, another map displaying precipitation averages in regions across were placed at the front of the reports (Butterfield 1989:3), and as the dry conditions persisted reservoir storage became the most prominent representation (Butterfield 1991:2; Roos et al. 1990:2).

Throughout, the 1987 – 1992 drought conditions were consistently compared to the 1976 – 1977 conditions in tables and figures, demonstrating a clear continuity between the two time periods. Figure 5.10 shows both the comparisons between dry years and the foregrounding of water storage. Runoff levels from different rivers across different dry periods are placed next to each other, allowing a reader to triangulate the 1988 water year by comparing it to other dry years. Many figures, charts, and graphs continued to rely on a water management approach to drought. But not every section and representation of drought mapped onto the 1976 – 1977 dry period. During the 1987 – 1992 drought, atmospheric explanations and more discussion of weather patterns were more visible.

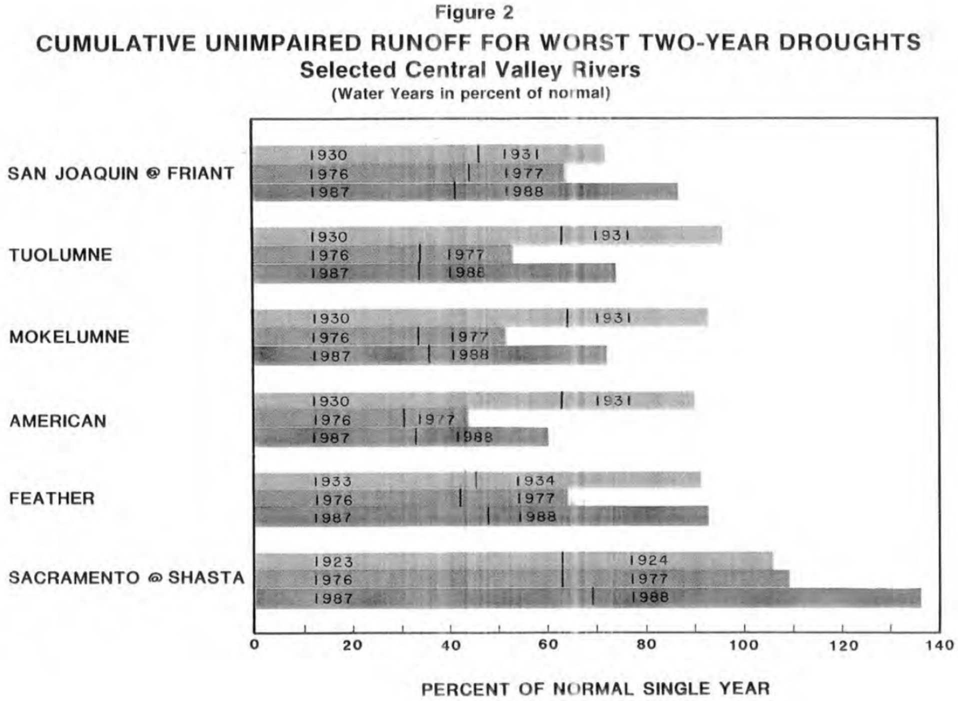


Figure 5.10: Reproduction of "Cumulative Unimpaired Runoff for Worst Two-Year Droughts" from Department of Water Resources Drought Contingency Planning Guidelines for 1989, page 4

During this drought period, there was increased discussion about atmospheric weather conditions and their impact on the state’s wet season. These discussions are grounded by climate scientists’ commitment to causal explanations and physical characteristics. Specifically, El Niño conditions were identified as the cause of the ongoing dry years. Climate researchers identified the El Niño conditions as the cause, noting that the system “represent an often dramatic shift in the planet's weather patterns, warming formerly chilly ocean waters, rerouting winds, and brewing storms and droughts in unexpected places” (Staff Writer 1988:B1). The dry conditions are explained by the ENSO pattern observed by climate scientists. In stark contrast to the 1976 – 1997 drought where very little climate science was used to define or understand the dry period, the 1987 – 1992 dry period is attributed to a larger meteorological phenomenon. Meteorologists and other climate researchers are able to shape explanations of drought through their research and representations.

This is also the first year that representations of drought utilize atmospheric patterns in official reports. The retrospective report on the 1987 – 1992 drought included diagrams that contrasted atmospheric pressure ridges that can lead to drought with the observed patterns in California (Priest et al. 1993:7).

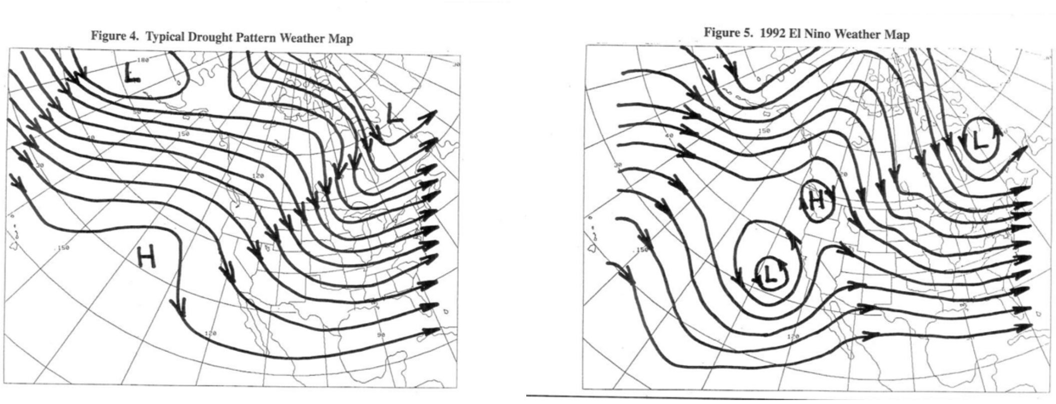


Figure 4. Typical Drought Pattern Weather Map

Figure 5. 1992 El Nino Weather Map

Figure 5.11: Reproduction of "Typical Drought Patterns Weather Map" and "1992 El Nino Weather Map" for comparison, from Department of Water Resources California's 1987 - 1992 Drought, A summary of six years of drought

The figures describe a typical drought weather pattern (left), and the El Niño pattern of 1992 that brought rain to Southern California but little rain to the Sierra Nevada Mountains. The authors of the report included these maps and a three-page section on climate factors in connection to drought, which demonstrates how climate science was shaping drought as a scientific fact.

The atmospheric models and climate science were still unable to determine when dry conditions would abate, and when the drought would end. The art of forecasting remained uncertain, as we can see in this quote from one long-range forecaster:

> “Just because rain doesn't start right away in October doesn't mean we're in for a drought,” agreed Daniel Cayan, a long-range forecast expert at the Scripps Institution of Oceanography. “A dry fall doesn't mean a dry winter -- and wet fall doesn't mean a wet

> winter. It's all just a little premature... In the fall period, the atmospheric circulation is kind of adjusting itself to a different set of conditions," he said. "It's a very changeable period, and we've found it one that's pretty difficult to forecast." (Bee 1987:B1)

Here, we can see the caution displayed by climate scientists to ascribe too much power to observed atmospheric conditions in the fall, pushing back against over-eager predictions. Climatologists and meteorologists are more tightly embedded in the network around drought than in the previous decade. But the science of drought is still hitting up against the needs of stakeholders and water managers dealing with the reality of drought conditions.

Distressed water managers and new environmental protections

Water district managers become more vocal stakeholders during the 1987 – 1992 drought. When water districts do not receive full allocation amounts, they need to make decisions about who is going to have their water deliveries reduced. Often, water managers in this position argue that the water supply is so poor that it *must* be defined as a drought because urban and agricultural users will experience burdensome reductions. For agricultural users, water managers reduce or completely shut off access to water. The Sacramento Bee reported on the dire circumstances: "In the Metropolitan district, meanwhile, [District Manager] Boronkay said he will be asking the board of directors next month to put its agricultural users on notice that they may be completely shut off from state water. 'This is the first time in history we have considered doing that,' Boronkay said" (Mayer 1988: B8). The water managers throughout the state articulate a definition of drought through their governance decisions. The definition is classic: there is not enough water in the water system to provide agricultural users their contracted water; therefore, California is experiencing a drought. It might be tempting to dismiss the claims of stakeholders as focused on mitigation and coping strategies rather than as work to define drought. However, I argue that these statements about the lack of water do work to highlight that ever-evasive line between "dry" and "drought". Drought is often defined as a lack of water for specific purposes, and stakeholders – in this case water district managers – articulate exactly what that lack looks like and for what purposes. The historic move to cut off water from agricultural users[68] defines the situation as a drought, and it pushes for a drought declaration. Additionally, the burden is shared by urban water users.

A second major shift in the network is evident during this drought. By 1987, environmentalists are enmeshed in the network through the legal process and lawsuits. Recall the court ruling in the 1970s and 1980s regarding water quality (United States v. State Water Resources Control Board 1986). Environmentalist groups like Environmental Defense Fund were key stakeholders that made use of state and federal courts to enforce and interpret environmental protections in the Bay-Delta. Over pumping in the Bay-Delta led to salinity intrusion and water quality deterioration for human and nonhuman water users (State Water Resources Control Board 1988). The salinity intrusion negatively impacted the area's ecology and the water quality for consumption in areas east of the Bay. Environmentalist groups took charge of enforcing fair water usage through lawsuits throughout the 1980s, and successfully enforced water quality standards that required more water allocations for environmental protections. Approximately 32% of California's surface water supplies (25 million acre-feet) were earmarked during this drought for environmental uses, placing it on-par with agricultural

---

[68] During the 1987 – 1993 drought, agricultural stakeholders maintain a prominent position in the network. The agricultural sector is still comprised of a large number of stakeholders that plant seasonal crops which can be fallowed for a season, but it is still a costly choice to make. Recall from the previous chapters, surface water conditions were less dire in this drought than the 1976 – 1977 drought. During this drought, farmers make plans to survive, but sound far less dire fatalistic about them. Discusses these strategies some farmers point to being in "fairly good shape, as long as the Bureau [of Reclamation] doesn't cut [their] water supplies anymore" (Borba 1988:B1). Additionally, to compensate for the delivery cuts already made farmers will "pump more expensive ground water, which is another incentive for conservation." Farmers make do how they can – fallowing some fields and pumping water from aquifers to make ends meet.

uses (Priest et al. 1993:i). Environmentalist organizations successfully placed environmental uses on equal footing with agricultural uses and reshaped drought. By expanding the network of stakeholders, environmentalists reorganize water allocations and water priorities, meaning that the same amount of water needed for a wider range of uses in future years.

Status of drought as a scientific fact

Drought's status as a scientific fact in 1987 – 1992 is informed by the definitions and representations forged by engineers and agricultural stakeholders in 1976. However, the influence of climate science begins to shape drought in the 1980s. During this time period, drought is not viewed as completely distinct physical causes and social impacts. The impacts of drought, as experienced by the agricultural stakeholders and water managers, are still central to the definitions and representations of drought in the 1980s. But they are no longer the sole definition. In 1987 – 1992, atmospheric explanations and representations for the cause of drought gained prominence. They were included in news reports discussing the drought, and they were also featured in government documents explaining why this six-year long drought occurred. Climate science actively shaped drought through providing a causal explanation for the prolonged dry period. However, indices and other scientific measures of drought remain mostly absent. Instead, stakeholders – including water managers and environmentalists – successfully wielded the impacts of dryness on water users and the environment to articulate that drought was present. At the end of this time period, drought is caused by larger weather and atmospheric patterns like ENSO conditions, but still only exists when agriculture and other sectors are impacted by those patterns.

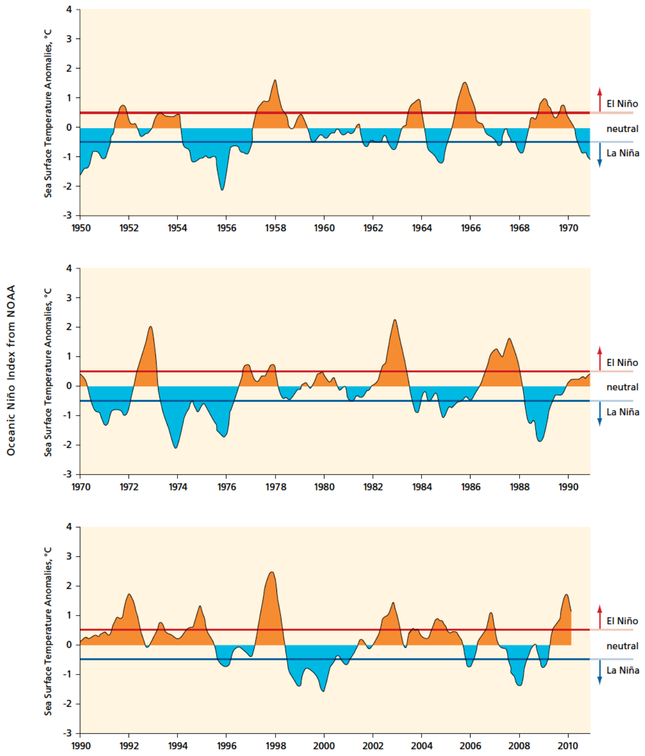
2007 – 2009 Drought

Science of drought and long-term forecasts

In the 2007 - 2009 drought, long range forecasts built on observed atmospheric patterns were called on to predict whether a dry year would be wet or dry. The forecasts were also built on historical observations where observed patterns could be mapped on to previous droughts. By 2007, drought is not just a lack of rain, it is a lack of rain caused by the high pressure ridges created by atmospheric conditions: "Forecasters say the current La Niña weather pattern, characterized by colder-than-average water in the central and eastern equatorial Pacific, will probably mean slightly more rain and snow than usual for Northern California. But it is less likely to bring rain to Southern California, where forecasters expect a bone-dry fall and continued high fire danger" (Lagos 2007:B5). 2007 was a dry year, and predictions based on ENSO patterns were mobilized to determine whether the following year might bring more precipitation. In this quote, the promise of a wetter season for Northern California was good news. Long-range weather forecasts and atmospheric explanations for dry seasons like the one above shows up more regularly in reports and comments – a departure from the previous two droughts. Additionally, the predictions' time scale change dramatically in representations during the 2007 – 2009 drought.

Qualifying weather anomalies through ENSO patterns became a historical project as well. Climate scientists at the National Oceanic and Atmospheric Administration (NOAA) applied the strategies developed in the 1980s and 1990s to craft an ENSO index, which was in turn used to contextualize past and present dry periods in California (Jones and Nguyen 2010:12).

Figure 7 — Historical El Niño and La Niña Episodes



NOAA data, http://www.cpc.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Figure 5.12: Reproduction of "Historical El Nino and La Nina Episodes" from Department of Water Resources California's Drought of 2007 - 2009, An Overview

It is noteworthy that the scientific approaches to drought are retroactively applied to previous droughts in order to contextualize the current one. Climate scientists are able to input atmospheric data into models and produce a broader understanding of past droughts to inform understandings of the current one. During the 2007 – 2009 drought, scientists and water managers grappled with the possibility of more persistent droughts and connections to climate change.

Tensions continue between environment and development

Environmental protections became a source of tension in the 2007 – 2009 drought. The 1987 court ruling that empowered the State Water Resources Control Board (SWRCB) to set and enforce water quality standards was reaffirmed in 2006. A federal appellate court declared that water quality and environmental protections were still not considered strongly enough when it came to water management practices in the Bay-Delta region (Central Delta Water Agency v. Bureau of Reclamation). The plaintiffs[69], which included various "Delta Parties" ranging from environmental groups to water agencies, argued for maintaining the standards even during dry periods, which would force the Central Valley Project (CVP) and the State Water Project (SWP) to keep more water in the Delta than they had in the past. This decision was consequential because in previous droughts, the CVP and SWP could relax water quality standards, allowing the projects to pump more water out of the valley for agricultural purposes. This practice often mitigated negative impacts on some secondary water users in the state's eastern regions. However, this option was taken off the table for the 2007-2009 and 2012-2016 droughts due to environmental protections.

The 2007 – 2009 drought was referred to as "political" because some agricultural stakeholders argued there was enough water in the state, but it was going to "silly little fish" (Scoville 2019). As discussed in Chapter 3, low snowpack measurements in the winter of 2008 led to reduced water allocations for the summer of 2008. However, rather than seeing reduced allocations as a reasonable result of low surface water storage, water district managers argued it was manufactured scarcity due to environmental regulations. Farmers, organized through

---

[69] Plaintiffs listed in the lawsuit were the Central Delta Water Agency; South Delta Water Agency; Alexander Hildebrand; R.C. Farms, Inc., Plaintiffs-appellants, Andsave San Francisco Bay Association; Natural Resources Defense Council; Environmental Defense Fund; Bay Institute of San Francisco; Pacific Coast Federation of Fishermen's Associations; United Anglers of California, Intervenors

advocacy and interest groups, made their dissatisfaction known: “Mike Young, president of the Kern County Farm Bureau… blamed the reductions on what he called a political drought. ‘Growers will suffer, and the general public will suffer as well,’ he said” (Pollock 2008:C1). Measured in tone, but very clear in intention: this agricultural stakeholder is clearly unhappy about the way that water is being dispersed across the state. Additionally, the differences between 1987 – 1992 and 2007 – 2009 droughts due to environmental regulations were noted in the opening pages of the formal the 2007 – 2009 drought report (Jones and Nguyen 2010:5). The report highlighted that the change in operating conditions meant there were lower allocations to SWP and CVP water users and fewer methods of transferring water between users in response to drought.

Status of drought as a fact

The representations of drought and the stakeholder tensions emerging in 1987 – 1992 shaped drought much more clearly in 2007 – 2009. Climate science explanations and representations became more routine in both explaining the existence of dry seasons, and in representing the dry season in government reports. The reports were once a bastion of runoff tables and maps of precipitation averages. Instead, ENSO conditions explained and represented droughts past and present, tying drought to atmospheric patterns and not just economic impacts. Additionally, the success of environmentalists in enrolling nonhuman stakeholders into the network dramatically reshaped drought in 2007 – 2009. Strategies for mitigating dryness and reducing impacts to growers were taken off the table. The farmers and ranchers resisted including new members of the network, identifying it as a “political” inclusion rather than rational. For agricultural stakeholders and some water managers, it was not “really” a drought because there was enough water in the system to meet more human needs. If environmental regulations had not changed since the 1970s, then it would have been a dry period, but not a drought. The contested definition in 2007 – 2009 shows how perfect agreement about drought's definition is elusive, and definitions from previous decades can remain powerful.

2012 – 2016 Drought

Climate Science – new tools and new scopes

Climate science tools and representations took a more prominent role in defining and shaping the 2012 – 2016 drought. The launch of the US Drought Monitor (USDM) in 1999 (Svoboda et al. 2002) provided a new tool for shaping discussions of drought, and fifteen years later journalists and other stakeholders are readily making use of it. For example, The Fresno reported that "today, 83% of the state is in severe drought, according to the U.S. Drought Monitor. Even worse, the Central Valley -- composed of the San Joaquin and Sacramento valleys -- is in extreme drought" (The Bee Editorial Board 2013:A11). In previous droughts, news articles utilized quotes from water managers and percent of average to define drought conditions. Now, the drought monitor provides an "objective" snapshot of water conditions that can be labeled "severe" and "extreme" with minimal quibbling.

Notably, this drought also featured pushback against the expectation that ENSO conditions map one-to-one onto drought conditions. This pushback came from climate scientists, and it was rooted in misconceptions of ENSO and how climate change might alter weather patterns. Both state officials and other forecasters pushed back against a simple ENSO explanation to explain the dry 2012 and 2013 water years in California. The pattern was absent in 2013, so forecasters made cautious long-term predictions:

> As for the winter ahead, state officials caution the final outcome is difficult to predict, partly because neither El Niño nor La Niña conditions dominate in the Pacific Ocean this year. The former condition indicates the ocean is warmer than average, while the latter is cooler. A strong signal in either direction can make predictions easier. This winter, forecasters say the ocean will be in a "neutral" condition, though [PhD Meteorologist Klaus] Wolter said it could shift into an El Niño pattern by springtime. (Weiser 2013:B1)

The connection between ENSO conditions and drought has been taken up by other members of the network, but not in a way climate scientists see as correct. In statements like this one, meteorologists are pushing back against assuming that a drought is always caused by either El Niño or La Niña conditions. The causal explanation provided by ENSO was compelling to the network, but it was not a perfect explanation. Drought can still occur even in neutral conditions.

However, climate scientists do not back away from atmospheric explanations for dry periods. The 2012 – 2016 drought is sometimes contextualized by scientists as part of a relatively dry decade (2006 – 2016) within broader patterns of warming and atmospheric patterns, using temperature representations and atmospheric data to explain drought as a weather phenomenon (Berner et al. 2017; Diffenbaugh, Swain, and Touma 2015; Dong et al. 2019). These connections between rising temperatures and dry conditions were the first attempts at understanding the mechanisms linking climate change to more frequent droughts. Climate change promised to destabilize the atmospheric and hydrological patterns that predications and water management practices were built on.

Representations of drought in official drought reports continue to feature more images informed by the commitments and definitions of climate science. The focus on contrasting predictive maps and observed maps also persisted. By 2015, ENSO conditions had been confirmed via observations. The 2012 – 2016 drought report used a figure to represent predicted and actual precipitation levels for 2015 – 2016 and contextualized the patterns via ENSO conditions (Jones 2021:12). In these maps (Figure 5.13), the ENSO conditions led to a predicted "split" between a wet winter in California and the remaining Southern half of the United States, which might have ended the drought. However, the majority of California experienced average or below average precipitation during this year.

Figure 1.4: Forecasted Versus Observed Precipitation During the Winter 2015-2016 El Niño

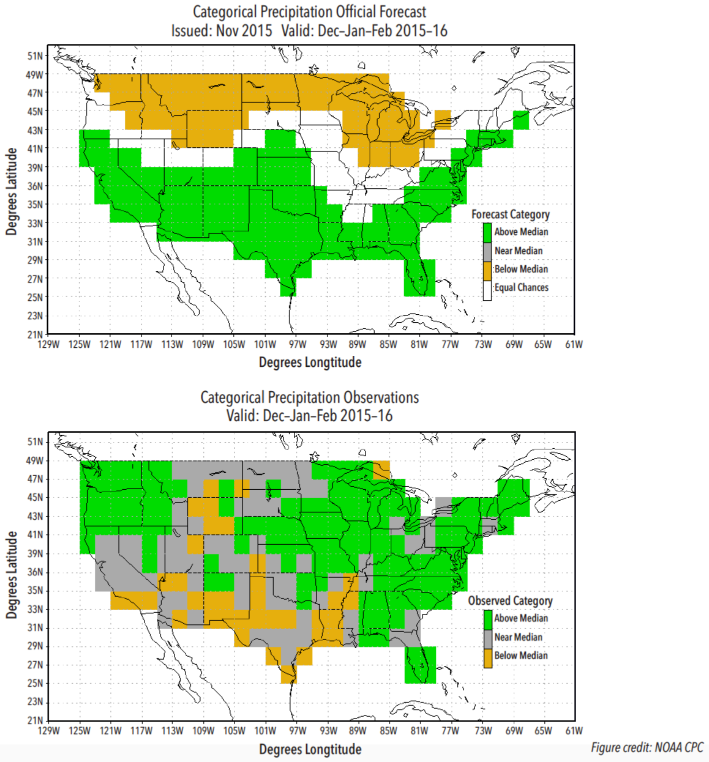


Figure 5.13: Reproduction of "Forecasted Versus Observed Precipitation During the Winter 2015-2016 El Nino" from Department of Water Resources California's Drought of 2012 - 2016, An Overview

The predicted and actual contrast emphasizes the comments from meteorologist Klaus Wolter. It has become easier since the 1980s to make assumptions about how ENSO conditions relate to a very particular and bifurcated outcome, and representations like these that demonstrate the messiness of the connections between ENSO conditions and droughts are far more common.

Stakeholders

In this section, I will not belabor the point that agricultural stakeholders, water district managers, and environmental stakeholders persist in their arguments about drought and water in California. The important changes between these two drought periods – increased environmental protections and the movement towards permanent crops to name two – have been covered elsewhere in the dissertation. These actors and their representations of drought have not departed from the ones discussed in the three previous drought periods. However, they must contend with an important change in the network with the re-inclusion of Native American tribes.

A major shift in the network of stakeholders was the horrendously late inclusion of Native American tribes and indigenous coalitions. The path into the network was through legal claims to primary water rights in the Klamath River and the Colorado River. In the decade between 2000 and 2018, some tribes in the Klamath River and the Colorado River Basins were awarded clear allotments of water from the two basins[70]. These allotments clarified that the reserve rights held by the tribes were the "oldest" water rights in the two river basins, apportioning thousands of acre-feet for tribal use (Wogan 2021). The uses are tied to a tribe's ability to fulfill the purposes of a reservation or to continue water's aboriginal uses. These rights exist beyond state law, and often take precedence to other water laws. The effect of these rulings during the 2012 – 2016 drought was immediate, particularly in Northern California.

The reserve rights meant that Klamath Tribes could cut off water to other users to preserve river flows and protect fisheries (Wogan 2021). In Northern California, specifically the Redding area, farmers "lost" access to water earlier in a dry period because the Klamath Tribes

---

[70] According to a 2019 report published by the Congressional Research Service, there are still dozens of unresolved tribal water claims in the Western United States (Stern 2019).

were able to keep the water in Oregon to preserve endangered fish species. One tribal council member articulates the tension between farmland and the ecosystems valued by the tribes: "'A lot of people's water could be shut off, and that has huge implications, and it affects peoples' livelihoods to the core,' said Jeff Mitchell, a tribal council member and its lead negotiator on water issues. 'But I also look at our fishery that is on the brink of extinction. We have a responsibility to protect that resource, and we'll do what we need to do to make sure that the fish survive'" (Barboza 2013:A1). The quote encapsulates the tensions between development, farming, and conservation at the heart of water allocations and water rights. By asserting their right to water, the Klamath Tribes again redistribute water across stakeholders in the network, which redefines drought. There is no change in precipitation, but there is a change in water allocation and usage. The altered allocations create drought conditions for farmers and others in Northern California, changing the threshold for "dry" conditions to be defined as a drought.

Status of drought as a fact

Drought had changed dramatically as a fact by 2012 – 2016. In just under forty years, drought had gone from an engineering problem that could be solved with more storage to part of California's landscape, dictated by atmospheric patterns. It is represented by multi-indicator models in the form of color-coded maps that communicate how dire a dry season is to a casual user. The growth of climate science has reshaped drought as a scientific fact and dramatically changed how it is depicted in research articles, newspapers, and official reports. However, climate scientists must work with the networks of stakeholders and interest groups engaged with drought as well.

The number of groups contending over water resources and how they should be used has also changed in the last sixty years. Water allocations were initially dictated by the needs of a growing state – expanding agricultural production and building new residential communities. By 2012, these are no longer the only needs under consideration. Environmentalists and Native American tribes have brought different commitments into the network. Water quality, environmental protections, and culturally significant practices and species are now on equal footing with growing in terms of amount of water allocated. Drought is persistently defined and represented through impacts on the economy and society. Now, with these new stakeholders at work to reallocate water and reshape priorities, drought itself is reshaped as well.

Conclusion

Reiterated fact making is a useful approach for teasing apart the actors, tools, and representations that shape drought as a social fact. At the close of the 2012 – 2016 period, the networks of scientists and stakeholders have shifted significantly since the 1970s. In turn, the shape and character of drought as a fact and a problem has changed as well. Reiterated fact making calls attention to how these actors, their tools, and frameworks shape scientific facts from start to finish. Drought's journey from lay category to scientific fact illustrates the utility of the reiterated fact making approach, but it also presents challenges to the network built up around the scientific fact itself. By the 1960s, economic sectors and communities already depended on water and were concerned with drought as a social problem. Therefore, the conceptualizations and tools developed to understand drought as a scientific fact run up against their expectations and needs. These expectations shape the tools themselves and create spaces for collaboration and a tightening of the network.

During the 1970s and 1980s, engineers defined and represented drought. The problem of dryness was treated as an engineering problem – one that could be solved by increased storage and irrigation measures. Drought was represented by maps with amount of precipitation levels or by bar graphs of runoff measurements. Climate sciences like meteorology and climatology developed a plethora of drought indices to study the physical properties of drought. The indices combine a handful of indicators to represent drought numerically. The index number communicates the severity and sometimes durability of a drought. These efforts culminated in the US Drought Monitor's development – a multi-indicator and multi-model rendering of drought of the contiguous USA. These representations maintain the map as a representation, but they communicate more information about drought in a single image than amount of precipitation. Additionally, climate science offered explanations for the cause of drought – rooting the phenomenon in the sky. Representations of drought also included maps of the atmosphere and how pressure ridges and ENSO conditions shape drought.

The shifts in the networks of scientists dramatically change what drought *is*. Drought is no longer an unknowable and unmeasurable natural disaster, only recognizable through its economic impacts. Drought changes from a problem of irrigation to an integer describing deficient precipitation to a multi-variable map as the expertise, tools, and methods of climate science change. Reiterated fact making provides a useful framework for tracing these changes, showing how new tools and theories developed by climate science reshape drought and its representations in California through the maps, graphs, and explanations offered.

The process of rendering drought into a scientific fact is not simple, and it is complicated by the persistence of a network of stakeholders and interests connected to water consumption. As water access is the foundation for much of California's growth, drought presents a very real problem for a wide range of stakeholders. As such, by the 1960s, there is a substantial network of stakeholders built up around water and drought, advocating for its declaration when their interests are threatened. This network shifts over time as well, reshaping the nature and declarations of drought alongside new scientific tools and innovations. Agricultural stakeholders and water district managers – once all powerful – had to contend with changes in who had access to water. Environmentalists asserted the need to protect against ecological disaster and asserted that position through water rights law. Similarly, various Native American tribes concretized the meaning of "reserve" rights – finally clarifying their primary water rights that were stolen centuries ago with the arrival of settlers. As new stakeholders enter the network, the places water is required multiplies – changing the very nature of drought itself.

Reiterated fact making provides a useful framework for understanding the persistence of these interests and how they interact with the actors, tools, and representations emerging in scientific communities. However, the network of stakeholders offers a complication that reiterated fact making must contend with. Stakeholders take up representations of drought crafted by climate science and reshape it as a fact through participating in the funding for research projects and providing new data[71]. But they also assert their interests and demand that climate science tools speak to those interests explicitly. And in the end, drought will always be tied to social impacts. So, reiterated fact making must be augmented slightly to include the existence of networks that persist.

Even with all of the changes over the previous sixty years, it is a recent shift in the network that leaves us with the most uncertainty. Climate change presents real threats to human and environmental survival. It also threatens to undermine the infrastructures, tools,

---

[71] Citizen scientists often participate in information gathering and measuring water across the state (Ambruster 2008).

measurements, and relationships among human actors that are so important to water management and determining drought. The specter of climate change looms ever larger as the current water year takes shape as another drought year.

Portions of Chapter 5 are currently being prepared for submission for publication. The dissertation author is a co-author with Daniel Navon, but the overlapping material is the dissertation author's original research.

CHAPTER 6: SO, WHEN *IS* A DROUGHT A DROUGHT?

California's 2020 – 2021 Drought: The ongoing sixth case

At the time of writing, Californians find themselves in the grip of another major, record breaking drought. As with the other cases in this dissertation, it is at once deeply familiar and quite different. In autumn 2021, the state had already endured significant dryness in through two previous water years (October through September) 2019-2020 with 16.33" (70%) statewide average precipitation and 2020-2021 with 11.83" (50%) of average. Confronted with a moderate La Nina condition that was projected to remain through winter 2022, on October 19, 2021, Governor Gavin Newsom declared a statewide drought emergency, including the final eight counties that had yet to be declared as experiencing drought. An official declaration of drought by the Governor's office is now typical to the process of determining if a dry period is a drought in California. Within the proclamation itself we find the usual suspects cited as driving forces for the declaration: dire conditions of California reservoirs; low moisture content in native vegetation; and a suffering agricultural sector. We also find a well-established mitigation strategy: that every California household cut its water use by 15%[72]. Additionally, the measurements that played a central role in previous decades back up the assertion that we find ourselves in a drought. Precipitation is half of what we would expect for an average year; runoff is projected to be half of expected averages; and Shasta and Oroville Lakes find themselves at

---

[72] On March 25, 2022, the LA Times reported data from the SWP that showed California's urban water users had saved less than half of the 15% target. Savings from July 2021 through March 2022 were only 6.4% with Bay Area residents hitting 11% and Los Angeles residents only reaching 5.1%. This difference is in contrast with previous droughts where residents often exceeded water saving goals. It is an open question why the numbers are this dire. One potential explanation is the classic reasoning that residents in Northern California are "closer" to the problem and so are more willing to cut water use. An alternate explanation is that Californians have kept their water saving practices from previous droughts, so there is simply less water to "save" in day to day lives. It will be up to future researchers to determine what is happening behind the numbers. It does indicate that there be limits to individual conservation as a response to droughts in the future.

64% and 75% of average (California Cooperative Snow Surveys 2022). However, this drought extends recent changes in drought definitions, embedding them more firmly in drought as a fact.

For the first time, the broader context of climate change and its impacts are explicitly included in this drought declaration. Governor Newsom's declaration sets itself apart from the previous executive orders by referencing more than water storage conditions or the potential for climate change impacts. The October 19th proclamation names climate change as a current, driving factor in the drought, writing that "climate change continues to intensify the impacts of drought on our communities, environment, and economy" (2021: 1). The order goes on to include long-term weather forecasts and the hot meteorological conditions of summer 2021 as reasons for the emergency. In the 2021 declaration, we can see what was new in the 2012 - 2016 drought become a standard component of the narrative surrounding drought and a continuity between cases. In 2021, climate science explanations of drought are firmly encoded in government documents, changing drought as both a scientific fact and a social problem. The change is possible because climate change is now party of the regular scientific and popular discourse, and the measurements and representations of drought reflect it.

Climate change is not only changing drought in California, but also reconfiguring the spatial and temporal scope of drought. Other states in the Southwest - including Arizona, Nevada, and New Mexico - have also been pummeled by consecutive dry seasons, much like California. The majority of years since 2000 have been dry across the region. The broad regional and multi-decade impacts have been described as a "megadrought" by scientists and journalists. A New York Times article published on February 14, 2022, reviewed scientific research that claims it is the worst drought in the last 1,200 years. A megadrought is a new iteration of drought as a scientific fact, and its articulation is made possible by reconstructing centuries water conditions and identifying mechanisms linking climate change to drought.

New methodologies and representations of drought continue to alter drought as a fact. Researchers utilized tree ring data to data to construct water conditions over many centuries before instrumental observations became available. This proxy record provides a much longer context in order to gage recent dryness, allowing calibration of the high severity of recent drought in California. Here, we see the persistence of epistemic path dependencies: research using tree ring data reconstructs water conditions based on the Palmer Drought Severity Index (Williams, Cook, and Smerdon 2022), bringing older metrics to new practices. The researchers were also able to attribute a significant influence of anomalous warmth as a factor that intensified land surface dryness, e.g., a mechanism that was not clearly operating in previous dry spells. The research team found that the interaction between higher temperatures and dry conditions made the current drought the worst in over a millennia. In 2021, drought is tied to temperature extremes as well as precipitation extremes. Essentially, the water conditions may have been of middling severity with cooler temperatures. But the rising temperatures mean that what water does fall on the ground is sucked back up into the atmosphere, making it much more difficult to end drought conditions. Climate science is able to offer concrete, causal explanations for precisely how climate change is altering drought. The material reality of nature itself is changing due to human activity, and it will in turn alter drought itself. Amidst these changes to drought, a deep continuity persists.

The longer record of wetness and dryness from methods like tree-ring data provides evidence of past, multi-decade drought episodes (Stine 1994). These megadroughts share similar definitional flexibility with “regular” droughts. In the New York Times article, journalist Henry

Fountain writes that "*Although there is no uniform definition*, a megadrought is generally considered to be one that is both severe and long, on the order of several decades. But even in a megadrought there can be periods when wet conditions prevail. It's just that there are not enough consecutive wet years to end the drought" [emphasis mine] (2022). As climate change becomes a central component of drought as a scientific fact, the openness present in the 1960s is still with us today. Although the concept of a megadrought challenges the state-based paradigm of drought presented in this dissertation, we can see how the path dependencies and networks established sixty years ago are still shaping drought as a fact in 2022.

In the remainder of the conclusion, I will take a step back to assess what we have learned about drought in California and why it matters to ongoing conversations in sociology and drought studies more broadly. First, I begin with a summary of findings, highlighting the conditions of possibility, path dependencies, and networks of experts that have shaped drought in California. Then, I discuss how my findings contribute to work in the Sociology of Knowledge, Environmental Sociology, and broader trends in mainstream sociology. Then, I pivot to discussing the potential of interdisciplinary research on drought that takes a sociological approach more seriously. I address the limitations of this particular study, and how they could be addressed through future sociological work on drought and climate change. Finally, I offer some insights on the future of drought in California and what this work has to say about addressing drought in the context of climate change. I aim for these thoughts to generate discussion about the bigger questions of water use, inequalities, and possible futures.

What we learned: Summary of findings

In this dissertation, I report on findings based on archival data I gathered about the production of drought as a scientific fact and social problem in California from 1959 - 2016. I compared four officially declared droughts to trace the development of drought as a scientific fact. The four cases were the 1976 – 1977, 1986 – 1992, 2007 – 2009, and 2012 – 2016 droughts. I also included the 1959 – 1961 drought in Southern California as important context for the trajectory of drought after the completion of the Central Valley and State Water Projects. The data is predominantly comprised of meeting minutes of governing bodies; correspondence between state actors, scientists, and citizens from different regions of the state; water laws and written opinions; newspaper articles; scientific articles; and published reports from government and research institutes. My analysis was guided by the theoretical framework reiterated fact making, calling attention to the conditions of possibility, path dependencies, and networks of expertise that make thinking of drought as a fact possible. The framework revealed important sociological insights, but it also deepened the understanding of California as a compelling case for studying.

The specificity of California and drought as a fact

California serves as a particularly interesting case for examining the connection between the physical indicators of drought and the declarations that follow. First, California has far more volatile precipitation levels year-to-year than many other regions of the United States. On average, the amount of precipitation in California's Sacramento-San Joaquin Delta region fluctuates by nearly 44%. The volatility in seasonal water flows has significant consequences for the water storage conditions and leads to more frequent multi-year droughts (Cayan et al. 2003;

Dettinger et al. 2011). California's engineered water system is also limited in its capacity to buffer against this volatility in comparison to other regions. California's water system via the CVP, SWP, and other local water storage has the capacity to mitigate about a year and a half of dry conditions, but it is not enough to overcome the variability in precipitation[73]. The susceptibility to multi-year dry spells makes California particularly useful for understanding drought as a fact because it has more consistent events to examine.

A second particularity of California is the dominance of agriculture as a water user. As reiterated throughout this dissertation, agriculture uses the majority of California's developed water – approximately 80%. Agriculture is a critical economic sector for the state, and it is regularly placed in a precarious position due to the volatility of precipitation and the limits of surface water storage. During drought years, agricultural sectors see relatively little reduction in water use and rely on groundwater stores to meet water needs (Helly et al. 2021). The dominance of agriculture in water use particularly during times of drought makes this sector important when discussing the reality of climate change, which I will discuss further at the end of the conclusion.

Finally, the material reality of water conditions and the process of officially declaring a drought are closely linked as a dry period persists. This conclusion may be viewed as obvious, but it is important to state clearly because the indicators are meaningful due to the history of California's water system and the actors that take them up in action. So, to start with the most obvious – drought declarations occur when the physical indicators of precipitation, reservoir storage, and runoff are dire and have been persistently below average for at least a full year – usually after a second dry year has shown its hand. The storage capacity of California's water

---

[73] In contrast to the Columbia and Colorado River systems which have low variability but low storage and high variability but high storage respectively (Cayan et al. 2003:12).

system makes it possible to mitigate a single dry year and not require a drought declaration. Official declarations of drought consistently occur at least halfway through a second consecutive dry year as government actors exercise caution during the first dry year. This leads to a lag between when water conditions are dry and when a drought is officially declared, providing for over a year of discourse to build up around drought as a fact. The variable hydrological conditions, the limits to surface storage capacity, and a persistent need for water in California make California a compelling case for understanding what makes a drought a *drought*. Examining the history of these specificities through a comparative historical project reveals how we arrived at this place and what we can learn about drought more generally using reiterated fact making.

Conditions of possibility

California's practices for capturing and conveying water made it possible for drought to emerge as a scientific fact in the 1960s by structuring access to water and reworking relationships between water and space. California's economic development during the eras of Spanish colonialism (1768 – 1821) and the Gold Rush (1848 – 1855) established a hierarchy of access to water, predicated on ownership of land or business. The various forms of water rights – pueblo, riparian, and appropriative – formalize these particular arrangements between society and the environment when they were codified into law during the 1920s. Appropriative water laws made it possible to legally disentangle land and water by allowing organizations remove water from one location for use in another. California water law shaped how drought emerged as a scientific fact by determining how water is distributed across the state and whose access is prioritized.

Additionally, early decisions about infrastructure and how state engineers deployed it as a solution to various water problems shaped drought over the last sixty years. In my research, I found that California's commitment and approach to tackling water issues through state bodies had far reaching implications for how drought emerged as a scientific fact. First, state engineers identified infrastructure as a solution to a sprawling water problem that mostly focused on flooding and irrigation. The construction of the Central Valley Project (CVP) made it possible to control flooding and store water to help improve farming conditions in the Central Valley. The CVP project also created the foundations for understanding drought as a problem that could be solved with water storage and transportation, rather than a matter of precipitation only. It set the conditions to understand drought as a mismatch between where the water was located and where it was needed. Together with the structure of water rights, the CVP set the stage for defining drought through water storage capacity and the practice of addressing drought through further infrastructure projects. All of which was undertaken by a growing state government.

Finally, it was necessary for a scientific field to take an interest in drought and work to develop a scientific explanation for drought. After World War II, meteorology and climatology became more prominent in academic and government positions. These climate sciences took an interest in disentangling drought’s physical characteristics from its social and economic impacts. This interest was critical for drought's emergence as a scientific fact. The meteorological interest in drought made it possible for government actors and stakeholders to think about drought as an objective, physical phenomena separate from the agricultural and economic disruptions.

Path dependency

In my research, I found that definitions of drought from early 20th century water management practices were embedded and re-embedded in water measurements. The drought that took place in the 1920s and early 1930s led to localized devastation and disrupted the agricultural sector for an extended period. The period was one of the driest on record, and it came to serve as the default categorization for a "critical" year. These conditions existed before either of California's massive infrastructure projects were completed, so similar localized conditions are not seen as often with the increase in statewide storage and water conveyance. However, as water standards and classifications are reworked in the 1980s and into today, this definition is still used to designate "critical" years and shapes our understanding of what a drought in California is scientifically. The definition is used to determine what levels of runoff, reservoir storage, and precipitation constitute a drought even today. The definition initially derived in the 1920s also persists through explicit comparisons between the different drought periods. Throughout formal and informal reporting, the declared droughts are compared to each other in order to set standards of for what conditions constitute a drought. The comparisons between different droughts over the years reify definitions from the past by asserting and reasserting that those specific conditions are what constitute a drought – even as the conditions shift over time from record-setting low levels of precipitation to a combination of storage, allocation, and precipitation during an era of warming temperatures. In turn, the comparisons shape future definitions by delimiting what really counts as a drought by attempting to map current conditions onto past ones.

Material path dependencies also shape drought by reconfiguring relationships between water and place. The State Water Project (SWP) enables statewide water storage and delivery, and it constrains alternative solutions to drought and patterns of water use. In the 1960s, Southern California suffered from a multi-year drought, and the State Water Project was proposed as the ultimate solution to drought as a problem. State actors argued that water was plentiful in the North, and if it could be captured and conveyed south, then drought would be mostly eradicated in California. The solution was not necessarily the best nor the most politically expedient, but it was passed in 1961 and initially completed in 1971[74]. The SWP's construction reconfigured water in California and shaped definitions of drought in all future instances. The SWP remade California's environment, and it made it possible for drought to be truly statewide by connecting water in Northern California all the way to Southern California. Water storage articulated as reservoir storage became a driving force of drought declaration. The SWP reshaped understandings of reservoirs themselves. The snowpack in the Sierra Nevada is frequently referred to as the state's "largest reservoir" illustrating the eroded distinction between built and natural. California's infrastructure undoes any meaningful distinction between the two. The material and epistemic path dependencies illustrated in this dissertation work together to delineate what conditions constitute a drought, embedding assumptions into thresholds, measurement tools, and governance practices over the sixty year period examined in this dissertation. They are causal mechanisms for when a drought is declared.

Networks of expertise

In this dissertation, I have identified changes to the network built up around drought and the resulting changes in drought as a scientific fact. The changes to the network can be described

---

[74] The SWP would be expanded in 1997 with the completion of the Coastal Branch. The expansion was started in 1994 after the prolonged drought from 1986 – 1992 that led to calls for importing SWP water according to the County of Santa Barbara (Carle 2004; Santa Barbara County Water Agency and Boyle Engineering Corp. 2003).

as new actors entering the network, bringing with them new tools for understanding drought and new claims to water. A network of engineers and agricultural stakeholders was already built up around drought in California by the 1960s when meteorology and climatology took a scientific interest in drought. Rather than dominating the network, drought's status as both scientific fact and social problem was maintained but altered. Scientific explanations for drought's causes and connection to larger atmospheric patterns were incorporated into the network over time, but social concerns and the interests of stakeholders continued to shape tools like indices and declarations at the state level.

Other interest groups also entered the network over time, typically groups who had been excluded from the network around drought due to historical disenfranchisement or modernist frameworks about the environment. Environmentalists and indigenous tribes were the two most consequential inclusions over the last sixty years. Environmentalists and environmental scientists successfully pushed for the inclusion of the environment itself into the network, expanding the spaces where drought is assessed. The changes pushed for my environmental organizations are one of the most important changes to California's water governance during the last fifty years. Indigenous tribes also won – over a long period of time – primary water rights to important river basins that had historically been denied to them. The inclusion of Native American tribes is much more recent, so the impacts of these changes remain unsettled. The two groups' entrance into the network altered the science of drought by changing which areas of the state were prioritized in research on drought impacts. Additionally, they reshaped drought as a scientific fact by successfully rearranging how water was distributed across the state and to whom it was allocated.

The changes to the composition of the network led to changes in the status of drought as a fact. The scientization of drought unfolded somewhat slowly, and the incorporation of scientific representations took many decades. I argue that the inclusion of these representations in government reports and updates demonstrates the acceptance of ideas about drought and how it was viewed as a physical, atmospheric phenomenon. Drought was always seen as a lack of precipitation in relation to the needs of economic stakeholders already established in California. However, climate scientists developed indices, maps, and explanations for drought that anchored the dry conditions monitored by engineers in broader atmospheric patterns, such as ENSO conditions, and the slow-changes brought on by climate change. The integration of the scientific explanations and tools changed drought as a fact by tying it to larger weather patterns that are beyond human control, making drought a persistent problem connected to the climate of California rather than an intermittent problem solved through engineering.

The changes to the stakeholders in the network also changed drought as a scientific fact by redistributing water resources and retooling the priorities of the state government. With the inclusion of environmentalists and environmental scientists, the focus of drought's impacts moved from agricultural sectors to other ecological spaces without human economic interests. The fish, plants, and landscapes in those spaces were included via environmental research and advocacy, and the solutions to drought changed to accommodate those interests as well. Additionally, the inclusion of tribal communities via water rights altered drought as a fact, and the lateness of their inclusion is horrifying. Until the final case in this dissertation, drought was defined as lack of water mostly for agricultural purposes. But with the inclusion of tribes via water rights, drought expanded to include a lack of water for historical, traditional practices that did not include agricultural production. The changes to the networks built up around drought led to changes in drought itself both through scientific understandings and reallocations of water, determined by water rights and decisions based on water storage.

Radical change and deep continuity

Reiterated fact making calls attention to the radical changes and deep continuities that underscore a scientific fact. For drought, continuity between cases is found in the inextricable connection between water, infrastructures, and social functioning. Drought has been - and will continue to be - a lack of water for certain purposes. It will always be tied to the amount of rain and snow that fall in California, and if that will be enough for farmers to plant, ranchers to feed cattle, restaurants to serve water, fish to swim, and communities to tend their gardens, among many other activities. However, drought has also changed dramatically over the last sixty years. It has gone from a well-established lay category and the concern of engineers and water district managers to a better-understood atmospheric and meteorological phenomenon. We now have large, publicly available and private data sets built around water measurements over the last near-century. The data sets can tell us about the weather patterns of a year and how it ties to dry conditions, and they serve as the foundation for the reconstruction of centuries worth of dry conditions via methods like tree-ring data. To answer the question "when is a drought a drought"? is to consider each of these distinct but interconnected elements of the complex assemblage of people, nature, tools, and representations that constitute drought in California.

Why it matters: Contributions

A comparative, sociological approach to scientific facts

In this dissertation, I have contributed to the sociology of knowledge, environmental sociology, and broader studies of drought. By utilizing reiterated fact making to study drought, I demonstrate that this is a flexible and compelling framework for examining the life course of a fact over time, even one that is much different from biomedical facts for which it was originally developed (Navon 2019). By emphasizing radical change and deep continuity, reiterated fact making calls attention to the conditions of possibility, path dependencies, and networks that shape a fact over decades. Reiterated fact making provides another tool to move research beyond specific spheres like policy or activism, or spaces like laboratories and social movement organizations where the focus often falls on different sets of actors (Epstein 1996; Haughton 1998). Instead, reiterated fact making shifts the analytic focus to the fact itself, allowing it to circulate through different spheres, accumulating new definitions, representations, funding sources, meanings, and organizations.

Additionally, I show that reiterated fact making can be used to study scientific facts that begin as salient lay categories before being transformed through scientific research. Regulatory facts are often depicted as "fact-adjacent" because it is difficult to develop unassailable scientific knowledge and expertise on such messy, complicated facts (Eyal 2019; Irwin 2002). Drought is without a doubt one such case with its thresholds and cutoffs embedded in a system of water regulation. It is tempting to focus on closure or lack of public debate as evidence of a fact's stability and the position of expertise more broadly, which can make the study of less stable facts daunting. However, studying such a fact with reiterated fact making uncovers the material relationships that enable and constrain a fact's trajectory from purely common knowledge to one of esoteric interest as well, highlighting points of conflict or sources of mistrust or confusion.

The trajectory of drought from lay category to scientific fact offers useful insights for research on other such "types" of facts that are often open or uncertain. Pre-existing networks work as their own kind of path dependency, closing off some possibilities of a fact's shape but not necessarily creating obstacles. Rather than overriding the existing knowledge, climate science extended that knowledge and created new tools for stakeholders to make use of. Reiterated fact making can be adjusted to understand changes to networks as a process of inclusion and transformation in addition to “build up”, so the framework can be systematically applied to scientific facts with a diverse trajectory. Researchers interested in climate science, economics, and urban planning can benefit from the analytic framework by considering existing networks and material arrangements as well. Rather than throwing our hands up at their complexity, reiterated fact making can lead to nuanced arguments about why they are so complex and offer a way of disentangling the various threads.

Finally, given California’s highly volatile climate, droughts will reoccur in the future. Climate models indicate that droughts may happen increasingly and with greater intensity in future decades (Pierce et al. 2018

Environmental sociology and the sociology of drought

I began this dissertation by engaging with environmental sociology, and specifically the debate on how to frame environmental problems. The question of framing will become more important as more environmental problems become the subject of sociological investigation. Reiterated fact making provides one possible framework that responds to the call for framings that bring the material back into environmental sociology while not abandoning important questions of power and politics (Freudenburg, Frickel, and Gramling 1995; Murphy and Dunlap 2012). Built into reiterated fact making is attention to both the material conditions and social meanings that shape environmental problems. It is also a systematic framing that does not prioritize any single axes of analysis over the other. It grounds the analysis of environmental problems in the conditions of possibility, path dependencies, and networks, and their material and political components. Additionally, the comparative historical approach shows makes it possible to examine the relationship more closely between "nature" and "society." By comparing changes over time, it is possible to trace the conjoint constitution of each category, illuminating how changes to one led to changes in the other over the decades.

I argue that mainstream sociology could benefit from this research, and I challenge sociologists beyond environmental sociology to take the nature of climate disasters more seriously and as worth direct engagement. In sociology, environmental questions are not often foregrounded. Historically, environmental sociology has been sidelined given its history of asking questions not immediately relevant to cities, migration flows, politics, economics, etc. Rather, more rural areas were prioritized (Scott and Johnson 2017). However, as climate change begins to disrupt labor flows (Entwisle, Verdery, and Williams 2020), destabilize governmental relations across the globe (Juhola, Keskitalo, and Westerhoff 2011; Rudel, Roberts, and Carmin 2011; Sundqvist et al. 2015), and threaten the foundations of social organization (Bohle, Downing, and Watts 1994; Brown, Hammill, and Mcleman 2007; Epstein 2001; Homer-Dixon 2010; Yearley 2009), environmental questions are more important to all sociological subdisciplines. It is tempting to treat aspects of climate change as exogenous factors whose impact must be assessed, but my work demonstrates the deeply social nature of the disasters themselves. Like Klinenberg (2015) showed in his study of a Chicago heatwave, material and cultural history shape how disasters affect the people and places they where they occur. As sociologists begin to grapple with how to study climate change, my work demonstrates the value in centering the droughts, floods, and other climate hazards that characterize those changes. In doing so, we can better understand the points where conflict emerge, the history that has shaped those conflicts, and where power is shaping the responses to them. Modeling impacts of disasters offers an overview of what impact a drought might have, but it does not give us the footing to locate points in the network and infrastructures where action can be taken. Taking the environmental problems created by climate change more seriously as sociologists also opens up the possibility for more direct engagement with the interdisciplinary and international work happening to address climate change.

Drought studies

My work also speaks to ongoing research in the interdisciplinary field of drought studies. In 2008, Giorgos Kallis called for "moving from the skies, literal or intellectual, to the ground" (109) to grapple with time and place specific droughts. While this project remains "in the air" in terms of non-academic engagement, my work to historicize the specificities of drought in California moves towards a grounded assessment of how drought occurs. While historical perspectives on drought are becoming more popular in drought studies, they are often built on physical indicators and reconstruction of water conditions in an area via tree ring data and instrumental records. The purpose of such studies is to understand the frequency and duration of drought events across the world (Dai 2011; Pederson et al. 2012; Williams, Cook, and Smerdon 2022), and the work is important for determining the rarity or commonness of our current meteorological conditions. My work demonstrates the limits of examining physical conditions alone by arguing that the built environment of a space does much to shape definitions of drought today and into the future. Rather than relying solely on physical data, we must integrate social histories of a place to understand how drought today is shaped by the decisions and interventions of the past to better understand how those forces will continue to operate in the future.

The comparative approach also illustrates how the drought we are currently experiencing in California (and more broadly over the entire Southwestern United States) is shaped not just by meteorological factors, but political decisions made in decades past. Some research into water security grapples with the role of infrastructure and political-economic factors (Dai 2011; Kiparsky et al. 2013; Ludwig et al. 2011), but this research remains focused on developing future pathways to water security rather than examining the history that formed the water scarcity itself. My dissertation offers a causal argument for how historic decisions regarding water rights, land ownership, and infrastructure projects led to the current conditions that exacerbate some forms of water insecurity. It will require more place-specific studies of droughts before we can build up any kind of integrated theory on how drought's history is shaping our research and experience on a statewide, national, or global scale. My research project offers one vision for how we might undertake a deeper examination of a singular drought event and argues that it is possible to separate out causal factors when considering why drought looks the way it does in a specific location.

What remains to be done: Limitations and future studies

Limitations

My dissertation is limited in its ability to address drought as a unified scientific fact and social phenomenon. As I worked, I realized just how much there was to study sociologically about drought. There are at minimum six other dissertation that could have been written on this subject with a slight adjustment to framing or more intensive focus on one of the many elements of drought. My own interests in infrastructure, measurements, and the array of interests connected to drought limited the study. A different sociologist of knowledge may have focused more intently on the development of climate science models and the collaborative efforts involved in working with stakeholders. A political sociologist might have focused on county level responses and reviewed drought mitigation plans across regions, comparing their understanding of "emergency" to develop an even more local understanding of drought.

As is the case in archival research, there are silences in these documents that leave out some of the messiness underlying logics of decision making. I cannot make claims about what government actors, scientists, or water managers were thinking and saying outside of these documents, limiting me to public statements that may not perfectly represent their positions or the trajectory of how those positions were developed. Instead, I must limit myself to what those positions are and the statements that ended up documented. However, the archival data itself proved to be rich and well worth exploring. It served as a strong foundation for the historical project I wanted to write.

Additionally, the archival sources are state-centric and shape my findings. The archives with the most robust resources on water in the state are state-based archives. This is in part due to the way in which California's state government positioned itself to be the arbiters of water rights, allocations, and emergency responses (Baker 2017, 2018; Carroll 2012). Therefore, there will be a large state presence in documents about drought and water in California. However, the use of these materials does lead my dissertation to be state-centric, which leaves out important levels of analysis. My argument closely focuses on the definitions formed by Governors, the Department of Water Resources, and the State Water Resources Control Board. This limits my ability to discuss drought at community levels and how different cities or counties confront this social problem. Additionally, there are likely very interesting negotiations, networks, and decisions made at these levels that shape drought as a fact and how the residents of those communities experience them.

Future studies

The findings of this study, along with its limitations, may help to develop future research projects. Future research might grapple more directly with the trajectory of decisions and decision makers involved in California's water dilemma to better understand not just *what* the path dependencies and networks mean for drought as a fact, but how the decisions were made that produced this result. Specifically, I hope that my historical project is useful for informing sociologists who are interested in researching how water management decisions are complicated by or ignore emerging information about climate science. This would speak to the integration of climate science into the preexisting network around drought.

Additionally, this dissertation underscores the imperative to better understand the inequalities that are persistent and embedded in water law and infrastructure. While I was able to argue that outcomes were inequitable, there is much space to better understanding the history of these inequalities and their how they are reproduced through legal and physical infrastructure today. As climate change threatens to worsen these inequalities, better understanding the mechanisms for how they are perpetuated is critical. I hope that my study of drought and how infrastructures, laws, and measurements shape it will offer some context for anyone doing the much harder work of developing studies and data that environmental and water justice advocates across the state can utilize. This is even more true for indigenous researchers who are interrogating what the exclusion of tribes from water projects and belated inclusion into water law means for the future.

Revisiting drought: Recommendations and predictions

In this section, I offer a few humble insights into drought itself, not just sociology, and how we might move forward in a world with looming megadroughts. To begin with, including more history of drought with intentional comparison will help illustrate what is *actually* different about future droughts and what is a persistent part of the drought experience. This could help reporters and journalists know what to emphasize as an escalation, and what is a durable part of drought in California. For example, I have argued that the Central Valley Project and the State Water Project were very successful in mitigating short term droughts by providing a one-year buffer before a declaration. However, it is easy to forget amidst that success that they have not always existed and have changed California intensely over the last sixty years. Engaging with their history may make it easier to imagine a world without them if addressing climate change requires dramatic changes. I believe it is necessary to take material history seriously when addressing drought in the new millennium, particularly as drought is predicted to become more frequent and severe in some regions.

Secondly, I hope that this dissertation shows the extent to which legacies of early statehood – the politics and assumptions of the period – still permeate something that is, on the surface, as apolitical as drought. Climate scientists warn of increasing dry conditions that will lead to more frequent droughts and more damaging wildfire seasons. To address those issues, we must grapple with the fact that California's water system is literally built on the practices and relationships born out of settler-colonialism. Los Angeles and San Diego are able to flourish in part because of the colonizing practices that led to the development of pueblo rights. We also know that settler-colonialism is deeply embedded in the internal colonial practices that many large infrastructural projects represent (Carroll 2006; Claire and Surprise 2022; Pritchard 2012). I think we are beginning to see a rethinking of these practices in some capacity. For example, the reworking of conservation in national parks and other spaces to mitigate the fire threats that the past conservation practices have created is a huge step in that direction (McGregor et al. 2010; National Parks Service 2022; Van and Forsyth 2011; Woodlee 2016). Additionally, San Diego County Water Authority has spent decades diversifying its water resources beyond the surface water conveyed through the SWP to increase the region's drought resilience (City News Service 2021). However, we are going to need to go further with these changes to address patterns of water consumption across the state.

My research has shown that drought in California is complex, so mitigating increasing water shortages in the future will not be simple. Rather than a singular, magical solution, multiple, layered strategies are needed to find a sustainable path forward. While it might be tempting to take the lesson from this dissertation that building more storage capacity could solve our problems, the solution is not as strong in practice. The sites for building reservoirs that can store affordable water are limited and cannot fill the gap between water demand and supply that exists now or in the future (Hanak et al. 2009). Rather, we must reimagine how we consume the water that we already have (OECD 2007).

In this vein, Californians must reflect on how water is used in all capacities, moving beyond simply evaluating direct uses like showers, gardening, and dishwashers. Instead, we should expand our scope to include the extended connections between water and the products we consume. According to a report by the Pacific Institutes, Californians use more water than the average resident in other developed (OECD) countries or the world in general (Fulton, Cooley, and Gleick 2012). Our economy and consumption habits are complex and connected by a global network of materials, labor, and markets, but identifying products that are high-water cost and not necessary for living would be a strong place to start cutting back our water consumption. In fact, expanding water assessments to include more than direct consumption is in itself and important step in grappling with patterns of water usage.

The largest source of intensive water use is agricultural products. More than 90% of California's total water footprint is linked to agricultural products, like meat, dairy, and produce, in contrast with the 4% associated with direct household water consumption (Fulton et al. 2012). Changing consumption patterns, especially the food we grow and buy, is hugely important for confronting the reality of climate change. Given that agriculture also accounts for approximately 85% of direct water consumption in California, this sector of the economy will need to get serious about sustainability and water use. California is using far more water than regions very similar to ours, such as the Mediterranean or Tijuana, and we will need to ask ourselves what we can – and must – live without if we are to confront the reality of climate change and the history of water and drought in the state.

Consequences of leaving history unaddressed

When I think about the future of drought in California, I think about Paulo Bacigalupi's 2015 novel *The Water Knife*, which I read while in Sacramento on a research trip for this project. The novel envisions a near-future dystopia where the Southwest is drying up. Water is worth more than gold, and water shares traded on a water exchange like stock shares in 2022. State water bureaus and agencies are the ultimate power and authority, and water knives are agents sent to murder for water rights. In this novel, people from Texas, New Mexico, and Arizona were displaced when water resources in those states dried up, creating a humanitarian refugee crisis as people moved into "water rich" California and Nevada. Documented primary water rights offer power to the wealthy – something literally worth killing over, while the majority of residents need to pay a premium for a gallon of water at a water pump in the center of town.

The specter of this novel haunts me years later because like most good science fiction it reminds us of what has happened in the past and warns us of a very real possibility for the future. Less than a century ago, refugees from the Dustbowl drought arrived in California, seeking work and security and finding very little of either. Soon, climate change will create new climate refugees once again, who will be forced to seek out safety and security. Additionally, Native American tribes were violently removed from their ancestral lands so miners could access water, and it took a century for a 1908 Supreme Court ruling to restore meaningful water rights. Now, tribes in Northern California who have received their water rights fear for their safety and wellbeing as farmers lose access to water their livelihoods depend on (Chabria 2021).

We are already seeing the ways in which climate change is destabilizing core components of California's water system – down to the measurement of precipitation itself (Allen and Luptowitz 2017; Mann and Gleick 2015; Schwartz 2022). Important work has been done to bolster regional sustainability (California Department of Conservation 2022; Frick et al. 2015; Thomas 2019), and household water use has gone down over the last thirty years as population expands (Cooley 2020; Lee, Nemati, and Dinar 2021; Mount and Hanak 2019). However, if California and the people, places, ecosystems, and more want to avoid a disastrous future, we are going to need to get more comfortable engaging with the decisions, policies, and structures built over the last one hundred years. Climate change will only exacerbate inequalities within states and countries, as well as between them (Islam and Winkel 2017). All decisions related to water, sustainability, and drought must be focused on addressing those inequalities and reducing them. Like many of the large problems facing cities, states, nations, and planets today – it is going to take the same kind of innovating to get us out of this mess as it took to create the structures and systems that brought us to this point.

APPENDIX A

U.S. Drought Monitor, Historically Observed Impacts in California

Category	Historically observed impacts
D0	Soil is dry; irrigation delivery begins early
	Dryland crop germination is stunted
	Active fire season begins
	Winter resort visitation is low; snowpack is minimal
D1	Dryland pasture growth is stunted; producers give supplemental feed to cattle
	Landscaping and gardens need irrigation earlier; wildlife patterns begin to change
	Stock ponds and creeks are lower than usual
D2	Grazing land is inadequate
	Producers increase water efficiency methods and drought-resistant crops
	Fire season is longer, with high burn intensity, dry fuels, and large fire spatial extent; more fire crews are on staff
	Wine country tourism increases; lake- and river-based tourism declines; boat ramps close
	Trees are stressed; plants increase reproductive mechanisms; wildlife diseases increase
	Water temperature increases; programs to divert water to protect fish begin
	River flows decrease; reservoir levels are low and banks are exposed
D3	Livestock need expensive supplemental feed, cattle and horses are sold; little pasture remains, producers find it difficult to maintain organic meat requirements
	Fruit trees bud early; producers begin irrigating in the winter
	Federal water is not adequate to meet irrigation contracts; extracting supplemental groundwater is expensive
	Dairy operations close
	Fire season lasts year-round; fires occur in typically wet parts of state; burn bans are implemented
	Ski and rafting business is low, mountain communities suffer
	Orchard removal and well drilling company business increase; panning for gold increases
	Low river levels impede fish migration and cause lower survival rates
	Wildlife encroach on developed areas; little native food and water is available for bears, which hibernate less
	Water sanitation is a concern, reservoir levels drop significantly, surface water is nearly dry, flows are very low; water theft occurs
	Wells and aquifer levels decrease; homeowners drill new wells
	Water conservation rebate programs increase; water use restrictions are implemented; water transfers increase
	Water is inadequate for agriculture, wildlife, and urban needs; reservoirs are extremely low; hydropower is restricted

D4	Fields are left fallow; orchards are removed; vegetable yields are low; honey harvest is small
	Fire season is very costly; number of fires and area burned are extensive
	Many recreational activities are affected
	Fish rescue and relocation begins; pine beetle infestation occurs; forest mortality is high; wetlands dry up; survival of native plants and animals is low; fewer wildflowers bloom; wildlife death is widespread; algae blooms appear
	Policy change; agriculture unemployment is high, food aid is needed
	Poor air quality affects health; greenhouse gas emissions increase as hydropower production decreases; West Nile Virus outbreaks rise
	Water shortages are widespread; surface water is depleted; federal irrigation water deliveries are extremely low; junior water rights are curtailed; water prices are extremely high; wells are dry, more and deeper wells are drilled; water quality is poor;

REFERENCES

Abbott, Andrew. 1988. *The System of Professions: An Essay on the Division of Expert Labor*. University of Chicago Press.

Akeman, Thom. 1987. "IT MAY BE STATE'S DRIEST YEAR IN DECADE." *The Sacramento Bee*, March 9, METRO FINAL, B1.

Alcamo, Joseph, Lilibeth Acosta-Michlik, Alexander Carius, Frank Eierdanz, Richard Klein, Dörthe Krömker, and Dennis Tänzler. 2008. "A New Approach to Quantifying and Comparing Vulnerability to Drought." *Regional Environmental Change* 8(4):137. doi: 10.1007/s10113-008-0065-5.

Allen, Robert J., and Rainer Luptowitz. 2017. "El Niño-like Teleconnection Increases California Precipitation in Response to Warming." *Nature Communications* 8(1):16055. doi: 10.1038/ncomms16055.

Alley, William M. 1984. "The Palmer Drought Severity Index: Limitations and Assumptions." *Journal of Applied Meteorology and Climatology* 23(7):1100–1109. doi: 10.1175/1520-0450(1984)023<1100:TPDSIL>2.0.CO;2.

Alston, Julian M., James T. Lapsley, and Olena Sambucci. 2020. "Chapter 8. Grape and Wine Production in California." *California Agriculture* 26.

Ambruster, Ariel. 2008. *Collaborative Versus Technocratic Polymaking: California's Statewide Water Plan*. California State University, Sacramento: Center for Collaborative Policy.

Anders, Allison Daniel, and Jessica Nina Lester. 2015. "Lessons from Interdisciplinary Qualitative Research: Learning to Work against a Single Story." *Qualitative Research* 15(6):738–54. doi: 10.1177/1468794114557994.

Anderson, Ben, Matthew Kearnes, Colin McFarlane, and Dan Swanton. 2012. "Materialism and the Politics of Assemblage." *Dialogues in Human Geography* 2(2):212–15. doi: 10.1177/2043820612449298.

Anthrop, Donald F. 1982. "The Peripheral Canal and the Future for Water in California." *Yearbook of the Association of Pacific Coast Geographers* 44:109–28.

Anaya-Morga, Laura. 2021. "California Records Driest Year in a Century." *Los Angeles Times*, October 18.

Archibald, Marybelle D. 1977. *Appropriative Water Rights in California: Background and Issues*. Staff Paper No. 1. Sacramento: State Water Resources Control Board.

Armstrong, David, and Jane Ogden. 2006. “The Role of Etiquette and Experimentation in Explaining How Doctors Change Behaviour: A Qualitative Study.” *Sociology of Health & Illness* 28(7):951–68. doi: 10.1111/j.1467-9566.2006.00514. x.

Arthur, W. Brian. 1989. “Competing Technologies, Increasing Returns, and Lock-In by Historical Events.” *The Economic Journal* 99(394):116–31. doi: 10.2307/2234208.

Attwater, William R., and James Markle. 1987. “Overview of California Water Rights and Water Quality Law Symposium: Revisiting California Water Law.” *Pacific Law Journal* 19(4):957–1030.

Auyero, Javier, and Debora Alejandra Swistun. 2009. *Flammable: Environmental Suffering in an Argentine Shantytown*. Illustrated edition. Oxford University Press.

Bachmair, Sophie, Kerstin Stahl, Kevin Collins, Jamie Hannaford, Mike Acreman, Mark Svoboda, Cody Knutson, Kelly Helm Smith, Nicole Wall, Brian Fuchs, Neville D. Crossman, and Ian C. Overton. 2016. “Drought Indicators Revisited: The Need for a Wider Consideration of Environment and Society.” *WIREs Water* 3(4):516–36. doi: 10.1002/wat2.1154.

Bacigalupi, Paolo. 2015. *The Water Knife*. Reprint edition. New York: Vintage.

Baker, Zeke. 2017. “Climate State: Science-State Struggles and the Formation of Climate Science in the US from the 1930s to 1960s.” *Social Studies of Science* 47(6):861–87. doi: 10.1177/0306312717725205.

Baker, Zeke, Julia A. Ekstrom, Kelsey D. Meagher, Benjamin Lee Preston, and Louise Bedsworth. 2020. “The Social Structure of Climate Change Research and Practitioner Engagement: Evidence from California.” *Global Environmental Change* 63.

Barad, Karen. 2003. “Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter.” *Signs* 28(3):801–31. doi: 10.1086/345321.

Barboza, Tony. 2013. “Klamath Water Wars Threaten to Flare Anew; New Rights Have given Tribes an Advantage over Farmers Just as a Severe Drought Has Gripped the Region.” *The Los Angeles Times*, May 7, A1.

Barnes, Jessica. 2014. *Cultivating the Nile: The Everyday Politics of Water in Egypt*. Duke University Press.

Beerman, Paul. 1961. “The Effect of Dry Years on Local Surface Supplies.” Los Angeles, California.

Bennett, Jane. 2005. “The Agency of Assemblages and the North American Blackout.” *Public Culture* 17:445–66. doi: 10.1215/08992363-17-3-445.

Berner, Logan T., Beverly E. Law, Arjan J. H. Meddens, and Jeffrey A. Hicke. 2017. “Tree Mortality from Fires, Bark Beetles, and Timber Harvest during a Hot and Dry Decade in the Western United States (2003–2012).” *Environmental Research Letters* 12(6):065005. doi: 10.1088/1748-9326/aa6f94.

Berry, Mike. 2014. “Neoliberalism and the City: Or the Failure of Market Fundamentalism.” *Housing, Theory and Society* 31(1):1–18. doi: 10.1080/14036096.2013.839365.

Berry, William L. 1961. “Planning for Maximum Use of Water.” Sacramento, California.

Best, Joel. 2012. *Social Problems*. 2 edition. New York: W. W. Norton & Company.

Birch, Kean, and Matti Siemiatycki. 2016. “Neoliberalism and the Geographies of Marketization: The Entangling of State and Markets.” *Progress in Human Geography* 40(2):177–98. doi: 10.1177/0309132515570512.

Blair, Thomas A. 1942. *Weather Elements, a Text in Elementary Meteorology*. n Revised edition. Prentice Hall.

Blum, Deborah. 1987. “ALL BETS OFF ON RAINFALL THIS AUTUMN.” *The Sacramento Bee*, August 31, STATE FINAL, B1.

Blumenstock, George. 1942. “Drought in the United States Analyzed by Means of the Theory of Probability.” 64.

Blumer, Herbert. 1971. “Social Problems as Collective Behavior.” *Social Problems* 18(3):298–306. doi: 10.2307/799797.

Bohle, Hans G., Thomas E. Downing, and Michael J. Watts. 1994. “Climate Change and Social Vulnerability: Toward a Sociology and Geography of Food Insecurity.” *Global Environmental Change* 4(1):37–48. doi: 10.1016/0959-3780(94)90020-5.

Bowers, Nathan A. 1928. “The St. Francis Dam Disaster.” *Engineering News-Record*, March 22, 100 (12), 3.

Bowker, Geoffrey C., and Susan Leigh Star. 2000. *Sorting Things Out: Classification and Its Consequences*. Revised edition. The MIT Press.

Boyt, W. G. 1941. “Factors Influencing Runoff during the Flood of December 1937, in Northern California.” *Eos, Transactions, American Geophysical Union* 22(1):124129.

Brands, H. W. 2003. *The Age of Gold: The California Gold Rush and the New American Dream*. New York: Anchor.

Brandt, Alf W. 1987. “United States v. State Water Resources Control Board: A Comprehensive Approach to Water Policy in California.” *ECOLOGY LAW QUARTERLY* 14:29.

Brown, Edmund G. 1961. “Address by Edmund G. Brown.” Biltmore Hotel, Los Angeles, California.

Brown, Jr., Jerry. 1977. *Executive Order B-27-77*. California State Archives, Department of Water Resources Collections.

Brown, Oli, Anne Hammill, and Robert Mcleman. 2007. “Climate Change as the ‘New’ Security Threat: Implications for Africa.” *International Affairs* 83(6):1141–54. doi: 10.1111/j.1468-2346.2007.00678. x.

Brown, Phil. 2013. *Toxic Exposures: Contested Illnesses and the Environmental Health Movement*. Columbia University Press.

Bruni, Attila, and Maurizio Teli. 2007. “Reassembling the Social—An Introduction to Actor Network Theory.” *Management Learning* 38(1):121–25. doi: 10.1177/1350507607073032.

Buttel, Frederick H., and Peter J. Taylor. 1992. “Environmental Sociology and Global Environmental Change: A Critical Assessment.” *Society & Natural Resources* 5(3):211–30. doi: 10.1080/08941929209380788.

Butterfield. 1989. *Drought: Contingency Planning Guidelines for 1989*. Department of Water Resources.

Butterfield, Suzanne. 1991. *California’s Continuing Drought*. California Department of Water Resources.

California Cooperative Snow Survey. 1976. *Water Conditions in California Report: February 1, 1976*. Bulletin 120-76. California Department of Water Resources.

California Cooperative Snow Survey. 1977. *Water Conditions in California Report: February 1,1977*. Bulletin 120-77. California Department of Water Resources.

California Cooperative Snow Survey. 1977. *Water Conditions in California Report: May 1, 1977*. Bulletin 120-77. California Department of Water Resources.

California Cooperative Snow Survey. 1988. *Water Conditions in California Report: April 1, 1988*. 120–88. California Department of Water Resources.

California Cooperative Snow Survey. 1988. *Water Conditions in California Report: May 1, 1988*. Bulletin 120-88. California Department of Water Resources.

California Cooperative Snow Survey. 1992. *Water Conditions in California Report: October 1, 1992*. 120–88. California Department of Water Resources.

California Cooperative Snow Survey. 2001. *Water Conditions in California Report: May 1, 2001*. Bulletin 120-01. California Department of Water Resources.

California Cooperative Snow Survey. 2002. *Water Conditions in California Report: May 1, 2002*. Bulletin 120-02. California Department of Water Resources.

California Cooperative Snow Survey. 2007. "Snow Course Measurements for April 2007." *Department of Water Resources: California Data Exchange Center*. Retrieved (https://cdec.water.ca.gov/reportapp/javareports?name=COURSES.200704).

California Cooperative Snow Survey. 2007. *Water Conditions in California Report: April 1, 2007*. 120–07. Sacramento.

California Cooperative Snow Survey. 2007. *Water Conditions in California Report: May 1, 2007*. 120–07. Sacramento: California Department of Water Resources.

California Cooperative Snow Survey. 2008. *Water Conditions in California Report: April 1, 2008*. 120–08. Sacramento: California Department of Water Resources.

California Cooperative Snow Survey. 2008. *Water Conditions in California Report: May 1, 2008*. 120–08. Sacramento: California Department of Water Resources.

California Cooperative Snow Survey. 2008. *Water Conditions in California Report: May 1, 2008*. Bulletin 120-08. Department of Water Resources.

California Cooperative Snow Survey. 2014. *Water Conditions in California Report: February 1, 2014*. Bulletin 120-14. California Department of Water Resources.

California Cooperative Snow Survey. 2014. *Water Conditions in California Report: May 1, 2014*. Bulletin 120-14. California Department of Water Resources.

California Cooperative Snow Survey. 2022. "Unimpaired Runoff Calculations." *Department of Water Resources*. Retrieved April 19, 2022 (https://cdec.water.ca.gov/snow/current/flow/index2.html).

California Cooperative Snow Surveys. 1985. *Water Conditions in California Fall Report: October 1985*. Sacramento: California Department of Water Resources.

California Cooperative Snow Surveys. 1987. *Water Conditions in California Report: October 1, 1987*. Sacramento: California Department of Water Resources.

California Cooperative Snow Surveys. 1991. *Water Conditions in California: May 1, 1991*. Bulletin 120-91. Sacramento: California Department of Water Resources.

California Cooperative Snow Surveys. 2006. *California Water Conditions: May 1, 2006*. Bulletin 120-06. Sacramento: California Department of Water Resources.

California Cooperative Snow Surveys. 2007. *Water Conditions in California Report: May 1, 2007*. Bulletin 120-07. California Department of Water Resources.
California Cooperative Snow Surveys. 2022. *Water Conditions in California Report: March 1, 2022*. 120–22. California Department of Water Resources.

California Department of Conservation. 2015. “Storage in Major Reservoirs as of September 30, 2015.” *California Department of Water Resources Data Exchange Center*. Retrieved April 18, 2022 (https://cdec.water.ca.gov/reportapp/javareports?name=STORAGE.201509).

California Department of Conservation. 2022. “Multibenefit Land Repurposing Program.”

California Department of Food and Agriculture. 1976. *Drought Damage to California Agriculture as of January 28, 1976*. Sacramento: California Department of Food and Agriculture.

California Department of Public Works. 1930. *Report to Legislature of 1931 on State Water Plan (1930)*. Bulletin No. 25. Sacramento.

California Department of Public Works. 1930. *Water Conditions in California Report: February 1, 1930*. 120–30. Sacramento: California Department of Public Works.

California Department of Public Works. 1930. *Water Conditions in California Report: May 1, 1930*. 120–30. California Department of Public Works.

California Department of Public Works. 1940. *Act Governing Supervision of Dams in California*.

California Department of Public Works. 1941. *Act Governing Supervision of Dams in California*.

California Department of Water Resources. 1961. *Water Conditions in California: Special Report for the Governors Dry Year Conference*. California Department of Water Resources.

California Department of Water Resources. 1978. *1976-1977 California Drought: A Review*. California Department of Water Resources.

California Department of Water Resources. 2008. *The State Water Project Delivery Reliability Report 2007*. California Department of Water Resources.

California Department of Water Resources. 2010. “Storage in Major Reservoirs as of September 30, 2009.” *California Department of Water Resources: California Cooperative Snow Surveys*. Retrieved (https://cdec.water.ca.gov/cgi-progs/snowsurvey_res/STORAGE.200909).

California Department of Water Resources. 2013. "Storage in Major Reservoirs as of September 30, 2013." *California Department of Water Resources Data Exchange Center*. Retrieved April 18, 2022 (https://cdec.water.ca.gov/reportapp/javareports?name=STORAGE.201309).

California Department of Water Resources. 2015. *Drought in California*. *Drought Brochure*. Sacramento: California Department of Water Resources.

California Department of Water Resources. 2017. "California State Water Project Milestones." *California State Water Project*. Retrieved April 17, 2022 (https://web.archive.org/web/20171219123245/http://www.water.ca.gov/swp/milestones.cfm).

California Department of Water Resources. 2017. *Management of the California State Water Project - Calendar Year 2015 Activities*. Bulletin 132-16. Sacramento: California Department of Water Resources.

California Department of Water Resources. 2017. *Water Year 2017: What a Difference a Year Makes*. California Department of Water Resources.

California Department of Water Resources. 2021. "Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices." *California Department of Water Resources Data Exchange Center*. Retrieved April 18, 2022 (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).

California Department of Water Resources, State of. 2022. "SWP Water Contractors." *California Department of Water Resources*. Retrieved April 18, 2022 (https://water.ca.gov/Programs/State-Water-Project/Management/SWP-Water-Contractors).

California Nevada Climate Applications Program. 2017. "California Precipitation." Retrieved April 22, 2022 (https://cwc.ca.gov/-/media/CWC-Website/Files/Documents/2019/08_August/Dettinger_CA_Precipitation.pdf).

California Proposition 9. 1982. *Water Facilities Including a Peripheral Canal*. Retrieved April 16, 2022 (https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/RestoretheDelta/RTD_140.pdf).

California, State of. 2022. "Agricultural Water Use Efficiency." *California Department of Water Resources*. Retrieved April 11, 2022 (https://water.ca.gov/Programs/Water-Use-And-Efficiency/Agricultural-Water-Use-Efficiency).

California, State of. 2022. "Drought." *California Department of Water Resources*. Retrieved April 9, 2022 (https://water.ca.gov/Water-Basics/Drought).

California, State of. n.d. “State Water Project.” Retrieved April 15, 2022 (https://water.ca.gov/Programs/State-Water-Project).

California State Water Resources Control Board. 1977. “State Water Resources Control Board Suggestions for Study by the State University and College System.”

California Water Boards. 2011. *Guidance Compendium for Watershed Monitoring and Assessment: Runoff Coefficent (C) Fact Sheet*. State Water Resources Control Board.

Callon, Michel. 1984. “Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay.” *The Sociological Review* 32:196–233. doi: 10.1111/j.1467-954X.1984.tb00113. x.

Callon, Michel. 1999. “Actor-Network Theory—The Market Test.” *The Sociological Review* 47(1_suppl):181–95. doi: 10.1111/j.1467-954X.1999.tb03488. x.

Caniglia, Beth, Beatrice Frank, Bridget Kerner, and Tamara L. Mix. 2016. “Water Policy And Governance Networks: A Pathway To Enhance Resilience Toward Climate Change.” *Sociological Forum* 31:828–45. doi: 10.1111/socf.12275.

Carle, David. 2004. *Introduction to Water in California*. University of California Press.

Carrão, Hugo, Simone Russo, Guadalupe Sepulcre-Canto, and Paulo Barbosa. 2016. “An Empirical Standardized Soil Moisture Index for Agricultural Drought Assessment from Remotely Sensed Data.” *International Journal of Applied Earth Observation and Geoinformation* 48:74–84. doi: 10.1016/j.jag.2015.06.011.

Carroll, Patrick. 1996. “Science, Power, Bodies: The Mobilization of Nature as State Formation.” *Journal of Historical Sociology* 9(2):139–67. doi: 10.1111/j.1467-6443.1996.tb00181.x.

Carroll, Patrick. 2006. *Science, Culture, and Modern State Formation*. 1 edition. University of California Press.

Carroll, Patrick. 2012. “Water and Technoscientific State Formation in California.” *Social Studies of Science* 42(4):489–516. doi: 10.1177/0306312712437977.

Carse, Ashley. 2012. “Nature as Infrastructure: Making and Managing the Panama Canal Watershed.” *Social Studies of Science* 42(4):539–63. doi: 10.1177/0306312712440166.

Carse, Ashley. 2017. “An Infrastructural Event: Making Sense of Panama’s Drought.” *Water Alternatives* 10(3):888–909.

Carter, Bob, and Simon M. Dyson. 2015. “Actor Network Theory, Agency and Racism: The Case of Sickle Cell Trait and US Athletics.” *Social Theory & Health* 13(1):62–77. doi: 10.1057/sth.2014.17.

Carter, Lloyd G. 2008. “QUENCHING THE DROUGHT - Water Problems Improve When Governor Puts Policy before Plumbing.” June 22, J1.

Casper, M. J., and A. E. Clarke. 1998. “Making the Pap Smear into the ‘Right Tool’ for the Job.” *Social Studies of Science* 28(2):255–90. doi: 10.1177/030631298028002003.

Cayan, Daniel R., Michael D. Dettinger, Kelly T. Redmond, Gregory J. McCabe, Noah Knowles, and David H. Peterson. 2003. “The Transboundary Setting of California’s Water and Hydropower Systems.” Pp. 237–62 in *Climate and Water*. Vol. 16, *Advances in Global Change Research*, edited by H. F. Diaz and B. J. Morehouse. Dordrecht: Springer Netherlands.

Cayan, Daniel R., Tapash Das, David W. Pierce, Tim P. Barnett, Mary Tyree, and Alexander Gershunov. 2010. “Future Dryness in the Southwest US and the Hydrology of the Early 21st Century Drought.” *Proceedings of the National Academy of Sciences* 107(50):21271–76. doi: 10.1073/pnas.0912391107.

Cayan, Daniel R., Kelly T. Redmond, and Laurence G. Riddle. 1999. “ENSO and Hydrologic Extremes in the Western United States.” *Journal of Climate* 12(9):2881–93. doi: 10.1175/1520-0442(1999)012<2881:EAHEIT>2.0.CO;2.

Chabria, Anita. 2021. “Racism, Drought and History: Young Native Americans Fight Back as Water Disappears.” *Los Angeles Times*, June 23.

Chiro, Giovanna Di. 2008. “Living Environmentalisms: Coalition Politics, Social Reproduction, and Environmental Justice.” *Environmental Politics* 17(2):276–98. doi: 10.1080/09644010801936230.

City News Service. 2021. “San Diego County Water Authority: Region ‘Drought Safe’ This Summer.” *KPBS Public Media*, June 21.

Claire, Theo, and Kevin Surprise. 2022. “Moving the Rain: Settler Colonialism, the Capitalist State, and the Hydrologic Rift in California’s Central Valley.” *Antipode* 54(1):153–73. doi: 10.1111/anti.12777.

Clark, J. 1980. *Environmental Defense Fund, Inc. v. East Bay Municipal Utility District*. (20 Cal.3d 327, 23422)

Clarke, Adele E. 1991. “Social Worlds Theory as Organizational Theory.” in *Social Organization and Social Process: Essays in Honor of Anselm Strauss*, edited by D. R. Maines.

Cohen, Daniel Aldana. 2016. “The Rationed City: The Politics of Water, Housing, and Land Use in Drought-Parched São Paulo.” *Public Culture* 28(2 (79)):261–89. doi: 10.1215/08992363-3427451.

Colorado River Research Group. 2016. *Tribes and Water in the Colorado River Basin*. University of Colorado Law School.

Cony, Ann. 1987. “Dry Spell Spells Trouble at the Ranch, Drought Pares Cattle Reproductive Rates, Weight; Forces Feed.” *The Sacramento Bee*, November 10, METRO FINAL, D1.

Cooley, Heather. 2020. *Urban and Agricultural Water Use in California, 1960–2015*. Pacific Institute.

Cooper, Simon. 2008. “Regulating Hybrid Monsters?: The Limits of Latour and Actor Network Theory.” *Arena Journal* (29/30):305–30. doi: 10.3316/ielapa.681606442619245.

Crow, Gary M., Linda Levine, and Nancy Nager. 1992. “Are Three Heads Better Than One? Reflections on Doing Collaborative Interdisciplinary Research.” *American Educational Research Journal* 29(4):737–53. doi: 10.3102/00028312029004737.

Cunningham, Alex. 1977. “Studies by State University and College.” California State Archives, Department of Water Resources Collections, Box 2.

Dai, Aiguo. 2011. “Drought under Global Warming: A Review.” *WIREs Climate Change* 2(1):45–65. doi: 10.1002/wcc.81.

Daipha, Phaedra. 2015. *Masters of Uncertainty: Weather Forecasters and the Quest for Ground Truth*. University of Chicago Press.

Dallman, Suzanne, Mary Ngo, Paul Laris, and Deborah Thien. 2013. “Political Ecology of Emotion and Sacred Space: The Winnemem Wintu Struggles with California Water Policy.” *Emotion, Space and Society* 6:33–43. doi: 10.1016/j.emospa.2011.10.006.

Daston, Lorraine, ed. 2000. *Biographies of Scientific Objects*. University of Chicago Press.

David, Paul A. 1985. “Clio and the Economics of QWERTY.” *The American Economic Review* 75(2):332–37.

Dean, Bartholomew, and Jerome M. Levi. 2003. *At the Risk of Being Heard: Identity, Indigenous Rights, and Postcolonial States*. University of Michigan Press.

Department of the Interior. 1920. *Official Register of the United States: Persons in the Civil, Military, and Naval Service, Exclusive of the Postal Service*. U.S. Government Printing Office.

Derksen, Linda. 2000. “Towards a Sociology of Measurement:” *Social Studies of Science*. doi: 10.1177/030631200030006001.

DeSombre, Elizabeth R. 2000. *Domestic Sources of International Environmental Policy: Industry, Environmentalists, and U.S. Power*. MIT Press.

Dettinger, Michael D., Fred Martin Ralph, Tapash Das, Paul J. Neiman, and Daniel R. Cayan. 2011. “Atmospheric Rivers, Floods and the Water Resources of California.” *Water* 3(2):445–78. doi: 10.3390/w3020445.

Devorkin, David H. 1992. *Science with a Vengeance: How the Military Created the US Space Sciences after World War II*. New York: Springer-Verlag Publishing.

Dietz, Thomas, Amy Dan, and Rachael Shwom. 2007. “Support for Climate Change Policy: Social Psychological and Social Structural Influences*.” *Rural Sociology* 72(2):185–214. doi: 10.1526/003601107781170026.

Dietz, Thomas, and Cameron T. Whitley. 2018. “Environmentalism, Norms, and Identity.” *Proceedings of the National Academy of Sciences* 115(49):12334–36. doi: 10.1073/pnas.1817487115.

Diffenbaugh, Noah S., Daniel L. Swain, and Danielle Touma. 2015. “Anthropogenic Warming Has Increased Drought Risk in California.” *Proceedings of the National Academy of Sciences* 112(13):3931–36. doi: 10.1073/pnas.1422385112.

Dong, Chunyu, Glen M. MacDonald, Katherine Willis, Thomas W. Gillespie, Gregory S. Okin, and A. Park Williams. 2019. “Vegetation Responses to 2012–2016 Drought in Northern and Southern California.” *Geophysical Research Letters* 46(7):3810–21. doi: 10.1029/2019GL082137.

Doolin, Bill, and Alan Lowe. 2002. “To Reveal Is to Critique: Actor–Network Theory and Critical Information Systems Research.” *Journal of Information Technology* 17(2):69–78. doi: 10.1080/02683960210145986.

Dowall, David E., and Jan Whittington. 2003. *Making Room for the Future: Rebuilding California’s Infrastructure*. Public Policy Instit. of CA.

Dryzek, John S., David Downes, Christian Hunold, David Schlosberg, and Hans-Kristian Hernes. 2003. *Green States and Social Movements: Environmentalism in the United States, United Kingdom, Germany, and Norway*. OUP Oxford.

Dunbar-Ortiz, Roxanne. 2015. *An Indigenous Peoples’ History of the United States*. Reprint edition. Boston: Beacon Press.

Dunlap, Riley E., and William R. Catton. 1994. “Struggling with Human Exemptionalism: The Rise, Decline and Revitalization of Environmental Sociology.” *The American Sociologist* 25(1):5–30. doi: 10.1007/BF02691936.

Dunlap, Riley E., and Angela G. Mertig. 2014. *American Environmentalism: The US Environmental Movement, 1970-1990*. Taylor & Francis.

Dunlap, Riley E., and William Michelson, eds. 2001. *Handbook of Environmental Sociology*. Westport, CT: Greenwood.

Dziegielewski, Benedykt, Hari P. Garbharran, and John F. Langowski Jr. 1993. *Lessons Learned From the California Drought (1987-1992)*. IWR Report 93-NDS-5. US Army Corp of Engineers.

Editorial. 2007. "Uttering the 'D' Word? - Dry January Brings on Worries of Drought." *Sacramento Bee, The (CA)*, January 25, METRO FINAL, B6.

Edwards, Paul N. 2004. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical System." in *Modernity and Technology*, edited by T. J. Misa, P. Brey, and A. Feenberg. The MIT Press.

Edwards, Paul N. 2010. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. MIT Press.

Egan, Timothy. 2001. "'Controlled' Blaze That Wasn't Haunts Firefighters in California." *The New York Times*, August 31.

Engle, Karen. 2010. *The Elusive Promise of Indigenous Development: Rights, Culture, Strategy*. Duke University Press.

Entwisle, Barbara, Ashton Verdery, and Nathalie Williams. 2020. "Climate Change and Migration: New Insights from a Dynamic Model of Out-Migration and Return Migration." *American Journal of Sociology* 125(6):1469–1512. doi: 10.1086/709463.

Epstein, Paul R. 2001. "Climate Change and Emerging Infectious Diseases." *Microbes and Infection* 3(9):747–54. doi: 10.1016/S1286-4579(01)01429-0.

Epstein, Steven. 1996. *Impure Science: AIDS, Activism, and the Politics of Knowledge*. University of California Press.

Epstein, Steven. 2009. *Inclusion: The Politics of Difference in Medical Research*. University of Chicago Press.

Escriva-Bou, Alvar, Jeffrey Mount, and Jelena Jezdimirovic. 2019. "Dams in California." Retrieved April 22, 2022 (https://www.ppic.org/wp-content/uploads/JTF_DamsJTF.pdf).

Eslamian, Saeid, Kaveh Ostad-Ali-Askari, Vijay Singh, Nicolas R. Dalezios, Mohsen Ghane, Yohannes Yihdego, and Mohammed Matouq. 2017. "A Review of Drought Indices." *International Journal of Constructive Research in Civil Engineering* 3(4). doi: 10.20431/2454-8693.0304005.

Evans, Rhonda, and Tamara Kay. 2008. "How Environmentalists 'Greened' Trade Policy: Strategic Action and the Architecture of Field Overlap." *American Sociological Review* 73(6):970–91. doi: 10.1177/000312240807300605.

Eyal, Gil. 2010. *The Autism Matrix*. Polity Press.

Eyal, Gil. 2013. “For a Sociology of Expertise: The Social Origins of the Autism Epidemic.” *American Journal of Sociology* 118(4):863–907. doi: 10.1086/668448.

Eyal, Gil. 2019. *The Crisis of Expertise*. 1st edition. Cambridge, UK; Medford, MA: Polity.

Fieldman, Glenn. 2011. “Neoliberalism, the Production of Vulnerability and the Hobbled State: Systemic Barriers to Climate Adaptation.” *Climate and Development* 3(2):159–74. doi: 10.1080/17565529.2011.582278.

Fimrite, Peter. 2013. “2013 Could Break Record for State’s Driest Year.” *The San Francisco Chronicle* 2.

Fleck, Ludwik. 1981. *Genesis and Development of a Scientific Fact*. University of Chicago Press.

Fletcher. 1983. *United States v. Adair*, 723 F.2d 1394 (9th Cir.)

Foster, John Bellamy. 1999. “Marx’s Theory of Metabolic Rift: Classical Foundations for Environmental Sociology.” *American Journal of Sociology* 105(2):366–405. doi: 10.1086/210315.

Foucault, Michel. 1994. *The Order of Things: An Archaeology of the Human Sciences*. Illustrated edition. New York: Vintage.

Fountain, Henry. 2022. “How Bad Is the Western Drought? Worst in 12 Centuries, Study Finds.” *The New York Times*, February 14.

Freudenburg, William R., Scott Frickel, and Robert Gramling. 1995. “Beyond the Nature/Society Divide: Learning to Think about a Mountain.” *Sociological Forum* 10(3):361–92. doi: 10.1007/BF02095827.

Frick, Karen Trapenberg, Karen Chapple, Elizabeth Mattiuzzi, and Miriam Zuk. 2015. “Collaboration and Equity in Regional Sustainability Planning in California: Challenges in Implementation.” *California Journal of Politics and Policy* 7(4). doi: 10.5070/P2cjpp7428924.

Frickel, Scott, and Neil Gross. 2005. “A General Theory of Scientific/Intellectual Movements.” *American Sociological Review* 70(2):204–32. doi: 10.1177/000312240507000202.

Frickel, Scott, and Kelly Moore. 2006. *The New Political Sociology of Science: Institutions, Networks, and Power*. University of Wisconsin Press.

Fu, Albert S. 2016. “Connecting Urban and Environmental Catastrophe: Linking Natural Disaster, the Built Environment, and Capitalism.” *Environmental Sociology* 2(4):365–74. doi: 10.1080/23251042.2016.1220891.

Fulton, Julian, Heather Cooley, and Peter H. Gleick. 2012. *California's Water Footprint*. Pacific Institute.

Gavin, Newson. 2021. "Proclamation of a State of Emergency." Retrieved April 16, 2022 (https://www.gov.ca.gov/wp-content/uploads/2021/10/10.19.21-Drought-SOE-1.pdf)

Gershunov, Alexander, Tamara Shulgina, Rachel E. S. Clemesha, Kristen Guirguis, David W. Pierce, Michael D. Dettinger, David A. Lavers, Daniel R. Cayan, Suraj D. Polade, Julie Kalansky, and F. Martin Ralph. 2019. "Precipitation Regime Change in Western North America: The Role of Atmospheric Rivers." *Scientific Reports* 9(1):9944. doi: 10.1038/s41598-019-46169-w.

Giannini Foundation of Agriculture Economics, University of California. 2018. *California Agriculture Dimensions and Issues*. 18–01. University of California Davis.

Gibbs, W. J., and J. V. Maher. 1967. "Rainfall Deciles Drought Inddicators." (48):0–0.

Giglioli, Ilaria, and Erik Swyngedouw. 2008. "Let's Drink to the Great Thirst! Water and the Politics of Fractured Techno-Natures in Sicily." *International Journal of Urban and Regional Research* 32(2):392–414. doi: 10.1111/j.1468-2427.2008.00789. x.

Goldman, Michael, and Rachel A. Schurman. 2000. "Closing the 'Great Divide': New Social Theory on Society and Nature." *Annual Review of Sociology* 26(1):563–84. doi: 10.1146/annurev.soc.26.1.563.

Goodhue, Rachael E., Philip Martin, and Leo K. Simon. 2020. "Chapter 7. California's Fruits and Tree Nuts." *California Agriculture* 20.

Gottlieb, Robert. 2005. *Forcing the Spring: The Transformation of the American Environmental Movement*. Island Press. California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. "DETF Supporting Data Volume 10: Meeting Notes 6-77 to 7-77." California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. "Drought Emergency Task Force Correspondence, January 1977 to July 1977." California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. "Drought Emergency Task Force Supporting Data: Volume 10 Meeting Minutes March 15 - April 4, 1977." California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. "Drought Emergency TAsk Force Supporting Data Volume 17: Press Releases." California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. "Drought Emergency Task Force Supporting Data, Volume 21 CSUC." California State Archives, Department of Water Resources Collections, Box 2.

Governor's Drought Emergency Task Force. 1977. *Status Report on Study Projects Submitted to The California State University and Colleges by the Governor's Drought Emergency Task Force*.

Governor's Office. 2008. "'The California Strategic Growth Plan' in Governor's Budget Summary 2008 - 2009."

Governor's Office. 2014. "Governor Brown Declares Drought State of Emergency."

Grantham, Theodore E., and Joshua H. Viers. 2014. "100 Years of California's Water Rights System: Patterns, Trends and Uncertainty." *Environmental Research Letters* 9(8):084012. doi: 10.1088/1748-9326/9/8/084012.

Great Britain Meteorological Office. 1951. *Meteorological Glossary*. Chemical Publishing Company.

Gregory, James Noble. 1991. *American Exodus: The Dust Bowl Migration and Okie Culture in California*. Oxford University Press.

Greider, Thomas, and Lorraine Garkovich. 1994. "Landscapes: The Social Construction of Nature and the Environment." *Rural Sociology* 59(1):1–24.

Grossi, Mark. 2007. "Dry Times Ahead - It's Not a Drought Just yet, but There's Talk of Conservation and Some Fear That a Second Dry Winter Could Spell Disaster for the Valley." *The Fresno Bee*, April 26, FINAL, A1.

Grossi, Mark. 2008. "First, the Good News - Recent Winter Storms Have Doubled the Snowpack in the Sierra, Easing Drought Anxieties. But Experts Say, 'We've Still Got a Long Way to Go.'" *The Fresno Bee*, January 13, A1.

Grossi, Mark. 2013. "Winter May Be among 10 Driest." *The Fresno Bee*, May 1.

Guttman, Nathaniel B. 1998. "Comparing the Palmer Drought Index and the Standardized Precipitation Index1." *JAWRA Journal of the American Water Resources Association* 34(1):113–21. doi: 10.1111/j.1752-1688.1998.tb05964.x.

Gwynn, Douglas, Orville E. Thompson, and Kathleen L'Ecluse. 1983. "The California Peripheral Canal: Who Backed It, Who Fought It." *California Agriculture* (January-February):3.

Hanak, Ellen. 2011. *Managing California's Water: From Conflict to Reconciliation*. Public Policy Instit. of CA.

Hanak, Ellen, Jay Lund, Ariel Dinar, Brian Gray, Richard Howitt, Jeffrey Mount, Peter Moyle, and Barton H. Thompson. 2009. *California Water Myths*. Public Policy Institute of California, Water Policy Center.

Haney, Timothy J. 2021. "Disrupting the Complacency: Disaster Experience and Emergent Environmentalism." *Socius* 7:2378023121992934. doi: 10.1177/2378023121992934.

Harper, Kristine C. 2003. "Research from the Boundary Layer: Civilian Leadership, Military Funding and the Development of Numerical Weather Prediction (1946-55)." *Social Studies of Science* 33(5):667–96. doi: 10.1177/0306312703335003.

Harpold, A. A., Michael D. Dettinger, and S. Rajagopal. 2017. "Defining Snow Drought and Why It Matters." *Eos: Science News by AGU*. Retrieved April 16, 2022 (http://eos.org/opinions/defining-snow-drought-and-why-it-matters).

Harpold, Adrian, Paul Brooks, Seshadri Rajagopal, Ingo Heidbuchel, Angela Jardine, and Clare Stielstra. 2012. "Changes in Snowpack Accumulation and Ablation in the Intermountain West." *Water Resources Research* 48(11). doi: 10.1029/2012WR011949.

Harvey, Penny, and Hannah Knox. 2015. *Roads: An Anthropology of Infrastructure and Expertise*. Cornell University Press.

Haughton, Graham. 1998. "Private Profits – Public Drought: The Creation of a Crisis in Water Management for West Yorkshire." *Transactions of the Institute of British Geographers* 23(4):419–33. doi: 10.1111/j.0020-2754.1998.00419. x.

Haydu, Jeffrey. 1998. "Making Use of the Past: Time Periods as Cases to Compare and as Sequences of Problem Solving." *American Journal of Sociology* 104(2):339–71. doi: 10.1086/210041.

Haydu, Jeffrey. 2009. "Reversals of Fortune: Path Dependency, Problem Solving, and Temporal Cases." *Theory and Society* 39(1):25. doi: 10.1007/s11186-009-9098-0.

Hayes, Michael, Mark Svoboda, Nicole Wall, and Melissa Widhalm. 2011. "The Lincoln Declaration on Drought Indices: Universal Meteorological Drought Index Recommended." *Bulletin of the American Meteorological Society* 92(4):485–88.

Healey, Justin. 2014. *Indigenous Rights*. Spinney Press.

Heddinghaus, Thomas R., and Paul Sabol. 1991. "A Review of the Palmer Drought Severity Index and Where Do We Go from Here?" P. 6 in. Salt Lake City, Utah.

Heim, Richard R. 2002. "A Review of Twentieth-Century Drought Indices Used in the United States." *Bulletin of the American Meteorological Society* 83(8):1149–66. doi: 10.1175/1520-0477-83.8.1149.

Helly, John, Daniel Cayan, Thomas Corringham, Jennifer Stricklin, and Todd Hillaire. 2021. "Patterns of Water Use in California." *San Francisco Estuary and Watershed Science* 19(4). doi: 10.15447/sfews.2021v19iss4art2.

Higgins, Vaughan. 2001. "Calculating Climate: 'Advanced Liberalism' and the Governing of Risk in Australian Drought Policy." *Journal of Sociology* 37(3):299–316. doi: 10.1177/144078301128756355.

Homer-Dixon, Thomas F. 2010. *Environment, Scarcity, and Violence*. Princeton University Press.

Hooks, Gregory, and Chad L. Smith. 2004. "The Treadmill of Destruction: National Sacrifice Areas and Native Americans." *American Sociological Review* 69(4):558–75. doi: 10.1177/000312240406900405.

Hoyt, John Clayton. 1936. *Droughts of 1930-34*. 680. Government Printing Office. doi: 10.3133/wsp680.

Hoyt, John Clayton. 1938. *Drought of 1936, with Discussion on the Significance of Drought in Relation to Climate*. 820. Government Printing Office. doi: 10.3133/wsp820.

Hoyt, William Glenn. 1936. *Studies of Relations of Rainfall and Run-off in the United States*. 772. U.S. Govt. Print. Off.,. doi: 10.3133/wsp772.

Hoyt, William Glenn. 1944. *J.C. and His 42 Years with the Water Resources Branch: A Semi-Intimate Biography Commemorating the Retirement of J.C. Hoyt from the Geological Survey on June 30, 1944*. [Washington?

Hundley, Norris. 2001. *The Great Thirst: Californians and Water-A History, Revised Edition*. First edition. University of California Press.

Hutchins, Wells A. 1956. *The California Law of Water Rights*. Sacramento, California: State of California, Printing Division.

Hutchins, Wells A. 1959. "Pueblo Water Rights in the West." *Texas Law Review* 38:748.

Ide, Tobias, Miguel Rodriguez Lopez, Christiane Fröhlich, and Jürgen Scheffran. 2021. "Pathways to Water Conflict during Drought in the MENA Region." *Journal of Peace Research* 58(3):568–82. doi: 10.1177/0022343320910777.

Irwin, Alan. 2002. *Citizen Science: A Study of People, Expertise and Sustainable Development*. Routledge.

Islam, S. Nazrul, and John Winkel. 2017. *Climate Change and Social Inequality. DESA Working Paper*. 152. United Nations Department of Economic and Social Affairs.

Jamison, Andrew. 2001. *The Making of Green Knowledge: Environmental Politics and Cultural Transformation*. Cambridge University Press.

Jasanoff, Sheila. 1995. *Handbook of Science and Technology Studies*. Sage Publications.
Jasanoff, Sheila. 2004. *States of Knowledge: The Co-Production of Science and the Social Order*. Routledge.

Jasanoff, Sheila S. 1987. "Contested Boundaries in Policy-Relevant Science." *Social Studies of Science* 17(2):195–230. doi: 10.1177/030631287017002001.

Johnson, Renée, and Betsy A. Cody. 2015. *California Agricultural Production and Irrigated Water Use*. R44093. Congressional Research Service.

Jones, Jeanine. 2000. *Preparing for California's Next Drought: Changes Since 1987 - 921*. California Department of Water Resources.

Jones, Jeanine. 2020. *California's Most Significant Droughts: Comparing Historical and Recent Conditions*. California Department of Water Resources.

Jones, Jeanine. 2021. *California's Drought of 2012–2016: An Overview*. California Department of Water Resources.

Jones, Jeanine. 2021. *Report to the Legislature on the 2012 - 2016 Drought: As Required by Chapter 340 of 2016*. California Natural Resources Agency.

Jones, Jeanine, and Thang (Vic) Nguyen. 2010. *California's Drought of 2007-2009: An Overview*. California Department of Water Resources.

Jones, Terry L., and Al Schwitalla. 2008. "Archaeological Perspectives on the Effects of Medieval Drought in Prehistoric California." *Quaternary International* 188(1):41–58. doi: 10.1016/j.quaint.2007.07.007.

Jordan, Kathleen, and Michael Lynch. 1998. "The Dissemination, Standardization and Routinization of a Molecular Biological Technique." *Social Studies of Science* 28(5–6):773–800. doi: 10.1177/030631298028005005.

Juhola, Sirkku, E. Carina H. Keskitalo, and Lisa Westerhoff. 2011. "Understanding the Framings of Climate Change Adaptation across Multiple Scales of Governance in Europe." *Environmental Politics* 20(4):445–63. doi: 10.1080/09644016.2011.589571.

Juska, Arunas, Lourdes Gouveia, Jackie Gabriel, and Susan Koneck. 2000. "Negotiating Bacteriological Meat Contamination Standards in the US: The Case of E.Coli O157:H7." *Sociologia Ruralis* 40(2):249–71. doi: 10.1111/1467-9523.00146.

Kahrl, William. 1990. "Remember This One? Let's Build a Peripheral Canal." *The Los Angeles Times*, September 2.

Kaika, Maria. 2003. “Constructing Scarcity and Sensationalising Water Politics: 170 Days That Shook Athens.” *Antipode* 35(5):919–54. doi: 10.1111/j.1467-8330.2003.00365. x.

Kaiser, David. 2002. “Cold War Requisitions, Scientific Manpower, and the Production of American Physicists after World War II.” *Historical Studies in the Physical and Biological Sciences* 33(1):131–59. doi: 10.1525/hsps.2002.33.1.131.

Kallis, Giorgos. 2008. “Droughts.” *Annual Review of Environment and Resources* 33(1):85–118. doi: 10.1146/annurev.environ.33.081307.123117.

Kallis, Giorgos, Isha Ray, Julian Fulton, and James E. McMahon. 2010. “Public Versus Private: Does It Matter for Water Conservation? Insights from California.” *Environmental Management* 45(1):177–91. doi: 10.1007/s00267-009-9403-8.

Kanazawa, Mark. 2015. *Golden Rules: The Origins of California Water Law in the Gold*. The University of Chicago Press.

Keeley, Jon E., and C. J. Fotheringham. 2001. “Historic Fire Regime in Southern California Shrublands.” *Conservation Biology* 15(6):1536–48. doi: 10.1046/j.1523-1739.2001.00097. x.

Keyantash, John, and John A. Dracup. 2002. “The Quantification of Drought: An Evaluation of Drought Indices.” *Bulletin of the American Meteorological Society* 83(8):1167–80. doi: 10.1175/1520-0477-83.8.1167.

Kiparsky, Michael, David L. Sedlak, Barton H. Thompson, and Bernhard Truffer. 2013. “The Innovation Deficit in Urban Water: The Need for an Integrated Perspective on Institutions, Organizations, and Technology.” *Environmental Engineering Science* 30(8):395–408. doi: 10.1089/ees.2012.0427.

Kleinman, D., and Mark Solovey. 1995. “Hot Science/Cold War: The National Science Foundation after World War II.” *Radical History Review* 1995:111–39. doi: 10.1215/01636545-1995-63-111.

Klinenberg, Eric. 2015. *Heat Wave: A Social Autopsy of Disaster in Chicago*. edited by W. a N. Preface. University of Chicago Press.

Kuhn, Thomas S. 1996. *The Structure of Scientific Revolutions*. 3rd edition. University of Chicago Press.

Laet, Marianne de, and Annemarie Mol. 2000. “The Zimbabwe Bush Pump: Mechanics of a Fluid Technology.” *Social Studies of Science* 30(2,):225–63.

Lagos, Marisa. 2007. “Rain, Snow - ’It Looks like Winter.” *The San Francisco Chronicle*, October 11, B5.

Lakoff, Andrew, and Stephen J. Collier. 2010. “Infrastructure and Event: The Political Technology of Preparedness.” Pp. 243–66 in *Political Matter*, *Technoscience, Democracy, and Public Life*. University of Minnesota Press.

Lampland, Martha, and Susan Leigh Star, eds. 2008. *Standards and Their Stories: How Quantifying, Classifying, and Formalizing Practices Shape Everyday Life*. Cornell University Press.

Langbein, Walter Basil. 1949. *Annual Runoff in the United States*. Vol. 52. *USGS Numbered Series*. 52. Washington, D.C.: U.S. Geological Survey. doi: 10.3133/cir52.

Latour, Bruno. 2007. *Reassembling the Social: An Introduction to Actor-Network-Theory*. 1st edition. Oxford University Press.

Latour, Bruno, and Steve Woolgar. 2013. *Laboratory Life: The Construction of Scientific Facts*. Princeton University Press.

Law, John. 2014. “After ANT: Complexity, Naming and Topology.” *The Sociological Review* 47(S1):1–14. doi: 10.1111/j.1467-954X.1999.tb03479. x.

Lawrimore, Jay, Richard Heim, Mark Svoboda, Val Swail, and Phil Englehart. 2002. “BEGINNING A NEW ERA OF DROUGHT MONITORING ACROSS NORTH AMERICA.” *Drought Mitigation Center Faculty Publications*.

Lee, Juhee, Mehdi Nemati, and Ariel Dinar. 2021. *How Has Residential Per Capita Water Consumption in California Changed Between 1994–2019? ARE Update*. 24(5). Giannini Foundation of Agriculture Economics, University of California.

Liang, ErYuan, XueMei Shao, HongYan Liu, and Dieter Eckstein. 2007. “Tree-Ring Based PDSI Reconstruction since AD 1842 in the Ortindag Sand Land, East Inner Mongolia.” *Chinese Science Bulletin* 52(19):2715–21. doi: 10.1007/s11434-007-0351-5.

Liu, Carol. 2001. *Groundwater Contamination: Quality Monitoring Program*. Vol. Division 6.

Longhofer, Wesley, and Evan Schofer. 2010. “National and Global Origins of Environmental Association.” *American Sociological Review* 75(4):505–33. doi: 10.1177/0003122410374084.

López, Ian Haney. 1996. *White by Law: The Legal Construction of Race*. New York University Press.

Lowen, Rebecca S. 1997. *Creating the Cold War University: The Transformation of Stanford*. University of California Press.

Ludwig, Ralf, Roberto Roson, Christos Zografos, and Giorgios Kallis. 2011. “Towards an Inter-Disciplinary Research Agenda on Climate Change, Water and Security in Southern

Europe and Neighboring Countries." *Environmental Science & Policy* 14(7):794–803. doi: 10.1016/j.envsci.2011.04.003.

Luebehusen, Eric. 2015. "California Drought Conditions September 29, 2015." *U.S. Drought Monitor Map Archive*. Retrieved April 8, 2022 (https://droughtmonitor.unl.edu/Maps/MapArchive.aspx).

Lyle, Kate. 2017. "Shaping the Future of Sociology: The Challenge of Interdisciplinarity beyond the Social Sciences." *Sociology* 51(6):1169–85. doi: 10.1177/0038038516653728.

Maddox, Darrell, and Joe Thome. 1988. "RANCHERS EXPECTING DISASTER, REQUESTING FEDERAL <strong>DROUGHT</Strong> AID." *The Fresno Bee*, April 14, HOME, B3.

Malnic, Eric. 1988. "There May Be a Drought, but It's Still Pretty Wet: [Orange County Edition]." *Los Angeles Times*, April 21, 3.

Mann, Michael E., and Peter H. Gleick. 2015. "Climate Change and California Drought in the 21st Century." *Proceedings of the National Academy of Sciences* 112(13):3858–59. doi: 10.1073/pnas.1503667112.

Marcus, George E., and Erkan Saka. 2016. "Assemblage:" *Theory, Culture & Society*. doi: 10.1177/0263276406062573.

Matthai, Howard Frederick. 1979. *Hydrologic and Human Aspects of the 1976-77 Drought*. Department of the Interior, Geological Survey.

Matthews, Jon. 1987. "WRUNG DRY ONCE, MARIN TRIES TO INSTILL CONSERVATION ETHIC." *The Sacramento Bee*, June 14, METRO FINAL, A19.

Mayer, Jim. 1988. "State Urges Less Water Use Reservoirs Abnormally Low Despite Recent Rains." *The Sacramento Bee*, April 21, B8.

McCullough, Charles A., and Helen J. Peters. 1976. *Special Report on Dry Year Impacts in California*. California Department of Water Resources.

McGregor, Sandra, Violet Lawson, Peter Christophersen, Rod Kennett, James Boyden, Peter Bayliss, Adam Liedloff, Barbie McKaige, and Alan N. Andersen. 2010. "Indigenous Wetland Burning: Conserving Natural and Cultural Resources in Australia's World Heritage-Listed Kakadu National Park." *Human Ecology* 38(6):721–29. doi: 10.1007/s10745-010-9362-y.

Meehan, Katie M. 2014. "Tool-Power: Water Infrastructure as Wellsprings of State Power." *Geoforum* 57:215–24. doi: 10.1016/j.geoforum.2013.08.005.

Meko, David, Charles W. Stockton, and William R. Boggess. 1995. "The Tree-Ring Record of Severe Sustained Drought." *JAWRA Journal of the American Water Resources Association* 31(5):789–801. doi: 10.1111/j.1752-1688.1995.tb03401.x.

Merton, Robert K. 1938. "Science and the Social Order." *Philosophy of Science* 5(3):321–37. doi: 10.1086/286513.

Merton, Robert K. 1942. "A Note on Science and Democracy." *Journal of Legal and Political Sociology* 1(1 and 2):115–26.

Merton, Robert K. 1973. *The Sociology of Science: Theoretical and Empirical Investigations*. University of Chicago Press.

Middleton-Manning, Beth Rose, Morning Star Gali, and Darcie Houck. 2018. "Holding the Headwaters: Northern California Indian Resistance to State and Corporate Water Development." *Decolonization: Indigeneity, Education & Society* 7(1):174–98.

Miller, Norman L., Kathy E. Bashford, and Eric Strem. 2003. "Potential Impacts of Climate Change on California Hydrology." *JAWRA Journal of the American Water Resources Association* 39(4):771–84. doi: 10.1111/j.1752-1688.2003.tb04404.x.

Millington, Nate. 2018. "Producing Water Scarcity in São Paulo, Brazil: The 2014-2015 Water Crisis and the Binding Politics of Infrastructure." *Political Geography* 65:26–34. doi: 10.1016/j.polgeo.2018.04.007.

Mills, Ralph D. 1977. "CSUC University Services and Action Program Concept Paper." California State Archives, Department of Water Resources Collections, Box 2.

Mishra, Ashok K., and Vijay P. Singh. 2010. "A Review of Drought Concepts." *Journal of Hydrology* 391(1):202–16. doi: 10.1016/j.jhydrol.2010.07.012.

Mizzell, Hope, Greg Carbone, Kirstin Dow, and Jinyoung Rhee. 2021. "Addressing Monitoring Needs for Drought Management."

Mollinga, Peter P. 2008. "Water, Politics and Development: Framing a Political Sociology of Water Resources Management." 1(1):17.

Mount, Jeffrey, and Ellen Hanak. 2019. *Water Use in California*. Public Policy Institute of California, Water Policy Center.

Mukerji, Chandra. 2014. *A Fragile Power: Scientists and the State*. Princeton University Press.

Mukerji, Chandra. 2021. *Impossible Engineering: Technology and Territoriality on the Canal Du Midi*. Princeton University Press.

Mullin, Megan, and Meghan E. Rubado. 2017. “Local Response to Water Crisis: Explaining Variation in Usage Restrictions During a Texas Drought.” *Urban Affairs Review* 53(4):752–74. doi: 10.1177/1078087416657199.

Murdoch, Jonathan. 1997. “Inhuman/Nonhuman/Human: Actor-Network Theory and the Prospects for a Nondualistic and Symmetrical Perspective on Nature and Society.” *Environment and Planning D: Society and Space* 15(6):731–56. doi: 10.1068/d150731.

Murphy, Michelle. 2006. *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers*. Duke University Press.

Murphy, Michelle. 2012. *Seizing the Means of Reproduction: Entanglements of Feminism, Health, and Technoscience*. Duke University Press.

Murphy, Raymond. 1994. “The Sociological Construction of Science without Nature.” *Sociology* 28(4):957–74. doi: 10.1177/0038038594028004010.

Murphy, Raymond. 2002. “The Internalization of Autonomous Nature into Society.” *The Sociological Review* 50(3):313–33. doi: 10.1111/j.1467-954X.2002.tb02807. x.

Murphy, Raymond, and Riley E. Dunlap. 2012. “Beyond the Society/Nature Divide: Building on the Sociology of William Freudenburg.” *Journal of Environmental Studies and Sciences* 2(1):7–17. doi: 10.1007/s13412-011-0057-5.

Nagourney, Adam. 2015. “California Imposes First Mandatory Water Restrictions to Deal With Drought.” *The New York Times*, April 1.

National Drought Mitigation Center. 2022. “Drought Classification | U.S. Drought Monitor.” Retrieved April 8, 2022 (https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx).

National Drought Mitigation Center. 2022. “State Impacts | U.S. Drought Monitor.” *U.S. Drought Monitor*. Retrieved April 8, 2022 (https://droughtmonitor.unl.edu/DmData/StateImpacts.aspx).

National Drought Mitigation Center. 2022. “What Is the USDM | U.S. Drought Monitor.” *U.S. Drought Monitor*. Retrieved April 8, 2022 (https://droughtmonitor.unl.edu/About/WhatistheUSDM.aspx).

National Parks Service. 2022. “Wildfires, Prescribed Fires, and Fuels - Wildland Fire Program.” *National Parks Service*. Retrieved April 15, 2022 (https://www.nps.gov/orgs/1965/wildfires-prescribed-fires-fuels.htm).

National Weather Service. 2022. “Climate Prediction Center - Monitoring & Data: Drought Monitoring.” *Climate Prediction Center - National Oceanic and Atmospheric*

Administration. Retrieved April 19, 2022 (https://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml).

Navon, Daniel. 2019. *Mobilizing Mutations: Human Genetics in the Age of Patient Advocacy*. University of Chicago Press.

Nie, Martin A. 1998. "Build It And They Will Come: A Reexamination of the California State Water Project." *Southern California Quarterly* 80(1):71–88. doi: 10.2307/41171881.

Niemeyer, S. 2008. "New Drought Indices." in *Options Méditerranéennes. Série A: Séminaires Méditerranéens (CIHEAM)*. CIHEAM-IAMZ.

Noble, David F. 1979. *America by Design: Science, Technology, and the Rise of Corporate Capitalism*. Oxford University Press.

Null, Sarah E., and Joshua H. Viers. 2013. "In Bad Waters: Water Year Classification in Nonstationary Climates." *Water Resources Research* 49(2):1137–48. doi: 10.1002/wrcr.20097@10.1002/(ISSN)1944-7973.IMPACRIVR1.

Nunis, Doyce. 1995. *The St. Francis Dam Disaster: Revisited*. Los Angeles: Historical Society of Southern California, Los Angeles.

O'Brien, Karen L., and Robin M. Leichenko. 2000. "Double Exposure: Assessing the Impacts of Climate Change within the Context of Economic Globalization." *Global Environmental Change* 10(3):221–32. doi: 10.1016/S0959-3780(00)00021-2.

O'Connell, Joseph. 1993. "Metrology: The Creation of Universality by the Circulation of Particulars." *Social Studies of Science* 23(1):129–73. doi: 10.1177/030631293023001005.

OECD. 2007. *Infrastructure to 2030 (Vol.2) Mapping Policy for Electricity, Water and Transport: Mapping Policy for Electricity, Water and Transport*. OECD Publishing.

Oladipo, E. Olukayode. 1985. "A Comparative Performance Analysis of Three Meteorological Drought Indices." *Journal of Climatology* 5(6):655–64. doi: 10.1002/joc.3370050607.

Olmstead, Alan L., and Paul W. Rhode. 2017. "A History of California Agriculture." *California Agriculture* 28.

O'Neill, Karen M. 2006. *Rivers by Design: State Power and the Origins of U.S. Flood Control*. Duke University Press Books.

Palmer, Wayne C. 1965. *Meteorological Drought*. Researcher Paper No. 45. U.S. Department of Commerce, Weather Bureau.

Palmer, Wayne C. 1968. "Keeping Track of Crop Moisture Conditions, Nationwide: The New Crop Moisture Index." *Weatherwise* 21(4):156–61. doi: 10.1080/00431672.1968.9932814.

Patricola, Christina M., John P. O'Brien, Mark D. Risser, Alan M. Rhoades, Travis A. O'Brien, Paul A. Ullrich, Dáithí A. Stone, and William D. Collins. 2020. "Maximizing ENSO as a Source of Western US Hydroclimate Predictability." *Climate Dynamics* 54(1):351–72. doi: 10.1007/s00382-019-05004-8.

Pawel, Miriam. 2018. *The Browns of California: The Family Dynasty That Transformed a State and Shaped a Nation*. Bloomsbury Publishing USA.

Pederson, N., A. R. Bell, T. A. Knight, C. Leland, N. Malcomb, K. J. Anchukaitis, K. Tackett, J. Scheff, A. Brice, B. Catron, W. Blozan, and J. Riddle. 2012. "A Long-Term Perspective on a Modern Drought in the American Southeast." *Environmental Research Letters* 7(1):014034. doi: 10.1088/1748-9326/7/1/014034.

Pellow, David N., and Hollie Nyseth Brehm. 2013. "An Environmental Sociology for the Twenty-First Century." *Annual Review of Sociology* 39(1):229–50. doi: 10.1146/annurev-soc-071312-145558.

Philander, S. G. H. 1985. "El Niño and La Niña." *Journal of the Atmospheric Sciences* 42(23):2652–62. doi: 10.1175/1520-0469(1985)042<2652:ENALN>2.0.CO;2.

Pierce, David W., Julie F. Kalansky, and Daniel R. Cayan. 2018. *Climate, Drought, and Sea Level Rise Scenarios for California's Fourth Climate Change Assessment*. CCCA4-CEC-2018–006. Division of Climate, Atmospheric Sciences, and Physical Oceanography: Scripps Institution of Oceanography.

Pierce, David W., and Daniel R. Cayan. 2013. "The Uneven Response of Different Snow Measures to Human-Induced Climate Warming." *Journal of Climate* 26(12):4148–67. doi: 10.1175/JCLI-D-12-00534.1.

Pint, Ellen M. 1999. "Household Responses to Increased Water Rates during the California Drought." *Land Economics* 75(2):246–66. doi: 10.2307/3147009.

Pollock, Dennis. 2008. "Farmers Brace for Reduced Water - Diversion to Save Delta Smelt Is Also Expected to Affect Urban Users." *The Fresno Bee*, March 15, C1.

Pollock, and Mark Grossi. 2008. "Westlands to Ration Water All Summer - Unprecedented Move Follows Dry 'Rainy Season.'" *The Fresno Bee*, May 31, C1.

Priest, Douglas, Devere Davis, Jake Angel, George Deatherage, Robert Fingado, and R. Dean Thompson. 1993. *California's 1987 - 92 Drought: A Summary of Six Years of Drought*. California Department of Water Resources.

Pritchard, Sara B. 2011. *Confluence: The Nature of Technology and the Remaking Of the Rhône*. Harvard University Press.

Pritchard, Sara B. 2012. “From Hydroimperialism to Hydrocapitalism: ‘French’ Hydraulics in France, North Africa, and Beyond.” *Social Studies of Science* 42(4):591–615. doi: 10.1177/0306312712443018.

Racanelli, P. J. 1986. *United States v. State Water Resources Control Board*. 182 Cal. App. 3d 82, 227 Cal. Rptr. 161.

Rasmusson, Eugene M., and Thomas H. Carpenter. 1982. “Variations in Tropical Sea Surface Temperature and Surface Wind Fields Associated with the Southern Oscillation/El Niño.” *Monthly Weather Review* 110(5):354–84. doi: 10.1175/1520-0493(1982)110<0354:VITSST>2.0.CO;2.

Rawls, James J., and Richard J. Orsi, eds. 1999. *A Golden State: Mining and Economic Development in Gold Rush California*. 1st Edition. University of California Press.

Rodrigue, Christine M., and Eugenie Rovai. 1996. “Weaving the Water Web: Evolution of the Legal Framework for Water Resource DEvelopment in California.” in *Southern California before 1900: Landscape, Climate, and Ecology*. California State University, Northridge.

Roos, Maurice, Douglas Priest, Frank Gehrke, Larry Lee, Lawrence Joyce, George Deatherage, and Robert Fingado. 1990. *Drought Conditions in California: September 1990*. California Department of Water Resources.

Ropelewski, C. F., and M. S. Halpert. 1986. “North American Precipitation and Temperature Patterns Associated with the El Niño/Southern Oscillation (ENSO).” *Monthly Weather Review* 114(12):2352–62. doi: 10.1175/1520-0493(1986)114<2352:NAPATP>2.0.CO;2.

Rorig, Miriam L., and Sue A. Ferguson. 2002. “The 2000 Fire Season: Lightning-Caused Fires.” *Journal of Applied Meteorology and Climatology* 41(7):786–91. doi: 10.1175/1520-0450(2002)041<0786:TFSLCF>2.0.CO;2.

Rudel, Thomas K., J. Timmons Roberts, and JoAnn Carmin. 2011. “Political Economy of the Environment.” *Annual Review of Sociology* 37(1):221–38. doi: 10.1146/annurev.soc.012809.102639.

Santa Barbara County Water Agency, and Boyle Engineering Corp. 2003. “Santa Barbara County Water Supply and Demand Update.”

Santos, Joseph T., and Arthur F. Godwin. 1978. *The 1976 - 1977 California Drought: A Review*. California Department of Water Resources.

Santos, Joseph (Tod). 1977. *The Continuing California Drought*. Sacramento: California Department of Water Resources.

Schnaiberg, Allan. 1980. *The Environment: From Surplus to Scarcity*. Oxford University Press.

Schonher, T., and S. E. Nicholson. 1989. "The Relationship between California Rainfall and ENSO Events." *Journal of Climate* 2(11):1258–69. doi: 10.1175/1520-0442(1989)002<1258:TRBCRA>2.0.CO;2.

Schultz, E. J. 2007. "Rejected Delta Plan Gets New Attention - Peripheral Canal Idea Gains Traction as State Eyes Focus on Troubled Water-Delivery Hub." *The Fresno Bee*, December 23, A1.

Schwartz, Andrew. 2022. "Opinion | I'm a Scientist in California. Here's What Worries Me Most About Drought." *The New York Times*, April 4.

Scott, James C. 1998. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. Yale University Press.

Scoville, Caleb. 2019. "Hydraulic Society and a 'Stupid Little Fish': Toward a Historical Ontology of Endangerment." *Theory and Society* 48(1):1–37. doi: 10.1007/s11186-019-09339-3.

Shapin, Steven. 2016. "A Taste of Science: Making the Subjective Objective in the California Wine World." *Social Studies of Science* 46(3):436–60. doi: 10.1177/0306312716651346.

Shapin, Steven, and Simon Schaffer. 2011. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Revised edition. Princeton University Press.

Sheffield, Justin, Gopi Goteti, Fenghua Wen, and Eric F. Wood. 2004. "A Simulated Soil Moisture Based Drought Analysis for the United States." *Journal of Geophysical Research: Atmospheres* 109(D24). doi: 10.1029/2004JD005182.

Shelton, Mercel J. 1959. "Progress of the California Water Plan." *Journal (American Water Works Association)* 51(11):1349–56.

Shukla, Shraddhanand, and Andrew W. Wood. 2008. "Use of a Standardized Runoff Index for Characterizing Hydrologic Drought." *Geophysical Research Letters* 35(2). doi: 10.1029/2007GL032487.

Skelton, George. 2019. "California Should Stop Thinking about More Dams. The State Is Brimming with Them." *Los Angeles Times*, March 4.

Smith, Dorothy E. 1990. *The Conceptual Practices of Power: A Feminist Sociology of Knowledge*. University of Toronto Press.

Smith, Haley. 2022. "As Drought Deepens, Californians Are Saving Less Water." *Los Angeles Times*, March 15.

Solovey, Mark. 2001. “Science and the State During the Cold War: Blurred Boundaries and a Contested Legacy.” *Social Studies of Science* 31(2). doi: 10.1177/030631270103100202.

Sowby, Robert B. 2018. “Comparison of Operational Energy Requirements in Publicly and Privately Owned U.S. Water Utilities.” *Utilities Policy* 54:92–95. doi: 10.1016/j.jup.2018.08.004.

Spencer, Thomas. 1988. “Metropolitan Water District of Southern California: Conservation Advertising and Decals.”

Sribnick, Ethan G. 2008. *A Legacy of Innovation: Governors and Public Policy*. University of Pennsylvania Press.

Staats, Elmer B. 1977. *California Drought of 1976 and 1977 - Extent, Damage, Ad Governmental Response*. CED 77 137.

Staff Writer. 1976. “And, For Several Good Reasons, Cattlemen Have Trouble Putting on a Happy Face.” *The Sacramento Bee*, December 9, 1.

Staff Writer. 1988. “AT DROUGHT’S DOOR TAPS ARE RUNNING LOW IN MANY AREAS; FIREFIGHTERS FEAR ANOTHER GRIM SUMMER.” *The Sacramento Bee*, April 10.

Staff Writer. 1988. “BETTING ON THE COME.” *Fresno Bee, The (CA)*, April 20, HOME, B8.

Staff Writer. 1988. “IT’S DRY, AND THAT’S NO SNOW JOB.” *The Sacramento Bee*, March 30, A1.

Staff Writer. 1988. “IT’S OFFICIAL: CALIFORNIA IS SUFFERING A DROUGHT.” *The Fresno Bee*, April 23, HOME, B1.

Staff Writer. 1988. “WINTER TOO DRY? SPRING LOOKS EVEN WORSE.” March 31.

Stafford, Harlowe M., and Harold C. Troxell. 1944. “Differences in Basin-Characteristics as Reflected by Precipitation-Runoff Relations in San Bernardino and Eastern San Gabriel Mountain Drainages.” *Eos, Transactions American Geophysical Union* 25(1):21–35. doi: 10.1029/TR025i001p00021.

Stafford, Robert T. 1990. *Emergency Assistance Act*.

Stahle, David W., Edward R. Cook, Malcolm K. Cleaveland, Matthew D. Therrell, David M. Meko, Henri D. Grissino-Mayer, Emma Watson, and Brian H. Luckman. 2000. “Tree-Ring Data Document 16th Century Megadrought over North America.” *Eos, Transactions American Geophysical Union* 81(12):121–25. doi: 10.1029/00EO00076.

Stahle, David W., Falko K. Fye, Edward R. Cook, and R. Daniel Griffin. 2007. “Tree-Ring Reconstructed Megadroughts over North America since a.d. 1300.” *Climatic Change* 83(1):133. doi: 10.1007/s10584-006-9171-x.

Stain, Helen J., Brian Kelly, Vaughan J. Carr, Terry J. Lewin, Michael Fitzgerald, and Lyn Fragar. 2011. “The Psychological Impact of Chronic Environmental Adversity: Responding to Prolonged Drought.” *Social Science & Medicine* 73(11):1593–99. doi: 10.1016/j.socscimed.2011.09.016.

Stanforth, Carolyne. 2006. “Using Actor-Network Theory to Analyze E-Government Implementation in Developing Countries.” *Information Technologies & International Development* 3(3):35–60.

Star, Susan Leigh. 1990. “Power, Technology and the Phenomenology of Conventions: On Being Allergic to Onions.” *The Sociological Review* 38(S1):26–56. doi: 10.1111/j.1467-954X.1990.tb03347. x.

Star, Susan Leigh. 1999. “The Ethnography of Infrastructure.” *American Behavioral Scientist* 43(3):377–91. doi: 10.1177/00027649921955326.

Star, Susan Leigh, and Karen Ruhleder. 1996. “Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces.” *Information Systems Research* 7(1):111–34.

State Water Contractors. 2022. “About Us.” *State Water Contractors*. Retrieved April 18, 2022 (https://swc.org/about-us/).

State Water Resources Control Board. 1971. “Water Rights Decision 1379.”

State Water Resources Control Board. 1978. *Water Quality Control Plan: Sacramento-San Joaquin Delta and Suisun Marsh*. State Water Resources Control Board.

State Water Resources Control Board. 1978. “Water Rights Decision 1485.”

State Water Resources Control Board. 1988. *Water Quality Control Plan For Salinity: San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Draft)*. State Water Resources Control Board.

Steinemann, Anne, Sam F. Iacobellis, and Daniel R. Cayan. 2015. “Developing and Evaluating Drought Indicators for Decision-Making.” *Journal of Hydrometeorology* 16(4):1793–1803. doi: 10.1175/JHM-D-14-0234.1.

Stern, Charles V. 2019. *Indian Water Rights Settlements*. R44148. Congressional Research Service.

Stern, Charles V., and Pervaze A. Sheikh. 2017. *Central Valley Project Operations: Background and Legislation*. 7–5700. Congressional Research Service.

Stern, Paul C., Thomas Dietz, Troy Abel, Gregory A. Guagnano, and Linda Kalof. 1999. “A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism.” *Human Ecology Review* 6(2):81–97.

Stine, Scott. 1994. “Extreme and Persistent Drought in California and Patagonia during Mediaeval Time.” *Nature* 369(6481):546–49. doi: 10.1038/369546a0.

Strangeways, Ian. 2006. *Precipitation: Theory, Measurement and Distribution*. Cambridge University Press.

Sub-Workgroup on Water Year Classification. 1989. *Bay-Delta Estuary Proceedings Water Year Classification Sub-Workgroup: Summary of Workshop Activities*. California Department of Water Resources.

Sundqvist, Göran, Ingemar Bohlin, Erlend AT Hermansen, and Steven Yearley. 2015. “Formalization and Separation: A Systematic Basis for Interpreting Approaches to Summarizing Science for Climate Policy.” *Social Studies of Science* 45(3):416–40. doi: 10.1177/0306312715583737.

Svoboda, Mark D., Brian A. Fuchs, Integrated Drought Management Programme, World Meteorological Organization, Global Water Partnership, University of Nebraska--Lincoln, and National Drought Mitigation Center. 2016. *Handbook of Drought Indicators and Indices.*

Svoboda, Mark, Doug LeComte, Mike Hayes, Richard Heim, Karin Gleason, Jim Angel, Brad Rippey, Rich Tinker, Mike Palecki, David Stooksbury, David Miskus, and Scott Stephens. 2002. “THE DROUGHT MONITOR.” *Bulletin of the American Meteorological Society* 83(8):1181–90. doi: 10.1175/1520-0477-83.8.1181.

Swidler, Ann, and Jorge Arditi. 1994. “The New Sociology of Knowledge.” *Annual Review of Sociology* 20:305–29.

Swyngedouw, Erik. 1999. “Modernity and Hybridity: Nature, Regeneracionismo, and the Production of the Spanish Waterscape, 1890-1930.” *Annals of the Association of American Geographers* 89(3):443–65.

Swyngedouw, Erik. 2006. “Circulations and Metabolisms: (Hybrid) Natures and (Cyborg) Cities.” *Science as Culture* 15(2):105–21. doi: 10.1080/09505430600707970.

Taenzler, Dennis, Alexander Carius, and Achim Maas. 2008. “Assessing the Susceptibility of Societies to Droughts: A Political Science Perspective.” *Regional Environmental Change* 8(4):161–72. doi: 10.1007/s10113-008-0067-3.

Tanaka, Keiko, and Lawrence Busch. 2003. “Standardization as a Means for Globalizing a Commodity: The Case of Rapeseed in China.” *Rural Sociology* 68(1):25–45. doi: http://dx.doi.org/10.1111/j.1549-0831.2003.tb00127.x.

Taylor, Peter J., and Frederick H. Buttel. 1992. “How Do We Know We Have Global Environmental Problems? Science and the Globalization of Environmental Discourse.” *Geoforum* 23(3):405–16. doi: 10.1016/0016-7185(92)90051-5.

Thomas, Brian F. 2019. “Sustainability Indices to Evaluate Groundwater Adaptive Management: A Case Study in California (USA) for the Sustainable Groundwater Management Act.” *Hydrogeology Journal* 27(1):239–48. doi: 10.1007/s10040-018-1863-6.

Thornthwaite, C. W. 1948. “An Approach toward a Rational Classification of Climate.” *Geographical Review* 38(1):55–94. doi: 10.2307/210739.

Thorpe, Charles. 2006. *Oppenheimer: The Tragic Intellect.* University of Chicago Press.

Tierney, Kathleen J. 2007. “From the Margins to the Mainstream? Disaster Research at the Crossroads.” *Annual Review of Sociology* 33(1):503–25. doi: 10.1146/annurev.soc.33.040406.131743.

Timmermans, Stefan, and Steven Epstein. 2010. “A World of Standards but Not a Standard World: Toward a Sociology of Standards and Standardization.” *Annual Review of Sociology* 36(1):69–89. doi: 10.1146/annurev.soc.012809.102629.

Trenberth, Kevin E. 1997. “The Definition of El Niño.” *Bulletin of the American Meteorological Society* 78(12):2771–78. doi: 10.1175/1520-0477(1997)078<2771:TDOENO>2.0.CO;2.

Trott, Stephen. 2006. *Central Delta Water Agency v. Bureau of Reclamation.* , 452 F.3d 1021, 449 F.3d 965 (9th Cir.).

Tsakiris, G., A. Loukas, D. Pangalou, H. Vangelis, D. Tigkas, G. Rossi, and A. Cancelliere. 2007. “Drought Characterization.” *OPTIONS Méditerranéennes. Série B: Etudes et Recherches (CIHEAM).*

United States Congress House Committee on Interior and Insular Affairs. 1956. *Central Valley Project Documents: Part One, Authorizing Documents*. U.S. Government Printing Office.

United States Geological Survey. 2021. “Runoff (Monthly & Annual) | USGS California Water Science Center.” *USGS California Water Science Center*. Retrieved April 19, 2022 (https://ca.water.usgs.gov/california-drought/california-drought-runoff.html).

US Army Corps of Engineers. 2020. “National Inventory of Dams.” *National Inventory of Dams*. Retrieved April 15, 2022 (https://nid.usace.army.mil/#/).

US Bureau of Reclamation. 2011. “Project Details - Central Valley Project.” *Central Valley Project*. Retrieved April 16, 2022 (https://web.archive.org/web/20110615011112/http://www.usbr.gov/projects/Project.jsp?proj_Name=Central%20Valley%20Project&pageType=ProjectPage).

U.S. Census Bureau. 1961. *General Population Characteristics of California*.

U.S. Census Bureau. 1982. *Characteristics of the Population of California*. PC80-1-A6. U.S. Department of Commerce Economics and Statistics Administration.

U.S. Census Bureau. 2000. “California: Resident Population and Apportionment of the U.S. House of Representatives.”

U.S. Census Bureau. 2010. *2010 Census: California Profile*. U.S. Department of Commerce Economics and Statistics Administration.

US Department of Commerce, National Oceanic and Atmospheric Administration. 2022. “What Are El Nino and La Nina?” Retrieved April 13, 2022 (https://oceanservice.noaa.gov/facts/ninonina.html).

U.S. Geological Survey. 2012. *California Water Science Center: Map of the Sacramento/San Joaquin Delta*.

Van, Wilgen Brian W., and Gregory G. Forsyth. 2011. “Towards Adaptive Fire Management for Biodiversity Conservation: Experience in South African National Parks.” *Koedoe : African Protected Area Conservation and Science* 53(2):1–9. doi: 10.10520/EJC132238.

Vasi, Ion Bogdan, and Brayden G. King. 2012. “Social Movements, Risk Perceptions, and Economic Outcomes: The Effect of Primary and Secondary Stakeholder Activism on Firms’ Perceived Environmental Risk and Financial Performance.” *American Sociological Review* 77(4):573–96. doi: 10.1177/0003122412448796.

Vicuna, S., and J. A. Dracup. 2007. “The Evolution of Climate Change Impact Studies on Hydrology and Water Resources in California.” *Climatic Change* 82(3):327–50. doi: 10.1007/s10584-006-9207-2.

Vogel, Nancy. 2007. “Drought Forces Lawmakers to Face Water Issues.” *The Los Angeles Times*, July 16.

Wang, Chunzai, Clara Deser, Jin-Yi Yu, Pedro DiNezio, and Amy Clement. 2017. “El Niño and Southern Oscillation (ENSO): A Review.” Pp. 85–106 in *Coral Reefs of the Eastern Tropical Pacific: Persistence and Loss in a Dynamic Environment*, edited by P. W. Glynn, D. P. Manzello, and I. C. Enochs. Dordrecht: Springer Netherlands.

Water Education. n.d. “Appropriative Rights.” *Water Education Foundation*. Retrieved April 21, 2022 (https://www.watereducation.org/aquapedia/appropriative-rights).

Webster, Andrew, and Lena Eriksson. 2008. “Governance-by-Standards in the Field of Stem Cells: Managing Uncertainty in the World of ‘Basic Innovation.’” *New Genetics and Society - NEW GENET SOC* 27:99–111. doi: 10.1080/14636770802077009.

Weghorst, Karen M. 1996. “The Reclamation Drought Index: Guidelines and Practical Applications.”

Weiser, Matt. 2008. “Sierra Snowpack about Average.” *Sacramento Bee, The (CA)*, March 27, METRO FINAL, B1.

Wells, Nathan, Steve Goddard, and Michael J. Hayes. 2004. “A Self-Calibrating Palmer Drought Severity Index.” *Journal of Climate* 17(12):2335–51. doi: 10.1175/1520-0442(2004)017<2335:ASPDSI>2.0.CO;2.

West, A. B. 1961. “Conservation of Water Through Prevention Losses to Surface Supplies.” Los Angeles, California.

White, R. C. L. 1955. *Drought and Effective Rainfall Frequency in Pastoral New South Wales, West of the Wheat Belt*. Meteorological Study No. 5. Bureau of Meteorology, Australia.

Wiel, Samuel Charles. 1911. *Water Rights in the Western States: The Law of Prior Appropriation of Water as Applied Alone in Some Jurisdictions, and As, in Others, Confined to the Public Domain, with the Common Law of Riparian Rights for Waters Upon Private Lands. Federal, California and Oregon Statutes in Full, with Digest of Statutes of Alaska, Arizona, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Philippine Islands, South Dakota, Texas, Utah, Washington and Wyoming*. Bancroft-Whitney.

Wiley, A. J., Geo D. Louderback, F. L. Ransome, F. E. Bonner, H. T. Cory, and F. H. Fowler. 1928. *Report of the Commission Appointed by Governor C. C. Young to Investigate the Causes Leading to the Failure of the St. Francis Dam*. Sacramento, California.

Williams, A. Park, Benjamin I. Cook, and Jason E. Smerdon. 2022. “Rapid Intensification of the Emerging Southwestern North American Megadrought in 2020–2021.” *Nature Climate Change* 12(3):232–34. doi: 10.1038/s41558-022-01290-z.

Woelfle-Erskine, Cleo. 2019. “Fishy Pleasures: Unsettling Fish Hatching and Fish Catching on Pacific Frontiers.” *Imaginations: Journal of Cross-Cultural Image Studies / Imaginations: Revue d’études Interculturelles de l’image* 10(1):325–52. doi: 10.17742/IMAGE.CR.10.1.11.

Wogan, Cameron F. 2021. *In the Matter of the Determination Ofthe Relative Rights of the Waters of the Klamath River, A Tributary of the Pacific Ocean*.

Woodlee, Laura. 2016. “Use of Prescribed Fire Is Heating Up: Educating about Controlled Burning Programs in the State Parks of Upstate South Carolina.” *Senior Theses* 1–16.

Wynne, Brian. 1992. "Misunderstood Misunderstanding: Social Identities and Public Uptake of Science." *Public Understanding of Science* 1(3):281–304. doi: 10.1088/0963-6625/1/3/004.

Yazzie, Melanie, and Cutcha Risling-Baldy. 2018. "Introduction: Indigenous Peoples and the Politics of Water." *Decolonization: Indigeneity, Education & Society* 7(1):19.

Yearley, Steven. 2009. "Sociology and Climate Change after Kyoto: What Roles for Social Science in Understanding Climate Change?" *Current Sociology* 57(3):389–405. doi: 10.1177/0011392108101589.

Zamani, Gh. H., Marjan J. Gorgievski-Duijvesteijn, and Kiumars Zarafshani. 2006. "Coping with Drought: Towards a Multilevel Understanding Based on Conservation of Resources Theory." *Human Ecology* 34(5):677–92. doi: 10.1007/s10745-006-9034-0.

Zargar, Amin, Rehan Sadiq, Bahman Naser, and Faisal I. Khan. 2011. "A Review of Drought Indices." *Environmental Reviews* 19(NA):333–49. doi: 10.1139/a11-013.

Zelezny, Lynnette C., Poh-Pheng Chua, and Christina Aldrich. 2000. "New Ways of Thinking about Environmentalism: Elaborating on Gender Differences in Environmentalism." *Journal of Social Issues* 56(3):443.

Zerubavel, Eviatar. 1982. "The Standardization of Time: A Sociohistorical Perspective." *American Journal of Sociology* 88(1):1–23.

Zilberman, David, Ariel Dinar, Neal MacDougall, Madhu Khanna, Cheril Brown, and Frederico Castillo. 2011. "Individual and Institutional Responses to the Drought: The Case of California Agriculture." *Journal of Contemporary Water Research and Education* 121(1).

Zito, Kelly. 2008. "State Takes Measures to Give Farmers More Water." *The San Francisco Chronicle*, June 13, B1.