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ARTICLE

Law, Land Use, and Groundwater Recharge

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Abstract. Groundwater is one of the world's most important natural resources, and its importance will increase as climate change continues and the human population grows. But groundwater management has traditionally been governed by lax and uneven legal regimes. To the extent those regimes exist, they tend to focus on the extraction of groundwater rather than the processes—referred to as groundwater recharge—through which water enters the subsurface. Yet groundwater recharge is crucially important to the maintenance of groundwater supplies, and it is also highly susceptible to human influences, particularly through our pervasive manipulation of land uses.

This Article discusses the underdeveloped law of groundwater recharge. It explains why groundwater-recharge law, or the lack thereof, is important; it discusses existing legal doctrines that affect groundwater recharge, occasionally by design but usually inadvertently; and it explains how more intentional and effective systems of groundwater-recharge law can be constructed. It also sets forth criteria for judging when regulation of groundwater recharge will make sense, and it argues that a communitarian ethic, rather than the currently prevalent laissez-faire approaches, should underpin those regulatory approaches. Finally, it suggests using regulatory fees as a key (but not exclusive) instrument of groundwater-recharge regulation.

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Table of Contents

Introduction

Every day, around the world, billions of people rely on water pumped from wells.[1] They do so because groundwater is an extraordinarily useful resource. It is available over broad areas; even in landscapes where surface-water streams are few and far between, many people can access groundwater simply by drilling a well.[2] Because some contaminants filter out as water moves through the subsurface, groundwater is often cleaner than surface water.[3] And because groundwater usually flows slowly and evaporates only minimally,[4] groundwater storage can often last much longer than surface-water storage; groundwater therefore can remain available even during extended droughts. These benefits extend to ecological systems as well as human extractive users.[5] Because groundwater tends to be cleaner, cooler, and more steadily available than surface runoff, it plays a crucial role in sustaining many rivers, streams, wetlands, and lakes.[6]

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[1] For statistics, see *Facts About Global Groundwater Usage*, NAT'L GROUND WATER ASS'N, https://perma.cc/PAH9-EWWZ (archived Mar. 8, 2021). In 2015, the U.S. Geological Survey estimated that 115 million people in the United States alone rely on groundwater for drinking water. *The Quality of the Nation's Groundwater*, U.S. GEOLOGICAL SURV. (Jan. 21, 2015), https://perma.cc/9HHD-8AGP; *see also* Mark Giordano, *Global Groundwater? Issues and Solutions*, 34 ANN. REV. ENV'T & RES. 153, 154 (2009). Giordano explains:

> There is no question that the use of groundwater has brought astounding benefits to literally billions of people. Probably the majority of the world's cities rely to some degree on groundwater for urban water supply, and it could be argued that groundwater in part enabled the global urbanization phenomena we are now witnessing. No less spectacularly, large-scale agricultural groundwater use has brought massive benefits to legions of small, poor (or previously poor) farmers, particularly in Asia.

Id.

[2] *See* Giordano, *supra* note 1, at 155.

[3] *Id.*

[4] *See id*; Peter Dillon & Muhammad Arshad, *Managed Aquifer Recharge in Integrated Water Resource Management*, *in* INTEGRATED GROUNDWATER MANAGEMENT: CONCEPTS, APPROACHES AND CHALLENGES 435, 445 (Anthony J. Jakeman et al. eds., 2016) (describing losses as high as 35% to 45% of stored surface water due to evaporation). *But see* E. Balugani et al., *Groundwater and Unsaturated Zone Evaporation and Transpiration in a Semi-arid Open Woodland*, 547 J. HYDROLOGY 54, 54-55 (2017) (noting that the low-evaporation assumption, though common, is probably incorrect and can lead to overestimation of recharge).

[5] *See* Derek Eamus et al., *Groundwater Dependent Ecosystems: Classification, Identification Techniques and Threats*, *in* INTEGRATED GROUNDWATER MANAGEMENT, *supra* note 4, at 313, 317-18 (describing types of groundwater-dependent ecosystems).

[6] *See generally* Masaki Hayashi & Donald O. Rosenberry, *Effects of Groundwater Exchange on the Hydrology and Ecology of Surface Waters*, 43 J. GROUNDWATER HYDROLOGY 327, 330-31 (2001) (describing flow patterns and temperature effects); S.D. Keesstra et al., *Soil as a Filter for Groundwater Quality*, 4 CURRENT OP. ENV'T SUSTAINABILITY 507 (2012) (describing the filtration function of soils and variables affecting pollutant filtering).

Despite its value, groundwater is often ignored, misunderstood, or taken for granted, and inattention often goes hand in hand with unsustainable exploitation.[7] Consequently, groundwater supplies in the United States and around the world are being depleted, in some places with alarming speed.[8] That depletion is already leading to shortages, which are likely to spread and intensify as a growing global population uses more water and as climate change accelerates water stress.[9] The human costs of these crises can be immense.[10] So, too, are the environmental consequences; many surface waterways would not flow, and some have already ceased flowing, without inflows from groundwater.[11]

Yet even as groundwater resources come under growing strain, many people are eyeing groundwater as an increasingly important source of future supply.[12] Their reasons are straightforward: We must get water from somewhere, and in a warming world, with more droughts and less water precipitating as snow, less surface water will be available in many places, particularly during warmer and dryer seasons.[13] Water managers might compensate for increasingly erratic flows by building more dams and surface reservoirs, but in many areas, few good dam sites remain.[14] Dam construction and operation are also expensive and environmentally destructive, and much

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[7] *See* Dave Owen, *Taking Groundwater*, 91 WASH. U. L. REV. 253, 255 (2013).

[8] *See* M. Rodell et al., *Emerging Trends in Global Freshwater Availability*, 557 NATURE 651, 655 (2018) (describing accelerating drawdown in California's Central Valley); Steven M. Gorelick & Chunmiao Zheng, Introduction to a Special Edition, *Global Change and the Groundwater Management Challenge*, 51 WATER RES. RSCH. 3031, 3031 (2015); J.S. Famiglietti, Commentary, *The Global Groundwater Crisis*, 4 NATURE CLIMATE CHANGE 945, 946 (2014).

[9] *See* Blanca E. Jiménez Cisneros & Taikan Oki, *Freshwater Resources*, *in* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY; PART A: GLOBAL AND SECTORAL ASPECTS 229, 241 (Field et al. eds., 2014), https://perma.cc/2JNQ-A8LS (describing projections of increased irrigation demand due to population and economic growth, as well as climate change).

[10] *See* Owen, *supra* note 7, at 305 n.319 (citing sources describing how groundwater shortages contribute to human conflicts, including the civil war in Syria).

[11] *See* THOMAS C. WINTER ET AL., U.S. GEOLOGICAL SURV., CIRCULAR 1139, GROUND WATER AND SURFACE WATER: A SINGLE RESOURCE 8-10 (reprt. 1999) (explaining interconnections between groundwater and surface flows); Famiglietti, *supra* note 8, at 947 ("Many of the world's largest rivers, for example, the Colorado, Indus, Murray and Yellow rivers, no longer reach the ocean, because of excessive water use and overallocation, including overpumping of groundwater.").

[12] *See* Richard G. Taylor et al., *Ground Water and Climate Change*, 3 NATURE CLIMATE CHANGE 322, 324 (2013) (describing projected increases in demand for groundwater).

[13] *See* Timothy R. Green et al., *Beneath the Surface of Global Change: Impacts of Climate Change on Groundwater*, 405 J. HYDROLOGY 532, 539-40 (2011).

[14] *See* Christine A. Klein, *On Dams and Democracy*, 78 OR. L. REV. 641, 697 & n.371 (1999).

of the water stored behind dams evaporates before it can be used.[15] Turning to groundwater—which often can be stored for longer periods, with lower evaporation losses and with less environmental impact—seems like an appealing alternative.[16]

These water-supply crises and opportunities are intertwined with legal challenges. The challenges arise partly from the physical nature of groundwater. Because groundwater moves in response to pumping, wells in one area can drain water from beneath neighboring lands,[17] generating conflicts between neighbors. At broader scales, groundwater's tendency to flow across property lines makes it a common-pool resource and creates the potential for a classic tragedy of the commons.[18] Some combination of property rights and regulatory governance is a standard response to such potential tragedies, and consequently, groundwater extraction is governed by common law water rights, legislation, and administrative regulations.[19] These systems are often underdeveloped;[20] even in the United States, regulation of groundwater pumping has lagged behind regulation of surface-water use, and groundwater laws often provide spotty and ineffective coverage.[21] Nevertheless, for groundwater pumping, the overall trend is toward more pervasive and sophisticated regulation.[22]

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[15] *See* COMM. ON SUSTAINABLE UNDERGROUND STORAGE OF RECOVERABLE WATER, NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., PROSPECTS FOR MANAGED UNDERGROUND STORAGE OF RECOVERABLE WATER 13-15 (2008).

[16] *See id.* at 15.

[17] *See* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 107 (1990) ("Water underlying any parcel of land . . . can be siphoned to a neighbor's land . . . .").

[18] *See* Barton H. Thompson, Jr., Essay, *Tragically Difficult: The Obstacles to Governing the Commons,* 30 ENV'T L. 241, 246, 250 (2000) ("[G]roundwater is . . . a natural commons.").

[19] *See generally* Owen, *supra* note 7, at 266-71 (describing groundwater law).

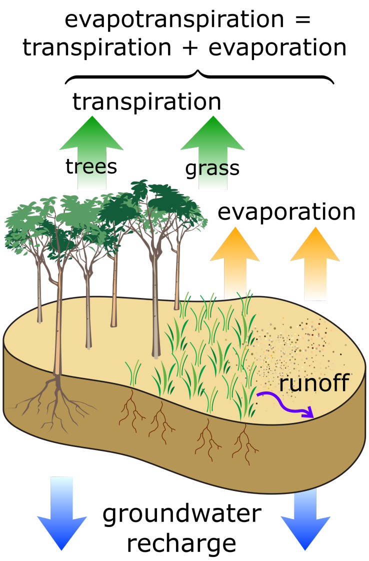
[20] *See* Famiglietti, *supra* note 8, at 946 ("[G]roundwater is often poorly monitored and managed. In the developing world, oversight is often non-existent."); Barton H. Thompson, Jr., *Beyond Connections: Pursuing Multidimensional Conjunctive Management,* 47 IDAHO L. REV. 273, 274 (2011) (describing "lax legal rules and poor enforcement").

[21] *See* Owen, *supra* note 7, at 266-71.

[22] *See id.* at 268-69; *see also, e.g.,* Tina Cannon Leahy, *Desperate Times Call for Sensible Measures: The Making of the California Sustainable Groundwater Management Act,* 9 GOLDEN GATE U. ENV'T L. REV. 5, 8-11 (2015) (chronicling the emergence of statewide groundwater-use regulation in California).

Figure

Near-Surface Hydrology



Source: M.W. Toews, Conceptual Diagram of Near-Surface Hydrology (2007), https://perma.cc/96T9-6ELN.

As shown in the Figure above, however, pumping groundwater out of the ground is only one part of the groundwater cycle. Before groundwater is available to pump, it needs to get into the ground, which happens through a process known as groundwater recharge.[23] Groundwater recharge involves water infiltrating through the ground surface, percolating downward through unsaturated soil or rock, and then hitting the water table—that is, the level below which the pore spaces in subsurface soil or rock are filled with water rather than air.[24]

Despite its crucial role in water cycles, groundwater recharge has not received much legal attention.[25] There are obvious reasons why groundwater

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[23] *See* WINTER ET AL., *supra* note 11, at 3.

[24] *See* C.W. FETTER, APPLIED HYDROGEOLOGY 5 (4th ed. 2001). This description assumes that the water percolates to a shallow, unconfined aquifer. Where confining layers—which are subsurface layers that limit water flow—exist, recharge processes are more complicated. *See Aquifers and Groundwater*, U.S. GEOLOGICAL SURV., https://perma.cc/3VP7-SQHV (archived Mar. 8, 2021).

[25] *See* Thompson, *supra* note 20, at 301 ("States also historically ignored the important connection between land use and land cover, on the one hand, and groundwater

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recharge is not a noticeable process; we usually do not see water's subterranean movements, and most people don't ponder where water goes when the ground surface dries up.[26] Additionally, recharge is a natural, gravity-driven process. In many places, water does not need legal assistance to move downward. Nevertheless, the locations and rates at which recharge occurs are heavily affected by pervasive human manipulation of the ground surface, and those human manipulations in turn are partially determined by law.

Human impacts on groundwater recharge take a variety of forms. Over much of the earth's land surface, humans determine what vegetation grows, and increasing the amount of water consumed by plants typically means reducing infiltration deeper into the ground.[27] People also decide where roads, buildings, and other impervious surfaces are constructed, and impervious surfaces control whether precipitation flows over or through the ground surface.[28] We move massive quantities of irrigation water, and some excess irrigation water becomes recharge.[29] Our often-antiquated systems for delivering water—for both agricultural and urban use—leak into the ground.[30] We constrain the movements of surface water, building levees that limit flooding and, therefore, limit the infiltration of surface water into areas adjacent to rivers and streams.[31] All of these manipulations of the land surface and the water cycle are at least partly the products of property rights, planning processes, permits, subsidies, and other regulatory decisionmaking, which

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recharge and quality, on the other."). The attention recharge does receive generally focuses on managed aquifer recharge (MAR), which usually involves diverting water from a river or stream during high-flow periods and injecting it into aquifers. I discuss managed aquifer recharge in more depth in Part II.D below.

[26] This is true of groundwater more generally. *See* Daniel L. Dickerson et al., *Groundwater in Science Education*, 18 J. SCI. TCHR. EDUC. 45, 46 (2006) (noting that students and science educators alike generally don't know much about groundwater).

[27] *See* Vildan Sahin & Michael J. Hall, *The Effects of Afforestation and Deforestation on Water Yields*, 178 J. HYDROLOGY 293, 303-04 (1996) (finding that increasing forest cover generally reduces water yields); *cf.* Bernt Matheussen et al., *Effects of Land Cover Change on Streamflow in the Interior Columbia River Basin (USA and Canada)*, 14 HYDROLOGICAL PROCESSES 867, 868 (2000) ("Removal of forest cover is known to increase streamflow as a result of reduced evapotranspiration and to increase peak flows as a result of higher water tables.").

[28] *See* Emily S. Bernhardt & Margaret A. Palmer, *Restoring Streams in an Urbanizing World*, 52 FRESHWATER BIOLOGY 738, 739-40 (2007).

[29] *See* Bridget R. Scanlon et al., *Impact of Land Use and Land Cover Change on Groundwater Recharge and Quality in the Southwestern US*, 11 GLOB. CHANGE BIOLOGY 1577, 1586 (2005) (finding much higher recharge rates in irrigated areas).

[30] David Schaper, *As Infrastructure Crumbles, Trillions of Gallons of Water Lost*, NPR (Oct. 29, 2014, 6:06 PM ET), https://perma.cc/23NQ-3FBK.

[31] *See* Jeffrey J. Opperman et al., *Sustainable Floodplains Through Large-Scale Reconnection to Rivers*, 326 SCIENCE 1487, 1488 (2009) (identifying groundwater recharge as a benefit of floodplains).

means that groundwater recharge is partially determined by law. Yet law's effects on groundwater recharge have received little attention from policymakers and academic researchers.

This Article begins to fill that gap, addressing the United States' laws at the intersection of land use and groundwater recharge. It begins, in Part I, with a primer on how groundwater recharge works and how humans influence groundwater-recharge processes. Part I also explains why attention to groundwater recharge has become increasingly important and how climate change is likely to further increase that importance in years to come. Part II then turns to traditional legal doctrines governing the quantity of groundwater recharge.[32] It describes a hodgepodge of doctrines, many of which affect recharge without any underlying plan or design, and none of which seem matched for an era in which water managers increasingly call for carefully planned uses of groundwater.

Part III considers the future of groundwater-recharge law. More specifically, it turns to three basic questions that legal regimes for groundwater recharge must address. The first question is whether more robust regulation of groundwater recharge makes sense at all. In some places, the answer to that question will be yes, while in others, those systems would be more trouble than they are worth. Part III offers criteria for judging which is which. The second question is what sort of ethic should underpin a system of groundwater-recharge law. Any system of natural-resource regulation (or nonregulation) reflects judgments, often implicit, about our appropriate relationships with the natural world and with each other. Part III exposes the laissez-faire judgments inherent in existing law and explains how a more communitarian ethic would provide a foundation for better legal regimes. The third and final question is what regulatory instruments a more robust system of groundwater-recharge law should employ. There are many possibilities: Property-based regimes, informational regulation, planning, performance standards, prohibitions, and

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[32] Laws protecting groundwater from recharged pollution are more extensive than laws governing the amount of groundwater supply. Hazardous-waste laws like both the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act are designed partly to keep pollutants out of groundwater. *See* Resource Conservation and Recovery Act of 1976, Pub. L. No. 94-580, 90 Stat. 2975 (codified as amended at 42 U.S.C. §§ 6901-6987); Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 96-510, 94 Stat. 2767 (codified as amended in scattered sections of 26, 33, and 42 U.S.C.). The Clean Water Act does so as well, though only in circumstances where discharges to surface water through groundwater are the "functional equivalent" of direct discharges to surface water. *See* County of Maui v. Haw. Wildlife Fund, 140 S. Ct. 1462, 1468 (2020). Some states also have laws or regulations designed to protect aquifers from contaminated recharge. *See, e.g.*, CONN. GEN. STAT. §§ 22a-354g to -354p (2021) (providing a program to protect aquifers from contamination); MD. CODE REGS. 26.08.02.09 (2021) (requiring state approval of discharges into aquifers).

financial incentives all might have roles to play. But Part III suggests particular attention to mechanisms that use impact fees to encourage better groundwater management and to create pools of money to support selective governmental interventions.

In some ways, answering these questions requires delving into the unique science and policy of an often-ignored hydrologic process. But in other ways, groundwater-recharge regulation presents a microcosm of problems that recur all along the frontiers of environmental and natural-resource law. Groundwater-recharge law remains underdeveloped partly because of data gaps and limited understanding, and similar limits and gaps challenge many areas of environmental and natural-resource regulation.[33] Groundwater-recharge problems often arise from the cumulative effects of many individual landowners' actions, rather than from a few readily identified and easily targeted actors.[34] This, too, creates challenges that often arise both within and beyond the environmental field.[35] Finally, groundwater-recharge management can create difficult tradeoffs among different policy goals, and the challenge of managing difficult tradeoffs again helps define environmental and natural-resource law.[36] Although every regulatory challenge is unique in some ways, these commonalities mean that a study of groundwater recharge can draw lessons from, and shed light upon, regulatory challenges that cut across the environmental field.

I. Groundwater Recharge and the Water Cycle

Groundwater is crucially important to humans and to natural systems. But it can fulfill that importance only if it somehow gets into the aquifers from which it is later pumped or from which it discharges into surface waterways. In many places, much of that infiltration occurred millennia ago;[37] some presently arid regions have large aquifers that formed from the melting of ice-age glaciers or during times when the climate was much wetter than it is today.[38] But in many areas, at least some of the water people pump from the

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[33] *See infra* notes 89-90 and accompanying text.

[34] *See infra* notes 97-99 and accompanying text.

[35] *See* Dave Owen, *Critical Habitat and the Challenge of Regulating Small Harms*, 64 FLA L. REV. 141, 143-44 (2012).

[36] *See infra* notes 92-96 and accompanying text; *see also* Cass R. Sunstein, *Cost-Benefit Default Principles*, 99 MICH. L. REV. 1651, 1653 (2001) (listing examples of unintended tradeoffs created by risk regulation).

[37] *See* Scott Jasechko et al., *Global Aquifers Dominated by Fossil Groundwaters but Wells Vulnerable to Modern Contamination*, 10 NATURE GEOSCIENCE 425, 426 (2017).

[38] *See, e.g.*, Jane Braxton Little, *The Ogallala Aquifer: Saving a Vital U.S. Water Source*, SCI. AM. (Mar. 1, 2009), https://perma.cc/V5H9-NY7J; Bridget R. Scanlon et al., *Global*

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ground was above the ground surface not so long ago, and it infiltrated through processes whose unabated continuation is by no means assured. This Part explains the pathways that water follows as it reaches subsurface aquifers and the many ways in which human activity can impede or accelerate movement along those paths.

A. Natural Water Cycles

Imagine, for a moment, a rainstorm falling onto a forest. Particularly in summer, when leaves are out, the forest canopy will intercept some of that rain.[39] Of the rain that does reach the ground surface, some will evaporate, and, if the rainstorm is large or the ground is already saturated, some will flow laterally over the ground surface, perhaps continuing to flow until it reaches wetlands or streams.[40] Water that does not evaporate or flow overland will continue its downward journey and will percolate through layers of leaves and duff and into the soil.[41] Along the way, much of it will be taken up by plants' root systems, particularly during growing seasons, and some will linger as soil moisture in the unsaturated zone.[42] Water that is in excess of plants' needs, or that root systems cannot intercept, will percolate further down, moving through pore spaces—and, in bedrock, through networks of fractures—until it reaches the water table.[43]

In other natural landscapes, similar processes occur, though the amount and locations of infiltration can be different. In desert landscapes, water movement through moisture-starved soils may be limited, and almost all precipitation evaporates or is transpired.[44] Consequently, over much of an arid

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Synthesis of Groundwater Recharge in Semiarid and Arid Regions, 20 HYDROLOGICAL PROCESSES 3335, 3349-50 (2006) (describing the origins of aquifers beneath the Sahara Desert).

[39] *See* COMM. ON REDUCING STORMWATER DISCHARGE CONTRIBUTIONS TO WATER POLLUTION, NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., URBAN STORMWATER MANAGEMENT IN THE UNITED STATES 131 (2009), https://perma.cc/NT4D-TBXQ.

[40] FETTER, *supra* note 24, at 37-39.

[41] *See id.* at 38-39.

[42] *See id.* at 28-30; *see Unsaturated Flow Basics*, U.S. GEOLOGICAL SURV., https://perma.cc/WY64-A2MD (last updated Jan. 2013).

[43] *See* FETTER, *supra* note 24, at 94; *Aquifer Basics: Igneous and Metamorphic-Rock Aquifers*, U.S. GEOLOGICAL SURV., https://perma.cc/HZT2-RGD9 (last updated Dec. 28, 2016) (describing water movement through secondary porosity). These processes are more complicated where confining layers—which are layers of impermeable subsurface material, like clay or nonporous bedrock—constrain the vertical movement of water. *See supra* note 24.

[44] *See* E.G. Jobbágy et al., *Water Subsidies from Mountains to Deserts: Their Role in Sustaining Groundwater-Fed Oases in a Sandy Landscape*, 21 ECOLOGICAL APPLICATIONS 678, 679 (2011) (noting the absence of recharge in most arid landscapes).

landscape, little groundwater recharge will occur.[45] But where surface runoff concentrates in ephemeral streams or wetlands, substantial volumes of water can percolate down to the water table.[46] Concentrated recharge also may occur where streams emerge from mountain ranges and enter valleys filled with sand and boulders, much like water that disappears after it is poured from a bucket onto a sandy beach.[47] Over time, these processes can accumulate huge volumes of groundwater, even in areas where the ground surface usually looks bone dry.[48]

As these examples illustrate, recharge occurs differently across different landscape types. Recharge rates also tend to be heterogeneous across smaller spatial distances, across seasons, and across different types of precipitation events. Several factors drive that heterogeneity. One factor is vegetation's demand for water.[49] That demand can vary significantly within and between landscape types.[50] It also can vary seasonally, particularly in temperate landscapes where winter halts most plant growth.[51] A second key factor is the permeability of soil and bedrock, which also can be heterogeneous across small spatial scales.[52] A third key factor is the duration and intensity of storms.[53] Brief, low-intensity storms may do little more than wet the ground surface and will often produce little infiltration.[54] Higher-intensity rainstorms can

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[45] *See id.*

[46] *See* Jacobus J. de Vries & Ian Simmers, *Groundwater Recharge: An Overview of Processes and Challenges*, 10 HYDROGEOLOGY J. 5, 8 (2002) (describing focused-recharge zones in desert landscapes—but also noting that alluvial soils and riparian vegetation can impede recharge); Warren W. Wood et al., *Quantifying Macropore Recharge: Examples from a Semi-arid Area*, 35 GROUNDWATER 1097, 1098 (1997) (describing recharge through cracks in the clay in playa basins).

[47] *See* FETTER, *supra* note 24, at 291-93.

[48] *See, e.g.*, Jobbágy et al., *supra* note 44, at 689 (describing substantial contributions from mountains to recharge in adjacent arid plains).

[49] *See, e.g.*, Scanlon et al., *supra* note 38, at 3350-51 (describing substantial recharge increases in nonvegetated and de-vegetated areas).

[50] *See, e.g.*, W.R. Dripps & K.R. Bradbury, *The Spatial and Temporal Variability of Groundwater Recharge in a Forested Basin in Northern Wisconsin*, 24 HYDROLOGICAL PROCESSES 383, 386-90 (2009).

[51] *See* Scott Jasechko et al., *The Pronounced Seasonality of Global Groundwater Recharge*, 50 WATER RES. RSCH. 8845, 8846 (2014) (describing seasonal variation and its causes).

[52] *See* Andreas Hartmann et al., *Enhanced Groundwater Recharge Rates and Altered Recharge Sensitivity to Climate Variability Through Subsurface Heterogeneity*, 114 PNAS 2842, 2842 (2017) ("Subsurface heterogeneity notably affects groundwater recharge . . . .").

[53] *See* Arik M. Tashie et al., *Identifying Long-Term Empirical Relationships Between Storm Characteristics and Episodic Groundwater Recharge*, 52 WATER RES. RSCH. 21, 22 (2016).

[54] *See id.* ("For infiltration to occur, precipitation must first exceed interception by the vegetation canopy. Subsequently, for infiltration to contribute to recharge, the soil must be wetted enough to allow vertical drainage below the root zone . . . .").

produce more infiltration,[55] but they also may deliver that precipitation faster than the ground can absorb it, which means a lower percentage of the storm's precipitation will infiltrate into the ground.[56] In short, in many landscapes, levels of recharge can vary significantly over both space and time.

B. Human Influences

In a variety of ways, humans affect these processes of groundwater recharge. Indeed, each of the key variables described above is highly susceptible to human influence. And that influence is pervasive. Leaving aside the driest desert areas, where little precipitation occurs anyway,[57] and tundra and taiga regions, humans have developed, farmed, grazed, deforested, or reforested most of the earth's terrestrial landscapes.[58] Groundwater recharge therefore has entered what some scientists call the Anthropocene Epoch, when environmental processes are rarely free of human influence.[59]

The most obvious way in which humans manipulate groundwater recharge is through the development of land surfaces. Human development usually brings impervious surfaces—typically roofs and pavement—to landscapes where vegetation and soils previously were present.[60] These impervious surfaces block recharge, and in urban landscapes, stormwater tends to flow over the ground surface rather than entering the ground.[61] At modest levels of precipitation and modest levels of urbanization, these changes might not alter recharge levels much. Gravity is persistent, and stormwater that would have infiltrated on one parcel may simply flow to the next parcel and infiltrate there. But as urbanization levels increase or as storms become larger—or both—flows intercepted by impervious surfaces may overwhelm the capacity of the pervious areas that remain.[62] A common consequence is flooding, and most cities therefore build networks of storm drains that convey

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[55] *See id.* (summarizing studies finding that in some landscapes, most recharge occurs during heavy-storm events).

[56] *Id.*

[57] Because of imported irrigation water or fossil aquifers, even highly arid areas may be farmed and thus may be sites for groundwater recharge.

[58] Andrew P. Jacobson et al., *Global Areas of Low Human Impact ("Low Impact Areas") and Fragmentation of the Natural World*, SCI. REPS., Oct. 2, 2019, at 1, 3 & fig.1, 4 & fig.2; Roger LeB. Hooke et al., *Land Transformation by Humans: A Review*, GSA TODAY, Dec. 2012, at 4, 6 (showing summary data).

[59] *See* Colin N. Waters et al., *The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene*, 351 SCIENCE 137, 138 (2016).

[60] *See* Bernhardt & Palmer, *supra* note 28, at 738-40.

[61] *See id.* at 740.

[62] *See* Shiqiang Du et al., *Quantifying the Impact of Impervious Surface Location on Flood Peak Discharge in Urban Areas*, 76 NAT. HAZARDS 1457, 1458 (2015).

surface flows directly into waterways, bypassing the aquifers through which much of the stormwater would otherwise pass.[63] These stormwater flows create major pollution problems, for urban stormwater gathers cocktails of pollutants as it passes over the ground surface.[64] The interruption of infiltration also can reduce aquifer recharge, sometimes significantly.[65]

Humans also influence recharge by managing vegetation.[66] Farming is one obvious example. Anywhere people introduce crops, they affect recharge levels, and whether they are increasing or decreasing those levels depends upon whether the crops demand more water than the vegetation they replace, whether a plowed or otherwise manipulated ground surface is more or less porous than a native landscape, and whether the farmers irrigate their plants.[67] Logging has similar effects.[68] Introduction of non-native species, either as cultivated plants or as unwanted invaders, also can affect recharge.[69] And even in landscapes that might appear natural, human choices have profound effects

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[63] *See* Dave Owen, *Urbanization, Water Quality, and the Regulated Landscape*, 82 U. COLO. L. REV. 431, 441 (2011).

[64] *See id.* at 441-42.

[65] *See* Chester L. Arnold, Jr. & C. James Gibbons, *Impervious Surface Coverage: The Emergence of a Key Environmental Indicator*, 62 J. AM. PLAN. ASS'N 243, 244-45 (1996). *But see* Dongmei Han et al., *Alterations to Groundwater Recharge Due to Anthropogenic Landscape Change*, 554 J. HYDROLOGY 545, 549 (2017) (noting that impervious surfaces can also *increase* recharge by concentrating surface flows). Other changes associated with urbanization—particularly reductions in vegetation levels, increases in imported irrigation water, and leaking pipes—can offset the impacts of impervious surfaces, and in urban areas that don't rely on groundwater pumping, the loss of recharge caused by impervious surfaces may not be problematic (it may even prevent problematically high groundwater levels). *See generally* John M. Sharp, Jr., *The Impacts of Urbanization on Groundwater Systems and Recharge*, AQUA MUNDI, June 2010, at 53-55 (describing the variety of ways in which urbanization can promote as well as inhibit recharge). But if an urban area does rely on groundwater pumping, or could do so, this lost recharge can be a significant problem.

[66] *See* Tashie et al., *supra* note 53, at 21 ("[M]any studies have found large increases in average annual recharge by the conversion of forests and shrubs to crops and grasses . . . ."). This relationship does not always exist, however. *See id.* at 22 (noting other studies that found that deforestation reduced recharge levels).

[67] *See* Han et al., *supra* note 65, at 546; Scanlon et al., *supra* note 38, at 3350-52 (providing examples).

[68] *See* U. Ilstedt et al., *Intermediate Tree Cover Can Maximize Groundwater Recharge in the Seasonally Dry Tropics*, SCI. REPS., Feb. 24, 2016, at 1, 1 (describing the "dominant paradigm" that forest cover decreases groundwater recharge).

[69] *See, e.g.*, NATURE CONSERVANCY & WATER FUNDS FOR AFR., THE GREATER CAPE TOWN WATER FUND: ASSESSING THE RETURN ON INVESTMENT FOR ECOLOGICAL INFRASTRUCTURE RESTORATION 8, 19-22 (2019), https://perma.cc/Y6TB-Z8D5 (describing invasive-species impacts in the Cape Town area, which recently experienced massive drought); Kimberly Burnett et al., *Economic Lessons from Control Efforts for an Invasive Species:* Miconia calvescens *in Hawaii*, 13 J. FOREST ECON. 151, 158 (2007) (describing an invasive species that could cause massive recharge depletion in Hawaii).

on vegetation levels and therefore on groundwater recharge. The United States' forests, for example, have been heavily affected by fire-management practices, not just in the modern Smokey Bear era of fire suppression but also during the precolonial era, when Native American tribes used fire to produce better landscapes in which to gather and hunt.[70] Such fire-management practices influence the amount of vegetation present in forests and, therefore, the balance of transpiration and recharge.[71]

Human decisions also affect the places where large volumes of water gather, and therefore where concentrated infiltration occurs. This happens in several ways. Developers and farmers drain or fill streams and wetlands, thus forcing water onto other parts of the landscape, where infiltration may occur to different extents.[72] Through their attempts to control floods, engineers often limit streams and rivers to narrow paths, isolating them from floodplains that might otherwise serve as infiltration zones.[73] Pipes leak, often heavily, and that leaked water becomes groundwater.[74] Local governments also must

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[70] *See* Scott L. Stephens & Neil G. Sugihara, *Fire Management and Policy Since European Settlement*, *in* FIRE IN CALIFORNIA'S ECOSYSTEMS 431, 431-34 (Neil G. Sugihara et al. eds., 2006).

[71] *See generally* Bharat Sharma Acharya et al., *Woody Plant Encroachment Impacts on Groundwater Recharge: A Review*, WATER, Oct. 17, 2018, at 1 (describing the varying influences of forest composition upon groundwater recharge); M.L. Wine & D. Cadol, *Hydrologic Effects of Large Southwestern USA Wildfires Significantly Increase Regional Water Supply: Fact or Fiction?*, ENV'T RSCH. LETTERS, Aug. 18, 2016, at 1 (concluding that the answer is fact, for two of the three studied watersheds); Alicia M. Kinoshita & Terri S. Hogue, *Increased Dry Season Water Yield in Burned Watersheds in Southern California*, ENV'T RSCH. LETTERS, Jan. 5, 2015, at 1, 7-8.

[72] *See, e.g.*, Lisa A. McCauley et al., *Land Use and Wetland Drainage Affect Water Levels and Dynamics of Remaining Wetlands*, ECOSPHERE, June 2015, at 1, 10 (describing connections between wetland filling, groundwater recharge, and flooding). While these relationships exist, in some places they may not matter to regional-scale groundwater storage. *See* Garth van der Kamp & Masaki Hayashi, *The Groundwater Recharge Function of Small Wetlands in the Semi-arid Northern Prairies*, 8 GREAT PLAINS RSCH. 39, 49-50 (1998) (finding that wetland draining may lower local water tables but have minimal impact on regional aquifers).

[73] *See* OFF. OF RSCH. & DEV., U.S. EPA, EPA/600/R-14/475F, CONNECTIVITY OF STREAMS & WETLANDS TO DOWNSTREAM WATERS: A REVIEW AND SYNTHESIS OF THE SCIENTIFIC EVIDENCE 3-11 to -12 (2015), https://perma.cc/PG52-QAML.

[74] *See* Han et al., *supra* note 65, at 548. The authors explain:

> If water supply to a newly urbanized area is sourced from outside the immediate catchment and is distributed by a pressurized mains network, this creates a new potential source of recharge, via pipeline leakages. Such inter-basin water transfer associated with urban development can have huge impacts on water balances and lead to enhanced recharge and rising water tables.

Id. (citations omitted); *see also, e.g.*, B. Garcia-Fresca, *Urban-Enhanced Groundwater Recharge: Review and Case Study of Austin, Texas, USA*, *in* URBAN GROUNDWATER: MEETING THE CHALLENGE 3, 7-8, 13-14 (Ken W.F. Howard ed., 2007).

choose between disposing of wastewater through septic systems, which can be significant pollution sources but also provide recharge, or through consolidated wastewater-treatment systems, which often bypass aquifers and release waters directly to surface waterways.[75] Perhaps most importantly, farmers deliberately introduce additional water to millions of acres of irrigated land.[76] Crops absorb some of this water, and some evaporates, but much of it infiltrates beneath fields or through leaky irrigation ditches.[77]

In addition to altering the earth's surface, humans also affect recharge by manipulating air temperatures and the amount and timing of rain and snow. At subglobal scales, people most often do this through large-scale landscape changes like deforestation.[78] Generally, removing forests reduces evapotranspiration, which then reduces atmospheric moisture in downwind areas, which in turn decreases precipitation and recharge in those same areas.[79] Conversely, adding irrigated areas can increase downwind precipitation and recharge.[80] The extent

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75. *See, e.g.*, Millicent Lawton, *Tapped Out*, COMMONWEALTH MAG. (Dec. 1, 2000), https://perma.cc/7PG6-2UYT (describing how removing wastewater has depleted local supplies in eastern Massachusetts). *See generally* S.S.D. Foster & P.J. Chilton, *Downstream of Downtown: Urban Wastewater as Groundwater Recharge*, 12 HYDROGEOLOGY J. 115, 115 (2004) (noting that urban wastewater is both a major pollution problem and an important resource).

76. *See* Guoyong Leng et al., *A Modeling Study of Irrigation Effects on Global Surface Water and Groundwater Resources Under a Changing Climate*, 7 J. ADVANCES MODELING EARTH SYS. 1285, 1285 (2015) ("[A]round 70% of global freshwater in 2000 was withdrawn for irrigation, which accounted for 90% of consumptive water use.").

77. Stephen Foster et al., *Impact of Irrigated Agriculture on Groundwater-Recharge Salinity: A Major Sustainability Concern in Semi-arid Regions*, 26 HYDROGEOLOGY J. 2781, 2781 (2018) ("Where flood irrigation techniques with surface water are practiced on permeable soils, they are a major source of groundwater recharge and often the predominant one in arid terrains.").

78. *See generally* R.A. Pielke Sr. et al., *An Overview of Regional Land-Use and Land-Cover Impacts on Rainfall*, 59 TELLUS 587, 588-91, 593, 595 (2007) (describing a variety of temperature effects in a variety of landscape types).

79. *See* Meine van Noordwijk et al., *Climate-Forest-Water-People Relations: Seven System Delineations*, *in* FOREST AND WATER ON A CHANGING PLANET: VULNERABILITY, ADAPTATION AND GOVERNANCE OPPORTUNITIES; A GLOBAL ASSESSMENT REPORT 27, 35-37 (Irena F. Creed & Meine van Noordwijk eds., 2018).

80. *See* Ahmed M. Degu & Faisal Hossain, *Investigating the Mesoscale Impact of Artificial Reservoirs on Frequency of Rain During Growing Season*, WATER RES. RSCH., May 5, 2012, at 1, 11-14 (finding evidence of increased atmospheric moisture downwind of dams, though primarily in Mediterranean climates); Anthony DeAngelis et al., *Evidence of Enhanced Precipitation Due to Irrigation over the Great Plains of the United States*, J. GEOPHYSICAL RSCH., Aug. 14, 2010, at 1, 2, 12 (summarizing prior research and finding evidence consistent with increased precipitation downwind of areas irrigated from the Ogallala Aquifer).

of these effects varies substantially, however, with factors like temperature and wind speed playing significant roles.[81]

An even more significant influence comes from anthropogenic climate change.[82] Climate change is warming the world, and that warming changes evapotranspiration levels, shrinks glaciers and winter snowpacks, and generates more intense storms and more frequent droughts.[83] These changes are making groundwater an increasingly appealing resource and thus are raising the importance of groundwater recharge.[84] But at the same time, these changes will affect the amount of recharge that occurs and the places where it happens, not always in consistent or predictable ways.[85] In some locations, reduced precipitation and warming-driven increases in evapotranspiration will combine to decrease recharge, sometimes dramatically.[86] Some locations are likely to see increases in precipitation, which may bring associated recharge increases.[87] And in some areas, a wide range of outcomes is possible.[88]

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[81] *See* van Noordwijk et al., *supra* note 79, at 36 (describing pronounced effects in tropical areas with low wind speeds).

[82] Because deforestation is a major driver of climate change, and because climate change threatens the viability of some forests, subglobal and global climate-related changes to recharge are interrelated. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 45 fig.1.5 (2015), https://perma.cc/J69G-38W4 (showing the relative influence of forestry and other land-use changes and of fossil-fuel combustion); John T. Abatzoglou & A. Park Williams, *Impact of Anthropogenic Climate Change on Wildfire Across Western US Forests*, 113 PNAS 11770, 11772 (2016) (estimating the "near doubling of forested burned area" attributable to anthropogenic climate change). *See generally* Wen-Ying Wu et al., *Divergent Effects of Climate Change on Future Groundwater Availability in Key Mid-latitude Aquifers*, NATURE COMMC'NS, July 24, 2020, at 1, 1-2 (explaining why different aquifers will be subject to different effects).

[83] *See* Jiménez Cisneros & Oki, *supra* note 9, at 235-36.

[84] *See* Green et al., *supra* note 13, at 539-40.

[85] *See* Tashie et al., *supra* note 53, at 21 ("[T]he influence of these [climate-]altered precipitation characteristics on groundwater recharge is complex and remains poorly understood.").

[86] *See* Thomas Meixner et al., *Implications of Projected Climate Change for Groundwater Recharge in the Western United States*, 534 J. HYDROLOGY 124, 132-35 (2016) (describing projected recharge decreases in several aquifers); Bjørn Kløve et al., *Climate Change Impacts on Groundwater and Dependent Ecosystems*, 518 J. HYDROLOGY 250, 250 (2014) ("The predicted climate change will exacerbate these concerns in many parts of the world by reducing precipitation and increasing evapotranspiration, both of which will reduce recharge . . . .").

[87] *See* Meixner et al., *supra* note 86, at 135 ("[T]he wet areas will get wetter and the dry areas will get drier.").

[88] *See* Gene-Hua Crystal Ng et al., *Probabilistic Analysis of the Effects of Climate Change on Groundwater Recharge*, WATER RES. RSCH., July 2010, at 1, 16-17 (describing a range of scenarios for the High Plains).

C. Regulatory Challenges

In summary, human activity pervasively affects groundwater recharge, and recharge is crucially important to people in many ways. Accordingly, one key point of this Article is that laws should address these interactions between groundwater recharge and human decisions. But the complex realities of groundwater management create three recurring challenges for any system of groundwater law. This Part closes by explaining those difficulties. Importantly, none of these challenges are unique to groundwater-recharge regulation; informational deficits, policy tradeoffs, and cumulative effects are the classic challenges of environmental and natural-resource law, and these issues arise in many other regulatory fields.[89] But each challenge arises with particular force in this realm.

First, complexities, data gaps, and uncertainties abound. Even at aggregate levels, the effects of recharge-altering practices can be difficult to measure. For example, while general relationships between urbanization and water cycles are well documented, scientists are still trying to understand many aspects of the movement of water through urban areas.[90] Additionally, developing a conceptual and aggregate understanding is quite different from understanding recharge effects at a parcel-by-parcel level—which might be important if law is to assign responsibilities or accord benefits to individual landowners. Similarly, effects of forest and fire management on recharge can be complicated and variable over time. Further complicating matters, offsetting effects often occur together. For example, in urban landscapes, imported water and reductions in vegetation can increase recharge, while impervious surfaces decrease recharge.[91] Sorting out the net effect of these changes can be difficult (and that net effect can vary from place to place).

Second, tradeoffs are pervasive. As may be obvious from the examples cited so far, desirable groundwater recharge sometimes derives from otherwise

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[89] *See, e.g.*, Owen, *supra* note 35, at 143-44 (describing the pervasiveness of cumulative-effects problems); Holly Doremus, *Data Gaps in Natural Resource Management: Sniffing for Leaks Along the Information Pipeline*, 83 IND. L.J. 407, 408 (2008) (describing informational challenges); Wendy E. Wagner, *Commons Ignorance: The Failure of Environmental Law to Produce Needed Information on Health and the Environment*, 53 DUKE L.J. 1619, 1720-26 (2004); Sunstein, *supra* note 36, at 1653-54 (describing examples of tradeoffs); William E. Odum, *Environmental Degradation and the Tyranny of Small Decisions*, 32 BIOSCIENCE 728, 728 (1982) (describing the challenges of responding to problems caused by incremental harms).

[90] *See* Brian Miles & Lawrence E. Band, *Green Infrastructure Stormwater Management at the Watershed Scale: Urban Variable Source Area and Watershed Capacitance*, 29 HYDROLOGICAL PROCESSES 2268, 2269-70 (2015) (explaining the complexities and uncertainties of urban stormwater flow).

[91] *See* Sharp, *supra* note 65, at 52-54 (noting the influence of vegetation changes and describing leaks as a source of groundwater recharge).

problematic practices. In both urban and agricultural landscapes, groundwater recharge is often a byproduct of inefficient or even sloppy water use.[92] Consequently, while people tend to praise efficient water use, efficiency improvements can have negative collateral consequences for groundwater recharge.[93] Similarly, if a goal is to maximize groundwater recharge (and, more generally, water outflows of any kind) from forested landscapes, the simplest measure might be to eliminate the forest, which could increase flooding, decrease water quality, and undercut many of the other benefits brought by forested landscapes.[94] Not every recharge-management measure will present difficult tradeoffs; there are also important synergies between increasing groundwater storage and other policy goals. Recharging urban stormwater, for example, is generally good for water storage and for surface-water quality (though it can also flood basements),[95] and allowing rivers back into their floodplains can benefit aquatic species and reduce flooding risks further downstream, as well as enhancing groundwater storage.[96] But in many circumstances, efforts to maximize groundwater recharge can create tensions with other important policy goals.

Third, groundwater-recharge challenges often arise from the collective effects of many individual actions.[97] In an urban area, for example, thousands of property owners are likely responsible for the roofs and paved areas that limit recharge—and for the leaky pipes that might partially offset the effects of those impervious surfaces. Even in rural areas, where parcels tend to be bigger, many landowners may share an aquifer's recharge area. This diffusion of ownership, and therefore of potential responsibility, does not always exist; in the American West, for example, a single entity—the U.S. Forest Service—

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[92] *See supra* notes 74-77 and accompanying text.

[93] *See, e.g.*, Matt Weiser, *Drip Irrigation: Not the Drought-Buster You Thought*, NEW HUMANITARIAN: WATER DEEPLY (Sept. 25, 2015), https://perma.cc/A6FX-TV9E ("Some critics of drip irrigation have another complaint: It eliminates groundwater recharge, a side benefit of the water wasted in flood irrigation."); Consejo de Desarrollo Economico de Mexicali, A.C. v. United States, 482 F.3d 1157, 1162-63 (9th Cir. 2007) (describing Mexico's reliance on an aquifer recharged by seepage from southern California's All-American Canal).

[94] *See, e.g.*, Scanlon et al., *supra* note 38, at 3350 (describing recharge-rate increases "up to about 2 orders of magnitude" associated with deforestation in Australia); van Noordwijk et al., *supra* note 79, at 45 (explaining ways in which intact forests support water quality).

[95] *See supra* notes 60-65 and accompanying text.

[96] CAL. DEP'T OF WATER RES., FLOOD-MAR: USING FLOOD WATER FOR MANAGED AQUIFER RECHARGE TO SUPPORT SUSTAINABLE WATER RESOURCES 24, 26 (2018), https://perma.cc/S6TD-4SJF.

[97] This challenge is not unique to groundwater. For a general discussion of the importance of cumulative-impact challenges, see Owen, *supra* note 35, at 143-44.

manages the land where most precipitation occurs.[98] But in many places, the large number of landowners involved can make it quite difficult for individual landowners to understand or even notice their contributions to larger problems or solutions, and collective-action challenges can inhibit any attempt at solutions.[99]

These complexities partly explain why groundwater-recharge law is not well developed, and they might also seem like good reasons to avoid its development. Indeed, as Part III explains in more detail, a threshold question about groundwater-recharge laws should be whether, for the particular place they are proposed, they will be more trouble than they are worth. But many places will not meet that description. In the United States alone, many areas already face severe groundwater-management challenges. A partial list might include California's San Joaquin Valley; the Ogallala Aquifer, which extends from New Mexico and Texas to South Dakota; the Atlantic coastal plain; much of the Colorado River watershed; and even the seemingly well-watered lower Mississippi River Valley.[100] In all of these places, water tables have plunged by dozens or even hundreds of feet, and groundwater depletion is so enormous that it is best measured in cubic kilometers.[101] Unfortunately, these places are not outliers. In a world with a growing human population and an increasingly unstable climate, the need for groundwater-recharge management and an associated body of law will often be unavoidable, even if developing those legal regimes will be difficult.

II. The Past and Present Law of Groundwater Recharge

So how has the law addressed these challenges? In the United States, for the most part, it hasn't, or at least hasn't done so pursuant to any conscious design.[102] Groundwater-recharge law does exist. But other than laws that

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[98] *See* U.S. DEP'T OF AGRIC. ET AL., PNW-GTR-812, WATER, CLIMATE CHANGE, AND FORESTS: WATERSHED STEWARDSHIP FOR A CHANGING CLIMATE 6 (2010), https://perma.cc/6ZJQ-CWYZ ("National forests alone provide . . . over half the water in the West.").

[99] *See, e.g.*, *Wells*, CAL. DEP'T WATER RES., https://perma.cc/ZY3W-TGB2 (archived Mar. 11, 2021) (estimating that "[a]s many as two million wells tap California's groundwater"). On collective-action challenges with groundwater (and other resources), see Thompson, *supra* note 18, at 249-53, 258-65.

[100] *See generally* LEONARD F. KONIKOW, U.S. DEP'T OF THE INTERIOR & U.S. GEOLOGICAL SURV., SCIENCE INVESTIGATIONS REP. 2013-5079, GROUNDWATER DEPLETION IN THE UNITED STATES (1900-2008) (2013), https://perma.cc/8ZHB-QCH5 (providing an overview of areas with severe groundwater depletion).

[101] *Id.* at 4-7, 23-24.

[102] My research assistants and I searched the statutes and regulations of every state for references to groundwater recharge. That search provides the primary basis for my claims about missing elements of groundwater-recharge law. For each state, my

footnote continued on next page

protect groundwater from polluted recharge[103] or address deliberate recharge of imported surface water,[104] groundwater-recharge law arises primarily as an incidental consequence of the pursuit of other priorities. Its coverage is also quite limited.

This Part surveys the law of groundwater recharge.[105] It focuses first on laws governing development of the land surface; then on laws affecting floodplains; then on laws governing vegetation management, primarily in forests and agricultural fields; and then, finally and more briefly, on the growing field of managed aquifer recharge.[106]

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research assistants and I searched Westlaw's databases of statutory text, regulatory text, and case law. We began searches using the search terms "groundwater recharg!" and "groundwater regulation." Because these search terms were both over- and underinclusive, we also used links and tables of contents to navigate from the code sections produced by our searches to other code sections. Finally, we supplemented the Westlaw searches with Google searches (using similar search terms), which we used to find agency websites and secondary-source coverage and to locate (or confirm the absence of) relevant code sections that our terms-based searches had missed.

[103] *See supra* note 32 (discussing federal laws protecting groundwater from contamination); *see, e.g.*, GA. CODE ANN. § 12-2-8 (2020) (providing authority for a regulatory program to protect recharge areas from potentially contaminating land uses); N.J. STAT. ANN. § 58:11A-13 (West 2021) (requiring recharge-area mapping and publication of model ordinances designed to limit groundwater-contamination threats); N.H. REV. STAT. ANN. § 485-C:1(II) (2021) ("The legislature finds that the most effective means of preserving the existing high quality of groundwater is by identification and careful management of operations or activities which may cause contamination of groundwater if not properly conducted.").

[104] These laws exist primarily in western states. *See, e.g.*, ARIZ. REV. STAT. ANN. § 45-811.01 (2021) (governing underground facility storage permits); OR. REV. STAT. § 537.135(1) (2019) (defining groundwater recharge as a beneficial use of surface water); IDAHO CODE § 42-4202 (2021) (governing the formation of aquifer-recharge districts, which oversee artificial-recharge projects).

[105] This summary omits laws with more attenuated connections to groundwater recharge. In a sense, any law that affects human development or land-use patterns has implications for groundwater, at least if one follows the causal chains far enough. *See, e.g.*, Dave Owen, *Water and Taxes*, 50 U.C. DAVIS L. REV. 1559, 1572-85 (2017) (describing water-use incentives created by tax provisions). But to keep the scope of coverage manageable, the discussion here is more focused.

[106] Because of its relatively small footprint upon the landscape, mining is not discussed. But many of the references to groundwater recharge in state law come from provisions requiring restoration of recharge after surface mining of coal is complete. *See, e.g.*, 312 IND. ADMIN. CODE 25-6-22(a) (2021) (requiring restoration of recharge capacity); MD. CODE REGS. 26.20.20.02 (2021) (same). Those provisions in turn derive from the federal Surface Mining Control and Reclamation Act of 1977. *See* Pub. L. No. 95-87, § 515(b)(10)(D), 91 Stat. 445, 489 (codified as amended at 30 U.S.C. § 1265(b)(10)(D)) (requiring state or federal permits to include provisions requiring the permittee to "restor[e] recharge capacity of the mined area to approximate premining conditions").

A. Developing Land

One of the most common ways humans affect recharge is by developing land. A robust legal regime for managing groundwater recharge therefore would address these impacts. Existing law is far from that ideal, however. Old common law doctrines, including the "common enemy rule," allow landowners to ignore changes to groundwater recharge.[107] In contrast, some newer legal requirements more directly address recharge, either by limiting the ability of development to create additional surface-water runoff or by protecting streams and wetlands—which often function as recharge zones—from being filled.[108] But the doctrines addressing development affect only small portions of the American landscape, and the scope of stream and wetland protections is currently under attack.

1. The common enemy

The oldest legal doctrine that directly (though not explicitly) addresses groundwater recharge is a property and tort rule known as the common-enemy doctrine.[109] On its face, the doctrine addresses the management of surface-water runoff before that surface water reaches a permanent watercourse or percolates into the ground.[110] It addresses, in other words, overland drainage of rain and snowmelt.[111] The core doctrine establishes that a landowner may do with that runoff as she will, even if that means redirecting it onto the property of downstream or downhill landowners.[112] The origins of the rule are obscure, but courts and scholars generally trace its roots to nineteenth-century preferences for economic development and even older British distaste for swamps.[113] The underlying ideas were that surface water was an inconvenience that each landowner was entitled to battle and that

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[107] *See* ANTHONY DAN TARLOCK & JASON ANTHONY ROBISON, LAW OF WATER RIGHTS AND RESOURCES § 3:12 (West 2020).

[108] *See infra* Parts II.A.2-.3.

[109] *See, e.g.*, Garbarino v. Van Cleave, 330 P.2d 28, 31 (Or. 1958) ("[N]o one has the right to complain that the volume of water in its natural channels is increased by the artificial drainage of lands which naturally drain therein." (quoting TOM W. SMURR, A TREATISE ON THE LAW OF FARM DRAINAGE FOUNDED ON THE LAWS AND JUDICIAL DECISIONS OF THE STATE OF ILLINOIS § 3, at 5-6 (1909))).

[110] *See* TARLOCK & ROBISON, *supra* note 107, § 3.12.

[111] *Id.*

[112] *See, e.g.*, Morrison v. Bucksport & Bangor R.R. Co., 67 Me. 353, 356 (1877) ("He may erect structures upon his own land as high as he pleases without regard to its effect upon surface water, no matter how much others are disturbed by it.").

[113] *See* Jill M. Fraley, *Water, Water, Everywhere: Surface Water Liability*, 5 MICH. J. ENV'T & ADMIN. L. 73, 79, 93-94 (2015) (describing the origins and evolution of the common-enemy rule).

maintaining a natural water cycle should not get in the way of economic exploitation of land.[114]

As usually stated, the common-enemy rule doesn't mention groundwater recharge, and cases involving the rule rarely discuss groundwater.[115] But the rule clearly is part of groundwater-recharge law. The rule exists because development of land (and conversion of wetlands to agricultural use) often generates additional surface runoff. At least some of that additional surface runoff occurs because water that previously infiltrated into the ground, and thus recharged groundwater, is rerouted over the ground surface. The rule, in other words, is about dealing with the prevention of recharge. And its core tenet—that landowners have no obligation to address the consequences of recharge prevention—generates no incentive to worry about recharge loss.

The traditional common-enemy rule no longer predominates in American common law.[116] In states that still endorse the rule, qualifications abound, and other jurisdictions instead apply a rule of reasonableness to increased runoff associated with development patterns.[117] But these alternative rules also are designed to accommodate some increase in runoff and, though they do not acknowledge it, concomitant decreases in groundwater recharge.[118] The common law of surface runoff, in short, assigns groundwater recharge no value.

2. Urbanization

With groundwater recharge, as with most areas of law, the era of common law primacy has largely passed, and many modern statutes and regulatory schemes address ways in which development decreases stormwater runoff and increases surface flow. That body of law comes partly from the federal government but primarily from state and local governments, which have broad authority over development through their powers to zone land and set

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[114] *See id.*

[115] For two cases involving the common-enemy rule that do mention groundwater, see *B & B, LLC v. Lake Erie Land Co.*, 943 N.E.2d 917, 922 (Ind. Ct. App. 2011); and *Scalesse v. Davis*, No. 36610-0-II, 2009 WL 342972, at *1, *4, *6 (Wash. Ct. App. Feb. 12, 2009). Neither case focuses on groundwater recharge.

[116] *See* TARLOCK & ROBISON, *supra* note 107, § 3.12.

[117] *Id.*; *see also* Fraley, *supra* note 113, at 95-96 (describing exceptions to the common-enemy rule).

[118] *See* TARLOCK & ROBISON, *supra* note 107, § 3.12 ("Most states follow a reasonable use rule that gives a property owner a qualified privilege to improve his property, alter drainage patterns, and tap into adjoining drains without the permission of the landowner.").

building codes.[119] In some places, these federal, state, and local laws promote groundwater recharge, though generally with the goal of limiting flooding rather than maintaining water supplies.[120] But the geographic coverage of recharge-promoting laws remains limited.[121]

Some groundwater-recharge law comes from laws focused primarily on stormwater management. The federal Clean Water Act requires midsized and larger municipalities to obtain (typically from state regulators) stormwater-discharge permits,[122] and those permits are supposed to include programs for managing postconstruction stormwater runoff—which, in lay terms, means managing water that the newly built impervious surfaces prevent from infiltrating into the ground.[123] Independent of Clean Water Act permitting requirements, some states and municipalities require new or retrofitted construction projects to be designed to infiltrate most stormwater on site, at least so long as storms remain below designated thresholds.[124] More ambitiously, some municipalities have created stormwater utilities, which charge property owners fees based on the amount of impervious area on their properties.[125] Municipal stormwater managers then use the resulting revenue for stormwater-management projects, some of which may involve constructing "green infrastructure" for infiltration.[126] Because of these

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[119] *See* ROBERT C. ELLICKSON, VICKI BEEN, RODERICK M. HILLS, JR. & CHRISTOPHER SERKIN, LAND USE CONTROLS: CASES AND MATERIALS 45 (4th ed. 2013) ("Public land use regulation in the United States traditionally has been mainly the province of local governments.").

[120] A notable exception is Delaware, which makes recharge protection a central goal of its laws governing development and impervious cover. *See* DEL. CODE ANN. tit. 7, § 6082(b) (2021).

[121] *See infra* notes 128-37 and accompanying text.

[122] 33 U.S.C. § 1342(p).

[123] 40 C.F.R. § 122.34(b)(5) (2020); *see also* Env't Def. Ctr., Inc. v. U.S. EPA, 344 F.3d 832, 846 (9th Cir. 2003).

[124] *See, e.g.*, SAN DIEGO COUNTY, CAL., CODE OF REGUL. ORDINANCES § 67.811(b) (2021) (providing stormwater-infiltration requirements for "Priority Development Projects"). *See generally* STORMWATER PERMIT MANUAL § 890 (West Supp. 2011) (summarizing state programs).

[125] *See* U.S. EPA NEW ENGLAND, EPA 901-F-09-004, FUNDING STORMWATER PROGRAMS 1 (2009), https://perma.cc/4FKR-B9ZS ("More than 800 communities or districts across the country have adopted a stormwater utility . . . ."). *See generally* Avi Brisman, *Considerations in Establishing a Stormwater Utility*, 26 S. ILL. U. L.J. 505 (2002) (describing the operation of stormwater utilities).

[126] *See* NAT'L ESTUARY PROGRAM, U.S. EPA, EPA 842-R-14-005, GETTING TO GREEN: PAYING FOR GREEN INFRASTRUCTURE; FINANCING OPTIONS AND RESOURCES FOR LOCAL DECISION-MAKERS 1-2, 6-7 (2014), https://perma.cc/CQ8J-954Z; Erin Adele Scharff, *Green Fees: The Challenge of Pricing Externalities Under State Law*, 97 NEB. L. REV. 168, 205-06 (2018).

requirements, there are some places in the United States where urbanization's impacts on groundwater recharge are highly regulated.[127]

Nevertheless, those places encompass a tiny percentage of the American landscape. Under the Clean Water Act, municipal stormwater permits only cover relatively densely populated areas, which means that many suburban and rural areas fall outside their coverage.[128] Many state and local stormwater-permitting programs cover only new development or redevelopment; existing impervious areas are often grandfathered.[129] Additionally, even highly developed urban areas with low population density—for example, shopping malls—may be uncovered.[130] Small projects also are routinely exempted from requirements for runoff control.[131] And outside of already-urbanized areas, few states and cities have robust stormwater-management programs.[132] The compliance costs associated with these programs can be substantial—particularly if they cover existing development—which makes them controversial.[133] Consequently, they have tended to emerge in places—the

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[127] *See* Owen, *supra* note 63, at 454-55.

[128] *See* 33 U.S.C. § 1342(p)(2)(D) (requiring permits only for municipal storm-sewer systems that serve over 100,000 people).

[129] *See, e.g.*, 1 MASS. DEP'T OF ENV'T PROT., MASSACHUSETTS STORMWATER HANDBOOK 1-2 (2008), https://perma.cc/VGL4-VZRB (to download, click "View the live page" and then click "Massachusetts Stormwater Handbook Vol. 1 Ch. 1, Stormwater Management Standards"). The handbook states:

> Loss of annual recharge to groundwater shall be eliminated or minimized through the use of infiltration measures including environmentally sensitive site design, low impact development techniques, stormwater best management practices, and good operation and maintenance. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from pre-development conditions based on soil type.

Id. at 1. That requirement applies to new but not existing development. *Id.* at 2.

[130] *See* Dave Owen et al., *Collaboration, Clean Water Act Residual Designation Authority, and Collective Permitting: A Case Study of Long Creek*, WATERSHED SCI. BULL., Fall 2010, at 25, 27 (describing a mall-dominated watershed in Maine).

[131] *See* WATER PERMITS DIV., U.S. EPA, SUMMARY OF STATE POST CONSTRUCTION STORMWATER STANDARDS 3 tbl.1 (rev. 2016), https://perma.cc/53BQ-NZ6S (summarizing state standards for postconstruction runoff, most of which exempt projects that disturb less than an acre).

[132] *See id.* at 1, 3 tbl.1 (summarizing coverage and finding that many states have no stormwater-control requirements outside MS4 areas, which are "sites in regulated Phase I and Phase II Municipal Separate Storm Sewer System areas"); *see also* Allison H. Roy et al., *Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States*, 42 ENV'T MGMT. 344, 349 (2008) (noting that despite some local governments employing "[c]omprehensive stormwater ordinances," there is "considerable variability in requirements within ordinances and [the] presence of such requirements nationwide").

[133] *See* Janet E. Milne, *Storms Ahead: Climate Change Adaptation Calls for Resilient Funding*, 39 VT. L. REV. 819, 862 (2015) (describing the political vulnerability of stormwater fees); Owen, *supra* note 63, at 486-88.

Chesapeake Bay[134] or Lake Tahoe[135] watersheds, for example—where a stressed and highly visible water resource inspires willingness to undertake ambitious regulatory programs, or in places where urban flooding problems lead municipal officials to think that green infrastructure might be cheaper than any alternative.[136] In most places, regulation of development's impacts on recharge remains minimal. And because the programs that do exist tend to be motivated by problems with flooding and surface-water pollution, not groundwater shortages, they are absent in many places where flooding and surface-water quality are less concerning but groundwater shortages are potentially severe.[137] In summary, groundwater-recharge protection is often an incidental consequence of a spotty and incomplete system of urban stormwater regulation.

In a few states, hints of an alternative system, in which maintaining groundwater recharge is a goal rather than an incidental consequence of land-use development, do exist. Several states require mapping of areas with high recharge potential, though generally for the purpose of facilitating pollution-prevention measures.[138] Delaware, in contrast to most other states, has taken its program a few steps further; it couples a statewide mapping program with a requirement that local governments integrate recharge protection into their systems for regulating development.[139] But Delaware is an outlier. Even states

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[134] *See* Md. Dep't of the Env't v. Cnty. Comm'rs, 214 A.3d 61, 69-78 (Md. 2019) (describing Chesapeake Bay protection and stormwater management in Maryland).

[135] *See* Tahoe-Sierra Pres. Council, Inc. v. Tahoe Reg'l Plan. Agency, 535 U.S. 302, 306-11 (2002) (describing the impetus for regulating runoff in the Lake Tahoe watershed); *Water Quality & Stormwater Management*, TAHOE REG'L PLAN. AGENCY, https://perma.cc/N8UL-CK3D (archived Mar. 11, 2021).

[136] *See, e.g.*, Bruce Stutz, *With a Green Makeover, Philadelphia Is Tackling Its Stormwater Problem*, YALE ENV'T 360 (Mar. 29, 2018), https://perma.cc/VSC8-4ZVK (describing Philadelphia's green-infrastructure program).

[137] *See* WATER PERMITS DIV., U.S. EPA, *supra* note 131, at 3 tbl.1 (summarizing state requirements, showing that many arid states have only minimal requirements and impose those requirements only in MS4 areas).

[138] *See, e.g.*, N.J. STAT. ANN. § 58:11A-13 (West 2021) ("The Department of Environmental Protection . . . shall prepare and publish a methodology which shall allow the user to define, rank and map aquifer recharge areas."); GA. COMP. R. & REGS. 391-3-16.02 (2021) (describing recharge-area mapping); CONN. GEN. STAT. § 22a-354c (2021) (requiring mapping of recharge areas for stratified-drift aquifers).

[139] *See Delaware GroundWater Recharge Potential*, DEL. FIRSTMAP DATA, https://perma.cc/WN8P-VLV3 (archived Mar. 11, 2021) (to interact with map, click "View the live page"); DEL. CODE ANN. tit. 7, § 6082(b) (2021) (requiring counties and municipalities to provide special planning for areas with "excellent ground-water recharge potential"). For an example of a local ordinance implementing these requirements, see Blades, Del., Wellhead and Excellent Groundwater Recharge Area Protection Ordinance (June 8, 2009).

that otherwise have highly sophisticated systems of water law do little to directly address the impacts of development on groundwater recharge.[140]

3. Stream and wetland fills

Beyond addressing the general impacts of urbanization (and of other land uses), a comprehensive legal system for groundwater-recharge management would protect ephemeral streams and wetlands. Often—particularly in arid landscapes—those ephemeral water features are important sites for recharge because only in areas where water is concentrated can it penetrate otherwise moisture-starved soils and percolate down to the water table.[141] In wetter landscapes, those streams and wetlands can play a somewhat different role, often by managing the timing of recharge and reducing fluctuations in stream levels—which means, in practical terms, putting more water into groundwater storage and less into floods.[142] Some laws have traditionally protected those features, but they are under attack.

In the United States, the primary protection of ephemeral streams and wetlands has come from the Clean Water Act.[143] Section 301 of the Act prohibits the unpermitted discharge of pollutants into "navigable waters,"[144] which the statute defines as "waters of the United States."[145] Section 404 permits discharges of dredged or fill material at "specified disposal sites" and thus creates an exception to section 301, but only if the discharging entity obtains a permit from the U.S. Army Corps of Engineers.[146] The Army Corps issues tens of thousands of these permits every year,[147] but they come with strings attached; generally, permit recipients must avoid impacting streams or

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[140] Water lawyers widely view Colorado, for example, as having one of the most sophisticated water-management systems in the country. But the Colorado statutory and administrative provisions pertaining to groundwater recharge are generally directed at managed recharge of surface water. *E.g.*, COLO. REV. STAT. § 37-90-137(9)(d) (2021) (establishing that the extraction of artificially recharged water is a beneficial use); COLO. CODE REGS. § 410-1 (2021) (establishing permitting rules for artificially recharged groundwater).

[141] *See* M.O. Cuthbert et al., *Understanding and Quantifying Focused, Indirect Groundwater Recharge from Ephemeral Streams Using Water Table Fluctuations*, 52 WATER RES. RSCH. 827, 827 (2016) ("Groundwater recharge in drylands predominantly occurs via leakage from ephemeral streams.").

[142] *See* McCauley et al., *supra* note 72, at 10 (asserting that losses of wetlands reduce groundwater storage and increase flooding).

[143] Clean Water Act, Pub. L. No. 92-500, 86 Stat. 816 (1972) (codified as amended at 33 U.S.C. §§ 1251-1388).

[144] 33 U.S.C. § 1311.

[145] *Id.* § 1362(7).

[146] *Id.* § 1344.

[147] *See* RYAN W. TAYLOR, FEDERALISM OF WETLANDS 88 (2013) (providing statistics).

wetlands if they can, minimize the unavoidable impacts they do create, and compensate for impacts that remain.[148] Neither these specific provisions nor the Clean Water Act more generally focuses on groundwater; Congress's central concern was with surface-water quality.[149] But an incidental consequence of protecting stream and wetland areas is to protect zones where recharge often occurs.[150]

These incidental protections have been evolving for decades.[151] For many years, the trend was toward greater protection of temporary waterways.[152] The Army Corps was initially reluctant to require permitting for small wetlands and streams, and while it acknowledged its regulatory jurisdiction over them, it generally let people fill them at will.[153] But over the course of several decades, extending through the Obama Administration, the Army Corps began requiring permitting for more small wetlands and more intermittent and even ephemeral streams, effectively increasing the scope of regulatory protections for many areas where concentrated recharge occurs.[154]

More recently, however, a countervailing trend has predominated. The shift has its roots in Supreme Court decisions. In 2001, in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, the Supreme Court held that isolated wetlands were not "waters of the United States" within the meaning of the Clean Water Act.[155] And in 2006, in *Rapanos v. United States*,[156] a fractured Court established multiple tests for the scope of federal Clean Water Act jurisdiction. One of those tests, which Justice Scalia articulated in a plurality opinion, would have eliminated Clean Water Act protection for most temporary streams and wetlands.[157] The *Rapanos* decision

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[148] *Permit Program Under CWA Section 404: Overview*, U.S. EPA, https://perma.cc/2NLG-PW3J (last updated June 17, 2020).

[149] *See* Kaela Shiigi, Note, *Underground Pathways to Pollution: The Need for Better Guidance on Groundwater Hydrologically Connected to Surface Water*, 46 ECOLOGY L.Q. 519, 524, 527 (2019) (noting that "the CWA does not mention hydrologically connected groundwater" and describing the legislative history behind this selective focus).

[150] *See* WINTER ET AL., *supra* note 11, at 9-10 (describing how "losing streams"—those that "lose water to ground water by outflow through the streambed"—can recharge aquifers).

[151] *See generally* Dave Owen, *Little Streams and Legal Transformations*, 2017 UTAH L. REV. 1 (describing changes in the law of stream protection).

[152] *See id.* at 15-31.

[153] *Id.* at 20-22.

[154] *See id.* at 29-31.

[155] 531 U.S. 159, 162-63 (2001).

[156] 547 U.S. 715 (2006).

[157] *See id.* at 732 (plurality opinion) ("On this definition, 'the waters of the United States' include only relatively permanent, standing or flowing bodies of water.").

initially had a modest impact because the Army Corps and the Environmental Protection Agency (EPA) generally followed a "significant nexus" test articulated by Justice Kennedy,[158] and the agencies often concluded that intermittent and ephemeral water features met this test.[159] And in 2015, the agencies finalized regulations that would have codified those broad protections.[160] But the Trump Administration launched a frontal assault on the 2015 regulations and on Clean Water Act jurisdiction more generally.[161] Its new regulations, finalized in 2020, eliminated all Clean Water Act protections for ephemeral streams and ephemeral (and some non-ephemeral) wetlands.[162]

This change does not necessarily mean that recharge zones can now be filled at will. The Clean Water Act reserves states' abilities to establish more stringent protections,[163] and states also have broad power to regulate land use,

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[158] *See id.* at 780, 782 (Kennedy, J., concurring in the judgment). Justice Kennedy explained that "wetlands possess the requisite nexus, and thus come within the statutory phrase 'navigable waters,' if the wetlands, either alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity of other covered waters more readily understood as 'navigable.'" *Id.* at 780.

[159] *See* J.B. Ruhl, *Proving the* Rapanos *Significant Nexus*, NAT. RES. & ENV'T, Summer 2018, at 51, 52 ("All circuit courts that have ruled on the matter have concluded that an area meeting Justice Kennedy's significant nexus test is within CWA jurisdiction, although some circuit courts have decided that jurisdiction applies if the area meets either the significant nexus test or the plurality's 'relatively permanent' test."); Owen, *supra* note 151, at 29-31 (describing regulatory protections for ephemeral streams).

[160] Clean Water Rule: Definition of "Waters of the United States," 80 Fed. Reg. 37,054 (June 29, 2015) (repealed 2019).

[161] *See* Definition of "Waters of the United States"—Recodification of Pre-Existing Rules, 84 Fed. Reg. 56,626 (Oct. 22, 2019) (to be codified at 33 C.F.R. pt. 328 and scattered parts of 40 C.F.R.) (repealing the 2015 rule); *Navigable Waters Protection Rule: Rulemaking Process*, U.S. EPA, https://perma.cc/3DCA-XDC4 (last updated Aug. 27, 2020); John Flesher, *Trump Administration Drops Obama-Era Water Protection Rule*, ASSOCIATED PRESS (Sept. 12, 2019), https://perma.cc/U48U-PY4L.

[162] The Navigable Waters Protection Rule: Definition of "Waters of the United States," 85 Fed. Reg. 22,250, 22,251 (Apr. 21, 2020) (codified at 33 C.F.R. pt. 328 and scattered parts of 40 C.F.R.). The Biden Administration has stated its interest in revisiting the 2020 regulations, and the EPA and Army Corps have requested stays in litigation challenging those regulations. *See* Jeremy P. Jacobs & Pamela King, *Biden Races Courts for Chance to Torpedo Trump Water Rule*, GREENWIRE (Apr. 28, 2021), https://perma.cc/3K64-5YVP (describing the evolving status of the litigation). But as this Article goes to press, neither the White House nor the EPA or Army Corps has stated specific plans for future rules, and the 2020 regulations remain in effect. *Id.*

[163] *See* PUD No. 1 of Jefferson Cnty. v. Wash. Dep't of Ecology, 511 U.S. 700, 723 (1994) (Stevens, J., concurring) ("Not a single sentence, phrase, or word in the Clean Water Act purports to place any constraint on a State's power to regulate the quality of its own waters more stringently than federal law might require.").

so states could step in to fill the emerging federal voids.[164] But in many areas, that void is unlikely to be filled. Many states have opted to just rely on federal law for stream and wetland protection.[165] Some even have laws specifically forbidding state agencies from adopting any protections that go beyond federal law.[166] And that federal protection now has an uncertain future.

The impacts of these regulatory changes upon recharge also are likely to be complex, and they may vary from watershed to watershed. One possibility is that filling more streams or wetlands means a reduction in the area where recharge occurs, which in turn means less recharge and more surface flow. Studies from the Northern Plains suggest that this outcome will sometimes occur.[167] But in other landscapes, different results are possible. Filling a stream or wetland does not eliminate the precipitation that once created that stream or wetland; it still must go somewhere, and its new flow path may offer greater or lesser possibilities for infiltration. Indeed, because wetlands and stream channels often concentrate vegetation as well as water, moving that water elsewhere in the landscape might reduce transpiration levels, which could sometimes lead to greater amounts of recharge.[168] The scientific literature on these questions is very limited—many studies note that streams and wetlands are important sites for recharge,[169] but few discuss how overall recharge levels would change if those streams or wetlands were lost. Thus, the reductions in stream and wetland protections may best be viewed as, among many other things, an uncontrolled experiment in groundwater-recharge manipulation.

B. Managing Floods

For some of the same reasons that temporary streams and wetlands can be important to groundwater recharge, floodplains also are important. Floodplains are zones where floodwaters spill beyond permanent surface-water features and inundate the landscape. Some of that water evaporates and

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[164] California is the most prominent state to have done so. *See* Bettina Boxall, *California Adopts New Wetlands Rules to Protect Them from Trump Rollbacks*, L.A. TIMES (Apr. 2, 2019, 4:15 PM), https://perma.cc/XL4Y-9A6B.

[165] *See* Phillip Bower & Megan McLean, *The Proposed WOTUS Rule: How Do States Regulate Nonfederal Wetlands?*, TRENDS (Am. Bar Ass'n Section Env't, Energy & Res., Chi., Ill.), Mar./Apr. 2019, at 6, 6-8 (noting that many states rely on Clean Water Act section 401 for wetlands authority).

[166] *See* Andrew Hecht, Note, *Obstacles to the Devolution of Environmental Protection: States' Self-Imposed Limitations on Rulemaking*, 15 DUKE ENV'T. L. & POL'Y F. 105, 115-16, 116 n.42 (2004).

[167] *See* McCauley et al., *supra* note 72, at 10.

[168] *See* van der Kamp & Hayashi, *supra* note 72, at 49 (explaining that in prairie wetlands, most recharged groundwater supports the vegetation surrounding the wetland).

[169] *See, e.g.*, OFF. OF RSCH. & DEV., U.S. EPA, *supra* note 73, at 1-8.

some of it eventually flows back into the river or stream from which it came. But in many floodplain areas, some floodwaters infiltrate into the ground, where they may be available for pumping or may gradually flow back through the ground and then into surface waterways.[170] Flood-zone recharge therefore can supply multiple important benefits: It can dissipate the flood, and it also stores water that can replenish surface flows in drier periods (or can be pumped for other human uses).[171]

Well-designed groundwater-recharge laws therefore might seek to preserve rivers' connections with their floodplains. They might do this in several ways. Local governments, which typically hold authority to zone land, might limit floodplain development and select undeveloped land uses that can accommodate some flooding.[172] State and federal river-management agencies, like the Army Corps or the Bureau of Reclamation, might manage dams to promote periodic flooding and might try to direct river flows into areas where groundwater recharge will occur.[173] And where flood-control infrastructure already exists, its governmental managers might seek to selectively dismantle it, ideally allowing floods to expand into areas with strong recharge potential (and with landowners who will agree, perhaps for a price, to allow flooding of their lands).[174] More ambitiously, and also more intrusively, government regulators might ask owners of flood-protected land to take some steps to compensate for the recharge those lands no longer provide.

For most of our history, however, the United States' policy has been to do exactly the opposite. For decades, the Army Corps and other federal, state, and local agencies have focused on keeping floodwaters out of floodplains.[175] They (and local governments and private entities) have built thousands of dams, often

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[170] *See* R. Doble et al., *Modelling Overbank Flood Recharge at a Continental Scale*, 18 HYDROLOGY & EARTH SYS. SCIS. 1273, 1274 (2014).

[171] *See* OFF. OF RSCH. & DEV., U.S. EPA, *supra* note 73, at 4-5 tbl.4-1.

[172] *See* James M. Holway & Raymond J. Burby, *Reducing Flood Losses: Local Planning and Land Use Controls*, 59 J. AM. PLAN. ASS'N 205, 212 (1993); JAMES M. WRIGHT, *Strategies and Tools to Maintain or Restore Floodplain Resources*, *in* FLOODPLAIN MANAGEMENT: PRINCIPLES AND CURRENT PRACTICES 9-1, 9-3 (2007), https://perma.cc/5K82-CD6M (providing examples of floodplain-compatible land uses).

[173] *See, e.g.*, Robert M. Gailey et al., *Maximizing On-Farm Groundwater Recharge with Surface Reservoir Releases: A Planning Approach and Case Study in California, USA*, 27 HYDROGEOLOGY J. 1183, 1185-86 (2019) (describing the possibility of using timed releases from Folsom Reservoir).

[174] *See, e.g.*, RAMONA O. SWENSON ET AL., NATURE CONSERVANCY, RESTORING FLOODS TO FLOODPLAINS: RIPARIAN AND FLOODPLAIN RESTORATION AT THE COSUMNES RIVER PRESERVE 3-4 (2003), https://perma.cc/X28K-S3QC (describing the use of intentional levee breaches for floodplain restoration).

[175] *See generally* A. Dan Tarlock, *United States Flood Control Policy: The Incomplete Transition from the Illusion of Total Protection to Risk Management*, 23 DUKE ENV'T L. & POL'Y F. 151 (2012) (describing the rise and partial fall of this policy).

partly for the legislatively specified purpose of storing floodwaters and thus eliminating downstream flooding.[176] Governmental and nongovernmental actors also have built thousands of miles of levees, again with the primary purpose of isolating rivers from their floodplains.[177] Development—often facilitated by local zoning laws and federal flood insurance—often springs up behind those levees, further limiting the option of allowing rivers beyond their banks.[178] Other land-management practices also disconnect rivers and streams from floodplains. Both cattle grazing, which is common on western lands, and urbanization can cause "downcutting" of streams, which means that streams erode deep gullies that prevent even high flows from spilling onto the surrounding land.[179] The consequence is that many formerly significant groundwater-recharge zones have been idled, with the idling directly caused by physical infrastructure and more indirectly facilitated by federal legislation and state and local land-use law. All of these flood-limiting practices tend to occur with little or no discussion of—let alone legal response to—their impacts on groundwater recharge. The upshot is that there are flood-prone regions—Houston and Baton Rouge, for example—where people must worry simultaneously about having too much water above the ground and not enough below, and where the land subsidence associated with groundwater deficits makes surface-water-flooding problems even worse.[180]

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[176] *Id.* at 160-65 (describing the emergence of flood-control dams); Dave Owen & Colin Apse, *Trading Dams*, 48 U.C. DAVIS L. REV. 1043, 1052-53 (2015) (summarizing statistics on the number of dams in the United States).

[177] *See* Kara Scheel et al., *Understanding the Large-Scale Influence of Levees on Floodplain Connectivity Using a Hydrogeomorphic Approach*, 55 J. AM. WATER RES. ASS'N 413, 414 (2019) (describing rivers disconnected from most of their floodplain, along with the difficulties of calculating aggregate-scale impacts of levees); U.S. Army Corps of Eng'rs, *Levees of the Nation*, NAT'L LEVEE DATABASE, https://perma.cc/EP8V-Y7QN (archived Mar. 11, 2021) (stating that, as of March 2021, the United States had 25,618 miles of levees).

[178] *See* Jessica Ludy & G. Matt Kondolf, *Flood Risk Perception in Lands "Protected" by 100-Year Levees*, 61 NAT. HAZARDS 829, 830-32 (2012) (observing that development often occurs behind levees, facilitated by misperceptions of risk and by the National Flood Insurance Program's classification of levee-protected areas as non-floodplain); Raymond J. Burby, *Flood Insurance and Floodplain Management: The US Experience*, 3 ENV'T HAZARDS 111, 111 (2001) ("[E]xtensive development has occurred in areas with the greatest risk from flood hazards, and the rate of development, rather than decreasing, has actually increased at unprecedented rates over the past 30 yr [sic].").

[179] *See, e.g.*, Robert J. Hawley et al., *Suburban Stream Erosion Rates in Northern Kentucky Exceed Reference Channels by an Order of Magnitude and Follow Predictable Trajectories of Channel Evolution*, GEOMORPHOLOGY, Mar. 1, 2020, at 1, 6 fig.3, 10 figs.10 & 11 (showing diagrams and photographs of downcutting suburban streams); A.J. Belsky et al., *Survey of Livestock Influences on Stream and Riparian Ecosystems in the Western United States*, 54 J. SOIL & WATER CONSERVATION 419, 427 (1999).

[180] *See, e.g.*, Bob Rehak, *How Montgomery County Could Keep Sinking*, HOUS. CHRON. (updated Nov. 5, 2018, 9:18 PM), https://perma.cc/B3XD-5WUC; ADRIAN MCINNIS ET AL.,

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There are also now areas where practices are changing. In Washington State, for example, the Washington Department of Ecology and the Nature Conservancy have partnered on a "Floodplains by Design" program designed to reintroduce rivers to surrounding floodplains.[181] The Natural Resource Conservation Service has spent millions of dollars purchasing flooding easements from willing landowners in flood-prone areas,[182] and while the regulatory criteria for selecting purchased lands do not include groundwater-recharge potential,[183] at least some of the resulting flooding is likely to recharge aquifers.[184] More recently, California's Central Valley Flood Protection Board adopted policies designed to encourage reconnection of rivers with their floodplains, partly with the goal of increasing groundwater recharge.[185] Some pilot projects show promising results.[186] Yet these remain isolated examples, and notably, the recharge benefits that occur generally happen because government or nonprofit entities pay landowners to partially restore recharge levels that their lands once provided for free.[187] The idea that anyone is obligated to allow floodplain recharge has not yet been part of the legal discussion.

C. Forests and Fields

As the preceding sections show, law affects groundwater recharge by regulating (or deliberately not regulating) development's impacts on surface-water runoff and by protecting (or deliberately not protecting) floodplains and

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WATER INST. OF THE GULF, STATE OF THE SCIENCE TO SUPPORT LONG-TERM WATER RESOURCE PLANNING 65 (2020), https://perma.cc/8Q3C-SHCD (describing historic subsidence in the Baton Rouge area); Steve Hardy, *Baton Rouge Water Company Says Industry Needs to Stop Drawing Water from Aquifer*, ADVOCATE (July 1, 2017, 4:02 PM), https://perma.cc/SB2V-3EUE.

[181] FLOODPLAINS BY DESIGN, https://perma.cc/5A7Y-7LMB (archived Mar. 11, 2021).

[182] *See* 16 U.S.C. § 2203 (authorizing floodplain-easement purchases); *see, e.g.*, *NRCS Offers More than $200 Million in Emergency Funding to Restore Flood-Prone Lands*, TRI-STATE LIVESTOCK NEWS (July 25, 2019), https://perma.cc/4376-V9SU.

[183] *See* 7 C.F.R. § 624.10 (2020) (providing limited criteria for choosing lands and not including groundwater-recharge potential).

[184] *See* Emergency Watershed Protection Program, 70 Fed. Reg. 16,921, 16,925 (Apr. 4, 2005) (codified at 7 C.F.R. pt. 624) (noting groundwater-recharge benefits).

[185] *See* Matt Weiser, *A Landmark California Plan Puts Floodplains Back in Business*, NEW HUMANITARIAN: WATER DEEPLY (Oct. 10, 2017), https://perma.cc/3M2N-3AEK.

[186] *See, e.g.*, SWENSON ET AL., *supra* note 174 (describing the benefits of floodplain restoration along California's Cosumnes River).

[187] *See, e.g.*, *EWP Floodplain Easement Program—Floodplain Easement Option (EWPP-FPE)*, USDA NAT. RES. CONSERVATION SERV., https://perma.cc/6CH8-DCCJ (archived Mar. 12, 2021) (describing the EWP Floodplain Easement Program, which relies on voluntary easement purchases).

temporary waterways. But collectively, developed areas, temporary waterways, and floodplains make up a small portion of the landscapes influenced by human activity. In many other areas, humans affect groundwater recharge primarily by managing forests, rangelands, and farms. These impacts should be important to a system of groundwater law, for most of our precipitation falls on forests and agricultural lands,[188] and much of that precipitation is transpired by vegetation.[189] Consequently, management of those lands can either increase or decrease recharge levels, sometimes significantly. With limited exceptions, however, law does not address these impacts.

1. Water and the woods

A comprehensive system of groundwater-recharge law would likely start in the woods. Most of the United States' freshwater flows begin in forests, and in the western United States the proportion is even higher.[190] Forests also regulate the timing and amount of water flows.[191] Most importantly, they limit recharge because trees and other plants use water; much of the precipitation that falls in forests is taken up by plants' roots and transpired.[192] But forests also facilitate recharge by covering the ground with decaying leaf litter, into which water readily infiltrates and through which lateral overland

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[188] This is because most of our nondesert land is either forested, cultivated, or grazed. *See* Cynthia Nickerson & Allison Borchers, *How Is Land in the United States Used? A Focus on Agricultural Land*, ECON. RSCH. SERV., U.S. DEP'T AGRIC. (Mar. 1, 2012), https://perma.cc/WDG2-2T5U (noting that in 2007, 51% of the United States' land area was in agricultural use); U.S. DEP'T OF AGRIC., U.S. FOREST RESOURCE FACTS AND HISTORICAL TRENDS 7 (2014), https://perma.cc/VD7S-UQL3 ("In 2012, forest land comprised 766 million acres, or 33 percent of the total land area of the United States."). There is some overlap between these two categories because some forested land is also agricultural.

[189] *See* Ronald L. Hanson, *Evapotranspiration and Droughts*, *in* NATIONAL WATER SUMMARY 1988-89—HYDROLOGIC EVENTS AND FLOODS AND DROUGHTS 99, 99 (Richard W. Paulson et al., 1991).

[190] U.S. DEP'T. OF AGRIC. ET AL., *supra* note 98, at 6 ("In the Western United States, 65 percent of the water supply comes from forests.").

[191] Katherine J. Elliott et al., *Water Yield Following Forest-Grass-Forest Transitions*, 21 HYDROLOGY & EARTH SYS. SCIS. 981, 981 (2017) ("Forests play a critical role in regulating hydrological processes in headwater catchments by moderating the timing and magnitude of streamflow.").

[192] *See* Matheussen et al., *supra* note 27, at 868 ("Removal of forest cover is known to increase streamflow as a result of reduced evapotranspiration and to increase peak flows as a result of higher water tables.").

flows are impeded.[193] Additionally, the water that trees transpire can create additional precipitation, and thus more recharge, further downwind.[194]

These activities are heavily impacted by human management of forests. Generally speaking, a forest with more growing biomass will transpire more water, which means that it will provide less recharge and less outflow.[195] Consequently, human activities that create or thicken forests, like fire suppression or forest planting, can reduce water supplies,[196] while thinning forests, letting them burn, or removing them entirely can enhance the quantity (though often not the quality) of water supplies.[197] These relationships are not always consistent; logging a forest, for example, can lead to road building, soil compaction, and more rapid snowmelt,[198] which can reduce recharge. And regenerating forests may actually transpire more water than the mature stands they replace.[199] Also, increasing water flows out of forests isn't necessarily the same as increasing groundwater recharge. Water may leave the forest primarily as surface flow, and unless those surface flows enter zones where a stream is losing water to its bed or floodplain (or to nearby irrigated areas), those flows may not become groundwater again.[200] Nevertheless, there are many areas where the water that fills aquifers must first pass through a forest,

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[193] *See* van Noordwijk et al., *supra* note 79, at 33.

[194] *Id.* at 35-36.

[195] *See* Ge Sun et al., *Impacts of Forest Biomass Removal on Water Yield Across the United States*, *in* 2016 BILLION-TON REPORT: ADVANCING DOMESTIC RESOURCES FOR A THRIVING BIOECONOMY—VOLUME 2, at 211, 212 (2017), https://perma.cc/J9QV-BTDW.

[196] *See* van Noordwijk et al., *supra* note 79, at 43 ("[M]ost studies [of afforestation] reported decreases in water yields following the intervention.").

[197] *See* Dennis W. Hallema et al., *Burned Forests Impact Water Supplies*, NATURE COMMC'NS, Apr. 10, 2018, at 1, 2; Julia A. Jones et al., *Forest Landscape Hydrology in a "New Normal" Era of Climate and Land Use Change*, *in* FOREST AND WATER ON A CHANGING PLANET, *supra* note 79, at 81, 85 (describing the effects of timber harvesting).

[198] *See* Jones et al., *supra* note 197, at 85.

[199] *See* Elliott et al., *supra* note 191, at 988-90 (finding that a growing forest used more water than a mature forest that had previously occupied the same land).

[200] This is likely to be true in humid climates, where rivers and streams continue to gain flow from surrounding groundwater over much of their course. It is less likely to be true in places like the American West, where arid lowland climates and pumping-related aquifer depletion mean that many low-elevation watercourses are disconnected from the water table. *See* Laura E. Condon & Reed M. Maxwell, *Evaluating the Relationship Between Topography and Groundwater Using Outputs from a Continental-Scale Integrated Hydrology Model*, 51 WATER RES. RSCH. 6602, 6610 fig.4 (2015) (showing groundwater-table depth and flow direction in the western and eastern United States); *see also, e.g.*, Rebecca Nelson & Leon Szeptycki, *Groundwater, Rivers, Ecosystems and Conflicts*, WATER IN THE WEST (updated Dec. 19, 2014), https://perma.cc/XE45-TBDT (describing areas where groundwater pumping has depleted surface-water ecosystems).

and human management of that forest partially determines the extent to which those aquifers fill.[201]

For all of these reasons, one might expect water law and forest law to be highly integrated. And in a few ways, they are and have been for a long time. In the nineteenth century, in reaction to massive floods that followed widespread clearcutting, the United States established its national forests.[202] Managing water flows was, and remains, a central purpose of federal forest law; indeed, the Supreme Court once held that timber provision and water-flow management were the *only* purposes for which the national forest system was originally created.[203] At the federal level, a series of additional statutes has broadened the purposes of forest management and has created a procedural framework for forest-management planning.[204] Within that framework, the sweeping and open-ended mandates of federal forest law leave ample room for the Forest Service to make water management generally, and promotion of groundwater recharge more specifically, a key component of its planning goals.[205] States, meanwhile, hold broad authority to regulate private and state-held forest lands[206] and could, in theory, use that authority to manage forests with water management as a central goal.

In practice, however, forest-management and water law mostly occupy different realms.[207] Several subareas of forest law exemplify this disconnect. One is fire-management policy. For decades, the Forest Service had a policy of

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[201] In California, for example, most precipitation falls, and recharge processes therefore begin, in the forested Sierra Nevada and the Coast Ranges, but the significant aquifers are in valleys. Claudia C. Faunt et al., *Introduction, Overview of Hydrogeology, and Textural Model of California's Central Valley*, *in* GROUNDWATER AVAILABILITY OF THE CENTRAL VALLEY AQUIFER, CALIFORNIA 1, 21 fig.A9 (Claudia C. Faunt ed., 2009) (showing a cross section of the Central Valley Aquifer).

[202] U.S. DEP'T OF AGRIC. ET AL., *supra* note 98, at 4 (describing the origins of the national forests).

[203] United States v. New Mexico, 438 U.S. 696, 707-13 (1978).

[204] *See* National Forest Management Act of 1976, Pub. L. No. 94-588, 90 Stat. 2949 (codified as amended in scattered sections of 16 U.S.C.); Forest and Rangeland Renewable Resource Planning Act of 1974, Pub. L. No. 93-378, 88 Stat. 476 (codified as amended at 16 U.S.C. §§ 1601-1614); Multiple-Use Sustained-Yield Act of 1960, Pub. L. No. 86-517, 74 Stat. 215 (codified at 16 U.S.C. §§ 528-531).

[205] *See* 16 U.S.C. § 528 ("It is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."); *id.* § 1604(e), (g) (directing the Forest Service to factor watersheds into forest management).

[206] *See* Blake Hudson, *Dynamic Forest Federalism*, 71 WASH. & LEE L. REV. 1643, 1668-70 (2014).

[207] *See* David Ellison et al., *Governance Options for Addressing Changing Forest-Water Relations*, *in* FOREST AND WATER ON A CHANGING PLANET, *supra* note 79, at 147, 151 ("[F]orest-water interactions have been almost entirely ignored in the management of global freshwater resources.").

aggressive fire suppression, which meant trying to put out every fire in the forests as quickly as possible.[208] That policy thickened forests, sometimes dramatically,[209] and may have reduced the amount of water exiting those forests.[210] But only recently has the Forest Service begun paying attention to the water-management implications of its fire-suppression policies, and the Forest Service still treats those implications as a matter to which attention is discretionary rather than as a field involving legal obligations.[211] Outside of the southeastern United States, where prescribed burning has been a common practice for decades, many states and private landholders are just as committed to fire suppression as the Forest Service.[212] That does not mean they succeed in preventing fires; one of the hardest lessons of forest-fire policy has been that suppression, in the long run, just makes the fires that do occur larger and more catastrophic (which also means providing episodic and unpredictable boosts to groundwater recharge and to surface-water flows).[213] But the emphasis on fire suppression has probably reduced past flows and, to the extent it is successful, will continue to limit flows in the future.[214]

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[208] *See* Stephens & Sugihara, *supra* note 70, at 433-34.

[209] *See* Aaron W. Fellows & Michael L. Goulden, *Has Fire Suppression Increased the Amount of Carbon Stored in Western U.S. Forests?*, GEOPHYSICAL RSCH. LETTERS, June 28, 2008, at 1, 1 (noting "a shift from sparser forests, which are dominated by a few large trees, to denser forests, which are dominated by many small trees").

[210] The relationships are complicated because a denser forest may have fewer large trees and therefore less overall biomass, *see id.*, but a forest dominated by large trees may use less water than one primarily composed of smaller, immature trees. *See* Elliott et al., *supra* note 191, at 987 (reporting findings "suggesting that the new forest used more water (i.e., had higher [evapotranspiration]) than expected had it not undergone treatment").

[211] *See, e.g.*, U.S. DEPT. OF AGRIC. ET AL., *supra* note 98, at 52 (describing management options but not legal obligations).

[212] *See* Sophie Quinton & Alex Brown, *California May Need More Fire to Fix Its Wildfire Problem*, PEW CHARITABLE TRS.: STATELINE (Sept. 18, 2020), https://perma.cc/7XF2-2XK4 (describing disincentives for burning on nonfederal land); *Fire*, OR. DEP'T FORESTRY, https://perma.cc/HA33-AGX8 (archived Mar. 12, 2021) ("ODF's firefighting policy is straightforward: Put out fires quickly at the smallest possible size."). On the different policies in the southeast, see Jim Brenner & Dale Wade, *Florida's Revised Prescribed Fire Law: Protection for Responsible Burners*, *in* PROCEEDINGS OF FIRE CONFERENCE 2000: THE FIRST NATIONAL CONGRESS ON FIRE ECOLOGY, PREVENTION, AND MANAGEMENT 132, 133 (K.E.M. Galley et al. eds., 2003) ("Florida has led the nation in acreage treated with prescribed fire every year since records have been kept . . . .").

[213] *See* Stephen J. Pyne, *Between Two Fires: The Past and Future of Fire in America*, 18 PENN ST. ENV'T L. REV. 129, 134-36 (2010) (describing the unraveling of fire suppression); Scott L. Stephens & Lawrence W. Ruth, *Federal Forest-Fire Policy in the United States*, 15 ECOLOGICAL APPLICATIONS 532, 533 (2005).

[214] *See* Gabrielle F.S. Boisramé et al., *Restoring a Natural Fire Regime Alters the Water Balance of a Sierra Nevada Catchment*, 55 WATER RES. RSCH. 5751, 5766 (2019) ("The reintroduction of a near-natural wildfire regime to the [Illilouette Creek Basin] has

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Similarly, while the negative impact of timber harvesting upon water *quality* has long been a subject of close legal attention (and deservedly so), the complicated relationship between timber harvesting and water *quantity* rarely becomes a focus of legal concern. The National Forest Management Act, for example, speaks directly to limiting the impact of timber harvesting on water quality, but says nothing specific about using forest management to augment the quantity of flows.[215] The Forest Service's implementing regulations share that same focus; they provide more detailed provisions for protecting watersheds from timber harvesting, but they likewise say nothing specific about using timber harvesting or fire policy to manage flow levels.[216] State laws are similar. California's forest-management rules, for example, contain many pages about protecting watersheds from timber-management practices but again say nothing about groundwater recharge or about managing the quantity of surface-water flows.[217] Water law in at least one western state also precludes land managers from claiming rights in additional flows created by vegetation management.[218] In Colorado, if a land manager removes invasive tamarisk trees from a watershed, thus reducing transpiration, the "developed water" produced by that activity is allocated under the normal rules of prior appropriation, and the landowner has no special claim to the increased flow.[219]

This disconnect between forest and water policy is not unique to the United States. In much of the world, forestry law is concerned primarily with timber production, erosion control, biodiversity protection, and, more recently, carbon sequestration.[220] Affecting groundwater recharge, and water-flow levels more generally, can be an important—and sometimes problematic—incidental

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reduced transpiration, increased peak snowpack while leading to earlier snowmelt overall, increased subsurface water storage in the basin, and is likely to have increased streamflow.").

[215] *See* 16 U.S.C. § 1604(g).

[216] *See* 36 C.F.R. § 219.8(a)(2) (2020) (requiring forest-management plans to address water quality and the ecological integrity of within-forest streams but establishing no clear requirements for addressing flows out of the forest).

[217] CAL. CODE REGS. tit. 14, §§ 916-916.12, 936-936.12, 956-956.12 (2021).

[218] *See* Se. Colo. Water Conservancy Dist. v. Shelton Farms, Inc., 529 P.2d 1321, 1325 (Colo. 1974) (en banc).

[219] *Id.* ("[T]hirsty men cannot step into the shoes of a 'water thief' (the phreatophytes.) . . . The property (the water) must return from whence it comes—the river—and thereon down the line to those the river feeds in turn.").

[220] *See* Ellison et al., *supra* note 207, at 151 ("To date, the traditional paradigm has been to manage forests for their ability to provide biomass, for their multi-functional uses, and/or for their ability to sequester carbon.").

consequence of forest policy.[221] But it has rarely been an element of legal frameworks. There are exceptions; South Africa, for example, requires developers of tree plantations to obtain water-supply permits.[222] But in most places, forest law and water-quantity law lack purposeful integration.

2. Agriculture, irrigated and otherwise

Just as forests have a complex relationship with groundwater, so does agricultural activity. In the United States and around the world, agriculture is the primary use of groundwater.[223] It also is often the most problematic use; the most extreme groundwater crises tend to occur in places, like California's San Joaquin Valley or the High Plains' Ogallala Aquifer, where use is primarily agricultural.[224] But even as it sometimes depletes aquifers, agriculture also can augment groundwater recharge. In some dryland agricultural areas, that increased recharge occurs because planted crops transpire less water than the vegetation they replace.[225] In irrigated areas, the recharge may come from excess application of water to crops.[226] That water may be from the same aquifer to which the recharge returns, and the recharge thus may just partially offset the depletion caused by groundwater pumping. Alternatively, the recharge may come from imported surface water and thus may increase aquifer storage—sometimes problematically, to the point of flooding crops—though it does so at the expense of surface flows someplace else.[227]

In theory, law could address these complicated interactions in several ways. Most obviously, state and local land-use laws determine where

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[221] *See, e.g.*, Shixiong Cao et al., *Greening China Naturally*, 40 AMBIO 828, 829 (2011) (describing the problematic and unanticipated water-supply impacts of China's afforestation policies).

[222] Bhaskar Vira et al., *Management Options for Dealing with Changing Forest-Water Relations*, *in* FOREST AND WATER ON A CHANGING PLANET, *supra* note 79, at 121, 135.

[223] *See The Basics: What Is Groundwater?*, GROUNDWATER FOUND., https://perma.cc/R4X5-ZRC7 (archived Mar. 12, 2021) (providing statistics on groundwater use in the United States); *Facts About Global Groundwater Usage*, NAT'L GROUND WATER ASS'N, https://perma.cc/26AQ-FGW6 (archived Mar. 12, 2021) ("About 70% of groundwater withdrawn worldwide is used for agriculture.").

[224] *See Groundwater Decline and Depletion*, U.S. GEOLOGICAL SURV., https://perma.cc/V4X2-47Y4 (archived Mar. 12, 2021) (mapping locations with heavy groundwater depletion).

[225] *See* Han et al., *supra* note 65, at 546.

[226] *Id.* at 547.

[227] *See, e.g.*, Firebaugh Canal Co. v. United States, 203 F.3d 568, 570-72 (9th Cir. 2000) (describing drainage problems caused by irrigating lands in California's San Joaquin Valley). The same combination of depletion in one place and excess water in another can arise if groundwater is pumped from below a confining layer and then recharges a shallow aquifer.

agriculture can occur and where competing land uses cannot occur,[228] and much of the field of surface-water law governs deliveries of irrigation water.[229] Both fields therefore incidentally help determine the locations and amounts of agriculture-related groundwater recharge. Additionally, as water law increasingly focuses on the efficiency of water use (and as technology makes efficient water use more feasible), it will necessarily limit the extent of groundwater recharge.[230] More specifically, land-use and water laws might create incentives for maximizing the benefits of agricultural recharge while minimizing its associated problems. That might mean, for example, trying to encourage irrigators to time applications of water so that recharge will augment dry-season surface flows.[231] Alternatively, it might mean asking irrigators who switch to lower-recharge practices to address the associated impacts to water uses that have come to depend on the recharge from prior practices.[232]

But with agricultural use, as with other areas of groundwater-recharge law, impacts upon recharge are addressed, if at all, primarily as the incidental consequences of laws focused on other matters. Policies that help determine where agriculture occurs, for example, generally focus on limiting development in prime agricultural areas; promoting groundwater recharge is not part of the calculus.[233] Similarly, states generally assign water rights without considering the effects of surface-water diversions on groundwater-

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[228] *See* Teri E. Popp, *A Survey of Governmental Response to the Farmland Crisis: States' Application of Agricultural Zoning*, 11 U. ARK. LITTLE ROCK L.J. 515, 521-34 (1988-1989) (describing relationships between farming and zoning powers).

[229] *See generally* BARTON H. THOMPSON, JR., JOHN D. LESHY, ROBERT H. ABRAMS & SANDRA B. ZELLMER, LEGAL CONTROL OF WATER RESOURCES: CASES AND MATERIALS (6th ed. 2018) (including dozens of cases involving irrigators).

[230] *See, e.g.*, Montana v. Wyoming, 563 U.S. 368, 371-72, 374 (2011) (describing Montana's allegations that increased agricultural-water-use efficiency led to reduced seepage and thus to lower Yellowstone River flows).

[231] *See, e.g.*, George Kourakos et al., *Increasing Groundwater Availability and Seasonal Base Flow Through Agricultural Managed Aquifer Recharge in an Irrigated Basin*, 55 WATER RES. RSCH. 7464, 7464, 7486-87 (2019) (examining the potential for seasonal recharge in California's Central Valley); Helen E. Dahlke et al., *Managed Winter Flooding of Alfalfa Recharges Groundwater with Minimal Crop Damage*, 72 CAL. AGRIC. 65, 65-66 (2018) (proposing managed flooding of agricultural fields as a recharge mechanism).

[232] *But see infra* notes 235-38 and accompanying text (discussing laws that allow irrigators to salvage recharged irrigation water without worrying about impacts on downstream or downgradient users).

[233] *See, e.g.*, *Prime Farmland and Farmland of Statewide Importance*, CAL. DEP'T CONSERVATION, https://perma.cc/X3J5-HA5F (archived Apr. 16, 2021) (describing the criteria for designating farmland without mentioning the potential to promote aquifer recharge).

recharge levels.[234] Even in places where irrigation-related recharge is highly problematic—which can happen where excess recharge raises the water table, flooding and often polluting plants' root zones—regulators do not factor that recharge into their assessment of the underlying surface-water right.

There is one water-rights doctrine that has more direct implications for agricultural recharge. In the western United States, the doctrine of recapture allows surface-water irrigators to reclaim surface water that recharged groundwater.[235] In other words, even after irrigation water has leaked through irrigation ditches or percolated below plants' root zones, that water remains part of the surface-water right, and the rightsholder can pump it back to the surface and reuse it.[236] As a closely related corollary to that rule, a surface-water-right holder also may change to different water-use practices, even if that means the quantity of groundwater recharge on her land decreases, and even if downgradient or downstream water users or ecosystems have come to rely on the recharge generated by the old water-use practices.[237] Those human users and ecosystems may use the recharge as long as it remains present, but they cannot demand its continuation.[238]

For a water-rights system, the doctrine of recapture has some important advantages. It allows water-right holders to reap the benefits of increased water-use efficiency, rather than locking them into practices that generate recharge but do so through excess water applications or leaky infrastructure.

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[234] *See, e.g.*, Wash. State Dep't of Ecology, Guidance to Applicants for New Water Right Permits: Instructions for Form No. ECY 040-1-14A (2020), https://perma.cc/QEA3-J3RG (explaining the required elements for a permit application, which do not include a discussion of recharge associated with water use); Ariz. Dep't of Water Res., Application Guidelines: Permit to Appropriate Public Water of the State of Arizona or to Construct a Reservoir 7 (2016), https://perma.cc/LC3B-3BJE (requiring a discussion of groundwater recharge, but only if the project is specifically designed as a recharge project).

[235] *See, e.g.*, *Montana*, 563 U.S. at 380-81; Barker v. Sonner, 294 P. 1053, 1054 (Or. 1931) (en banc) ("[A]n appropriator is justified in recapturing waste water remaining upon his land . . . .").

[236] *See, e.g.*, United States v. Haga, 276 F. 41, 43 (D. Idaho 1921) (stating that the rights of surface-water appropriators extend "to what is commonly known as wastage from surface run-off and deep percolation"); Bidleman v. Short, 150 P. 834, 836 (Nev. 1915) ("So long as such waters exist upon their lands, it is their property . . . .").

[237] *See* Ariz. Pub. Serv. Co. v. Long, 773 P.2d 988, 996-97 (Ariz. 1989) (en banc) ("If the senior appropriator, through scientific and technical advances, can utilize his water so that none is wasted, no other appropriator can complain.").

[238] *See, e.g.*, Stevens v. Oakdale Irrigation Dist., 90 P.2d 58, 61 (Cal. 1939) (en banc) (per curiam) ("It is the general rule, probably subject to exceptions not here involved, that the producer of an artificial flow is for the most part under no obligation to lower claimants to continue to maintain it."); Lambeye v. Garcia, 157 P. 977, 978-79 (Ariz. 1916) ("[W]hile the water so denominated as waste water may be used after it escapes, no permanent right can be acquired to have the discharge kept up . . . .").

Relatedly, it facilitates transfers of water to higher-value users; many transfers occur because agricultural users adopt more efficient practices and then sell the saved water.[239] But the doctrine accomplishes these beneficial outcomes at the expense of potential reliance interests in groundwater recharge. More generally, it continues the theme, which is reflected across many areas of water-related law, of treating groundwater recharge as an incidental consequence of doctrines and practices focused on other aspects of water management.

D. Managed Aquifer Recharge

A recurring theme of the discussion so far has been law's indifference, or just glancing attention, to groundwater recharge. But there are management practices that take a very different approach, and they come with an emerging body of law. Increasingly, water managers are turning to a practice known as managed aquifer recharge (MAR) to improve management of water supplies.[240]

MAR generally involves using empty aquifer space to store water from some other source.[241] Typically the source is surface water,[242] though some MAR projects rely on groundwater from other aquifers[243] or on treated municipal wastewater.[244] The project managers typically use discrete infrastructure—often infiltration basins or injection wells—to place the water in the subsurface.[245] Many projects are run by water districts, which develop

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[239] *See* PETER W. CULP, ROBERT GLENNON & GARY LIBECAP, HAMILTON PROJECT & STANFORD WOODS INST. FOR THE ENV'T, DISCUSSION PAPER 2014-05, SHOPPING FOR WATER: HOW THE MARKET CAN MITIGATE WATER SHORTAGES IN THE AMERICAN WEST 7 (2014) (explaining how markets can create incentives for increased water-use efficiency).

[240] *See generally* COMM. ON SUSTAINABLE UNDERGROUND STORAGE OF RECOVERABLE WATER, NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 15 (describing MAR concepts and projects).

[241] *See, e.g.*, CAL. DEP'T OF WATER RES., *supra* note 96, at 12 (defining "managed aquifer recharge").

[242] *See, e.g.*, Anita Milman et al., *Groundwater Recharge for Water Security: The Arizona Water Bank, Arizona*, 5 CASE STUD. ENV'T, no. 1, 2021, at 1, 1 (describing how the Arizona Water Bank stores water diverted from the Colorado River).

[243] *E.g.*, *Aquifer Storage & Recovery*, SAN ANTONIO WATER SYS., https://perma.cc/L97F-PVNQ (last updated Mar. 11, 2021) (describing a program to store excess Edwards Aquifer water in another aquifer).

[244] *E.g.*, *What Is SWIFT?*, HRSD, https://perma.cc/49NE-9UDR (archived Apr. 20, 2021) (describing the Hampton Roads Sanitary District's Sustainable Water Initiative for Tomorrow (SWIFT), which uses recharge of treated wastewater to combat saltwater intrusion in a coastal Virginia aquifer).

[245] *See* COMM. ON SUSTAINABLE UNDERGROUND STORAGE OF RECOVERABLE WATER, NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 15, at 27-29 (describing recharge methods); *see also, e.g.*, *Recharge and Recovery*, KERN WATER BANK AUTH.,

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the projects primarily or exclusively for their own use,[246] but others function as shared banks, which multiple participating agencies or third parties may use for water deposits and withdrawals.[247] Any MAR project requires systems of monitoring and accounting as well as physical infrastructure, especially because these MAR projects typically use aquifers where other landowners hold rights to native groundwater.[248] States generally treat the MAR water as legally separate from that native groundwater—legally, it is classified as stored surface water[249]—but the physical commingling of the two resources can create some accounting challenges and complex legal questions.[250]

A full discussion of the variety of MAR projects and the legal frameworks needed for their success is a subject for a different article.[251] For present purposes, two key points should suffice. The first is that MAR projects come in a wide variety of forms. Some involve diversion of surface water and infiltration at discrete and limited sites, but other projects involve the kinds of land-use practices that have been the primary focus of this Article; they have used deliberate flooding of agricultural fields,[252] removal of invasive

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https://perma.cc/9QNZ-5FX5 (archived Mar. 12, 2021) (explaining how water is recharged into storage in Kern County, California).

[246] *See, e.g.*, Kathleen Miller et al., *An Urban Drought Reserve Enabled by State Groundwater Recharge Legislation: The Bear Canyon Recharge Project, Albuquerque, New Mexico*, 5 CASE STUD. ENV'T, no. 1, 2021, at 1, 1 (describing a project run by a single water district for the benefit of a single city).

[247] *See, e.g.*, Michael Kiparsky et al., *Groundwater Recharge for a Regional Water Bank: Kern Water Bank, Kern County, California*, 5 CASE STUD. ENV'T, no. 1, 2021, at 1, 4-9 (describing the Kern Water Bank, which provides storage capacity to multiple member agencies and also allows those agencies to market their stored water); *Groundwater Banking*, SEMITROPIC WATER STORAGE DIST., https://perma.cc/E6V5-TPWU (archived Mar. 12, 2021) (describing another southern California groundwater bank).

[248] *See* William Blomquist et al., *Institutions and Conjunctive Water Management Among Three Western States*, 41 NAT. RES. J. 653, 657-59 (2001) (describing these challenges and the advantages of clear rights in stored water).

[249] *See* GREGORY A. THOMAS, NAT. HERITAGE INST., DESIGNING SUCCESSFUL GROUNDWATER BANKING PROGRAMS IN THE CENTRAL VALLEY: LESSONS FROM EXPERIENCE 21-22 (2001), https://perma.cc/UNL7-32AL (describing the legal status of banked water).

[250] *See* Blomquist et al., *supra* note 248, at 658-59 (describing these challenges).

[251] I have separated out MAR in large part because MAR law is primarily *surface*-water law, while the focus of this Article is on the intersection of land-use and groundwater law.

[252] *See, e.g.*, Richard G. Niswonger et al., *Managed Aquifer Recharge Through Off-Season Irrigation in Agricultural Regions*, 53 WATER RES. RSCH. 6970, 6971 (2017) (describing "Ag-MAR" projects); Helen E. Dahlke et al., *Managed Aquifer Recharge as a Tool to Enhance Sustainable Groundwater Management in California: Examples from Field and Modeling Studies*, *in* ADVANCES IN CHEMICAL POLLUTION, ENVIRONMENTAL MANAGEMENT AND PROTECTION: ADVANCED TOOLS FOR INTEGRATED WATER MANAGEMENT 215, 245-46 (Jan Friesen & Leonor Rodríguez-Sinobas eds., 2018) (providing a case study from California's Kings River Basin).

vegetation,[253] and recharge of municipal wastewater and stormwater runoff.[254] In one of the most innovative projects, water managers in California's Pajaro Valley have created a "recharge net metering" system, whereby landowners who augment groundwater recharge can obtain reductions in their otherwise substantial groundwater pumping fees.[255] The second point is that many MAR projects are modest in scale, at least compared to overall volumes of groundwater storage and use.[256] With some notable exceptions,[257] they typically cover limited areas, and they often are run by a single entity or a limited set of participants.[258] Because of that modest scale, the vast majority of the world's groundwater recharge occurs outside of MAR projects, and most groundwater users cannot take advantage of a MAR project.[259] Consequently, while the law of MAR projects is complicated and likely to be increasingly important, a study of groundwater-recharge law that focuses solely on MAR projects would miss much of the action.

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[253] *See, e.g.*, Nature Conservancy, Case Study: Ventura County; Removing Arundo donax to Improve Groundwater Supply and Enhance Habitat (2019), https://perma.cc/9N37-7ELR (describing an invasive-species-removal program).

[254] *E.g.*, *Groundwater Management*, ORANGE CNTY. WATER DIST., https://perma.cc/HG48-QPEA (archived Mar. 12, 2021).

[255] *See* MICHAEL KIPARSKY ET AL., RECHARGE NET METERING TO ENHANCE GROUNDWATER SUSTAINABILITY 2 (2018), https://perma.cc/GPA8-9CW6.

[256] *See, e.g.*, Res. Conservation Dist. of Santa Cruz Cnty. et al., Recharge Net Metering (ReNeM) in the Pajaro Valley 2 (2017), https://perma.cc/R47H-8ZQQ (noting the program's goal to "generate ~1000 ac-ft/yr in total of infiltration benefit"); Miller et al., *supra* note 246, at 1 (describing a small project in New Mexico). Water managers often estimate that an acre-foot of water can supply up to two households for one year. *See Acre Foot*, WATER EDUC. FOUND., https://perma.cc/DH9D-RJ8K (archived Mar. 12, 2021). Using that estimate, 2,000 acre-feet would only be enough to supply a small town.

[257] *E.g.*, *Groundwater Banking*, *supra* note 247 (stating that the Semitropic Groundwater Storage Bank "[c]an store a total of 1.65 million acre feet—enough water to meet the yearly needs of approximately 3.3 million households").

[258] *See, e.g.*, *Aquifer Storage & Recovery*, *supra* note 243 (describing a project managed by a single water district); *What Is SWIFT?*, *supra* note 244 (same).

[259] One comparison illustrates this disparity. The Kern Water Bank, which is one of California's few large-scale MAR projects, received approximately 2.5 million acre-feet of water for recharge between 1995 and 2017, for an annual average of just under 109,000 acre-feet. *See* Kiparsky et al., *supra* note 247, at 4. That is a large amount of water, but in the Tulare Lake Basin—the California region in which the Kern Water Bank is located—average groundwater use is approximately 6.185 million acre-feet per year, according to California Department of Water Resources statistics. *See California's Groundwater*, MAVEN'S NOTEBOOK, at fig.2-8 (updated Apr. 1, 2020), https://perma.cc/WF9B-BNTP (to view statistics, click "California's groundwater use by the numbers").

III. The Future of Groundwater-Recharge Law

A key point of this Article so far has been that law is largely indifferent to groundwater recharge. This Part turns from describing that state of affairs to asking whether the status quo is appropriate and how things might be different. Those inquiries break down into three sub-questions. First, what circumstances would justify a more robust and intentional legal regime for groundwater recharge? Second, what ethic should underpin groundwater-recharge regimes? And third, what legal instruments might more robust systems of groundwater-recharge law use? The answers to each question will be contextual; the heterogeneity of groundwater hydrology and its human influences means that one-size-fits-all regimes have little promise in this realm. Nevertheless, the discussion that follows provides a framework for the development of more site-specific regimes and, more generally, for more functional groundwater-recharge law.

A. The Circumstances for Groundwater-Recharge Law

Any effort at developing groundwater-recharge law should begin with a threshold question: Is such law worth having at all? Or, to put it somewhat more precisely: Is there need for a set of laws targeted at groundwater recharge, or is the currently prevalent system, in which groundwater-recharge law exists primarily as an incidental consequence of other legal goals, adequate to the task at hand?

Similar questions often arise with natural resources,[260] and they are not new to the field of groundwater law, but they have arisen more often for groundwater pumping than for recharge.[261] In 1861, for example, the Ohio Supreme Court explained why it was rejecting any common law limitations on groundwater extraction:

> Because the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed . . . an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible.[262]

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[260] *See, e.g.*, Jianlin Chen, *Optimal Property Rights for Emerging Natural Resources: A Case Study on Owning Atmospheric Moisture*, 50 U. MICH. J.L. REFORM 47 (2016); Alan J. Alexander, Note, *The Texas Wind Estate: Wind as a Natural Resource and a Severable Property Interest*, 44 U. MICH. J.L. REFORM 429 (2011); Sara C. Bronin, *Solar Rights*, 89 B.U. L. REV. 1217 (2009).

[261] For a case exemplifying this absence of regulation, see *Maddocks v. Giles*, 728 A.2d 150, 152-54 (Me. 1999) (declining to abandon the absolute-dominion rule, which allows unregulated and unlimited groundwater pumping).

[262] Frazier v. Brown, 12 Ohio St. 294, 311 (1861), *overruled by* Cline v. Am. Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984).

Much of the law of groundwater extraction derives from scientists' and then lawmakers' increasing rejection of these beliefs.[263] But for groundwater recharge, with all its complexities and uncertainties, the challenges of administration can still be substantial.

A classic theoretical framework for answering the questions posed above comes from the work of economist Harold Demsetz.[264] He posited that property-rights regimes emerge when the costs of an open-access regime begin to exceed the costs of dividing the resource between holders of defined rights.[265] So, for example, when scarcity makes a previously abundant resource more valuable, resource users may decide that the process of defining rights in the resource is worth the associated transaction costs.[266] Subsequent theorists have critiqued, expanded upon, and refined this theory.[267] Some expanders have pointed out that the theory might explain the emergence of a variety of governance regimes, not just systems of property rights.[268] Meanwhile, critics have pointed out that the theory may do better as a normative account explaining when governance regimes ought to emerge than as a descriptive account explaining when they actually will.[269] Politics, they argue, can play more of a causal role than aggregate economic utility.[270] But as a commonsense metric for judging when groundwater-recharge governance would be helpful, Demsetz's focus on transaction costs and externalities still works reasonably

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[263] *See* Owen, *supra* note 7, at 266-71, 268 n.102, 269 nn.111-12 (describing groundwater-pumping laws' uneven evolution toward heightened regulation); Marion Rice Kirkwood, *Appropriation of Percolating Water*, 1 STAN. L. REV. 1, 11 (1948) (describing the emergence of statutory regimes for the management of groundwater pumping).

[264] Harold Demsetz, *Toward a Theory of Property Rights*, AM. ECON. REV., May 1967, at 347; *see also* Thomas W. Merrill, *Introduction: The Demsetz Thesis and the Evolution of Property Rights*, 31 J. LEGAL STUD. S331, S331 (2002).

[265] *See* Demsetz, *supra* note 264, at 350 ("[P]roperty rights develop to internalize externalities when the gains of internalization become larger than the cost of internalization.").

[266] *See id.* at 351-53 (discussing the emergence of property rights in furs).

[267] *See generally* Merrill, *supra* note 264, at S333-35 (describing some of that literature).

[268] *See* Henry E. Smith, *Exclusion Versus Governance: Two Strategies for Delineating Property Rights*, 31 J. LEGAL STUD. S453, S464 (2002).

[269] *See, e.g.*, Saul Levmore, *Two Stories About the Evolution of Property Rights*, 31 J. LEGAL STUD. S421, S429 (2002) (arguing that interest-group politics also provides a plausible origin story for property rights); *see also* James E. Krier, Essay, *Evolutionary Theory and the Origin of Property Rights*, 95 CORNELL L. REV. 139, 143 (2009) ("Even if *Toward a Theory of Property Rights* has little if any theory about the evolution of property rights, it can be used to illuminate the subject.").

[270] *See* Stuart Banner, *Transitions Between Property Regimes*, 31 J. LEGAL STUD. S359, S360-61, S370-71 (2002) (noting that societies may just "reallocate property rights when some exogenous political realignment enables a powerful group to grab a larger share of the pie" and providing theories about how this might happen).

well. The key question, then, is whether the benefits of creating that regime will outweigh the associated burdens.

Sometimes the answer to this question will be no. There are places—rural Maine, for example—where groundwater is so abundant that there is no need for the government to regulate the quantity of recharge.[271] Conversely, in some deserts, groundwater scarcity is a problem, but there is essentially no recharge to manage.[272]

Even where scarcity is present, the costs of legal intervention will still sometimes outweigh the benefits. There are two primary reasons why. First, any effective groundwater-recharge regime is likely to require information about the amounts and locations of groundwater recharge, and that information may be difficult to obtain.[273] Regulators might compensate for that difficulty by using workable generalizations—perhaps grounded in simulation models—rather than site-specific data.[274] But reaching even those workable generalizations takes effort, and individual landowners are likely to object whenever the generalizations arguably do not apply.[275] Second, even where scarcity exists and there is enough information to support a legal regime, lawmakers might reasonably worry about the negative externalities associated with regulation. If, for example, laws designed to enhance groundwater recharge would encourage otherwise problematic practices, like

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[271] *See, e.g.*, Maddocks v. Giles, 728 A.2d 150, 152, 154 (Me. 1999) (noting an absence of evidence that the "absolute dominion rule," which rejects any property-rights limitation on groundwater pumping, has been flawed in Maine).

[272] *See, e.g.*, *Mojave Groundwater Resources*, U.S. GEOLOGICAL SURV., https://perma.cc/9YDA-MGVD (archived Mar. 12, 2021) ("Recharge to the groundwater system from direct infiltration of precipitation is minimal.").

[273] *See* LAUREN EVERETT, NAT'L ACADS. OF SCIS., ENG'G & MED., GROUNDWATER RECHARGE AND FLOW: APPROACHES AND CHALLENGES FOR MONITORING AND MODELING USING REMOTELY SENSED DATA 1-2 (2019), https://perma.cc/LGG7-85F6 (describing the importance and complexities of groundwater data).

[274] *See generally* Ajay Singh, *Groundwater Resources Management Through the Applications of Simulation Modeling: A Review*, SCI. TOTAL ENV'T, Nov. 15, 2014, at 415 (describing the evolution and types of groundwater models). On the advantages and disadvantages of regulating through proxy measures and simulation models, see generally Robert L. Glicksman, *Bridging Data Gaps Through Modeling and Evaluation of Surrogates: Use of the Best Available Science to Protect Biological Diversity Under the National Forest Management Act*, 83 IND. L.J. 465 (2008); and James D. Fine & Dave Owen, *Technocracy and Democracy: Conflicts Between Models and Participation in Environmental Law and Planning*, 56 HASTINGS L.J. 901 (2005) (describing challenges with air-quality modeling).

[275] I have heard modelers lament this tendency to focus on "my favorite pixel"; they worry that people are holding models to a false standard of perfection. But one can understand why people might judge a model based on its specific application to places they know—or own.

increasing surface-water diversions or accelerating harvests of forests, a laissez-faire regime may be the better choice.[276]

Nevertheless, there are likely to be many places where the informational challenges of developing a legal regime are worth confronting. Southern California provides a classic example. The region's water-supply challenges are famous, but heavy storms do hit southern California, particularly in its mountainous areas, and those storms create surges of surface flow that recharge the region's large aquifers.[277] The extent to which that recharge happens will depend upon vegetation management in the mountains and on urban development; it is sensitive to human intervention.[278] In such a place, the scarcity that favors legal governance of recharge clearly does exist.

Additionally, the data challenges that might undermine regulatory interventions are diminishing,[279] or at least could diminish if political will is present. Groundwater monitoring and modeling are evolving sciences, and remote-sensing technologies now allow levels of precision and accuracy that were unthinkable a generation or two ago.[280] Additionally, many groundwater-data gaps reflect political choices rather than scientific challenges. The frequent unavailability of pumping data is one obvious example.[281] One challenge for a groundwater-recharge regime would likely be the absence of such data; it is hard to determine the effectiveness of recharge

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[276] *See supra* note 94 and accompanying text (noting that permanently removing forests might be effective for enhancing groundwater recharge and problematic for many other reasons). Prohibitions on this sort of action could be included in the legal regime, of course, and they might be effective. But they also could make the legal regime more complicated, which might diminish its value.

[277] *See, e.g., Mojave Groundwater Resources, supra* note 272 (noting that aquifers in the Mojave Desert receive recharge from ephemeral surface-water flows out of the surrounding mountains); GREGORY C. LINES, U.S. GEOLOGICAL SURV., WATER-RESOURCES INVESTIGATIONS REP. NO. 95-4189, GROUND-WATER AND SURFACE-WATER RELATIONS ALONG THE MOJAVE RIVER, SOUTHERN CALIFORNIA 41 (1996), https://perma.cc/7QXK-PBNT ("The flood-plain aquifer receives virtually all of its recharge from the river, and most of the water originates in the headwaters."); *see also* Jobbágy et al., *supra* note 44, at 679 ("More-distant sources of recharge are particularly significant in arid regions located downstream of water-yielding mountains."); Scanlon et al., *supra* note 38, at 3345-46 (finding that recharge in the American Southwest often occurs in mountains or at mountain fronts).

[278] *See* Kinoshita & Hogue, *supra* note 71, at 5-6 (finding a relationship between fires and water flows); NAT. RES. DEF. COUNCIL & PAC. INST., NO. 14-05-G, STORMWATER CAPTURE POTENTIAL IN URBAN AND SUBURBAN CALIFORNIA 6 (2014), https://perma.cc/Q5AY-S9XF.

[279] *See* EVERETT, *supra* note 273, at 3-6 (describing older and emerging technologies).

[280] *See generally id.* (describing the capabilities but also the limitations of emerging technologies).

[281] *See* François Molle et al., *The Local and National Politics of Groundwater Overexploitation*, 11 WATER ALTERNATIVES 445, 450 (2018) (providing examples of United States regions and other countries where groundwater pumping is poorly managed and monitored).

practices without knowing how much water is stored within an aquifer and how much is coming out. And those data are often missing not because of some technological limitation—well meters have existed for a long time—but because many groundwater users prefer to have their pumping remain unmonitored and because lawmakers have acquiesced to that preference.[282]

Similarly, while externalities or offsetting effects might make regulatory intervention inappropriate in some places, there are other places where regulation ought to create win-win scenarios. For one example, consider a coastal urban area where groundwater is an important water-supply source, interrupted recharge is contributing to declining water tables (and surface-water flooding), and those declining water levels are causing land subsidence, seawater intrusion, and the potential loss of the area's water supply. In such a place, groundwater-recharge regulation could be crucial to the city's survival. Worldwide, millions of people live in places, like Houston or Jakarta, that fit that description.[283]

Cape Town, South Africa, exemplifies another type of circumstance in which groundwater-recharge law could be crucially important. In 2018, the city nearly ran out of water.[284] The crisis arose partly because non-native vegetation had increased transpiration levels and decreased recharge throughout much of the watershed that supplies the city.[285] In such a location, developing a legal structure for recharge management is exceedingly important. And Cape Town is not the only place where legal interventions targeted at vegetation management could be valuable. In the western United States, recharge-promoting policies also might mesh well with reformed fire-management strategies, leaving many areas with more water, healthier ecosystems, and less risk of catastrophic fire.[286]

These examples illustrate a broader point. In a world where groundwater is crucially important and frequently over-tapped, and where populations are

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[282] *See* EVERETT, *supra* note 273, at 3 ("In many cases, political restrictions exacerbate [data gaps]; wells may be monitored, but the data are not made available.").

[283] *See* Amanda Ruggeri, *The Ambitious Plan to Stop the Ground from Sinking*, BBC: FUTURE (Dec. 1, 2017), https://perma.cc/ZQ7V-GQGX (describing subsidence problems around the world—and the use of recharge programs as a partial response). For a general description of the challenges of coastal-aquifer management, see generally Holly A. Michael et al., *Science, Society, and the Coastal Groundwater Squeeze*, 53 WATER RES. RSCH. 2610 (2017).

[284] *See* NATURE CONSERVANCY & WATER FUNDS FOR AFR., *supra* note 69, at 11 (noting that Cape Town narrowly escaped "Day Zero," when taps stop running).

[285] *See id.* at 20-21, 28 (estimating water-yield losses caused by invasive species at 55 billion liters per year).

[286] *See generally* Boisramé et al., *supra* note 214 (describing the advantages of a more natural fire regime).

growing and the climate is changing, there will be places where people cannot afford *not* to have groundwater-recharge law.

B. A Groundwater-Recharge Ethic

In *Frazier v. Brown*,[287] the decision that accorded groundwater movements "occult" status, the Ohio Supreme Court did not rest its rule of nonregulation solely on scientific uncertainty. Instead, and somewhat less colorfully, it also warned that groundwater-use regulation would inappropriately interfere with economic development.[288] That claim underscores the importance of a second key question for groundwater-recharge law: What sort of ethic should underpin such laws? The question in turn incorporates two somewhat overlapping questions. First, what sort of ethical relationship between different groups of people should be embodied in groundwater-recharge law? Second, what sort of environmental ethic should that law contain?

Answers to these questions already are embedded, largely implicitly, in the laws—and legal gaps—that touch on groundwater recharge. Like the Ohio Supreme Court's opinion in *Frazier*, those answers generally reflect a laissez-faire ethic favoring landowners' discretion rather than the protection of water rights and natural systems. The implicit ethic embedded in the common-enemy rule, for example, favors governmental nonintervention—not just from regulatory agencies but also from courts—in the actions of landowners.[289] By denying downhill or downstream landowners any claim against their neighbors' surface-water management, the common-enemy rule effectively says that upstream landowners can do as they will and downstream landowners (and water-right holders) will respond as they must.[290] That same ethic is implicit in most existing groundwater-recharge laws' treatment of the natural environment. By establishing almost no requirements for maintaining or enhancing recharge that provides environmental benefits—and by providing no rewards for landowners who do create such benefits—groundwater-recharge law suggests that a landowner's autonomy to manage his or her own land counts more than affected natural systems or maintenance of the collective benefits of shared aquifers.[291]

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[287] 12 Ohio St. 294 (1861), *overruled by* Cline v. Am. Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984).

[288] *Id.* at 311.

[289] *See supra* notes 109-18 and accompanying text.

[290] *See, e.g.*, Morrison v. Bucksport & Bangor R.R. Co., 67 Me. 353, 355-56 (1877) ("[A]ny proprietor of land may control the flow of mere surface water over his own premises, according to his own wants and interests, without obligation to any proprietor either above or below. . . . If all this were not so, men could not reconstruct and utilize their landed estates without infinite trouble and suits.").

[291] *See supra* Parts II.B-.C.1 (discussing how groundwater-recharge benefits are essentially irrelevant to laws governing forests and floodplains).

Interestingly, groundwater-recharge law largely maintains that ethic even when it operates to the detriment of other property-rights holders. A water-right holder generally has no claim against a landowner who changes cropping patterns in ways that limit recharge, for example, or who eliminates leakage upon which the rightsholder had come to rely.[292]

Other ethical frameworks are possible. As a modest adjustment, groundwater-recharge law could favor different types of property owners; it might prioritize the interests of landowners who are impacted by changed runoff patterns rather than those who create the impacts. Or, alternatively, groundwater-recharge law might prioritize previously established water-use rights over landowners' discretion to manage land surfaces.[293] Both of these changes would reflect an underlying preference for maintaining some form of the status quo, or for protecting earlier-established rights, rather than for promoting landowners' discretion to change their land uses as they see fit.

Groundwater-recharge law also could favor more of a communitarian or environmentalist ethic. Rather than simply trying to favor one class of private property owners, or to minimize governmental involvement, groundwater-recharge law could treat maintenance of shared aquifers—and the surface waterways that aquifers support—as a collective responsibility.[294] Some areas of groundwater-recharge law do reflect such an ethic. Stormwater-management fees, for example, reflect an implicit judgment that stormwater-management is a collective good, the protection of which leads to individualized obligations.[295] But within the limited and inchoate field of groundwater-recharge law, that is a relatively rare approach.

More widespread adoption of a communitarian environmental ethic would make sense. On utilitarian grounds, it holds clear value—at least in situations where groundwater is scarce and regulators could track recharge effectively enough to administer a legal regime. Laissez-faire regimes for groundwater recharge allow all kinds of externalities, some positive but many negative, and provide no mechanism for compelling internalization of those costs. The likely result is a series of decisions that make sense for individual landowners but not

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[292] *See* Montana v. Wyoming, 563 U.S. 368, 380-81 (2011) (explaining the rule of recapture).

[293] Many western states have already made this shift for groundwater and surface-water rights. Where groundwater users once could pump without worrying about impacts on surface water, both types of rights are now part of the same regulatory system, with groundwater rights often subordinated because of their later origin. *See, e.g.*, Blomquist et al., *supra* note 248, at 674 (describing Colorado's system).

[294] *See* Eric T. Freyfogle, Essay, *Water Rights and the Common Wealth*, 26 ENV'T L. 27, 36-38 (1996) (arguing that water ethics should recognize and embrace humans' roles in natural and human communities).

[295] For a general description of stormwater utilities, see Brisman, *supra* note 125.

for collective welfare.[296] An individual landowner, for example, might benefit if levees isolate his land from a river's floodplain and thus limit recharge on that land, but that kind of decision may deprive the river of important dry-season flows while also increasing flood risk, and the landowner has no reason to worry about those costs.[297] They literally can just be shifted downstream. Likewise, individual decisions to develop land without regard to stormwater recharge may make sense for the developers, but the collective consequences may be urban flooding, the loss of important groundwater supplies, and the need for expensive stormwater-management infrastructure.[298]

Nonutilitarian ethical theories lead—mostly—in similar directions. Any ethic that values sustainability or functioning environmental systems carries the corollary necessity of recognizing individual responsibility to maintain and contribute to recharge. If, to quote the famous naturalist Aldo Leopold, "[a] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community," then preserving groundwater recharge, and thus the streams and wetlands it sustains, is often the right thing to do.[299] Similarly, if ensuring fairness and combatting social subordination is a key goal, then regulating recharge-limiting activities—which often will be carried out by developers, government agencies, major landowners, or other powerful actors, and will often operate to the detriment of widely needed water supplies—again will often make sense. Even if one leaves redistribution and environmental values to the side, adopts a purely anthropocentric ethic, and argues that the primary goal of a legal regime should be to protect property rights, the current nonregulatory approach holds little justification. Practices that affect groundwater recharge routinely affect, often adversely, other people's rights in water and land, and nonregulation amounts to valuing one set of property rights over other sets of property rights, often without any justification other than inertia. Only if governmental nonintervention is at the core of the ethical theory, rather than serving as a means to accomplish some other goal, does treating groundwater recharge as a subject unfit for legal governance make any sense.

Nevertheless, even if it makes sense to acknowledge collective responsibility for groundwater-recharge protection, that raises a secondary question. How far should individual landowners' obligations to provide collective benefits go? If a landowner is to be penalized for inhibiting recharge

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[296] *See* Richard A. Epstein, *Holdouts, Externalities, and the Single Owner: One More Salute to Ronald Coase*, 36 J.L. & ECON. 553, 558-59 (1993) (explaining this classic account of how externalities lead to suboptimal decisionmaking).

[297] *See supra* notes 170-80 and accompanying text (describing how levees limit groundwater recharge).

[298] *See supra* notes 60-65 and accompanying text.

[299] ALDO LEOPOLD, *The Land Ethic*, *in* A SAND COUNTY ALMANAC, WITH OTHER ESSAYS ON CONSERVATION FROM *ROUND RIVER* 237, 240 (2d prtg. 1969).

or rewarded for creating it, whoever is calculating the penalty or benefit must ask, "compared to what?"[300] In other words, the law must select some level of recharge (or permissible range of levels) that would be appropriate for that parcel and then must compare the actual level of recharge to that baseline level. Selecting those baselines can be tricky. Setting a baseline requires navigating thorny questions about ethics and feasibility as well as developing precise measures, neither of which is easy.[301] Imagine, for example, a land-use change that increases recharge on property that has been used for timber production for decades, and imagine also that the level of recharge on that property has been less under timber production than it would have been under natural conditions. Is the landowner entitled to claim a benefit because she has increased recharge relative to preexisting conditions, or should she pay a penalty because she has reduced recharge relative to natural conditions? There are potential fairness and efficiency arguments in favor of either course, and the answer isn't obvious. Yet for a recharge regime to be functional, a baseline is indispensable.

I would not suggest any universal answer to this question. Indeed, similar questions recur throughout environmental and natural-resource law—they come up, for example, any time lawmakers erect a cap-and-trade regime for greenhouse gases or other pollutants—and legal systems' answers are all over the map.[302] Nevertheless, several factors might inform a legal regime's approach to selecting baselines. First, lawmakers ought to consider the social utility of the activity causing the recharge impact. If that activity is otherwise highly valuable, then some relaxing of recharge obligations might be appropriate.[303] Second, historic practices and reliance interests ought to matter;[304] lawmakers might reasonably impose different recharge obligations on a proposed new activity in a floodplain than on a community that has occupied that floodplain for decades. Third, and perhaps most importantly,

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[300] For a general discussion of the challenge of setting analytical baselines, see J.B. Ruhl & James Salzman, *Gaming the Past: The Theory and Practice of Historic Baselines in the Administrative State*, 64 VAND. L. REV. 1 (2011).

[301] *See id.* at 13-15 (discussing the challenges of choosing between "ancient" and "recent" baselines).

[302] *See* Dave Owen, *Auctions, Taxes, and Air*, 65 UCLA L. REV. DISC. 64, 70-71 (2017). *See generally* Bruce R. Huber, *Transition Policy in Environmental Law*, 35 HARV. ENV'T L. REV. 91 (2011) (exploring multiple approaches to the challenge of allocating the burdens of new regulatory instruments).

[303] An example might be recharge impacts resulting from the restoration of degraded forest landscapes. *See* Elliott et al., *supra* note 191, at 987, 991-92 (describing the increasing water demand of a regenerating forest).

[304] *See, e.g.*, Ann M. Eisenberg, *Just Transitions*, 92 S. CAL. L. REV. 273, 275-85 (2019) (describing the argument for assistance, in the context of decarbonization, to people who have depended on the old legal regime).

ethics often must give way to politics.[305] If the only way to get a groundwater-recharge regime in place is to minimize burdens upon existing landowners, that may be preferable to having no regime at all.[306] But fourth, and finally, the presently prevalent approach, in which landowners can be asked to depart from present conditions only if someone pays, has thin ethical justifications. Those present conditions were not divinely ordained; instead, they often reflect human-constructed legal regimes that allowed some property owners to exploit collectively shared resources to the detriment of the rest of the public. Continuing those practices need not and should not be a given.

C. The Instruments of Groundwater-Recharge Law

Even where groundwater-recharge law seems possible and normatively justified, a third key question remains: How should it be done? Other existing laws provide a wide variety of potential models,[307] and this Subpart explores which techniques would make sense. Again, it offers no single recommendation; instrument choice instead should depend on the nature of the goals of regulatory interventions, the nature of the practices being regulated, and the actors involved. Nevertheless, this section does offer an argument for the selective use of financial-incentive systems—like stormwater utilities—that use impact fees to encourage more effective recharge management.[308]

For groundwater-recharge law, the range of potential instruments is large. Changes to property and tort doctrines might be one place to start; one could eliminate the common-enemy rule or limit the ability of landowners to change land-use practices and recover previously recharged water, and then leave implementation to private litigation before judges. Many environmental law regimes rely on evaluation and disclosure requirements, and such requirements might lead to modest improvements in groundwater-recharge management.[309] The Forest Service, for example, might establish more explicit and demanding requirements for factoring groundwater recharge into forest-management

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[305] *See, e.g.*, Ruhl & Salzman, *supra* note 300, at 2-4 (noting the political origins of "no net loss" policies for wetlands).

[306] The political challenges of achieving groundwater-pumping regulation, even in places where it appears to be badly needed, counsel that these difficulties may be large. *See, e.g.*, Leahy, *supra* note 22, at 39 (describing the long and difficult process of moving toward statewide groundwater-use regulation in California).

[307] For an accessible summary and classification of regulatory instruments, see James Salzman, Teaching Supplement, *Teaching Policy Instrument Choice in Environmental Law: The Five P's*, 23 DUKE ENV'T L. & POL'Y F. 363, 363-64 (2013).

[308] *See generally* Brisman, *supra* note 125 (describing stormwater utilities).

[309] *See, e.g.*, 42 U.S.C. § 4332(C) (requiring environmental-impact statements for "major Federal actions significantly affecting the quality of the human environment").

planning and environmental-impact studies.[310] Environmental and natural-resource laws also often establish best-management-practice requirements or restrict problematic activities, and such prescriptive regulation also can (and sometimes does) play a part in groundwater-recharge management.[311] So, for example, state and local land-use regulators might require developers to build projects that will recharge most stormwater on-site[312] or might restrict particularly recharge-limiting agricultural practices.[313]

Each of these traditional approaches is likely to make sense in some circumstances, and sometimes in combination. Information requirements, for example, might be an effective mechanism for gently and gradually pushing federal land managers to take recharge management into account.[314] Likewise, best-management-practice requirements often make sense if regulators generally understand that a practice—perhaps using pervious pavement for new construction, for example—is effective at enhancing recharge, but those regulators lack the resources to establish and then monitor compliance with site-specific performance standards.[315] But one particular regulatory instrument holds special promise in this realm. That mechanism uses impact fees to deter negative impacts on recharge and to create an aggregated pool of funding, which then can support collective efforts at further recharge protection or management.

This basic model already exists in the realm of groundwater-recharge management (and in some other areas of environmental regulation, for it is a close cousin to Pigovian taxation[316]), and municipal stormwater utilities are

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[310] *See* Martin Nie & Michael Fiebig, *Managing the National Forests Through Place-Based Legislation*, 37 ECOLOGY L.Q. 1, 5, 11-13 (2010) (explaining the planning framework of national forest-management laws, as well as the flexibility that this framework allows).

[311] *E.g.*, 33 U.S.C. § 1329(b)(2)(A) (requiring the development of best management practices for managing nonpoint-source pollution). *See generally* Eric Biber & J.B. Ruhl, *The Permit Power Revisited: The Theory and Practice of Regulatory Permits in the Administrative State*, 64 DUKE L.J. 133 (2014) (describing a wide variety of permit programs).

[312] *See supra* note 124 and accompanying text.

[313] *See* Vira et al., *supra* note 222, at 121, 135 (describing South Africa's permitting requirements for tree plantations).

[314] In theory, this could happen under existing law, and perhaps some environmental studies do address recharge in thoughtful and useful ways. But I could not find any cases in which the U.S. Forest Service's consideration of recharge impacts was a litigated issue.

[315] For evaluation and discussion of a range of best-management practices for urban stormwater, see generally U.S. EPA, EPA-821-R-99-012, PRELIMINARY DATA SUMMARY OF URBAN STORM WATER BEST MANAGEMENT PRACTICES (1999), https://perma.cc/B8MV-ZJEX.

[316] *See* Scharff, *supra* note 126, at 195-209 (providing a definition of Pigovian tax and comparing Pigovian taxes and Pigovian fees).

the clearest example of this approach.[317] A typical stormwater utility collects fees from landowners in its service area.[318] The amount of the fee depends on the amount of impervious cover on the landowner's property, with potential fee offsets if the landowner installs stormwater-infiltrating features that counteract the impacts of that impervious cover.[319] The funds produced by the fees support maintenance of existing stormwater infrastructure, but they can also support projects that reduce runoff and enhance recharge, and municipal stormwater managers can select the projects that they think will produce the highest-value return at the lowest cost.[320]

This regulatory model has several key advantages. First, it addresses the common regulatory challenge of dealing with collectively significant problems that arise from actions that seem individually insignificant.[321] Those problems are often quite difficult to address, partly because individual actors do not understand the connections between their small actions and the larger problem that results and also because regulating the behavior of many small actors can create major coordination challenges.[322] The stormwater-utility model navigates those challenges by asking each actor to make a contribution—often a fairly modest one—to a collective and coordinated response.[323] Second, this model offers fairness. It requires everyone who contributes to a water-management challenge to contribute to the response, but it tailors the degree of obligation to each individual landowner's degree of contribution.[324] Third, this regulatory model preserves flexibility. A facility that really needs its impervious surfaces still can have them; it just has to pay larger impact fees.

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[317] *See id.* at 205-06. *See generally* Brisman, *supra* note 125 (providing a general discussion of stormwater utilities).

[318] *See, e.g., Stormwater Service Charge*, PORTLAND, ME, https://perma.cc/4P2R-GPND (archived Mar. 12, 2021).

[319] *See Stormwater Billing*, PORTLAND, ME, https://perma.cc/7QBE-EQYG (archived Mar. 12, 2021) (explaining how bills are calculated); *Stormwater Credits*, PORTLAND, ME, https://perma.cc/JS8V-UUZF (archived Mar. 12, 2021); Brisman, *supra* note 125, at 524-27 (describing several cities' credit programs).

[320] *See* Owen et al., *supra* note 130, at 29 & n.9.

[321] *See* Kevin M. Stack & Michael P. Vandenbergh, *The One Percent Problem*, 111 COLUM. L. REV. 1385, 1386-89 (2011) (describing the prevalence of large problems arising from accumulations of small actions); Owen, *supra* note 35, at 143-44 (describing the importance of these problems to environmental law).

[322] *See* Stack & Vandenbergh, *supra* note 321, at 1393-402; Odum, *supra* note 89, at 729 (describing the need for, and pressures against, "holistic" thinking).

[323] *See* Brisman, *supra* note 125, at 517 (describing rate structures).

[324] *See For Residents*, PORTLAND, ME, https://perma.cc/F9HV-9X2T (archived Mar. 12, 2021) (arguing that a stormwater charge is a more equitable way of allocating the financial burdens of stormwater management); Brisman, *supra* note 125, at 516-17.

A key question, then, is whether and how this type of model might be deployed to address other recharge-management challenges. Floodplains provide one potential opportunity. If landowners in levee-protected floodplain areas were charged groundwater-recharge impact fees, the fees might create an additional deterrent to floodplain construction, and authorities might then use those fees for selective buyouts of flood-prone areas, perhaps allowing them to become recharge zones again. Similarly, in areas where new timber-management or cropping patterns will diminish recharge, regulators might again impose impact fees, which they might use to support recharge-enhancing practices elsewhere in the watershed. The model also can use payments rather than fees.[325] Suppose, for example, that a city's water supply depends on forested lands traditionally managed for timber harvesting and recreation. That city could develop a groundwater-recharge fund, which would pay landowners for prescribed burning, invasive-species removal, or other recharge-promoting activities, with the understanding that the city will then hold rights to the resulting enhanced flows.[326]

These types of fee- or payment-based models will not make sense in all circumstances. Like any effort to commodify the value of land-use changes, they will require reasonably accurate accounting methods, lest users wind up paying for or receiving credit for recharge that the land-use changes never actually produce.[327] That reasonably accurate information isn't always available.[328] Fee- or payment-based models also do not avoid difficult questions about ethics and fairness. Deciding who should pay or be paid, and how much, requires thinking through difficult questions about the extent to which people are entitled to alter land even when those alterations adversely affect the interests of others.[329] Our systems of property and regulatory law generally reject both "as much as you want" and "not at all" as answers to that question,

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[325] *See* Carolyn Kousky & Sarah E. Light, *Insuring Nature,* 69 DUKE L.J. 323, 347-50 (2019) (describing "[p]ayments for ecosystem services").

[326] *See generally* LATIN AM. WATER FUNDS P'SHIP, WATER FUNDS: CONSERVING GREEN INFRASTRUCTURE; A GUIDE FOR DESIGN, CREATION AND OPERATION (2012), https://perma.cc/G5J2-MCKP (describing water funds, which use a similar model).

[327] The literature on compensatory mitigation often identifies this problem. *See* Martin W. Doyle & F. Douglas Shields, *Compensatory Mitigation for Streams Under the Clean Water Act: Reassessing Science and Redirecting Policy,* 48 J. AM. WATER RES. ASS'N 494, 495-96 (2012) (finding that stream-mitigation projects routinely failed to deliver promised environmental benefits); Margaret A. Palmer & Kelly L. Hondula, *Restoration as Mitigation: Analysis of Stream Mitigation for Coal Mining Impacts in Southern Appalachia,* 48 ENV'T SCI. & TECH. 10552, 10558 (2014) (same).

[328] *See generally* Eric Biber, *The Problem of Environmental Monitoring,* 83 U. COLO. L. REV. 1, 20-22 (2011) (describing pervasive data gaps in environmental-monitoring programs).

[329] *See* John D. Echeverria, *Regulating Versus Paying Land Owners to Protect the Environment,* 26 J. LAND RES. & ENV'T L. 1, 31-33 (2005).

but there are many possible points on the spectrum in between[330]—and, as the previous Subpart discussed, many plausible ways of setting the baseline.[331] Finally, just because fees make sense in both economic and fairness terms does not always make them politically palatable. People often don't understand what the fee is paying for, and even when they do, opposition to fee-based regulatory systems can be intense.[332]

Nevertheless, the fact that fee-based models will be impractical in some places and unpalatable in others should not detract attention from their possibilities. No regulatory model is perfect, and most regulation—even badly needed regulation—can be unpopular. In places where improved groundwater recharge requires some legal intervention, they offer a particularly promising approach.

Conclusion

Climate is always variable, but recent years have brought particularly dramatic fluctuations—and also harbingers of the future—to the United States. Droughts have battered much of the American West, but interspersed between those drought years have been some of the wettest winters on record. Groundwater storage is crucially important for mitigating the effects of these extremes. But much of the West, and indeed much of the world, has given little attention to the laws that affect water's pathways into aquifers. And many of the legal regimes that incidentally impact groundwater recharge are counterproductive.

This Article has argued for more intentional laws governing groundwater recharge. Those laws will not be needed everywhere, nor will they be easy to design or implement. Challenges of information, coordination, ethics, and instrument design will be significant, and the politics of any new body of regulatory law can be difficult. But similar challenges arise, and have been at least partially surmounted, in many other fields of environmental and natural-resource law. The severity of our coming water-management challenges will require similar efforts for groundwater recharge.

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[330] *See, e.g.*, Lucas v. S.C. Coastal Council, 505 U.S. 1003, 1016 & n.7 (1992) (stating that land-use regulations that deprive owners of all economically viable use of property are takings); Pa. Coal Co. v. Mahon, 260 U.S. 393, 413 (1922) (noting the government's power to restrict some property uses).

[331] *See supra* notes 300-06 and accompanying text.

[332] *See* Owen, *supra* note 105, at 1609 (noting political opposition to stormwater fees in Maryland).