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Scientific, Legal, and Ethical Foundations for Texas Water Law

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CHAPTER 1

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I. Introduction to Water Law

Water law is the field of law concerned with the ownership, allocation, and use of water resources, both surface and subsurface. Although most closely related to property law, recent developments in other legal fields, especially in environmental law, have heavily influenced the interpretation, application, and development of water law. As a result, water law today encompasses a broad perspective and often takes into account individual and community rights, environmental issues, commerce and economics, and other societal and legal concerns.

Significantly, modern water law is an interdisciplinary practice. In light of the continuously expanding body of knowledge of the hydrologic cycle, groundwater flow, wetlands, and fresh water resources in general, the field has expanded to include scientific considerations related to the management, use, and allocation of fresh water resources. It is now no longer enough merely to be versed in water law. Rather, a water lawyer today must understand technical concepts such as hydrostatic pressure and Darcy's law, flow regimes, drainage basins, ecosystems needs, consumptive uses, and crop yields.

Ultimately, though, water law advances societal values and goals related to fresh water resources. It is a means for bridging the gap between the demand for water and the availability of the resource. And therein lays the challenge—learning to practice water law to better society as well as to ensure the client's interests.

Section I of this chapter provides an overview of the scientific, legal, and ethical foundations that are pertinent to Texas water law. Section II discusses the availability of fresh water in Texas and beyond, and Section III addresses the hydrologic cycle and its relevance to water law. Section IV covers some of the basic concepts of the science of water that are particularly significant for understanding and applying water law. Last, Sections V and VI discuss the value and ethic of water.

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II. Water, Water Everywhere

A. Available Fresh Water Resources in Texas

1. Surface Water

With 191,000 miles of streams and rivers, 15 major river basins, and 196 reservoirs in Texas, surface water is an integral part of the Texan culture, history, and economy. Texas Water Development Board, *Water for Texas 2012* 159 (2012) [hereinafter 2012 State Water Plan], *available at* www.twdb.state.tx.us/waterplanning/swp/2012/. Surface water is also a significant water source for Texas citizens, constituting 40 percent of the total water used in 2008. Of the major rivers in Texas, eight are designated coastal basins. 2012 State Water Plan, at 159. These basins affect the health of the bays and estuaries along the Texas coastline and provide one of the few sources of fresh water to communities in those regions.

Many of these rivers start their journey at a spring, where water bubbles out of the ground to start its passage above ground. Springs are responsible for the location of numerous Texas cities and are an integral part of Texas culture. *See* Gunnar A. Brune & Helen C. Besse, 1 *Springs of Texas* (new ed. 2002) [hereinafter Brune & Besse]; Larry McKinney, *The State of Springs*, *Texas Parks & Wildlife* 26, 29 (July 2005) [hereinafter McKinney, *The State of Springs*], *available at* www.tpwmagazine.com/archive/2005/jul/ed_1/. A 2003 U.S. Geological Survey database listed 1,891 springs in Texas, although some experts think the total is more than twice that. Franklin T. Heitmuller & Brian D. Reece, *Database of Historically Documented Springs and Spring Flow Measurements in Texas*, U.S. Geological Survey Open-file Report 03-315 (2003), *available at* http://pubs.usgs.gov/of/2003/ofr03-315/; McKinney, *The State of Springs*, at 29. The majority of the springs cataloged are in the Hill Country region of Central Texas; historically, however, springs have flowed throughout Texas even if they do not do so today. *See* Brune & Besse. The disappearance of Texas springs over the past thirty years marks the loss of both a water resource and a piece of the state's history. Wendee Holtcamp, *Aquatic Islands in a Sea of Land, Texas Parks & Wildlife* 36, 41 (July 2005), *available at* www.tpwmagazine.com/archive/2005/jul/ed_3/.

In addition to its river basins, Texas has a large system of reservoirs that provide water to its citizens. Of the 196 reservoirs with a storage capacity of at least 5,000 acre-feet, 175 have a potable water supply function. Texas Water Development Board, 2 *Water for Texas 2007* 142 (2007) [hereinafter 2007 State Water Plan]. These reservoirs were constructed primarily in the 1960s and 1970s to provide a source of fresh water for municipal, industrial, and agricultural purposes as well as for flood control. Today, they constitute more than half of the state's available surface water. The 2012 State Water Plan recommended twenty-six new major reservoirs that would produce 1.5 million acre-feet per year in 2060, assuming they were built and filled as projected. 2012 State Water Plan, at 236. Under Senate Bill 3, 80th Legislative Session, the legislature designated as sites of unique value for the construction of a reservoir all sites recommended for such designation in the 2007 State Water Plan. Act of June 16, 2007, 80th Leg., R.S., ch. 1430 (codified at Tex. Water Code § 16.051(g-1)). See Chapter 33 of this book regarding reservoirs.

2. Groundwater

In addition to surface water, Texas is heavily dependent on the state's groundwater resources. In the past several decades, nearly 140,000 water wells have been recorded and inventoried by the Texas Water Development Board. *See* Texas Water Development Board, *Groundwater Data*, *available at* www.twdb.state.tx.us/groundwater/data/. The state officially recognizes nine major and twenty-one minor aquifers that, together, provided 59 percent of the water used in Texas in 2003. 2012 State Water Plan, at 163. It is noteworthy that these thirty aquifers do not represent all the groundwater in Texas. Although they are excluded from the official count because of their size or significance, numerous other aquifers scattered throughout the state are important locally to homeowners, farmers, ranchers, and various businesses. 2007 State Water Plan, Vol. II, at 186.

Many areas of Texas rely heavily, if not exclusively, on groundwater supply to meet municipal and agricultural needs. In 2008, groundwater provided 60 percent of the 16.1 million acre-feet of water used in the state. 2012 State Water Plan, at 163. As a result, the rate of pumping of many of Texas's aquifers in excess of natural recharge has resulted in the progressive dewatering of many of the state's aquifers. 2012 State Water Plan, at 163. The Panhandle gets 88 percent of its water from the Ogallala Aquifer, and the San Antonio region depends on the Edwards Aquifer for more that 90 percent of its drinking water. 2012 State Water Plan, at 34; San Antonio Water System, *Edwards Aquifer Pumping Rights Acquisition*, www.saws.org/Your_Water/WaterResources/projects/edwards.cfm. Areas of the state with more precipitation, such as East Texas, depend more heavily on surface water resources. If Texas follows the trend seen in the rest of the world, dependency on aquifers will continue to increase. *Cf. Water For People, Water For Life; The United Nations World Water Development Report* at 78, U.N. Sales No. 92-3-103881-8 (2003) (asserting that groundwater today is "the world's most extracted raw material").

Due to the declines of several aquifers, groundwater availability is projected to decrease from 13.3 million acre-feet per year in 2010 to 10.1 million acre-feet per year in 2060. 2012 State Water Plan, at 165–66. Some of these reductions in available water have already been observed, including declines in aquifer water levels averaging one-hundred feet or more per year. 2007 State Water Plan, Vol. II, at 176. Not surprisingly, the largest decrease in levels was in the Trinity Aquifer in the Dallas–Fort Worth area, which has some of the densest population in the state. Similar impacts are expected in the future based on population predictions. Steve Satterwhite & Richard Whittaker, *There's Not Enough*, *The Texas Observer*, Apr. 6, 2007, *available at* www.texasobserver.org/2463-theres-not-enough-as-the-drought-saps-rural-texas-lawmakers-confront-a-state-thats-running-out-of-water/. In 2011, the Ogallala Aquifer located in the Texas Panhandle experienced the largest one-year decline in twenty-five years. Kate Galbraith, *Drought Caused Big Drop in Texas Portion of Ogallala*, *The Texas Tribune*, July 3, 2012, *available at* www.texastribune.org/2012/07/03/drought-caused-huge-drop-texas-portion-ogallala/. Even before the 2011 drought, the Ogallala Aquifer was declining at an average of three-quarters of a foot per year. Kate Galbraith, *Texas Farmers Battle Ogallala Pumping Limits*, *The Texas Tribune*, Mar. 18, 2012, *available at* www.texastribune.org/texas-environmental-news/water-supply/texas-farmers-regulators-battle-over-ogallala/.

Because aquifers are not visible, the state is continually updating their boundaries and trying to understand their characteristics. The Texas Water Development Board, in cooperation with other state and federal agencies, monitors groundwater across the state. 2012 State Water

Plan, at 25–28. Local groundwater conservation districts also track changes in water levels and attempt to quantify available water in their areas. In addition to quantity, water quality is critical to availability and usefulness. A statewide monitoring program samples hundreds of sites with the goal of ensuring clean drinking water for Texas citizens. 2012 State Water Plan, at 28. For effective water planning, water source characteristics must be evaluated in relation to how the water is currently used as well as how it will be needed in the future.

B. Water Use Patterns in Texas

Water availability and use patterns in Texas have experienced dramatic changes over the past century. A growing population and a dynamic economy, coupled with all too frequent droughts (eleven significant ones between 1891 and 1990), engendered an evolution in water resource management that has forever left its mark on the state. *See* Joe G. Moore, Jr., *A Half Century of Water Resources Planning and Policy, 1950–2000*, *in Water for Texas* 7 (Jim Norwine et al. eds., Texas A&M University Press 2005); Rima Petrossian, *Water Use Patterns and Trends: The Future in Texas*, *in Water for Texas* 52.

In recent years, for example, the state's burgeoning population has spurred a shift from agricultural to municipal water use. In 1974 irrigation accounted for more than 75 percent of the total water used in the state, but by 2004 that percentage had dropped to less than 60. *See* Texas Water Development Board, *Historical Water Use Information*, www.twdb.state.tx.us/wushistorical/ [hereinafter Historical Water Use]. In contrast, during the same time frame, municipal use grew from 11 percent to nearly 25 percent of the total water used in Texas. The bulk of that increase came from municipal use of surface water resources, which increased from 18.8 percent to more than 40 percent of all surface waters used in Texas, while municipal use of groundwaters accounted for 8 percent of all groundwaters used in the state in 1974, peaked at 20.5 percent in the late 1980s, and then settled at 13.75 percent in the early 2000s. *See* Historical Water Use. In addition to population growth, other reasons for the decrease in water use for irrigation include a decrease of irrigated land from 8.6 million acres in 1974 to 6.35 million acres in 2000 and the use of improved water conservation techniques. *See* Amy Hardberger, *From Policy to Reality: Maximizing Urban Water Conservation in Texas* 3, Environmental Defense Fund (2008), *available at* www.texaswatermatters.org/pdfs/Texas_Water_Pub_08.pdf [hereinafter *From Policy to Reality*]. Irrigation demand is expected to decline over the planning horizon by 17 percent over the next fifty years in part due to improvements in irrigation efficiency and the loss of irrigated farmland to urban development in some regions. 2012 State Water Plan, at 141.

Other noteworthy trends in Texas water-use patterns can be identified. Between the 1950s and late 1970s, the average per capita municipal use statewide rose from around 100 gallons per day to 182 gallons per day. *See From Policy to Reality*, at 3. That rate declined in the 1980s and leveled off at around 158 gallons per capita per day in the mid-1990s. Since then, it has swollen to 191 gallons per capita per day in 2001, in part as a result of the ongoing drought. *See From Policy to Reality*, at 3. During dry conditions, water consumption can increase considerably due to outdoor watering, accounting for 50 to 80 percent of a home's water use. Texas Water Development Board, *Conserving Water Outdoors*, *available at* www.twdb.texas.gov/publications/brochures/conservation/doc/ConservingWaterOutdoor.pdf.

Another significant trend can be seen in the state's industrial and manufacturing sector, whose water use has been relatively consistent over the past thirty years. In 1974, the sector used just less than 1.6 million acre-feet of water. That number has fluctuated downward on occasion (as low as 1.37 million acre-feet in 2000); however, by 2004, it was at 1.53 million acre-feet. *See* Historical Water Use. Likewise, as a percentage of the total water used in the state, use by the industrial and manufacturing sector has reliably fluctuated between 8.4 and 10.8 percent during the past thirty years and in 2004 was 9.9 percent of the total water used in Texas. *See* Historical Water Use.

In addition, the continuing growth in shale gas and oil drilling in Texas, especially efforts that use hydraulic fracturing techniques ("fracking"), is also increasing the amount of water used across the state. *See* James Bene et al., Northern Trinity/Woodbine Aquifer Groundwater Availability Model 14–15, *available at* http://rio.twdb.state.tx.us/RWPG/rpgm_rpts/0604830613_BarnetShale.pdf. In the last few years, shale growth has increased exponentially in southeast Texas's Eagle Ford Shale. The Texas Railroad Commission issued more than four thousand drilling permits in 2012 alone. *See* Texas Railroad Commission, Texas Eagle Ford Shale Drilling Permits Issued 2008 through May 2013, *available at* www.rrc.state.tx.us/eagleford/EagleFordDrillingPermitsIssued.pdf. These wells rely almost entirely on groundwater for the fracking process. Shale development is especially concerning since, to date, the State Water Plan has not included in its water use and availability projections the significant amounts of water used in such operations. In the 2012 State Water Plan, the Texas Water Development Board indicated that water use in the mining sector will be monitored during the next regional water planning cycle. 2012 State Water Plan, at 140. For effective planning, though, Texas must look beyond how water was used in the past and fully assess how water will be needed and used in the future.

C. Future Uses and Needs in Texas

Although everyone agrees that the demand for water in Texas will increase, the amount of that increase and the best way to prepare for that need are subjects of ongoing debates. The state is projected to grow approximately 82 percent, from 25.4 million people in 2010 to 46.3 million by 2060. 2012 State Water Plan, at 132. Moreover, water use by the industrial and manufacturing sector is expected to intensify in the next few decades and grow to 2.9 million acre-feet by 2060. 2012 State Water Plan, at 140. These additional people and the increased business and industry in Texas will require more water. To complicate issues, growth is not predicted to be equal across the state. Some areas will grow more than others, and additional water resources will be needed.

Projections calculated by multiplying projected population by total per capita water use indicate that, by 2060, municipal water demands for the state are expected to nearly double the 2010 rate, from 4.9 million acre-feet to 8.4 million acre-feet. 2012 State Water Plan, at 3, 136. Assuming Texas maintains the use patterns of the 2000s, more than 50 percent of the state's population in 2060 will face a water need of at least 45 percent of their projected demand during a repeat of drought conditions if no additional supply is created. 2012 State Water Plan, at 177. The good news is that water demand is not predicted to escalate in the same ratio as population. Texas's water demand is expected to increase only 22 percent, from 17.5 million acre-feet in 2000 to a total of 21.6 million acre-feet in 2060. 2012 State Water Plan, at 136. One significant reason for the moderate total increase is that more water is expected to shift from agricultural uses to municipal uses. 2012 State Water Plan, at 136. Historically, the highest percentage of water was used for irrigation purposes. Using water differently through a better understanding of conservation and efficiency can also alter these predictions.

The cities of San Antonio and El Paso exemplify the impact that conservation and efficiency measures can have on reducing demand. In 2000, El Paso's water projections showed that the city's water supply would be completely depleted in twenty-five years. E. Dan Klepper, *¡Agua Caliente!*, *Texas Parks & Wildlife* 16–17 (July 2002). Using a combination of diversification of supply, technology, and efficiency programs, the city has been able to stabilize its water usage even though its population increased. Conservation efforts have reduced per capita consumption from 210 gallons a day to less than 140. David Crowder, *Water Supply Plentiful as Boom Nears*, *El Paso Times*, Jan. 29, 2007, *available at* www.elpasotimes.com/ci_5108854. Similarly, San Antonio has reduced its per capita water use by 40 percent despite a 70 percent population increase since 1980. David McLemore, *S.A. Sets Conservation Example*, *Dallas Morning News*, Apr. 2, 2007.

Although conservation measures should be included in any water planning effort, the future of Texas water cannot rely entirely on conservation. Other solutions must be found. The 2012 State Water Plan reviews the state's current water resources and summarizes sixteen regional plans created by local planning groups based on area water resources. 2012 State Water Plan, at 2. See also Chapter 20 of this book for further discussion of state water planning. Based on this information, the 2012 State Water Plan proposes a series of water management strategies in an effort to plan for Texas's water future. Some of these are more controversial than others. For example, a large portion of the proposed future water would come from new reservoirs. 2012 State Water Plan, at 190. Many groups question this solution for political reasons, while others raise issues such as environmental impacts and evaporation rates and sedimentation, which are common in reservoirs, particularly in climates similar to those found in Texas. Elena Schneider, *Reservoirs Make Comeback in Parched Texas*, *The Texas Tribune*, Mar. 4, 2013, *available at* www.texastribune.org/2013/03/04/reservoirs-make-comeback-parched-texas-landscape/. Other proposed water management strategies include improved management of existing supply, water reuse, desalination, long-haul transport, and changes in agricultural practices. In spite of the debates over which approach is best, one thing is clear: the future of Texas is inextricably tied to the threat of water scarcity, and solutions must be found. In order for these solutions to be effective, the science must first be understood.

III. Water and the Hydrologic Cycle

A. Understanding the Hydrologic Cycle

Unlike other natural resources, "the total volume of water in nature is fixed and invariable." David Keith Todd, *Groundwater Hydrology* 13, 14–16 (John Wiley 2d ed. 1980) [hereinafter Todd]. This is referred to as the world water budget. R. Allen Freeze & John A. Cherry, *Ground Water* 5 (Prentice Hall 1979) [hereinafter Freeze & Cherry]. Although the total quantity is unchanging, the form and the location of the water are constantly shifting. The water, or hydrologic, cycle is the continuous circulation of water—solid, liquid, gas, or vapor—on earth. (See Plate 1, Diagram of the hydrologic cycle, U.S. Geological Survey, *Water Science for Schools: The Water Cycle*, *available at* http://ga.water.usgs.gov/edu/watercycle.html.) *See* C. W. Fetter, *Applied Hydrogeology* (Prentice Hall 3d ed. 1994) [hereinafter Fetter]; Michael Price, *Introducing Groundwater* (Routledge 1996) [hereinafter Price]. This constant cycle has no beginning or ending. Water falls to the earth's surface as precipitation, such as rain, snow, or sleet, and flows over the earth's surface into fluid bodies, including rivers, lakes, and wetlands, or solid bodies, such as snow and ice, or seeps into the ground to become groundwater. Fetter, at 5–6; Price, at 15–16. Throughout its surface travels and especially when it reaches large bodies of water, much of the water evaporates through the effects of solar energy and returns to the atmosphere, where it continues in the cycle. Fetter, at 5–6; Price, at 15–16.

As for the water that seeps into the ground, in most cases the earth acts as a conduit allowing it to travel back to the surface where it can discharge, only to evaporate into the atmosphere to start the cycle again. Todd, at 13–15. Water typically percolates into the earth vertically downward until it reaches the groundwater table, where it flows in a more lateral direction through the porous spaces in the geologic formation. The rate of percolation into the subsurface and the flow of groundwater within aquifers are considerably slower than surface water flow, but both eventually allow water to return to the atmosphere and continue in the cycle. Price, at 17.

Normally, such water emerges in natural discharge sites, such as springs, rivers, lakes, lagoons, swamps, and the sea. Herman Bouwer, *Groundwater Hydrology* 293 (McGraw-Hill 1978) [hereinafter Bouwer] (noting that springs are the most conspicuous avenues for the natural return of groundwater to the surface). Plants also consume or absorb some water, which they then transpire through their leaves back into the atmosphere. Price, at 15–16 (discussing the processes of interception and transpiration of water by foliage). Other groundwater can remain in the ground as aquifer storage, which serves as an underground reservoir from which humans withdraw needed fresh water. However, due to the growing need for water, pumping of groundwater from wells is one of the greatest sources of aquifer discharge, the consequence of which is to remove water, at least temporarily, from the hydrologic cycle. Although the cycle may appear complex, its foundation hinges on the relationship between water in its various settings, including the surface and subsurface.

B. Surface and Groundwater Interrelationship

Groundwater is a significant component of the hydrologic cycle. This is especially evident given the vast quantity of water found under the ground. Price, at 2. From a hydrologic point of view, however, groundwater is neither similar nor dissimilar to surface water resources. Ground and surface waters are, in fact, part and parcel of the same thing, namely, water moving through the various stages of the hydrologic cycle. Thomas C. Winter et al., *Ground Water and Surface Water, A Single Resource*, U.S. Geological Survey Circular 1139, 76 (1998) [hereinafter Winter et al.], *available at* http://pubs.usgs.gov/circ/circ1139 (emphasizing the importance of considering groundwater and surface water collectively). Groundwater can assist surface water by sustaining stream flow when surface runoff is low; likewise, surface recharge features, including stream beds, can assist in aquifer replenishment. Todd, at 16. The relationship between these water sources is natural; however, it is not inalterable and can be influenced by external influences. See Chapter 5 of this book regarding conjunctive management and use.

C. Climate Change and the Hydrologic Cycle

Unfortunately, the hydrologic cycle is not immune to the impacts of mankind. In addition to the dewatering of surface water and groundwater resources created by pumping, global climate change affects many aspects of the hydrologic cycle. Intergovernmental Panel on Climate Change, *Summary for Policymakers* 7 (2007) [hereinafter IPCC]. Human activities, such as burning fossil fuels and clearing forests, have released large quantities of carbon dioxide and other global warming gases into the atmosphere. *Massachusetts v. EPA*, 549 U.S. 497, 504–07 (2007). These gases trap the sun's heat and slow its escape back into space, thereby threatening to disrupt the delicate balance needed to sustain earth's ecosystems.

During the past one hundred years, average temperatures worldwide have risen more than one degree Fahrenheit. The year 2012 was the warmest year on record, and 2011 was the driest in Texas. Betsy Blaney, *2012 Warmest Year Ever in Texas* (Jan. 9, 2013), http://news.yahoo.com/2012-warmest-ever-texas-141853971.html. One of the most important potential impacts of climate change is its effect on water resources. A 2007 report of the United Nation's Intergovernmental Panel on Climate Change (IPCC) predicted a 10–30 percent decrease in river runoff and water availability in dry climates at midlatitudes as early as mid-century. IPCC, at 7.

The hydrologic cycle does not always function in the same place or in the same manner. It can vary in terms of time and space as well as scale. Although the rates vary, precipitation falls nearly everywhere, and the return of that water through evaporation is, likewise, almost universal. Winter et al., at 2. As a consequence, some water will never reach an ocean as runoff before being returned to the atmosphere. Climatic changes can exacerbate these tendencies or shift the location of the water so that while the world water budget remains constant, the location of the water is unbalanced. *See* Michael Overman, *Water: Solutions to a Problem of Supply and Demand* 45 (Doubleday 1969). Some areas may have very little water, resulting in scarcity and droughts, while other areas have more than is needed, often occurring in the form of destructive floods and storms.

Texas is unique in its range of geographic and topographic regions. The local climate is determined by fronts coming in from the north and moist air moving in from the Gulf of Mexico. *The Impact of Global Warming in Texas* 42 (Gerald R. North et al. eds., University of Texas Press 1995) [hereinafter *Impact of Global Warming*]. These forces are critical in determining much of the state's weather patterns. Even a small shift in these systems may have large impacts on the state's water supply and may alter these geographic provinces. For example, if the dry climate of West Texas migrates eastward, it potentially could transform the Hill Country.

If the model predictions about climate change are correct, global warming could have significant impacts on Texas's water resources. Models show that Texas may be subject to increasing temperatures that could reduce soil moisture, which affects agricultural water needs as well as the amount of water allowed to percolate through the subsurface. *Impact of Global Warming*, at 42. More heat could also result in increased evaporation, possibly affecting the economics and reliability of reservoirs and other surface water resources. Furthermore, climate change may alter precipitation patterns in Texas, shifting or decreasing rainfall across parts of the state. Decreased rainfall will diminish river flows and aquifer recharge and affect water supply planning.

The hydrologic cycle and climate change are natural processes. Because water is an integral part of human life and development, however, law and policy are injected into the natural process as a means for managing water resources for the benefit of people and communities. This interaction creates new and varying definitions and interpretations of nature's mechanisms that must be understood in their proper context. Unfortunately, climate change and its potential impacts have not been integrated into the Texas State Water Plan or Texas policy.

D. Relationship of the Hydrologic Cycle to Water Law

"The hydrologic cycle controls the distribution of water available for human use on the earth's surface. Water law is a function of the incomplete fit between water availability and the demand for various uses." A. Dan Tarlock, *Law of Water Rights and Resources*, *Environmental Law Series* 2-2 (West 1998 & Supp. 2006). A common shortfall in water law is the failure to consider the entire hydrologic cycle. In Texas, for example, surface and groundwater are regulated under different legal regimes. Whereas surface water is primarily managed under a state-run prior appropriation permit system, groundwater is governed by landowners under the "rule of capture," with various modifications imposed by local groundwater conservation districts. See Chapter 3 of this book regarding surface water law, Chapter 4 regarding groundwater law, and Chapter 5 regarding conjunctive management and use.

The consequence of these disparate regulatory structures is that interrelated surface and groundwaters are often managed independently and with little thought to their impact on each other. An example of this situation is the elimination of Comanche Springs in Fort Stockton, Pecos County, Texas, in the late 1950s. These surface springs became dry because of overpumping of the Edwards-Trinity Plateau Aquifer, which was drained in accordance with the rule of capture. Brune & Besse, at 357. Pumping for fruit irrigation dried up this "oasis in the desert" and severely affected the local community, which had used the springs as a tourist attraction. Art Chapman, *Running Dry*, *Fort Worth Star-Telegram*, Feb. 14, 2007, at B4; *see also Pecos County Water Control and Improvement District No. 1 v. Williams*, 271 S.W.2d 503 (Tex. Civ. App.—El Paso 1954, writ ref'd n.r.e.).

Some water law principles can be considered in the context of the hydrologic cycle. Perhaps the simplest way is through the application of conjunctive use principles. Though not incorporated into Texas law, conjunctive use principles recognize the relationship between surface water and groundwater and seek to regulate water as a system and not as individual resources. While not mandated under Texas law, conjunctive use is applied in the management of the Edwards Aquifer and the various springs fed from that aquifer. *See* Todd H. Votteler, *The Little Fish That Roared: The Endangered Species Act, State Groundwater Law, and Private Property Rights Collide over the Texas Edwards Aquifer*, 28 Envtl. L. 845 (1998) [hereinafter Votteler]. See Chapter 5 of this book regarding conjunctive management and use.

IV. The Legal and Scientific Language of Fresh Water Resources

One of the more troublesome aspects of water law can be the divergence often encountered between legal and scientific definitions, as well as among subfields of the law. Although the vocabulary used by the various communities can overlap, the meanings ascribed by each to various terms and concepts may differ significantly. For example, the scientific understanding of "surface water" is markedly different from the legal meaning provided under the Texas Water Code (see below). Moreover, that term has different legal definitions depending on whether it is used in the context of water quality standards or water rights (see below). At the very least, such differences can result in confusion or misunderstanding. At worse, they can result in laws that fail to reflect scientific reality or misapply the law. Accordingly, it is imperative that anyone who enters the field of water law be well versed in the scientific and the various legal understandings of the terms and concepts relevant to the subject matter.

A. Understanding Surface Water

Surface water is the water resource most familiar and understandable to people because, unlike groundwater, it is visible and tangible. Generally surface water is what it sounds like: water that exists on the surface of the earth. It can take many forms, but most commonly it occurs as rivers, streams, lakes, wetlands, and reservoirs. Surface water also includes the solid forms of water—snow and ice. Winter et al., at 1.

Legally, the definition of surface water in Texas varies. One Texas court of appeals indicated that "[i]n common usage, the term simply means 'natural water that has not penetrated much below the surface of the ground.'" *Dietrich v. Goodman*, 123 S.W.3d 413, 417 (Tex. App.—Houston [14th Dist.] 2003, no pet.) (citing *Webster's Third New International Dictionary* 2300 (1993)). This "common" understanding appears to comport with the general definition provided for surface water under chapter 30 of the Texas Administrative Code, which encompasses—

> [l]akes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, wetlands, marshes, inlets, canals, the Gulf of Mexico inside the territorial limits of the state [from the mean high water mark (MHWM) out 10.36 miles into the Gulf], and all other bodies of surface water, natural or artificial, inland or coastal, fresh or salt, navigable or nonnavigable, and including the beds and banks of all watercourses and bodies of surface water, that are wholly or partially inside or bordering the state or subject to the jurisdiction of the state; except that waters in treatment systems that are authorized by state or federal law, regulation, or permit, and which are created for the purpose of waste treatment are not considered to be water in the state.

30 Tex. Admin. Code § 307.3(a)(66). That definition, however, is applicable only with regard to surface water quality standards in Texas as provided for by the Texas Commission on Environmental Quality. See also Chapter 32 of this book discussing the definition of surface water in relation to flood management.

When "surface water" is discussed with reference to water rights (with regard to section 11.086 of the Texas Water Code), however, the phrase is often used interchangeably with the term "state water." Under section 11.021(a) of the Texas Water Code, "state water" is defined as "[t]he water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state." Tex. Water Code § 11.021(a). By definition and by case law interpretation, it does not include "diffused surface water." *See Dietrich*, 123 S.W.3d at 417–18.

Diffused surface water is understood to mean "water or natural precipitation diffused over the surface of the ground until it either evaporates, is absorbed by the land, or reaches a bed or channel in which water is accustomed to flowing." *Raburn v. KJI Bluechip Investments*, 50 S.W.3d 699, 704 (Tex. App.—Fort Worth 2001, no pet.) (citations omitted); *Dietrich*, 123 S.W.3d at 418–19. As a result, and in contrast to the scientific understanding of the term, diffused water is never found in a natural watercourse. *Dietrich*, 123 S.W.3d at 418. Accordingly, diffused water belongs to the landowner until it enters a natural watercourse. State water does not include diffused surface water or groundwater. State water in Texas is the property of the state. *See* Tex. Water Code § 11.021(a).

Based on the above definition, water in a watercourse is state water. A watercourse, however, entails a precise understanding. As defined by Texas case law, a "watercourse" is any "body of water flowing in a reasonably definite channel with bed and banks." *Watts v. State*, 140 S.W.3d 860, 866 (Tex. App.—Houston [14th Dist.] 2004, pet. ref'd) (quoting *Black's Law Dictionary* 1585 (7th ed. 1999)). To constitute a watercourse, the body of water must have (1) a bank and bed, (2) a current of water, and (3) a permanent supply source of water. *Hoefs v. Short*, 273 S.W. 785, 786–87 (Tex. 1925); *see also* 30 Tex. Admin. Code § 297.1(59) (defining a "watercourse" as "[a] definite channel of a stream in which water flows within a defined bed and banks, originating from a definite source or sources" and noting that the "water may flow continuously or intermittently, and if the latter with some degree of regularity, depending on the characteristics of the sources").

Permanent does not mean continuous, but rather an established source of water that occurs with some regularity such that it "establish[es] and maintain[s] a running stream for considerable periods of time." *Hoefs*, 273 S.W. at 788. In some cases, it can include streams that may be dry for extended periods of time. *Hoefs*, 273 S.W. at 787. Moreover, according to the *Watts* court, a watercourse "may be either artificial, *i.e.,* man-made, or natural." *Watts*, 140 S.W.3d at 866 (citing *Black's Law Dictionary* at 1586). As a result, under Texas law, the vast majority of Texas lakes, rivers, streams, channels, and other conduits of water are watercourses. Those watercourses made up of rivers and streams, however, can be subdivided into subcomponents. Like most things, rivers and streams have a beginning, a middle, and an end.

1. Headwaters and Mouth of a River

Rivers are large natural streams of water flowing in channels and emptying into larger bodies of water. Brian J. Skinner & Stephen C. Porter, *Physical Geology* 270 (John Wiley 1987). The beginning of a river is its source, also called the headwaters. It is the original point from which the river flows. Located at higher elevations, the source may be fed by an underground spring or by runoff from rain, snowmelt, or glacial melt. E. C. Pielou, *Fresh Water* 81–82 (University of Chicago Press 1998) [hereinafter Pielou]. In contrast, the river mouth is the end point of a river; it is the place where a river flows into a larger body of water, such as another river, a lake, or an ocean. V. N. Mikhailov, *Principles of Typification and Zoning of River Mouth Areas*, 31 Water Res. 1 (Jan. 2004).

2. Tributary

River systems consist of a network of links and nodes that make up the middle portion of a river. These links and nodes are called tributaries. Michael A. Summerfield, *Global Geomorphology* 208–09 (Longman 1991) [hereinafter Summerfield]. A tributary is a stream that flows into and contributes to a larger stream or another body of water. *Cf.* Tex. Water Code § 41.009 (defining "tributary" in the Rio Grande Compact to mean "any stream which naturally contributes to the flow of the Rio Grande") and Tex. Water Code § 46.013 (defining "tributary" in the

Red River Compact to mean "any stream which contributes to the flow of the Red River"). As more and more tributaries join together, the flow accumulates and expands the size of the river. Summerfield, at 208–09. Some rivers have many branches, or bifurcations, of tributaries, while others do not. Often the amount of bifurcation is attributable to the types of rock and soil found in the area as well as the length of overland flow. The longer the flow distance of a river, the more branches it is likely to have. Because water supply in a river is achieved through accumulation, the flow of each tributary is important, and its absence can have impacts downstream. Summerfield, at 208–09.

3. Watershed, Drainage Basin, and Catchment Area

A watershed is the area of land surface in which water, generated by precipitation, flows or drains from the land into a particular river, stream, or the ocean. Summerfield, at 207; Environmental Protection Agency, *Wetlands and Watersheds*, www.epa.gov/wetlands/facts/fact26.html. A watershed can also be referred to as a drainage basin or catchment area. It is the "fundamental geographic unit of hydrology" and is the most important factor through which to understand local precipitation and runoff. Office of Technology Assessment, *Water Supply: The Hydrologic Cycle* 37, *in Perspectives on Water Uses and Abuses* (David H. Speidel et al. eds, Oxford University Press 1988). Drainage basins are generally well defined and can be identified by tracing a line along the highest elevations between two areas on a map. Areas of higher elevation that form the boundaries of a watershed are called drainage divides. Summerfield, at 207. These irregular boundaries generally follow local topography. William S. Carlsen et al., *Watershed Dynamics* 4 (National Science Teachers Association 2004) [hereinafter Carlsen et al.].

Watersheds vary greatly in size and shapes depending on regional geology. Carlsen et al., at 4–5; Pielou, at 84–86. Large watersheds, like the area that drains into the Mississippi River, contain many smaller watersheds, or subwatersheds, that flow into the river. Carlsen et al., at 5; Coastal America, *Toward a Watershed Approach: A Framework for Aquatic Ecosystem Restoration, Protection, and Management* (1994). Under Texas case law, "[a] 'watershed' is a topographical designation to describe an area in which surface water flows during a rain event because of gravity toward a 'watercourse' such as a river, bayou, ditch or creek." *Texas Woman's University v. Methodist Hospital*, 221 S.W.3d 267, 275–76 (Tex. App.—Houston [1st Dist.] 2006, no pet.). Under title 30 of the Texas Administrative Code, a "watershed" "designate[s] the area drained by a stream and its tributaries, or the drainage area upstream from a specified point on a stream." 30 Tex. Admin. Code § 297.1(61). This latter definition applies to procedural and substantive water rights (30 Tex. Admin. Code chs. 295 and 297, respectively) as well as water conservation and drought contingency plans (30 Tex. Admin. Code ch. 288).

4. Base Flow

The water in a river consists of water from various sources. River discharge is the volume of water that passes through a given cross section of the river in a set amount of time. The quantity of discharge sustained without the addition of water from precipitation, runoff, or melting snow is called "base flow." Summerfield, at 193. Under title 30 of the Texas Administrative Code, base flow is "[t]he portion of streamflow uninfluenced by recent rainfall or flood runoff and is comprised of springflow, seepage, discharge from artesian wells or other groundwater sources, and the delayed drainage of large lakes and swamps." 30 Tex. Admin. Code § 297.1(6). Under certain circumstances, "[a]ccountable effluent discharges from municipal, industrial, agricultural, or other uses of ground or surface waters may be included" in determining base flow. 30 Tex. Admin. Code § 297.1(6). Base flow is important because it is a quantity of water that maintains a perennial or continuous stream.

5. Underflow

Under Texas law, the "underflow" refers to water found within the bed and banks of a river. Although this water is found within the ground, it is regarded as "state water" and is subject to prior appropriation. According to title 30 of the Texas Administrative Code, the underflow of a river refers to—

> [w]ater in sand, soil, and gravel below the bed of the watercourse, together with the water in the lateral extensions of the water-bearing material on each side of the surface channel, such that the surface flows are in contact with the subsurface flows, the latter flows being confined within a space reasonably defined and having a direction corresponding to that of the surface flow.

30 Tex. Admin. Code § 297.1(55).

6. Environmental Flows

"Environmental flows" is a term that refers to both instream flows and fresh water inflows into bays and estuaries. At its most basic level, "instream flows" means the water in streams, rivers, and lakes. *See* Tom Annear et al., *Instream Flows for Riverine Resource Stewardship* 1 (Instream Flow Council 2002) [hereinafter Annear et al.]. Instream flows support a variety of fishery and aquatic wildlife resources and the ecological processes of riverine systems. Annear et al., at xix. Fresh water inflows into bays and estuaries is the water necessary to sustain a broad range of biological needs in those coastal systems. Rivers serve many functions, including moderating floods and droughts, renewing soil fertility, often recharging certain aquifers, and providing habitat and breeding sites for fish and wildlife. Sandra Postel & Brian Richter, *Rivers for Life: Managing Water for People and Nature* 2 (Island Press 2003). Fresh water from rivers meets and mixes with seawater in estuaries, dynamic systems that in Texas create diverse wetlands that support the production of 100 million pounds of seafood annually and sustain a birding paradise. Larry McKinney, *Texas: The State of Rivers*, *Texas Parks & Wildlife* 23 (July 2004), *available at* www.tpwmagazine.com/archive/2004/jul/ed_2/. In 2007, as part of the omnibus bill S.B. 3, the state legislature enacted a new statutory scheme for protecting the environmental flows that support the state's riverine and bay systems. See Chapter 11 of this book regarding environmental flows.

B. Understanding Groundwater

Groundwater makes up only three-quarters of 1 percent of the total volume of fresh and saltwater found in nature. Nonetheless, it makes up nearly 97 percent of the fresh water readily available on earth for consumption. *See* Bouwer, at 1–3.

Water is found throughout the subsurface in various quantities. The term "groundwater," however, does not encompass all subsurface waters. Rather, it specifically pertains only to subsurface water found within the saturated zone of a porous geologic formation as well as water that may be mechanically extracted from a saturated formation. The saturated zone is the "[p]ortion of the geologic profile below the groundwater table, in which the pores or voids between the soil particles are filled with water." *Kansas v. Colorado*, No. 105, 1994 WL 16189353, at *1 (U.S. Oct. 3, 1994); *see also Shurbet v. United States*, 242 F. Supp. 736, 740 (N.D. Tex. 1961) (describing the saturated zone as "the underground area containing water-bearing material from which water can be artificially extracted"); *compare with* 30 Tex. Admin. Code §§ 330.3(134), 334.481(51), 335.1(134) (defining the saturated zone as "[t]hat part of the earth's crust in which all voids are filled with water" in the context of rules for industrial solid and municipal hazard wastes). Groundwater does not include water found in the unsaturated zone of such formations. *See* Price, at 7 (describing the difference between surface and groundwater); Ralph C. Heath, *Basic Ground-Water Hydrology*, Water Supply Paper 2220, 1, 4 (U.S. Geological Survey, 10th prtg. 2004, revised) [hereinafter Heath]. In the context of underground and above-ground storage tanks, the unsaturated zone is defined in chapter 30 of the Texas Administrative Code as—

> [t]he subsurface zone containing water under pressure less than that of the atmosphere (including water held by capillary forces within the soil) and containing air or gases generally under atmospheric pressure. This zone is bounded at the top by the ground surface and at the bottom by the upper surface of the zone of saturation (i.e., the water table).

30 Tex. Admin. Code § 334.2(116); *compare with* 30 Tex. Admin. Code § 334.481(62) (applicable in the context of the storage, treatment, and reuse procedures for petroleum-substance contaminated soil related to underground and above-ground storage tanks), *and* 30 Tex. Admin. Code § 335.1(165) (applicable in the context of industrial solid and municipal hazardous wastes) (describing the unsaturated zone as "[t]he zone between the land surface and the water table"). It is economically infeasible and often physically impossible to pump water from the unsaturated zone.

In Texas, "groundwater" is defined as "water percolating below the surface of the earth." Tex. Water Code §§ 35.002(5), 36.001(5); *compare with* 30 Tex. Admin. Code § 297.1(21) (defining groundwater as "[w]ater under the surface of the ground other than underflow of a stream and underground streams, whatever may be the geologic structure in which it is standing or moving"); Tex. Spec. Dist. Code § 8801.001(4) (defining groundwater as "water located beneath the earth's surface" but excluding "water produced with oil in the production of oil and gas"); 30 Tex. Admin. Code §§ 330.3(61), 334.481(28), 335.1(66); 31 Tex. Admin. Code § 601.3(6) (defining groundwater as "[w]ater below the land surface in a zone of saturation"). A groundwater reservoir is a "specific subsurface water-bearing reservoir having ascertainable boundaries containing groundwater." Tex. Water Code §§ 35.002(6), 36.001(6). Groundwater in Texas is specifically excluded from the definition of state water and is subject to the rule of capture as modified by the various groundwater conservation districts across the state. See Chapter 4 of this book for a discussion of the rule of capture. This is true even where percolating water supplies a surface stream. *See Denis v. Kickapoo Land Co.,* 771 S.W.2d 235, 236 (Tex. App.—Austin 1989, writ denied).

1. Aquifer

An “aquifer” is a relatively permeable geologic formation (composed of unconsolidated material such as sand or gravel) that has sufficient water storage and transmitting capacity to provide a useful water supply via wells and springs. *See* Heath, at 6; Price, at 9; *compare with* 30 Tex. Admin. Code §§ 330.3(8), 335.1(8) (describing an “aquifer” as “[a] geological formation, group of formations, or portion of a formation capable of yielding significant quantities of groundwater to wells or springs”), § 230.2(1) (defining an “aquifer” as “[a] geologic formation, group of formations, or part of a formation that contains water in its voids or pores and may be used as a source of water supply”); *Mitchell Energy Corp. v. Bartlett*, 958 S.W.2d 430, 434 (Tex. App.—Fort Worth 1997, writ denied) (asserting that “[a]n aquifer is an underground rock stratum with sufficient permeability to permit movement of water through it”). Accordingly, an aquifer encompasses the saturated portion or saturated zone within a porous geologic formation.

It is noteworthy that aquifers are very often in a state of flux, meaning that the volume of water contained and/or flowing through the geologic formation is constantly changing. These changes are the result of variations in the amount of water flowing into (recharge) and out of (discharge) the saturated zone. When the water table (see definition below) drops during a drought or when human withdrawals exceed recharge, the portion of the geologic formation that is described as an “aquifer” decreases in volume. Conversely, when the water table rises as a result of rainfall or another increase in the recharge, or even a reduction in human withdrawals, the portion of the geologic formation that conforms to the definition of an “aquifer” increases the volume.

All aquifers have an impermeable base layer that prevents water from seeping to lower-lying strata, thus creating a natural water reservoir within the porous geologic formation. *See* Bouwer, at 4 (listing some materials that constitute the impermeable layer, including clays or “other fine-textured granular material, or of shale, solid limestone, igneous rock, or other bed-rock”). At any given location, the land surface may be underlain by one or more distinct aquifers separated by impermeable layers (like different apartments separated by floors in a multilevel apartment building), depending on the composition of the underlying strata. *See* Fetter, at 511.

a. Unconfined or Water-Table Aquifer

An *unconfined aquifer* (see Figure 1) is an aquifer bounded by an impermeable base layer of rock or sediments, and overlain by layers of permeable materials extending from the land surface to the impermeable base of the aquifer. *See Shurbet*, 242 F. Supp. at 741 (defining an “unconfined aquifer” as an aquifer “in which the water is not confined between two impervious layers and in which the water level in a well drilled in the aquifer reflects the general level of the water table throughout the aquifer”); *see also* Heath, at 6; Price, at 10–11. Such an aquifer also may be referred to as a *water-table aquifer* because its upper limit is defined by the water table. *Cf.* Heath, at 6.

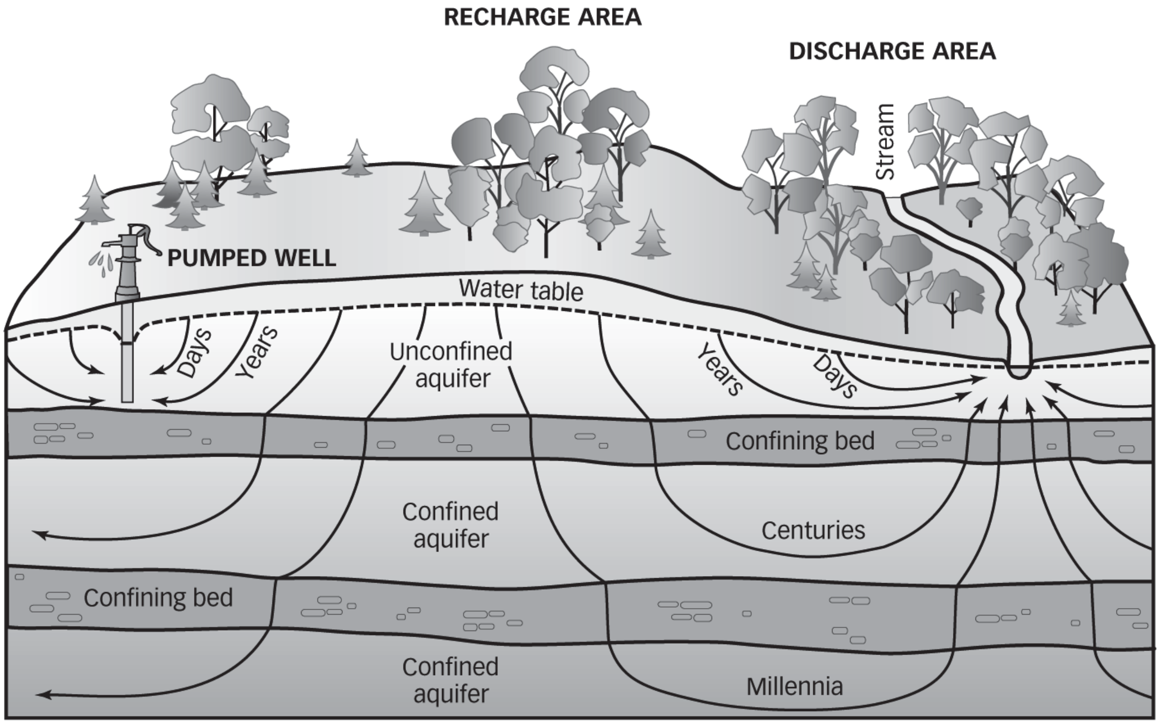

Figure 1. Diagram of an unconfined aquifer overlaying confined aquifers and groundwater flow paths with general length, depth, and travel time from points of recharge to points of discharge. Thomas C. Winter et al., *Ground Water and Surface Water, A Single Resource*, 1139 U.S. Geological Survey Circular 5 (1998), *available at* http://pubs.usgs.gov/circ/circ1139.

Although not always the case, unconfined aquifers are often directly related to a surface body of water, such as a river or lake. *See* Bouwer, at 4, 6 (explaining that seepage and drainage from rivers and lakes connect unconfined aquifers to surface bodies of water). Rivers, for example, tend to have interrelated unconfined aquifers located directly underneath and following the course of the riverbed. *See* Bouwer, at 3–4 (noting that, depending on the strata underneath and beside the river, an unconfined aquifer hydraulically related to a river is generally spread out laterally on both sides of and below the river). This scenario can create considerable complications when considering the legal distinctions between a river's underflow and an interrelated aquifer (see definition of underflow above). Unconfined aquifers, however, can also exist independent of a surface body of water. The Ogallala Aquifer is an example of an unconfined aquifer with little hydraulic connection to any surface water bodies. Rex C. Buchanan et al., *The High Plains Aquifer*, Publ. Info. Circular 18 at 1 (KA Geol. Survey 2001) [hereinafter Buchanan et al.], *available at* www.kgs.ku.edu/Publications/pic18/index.html.

b. Confined or Artesian Aquifer

In contrast, a *confined aquifer* (also known as an *artesian aquifer*) (see Figure 1) is an aquifer contained between two impermeable layers—the base, or "floor," and the "ceiling" strata—that subject the stored water to hydraulic pressure exceeding atmospheric pressure. *See Shurbet*, 242 F. Supp. at 741 (defining a confined aquifer as an aquifer that "is confined under hydrostatic pressure between two relatively impermeable beds, and in which the water level in a well drilled in the aquifer will rise above the top of the aquifer"); *see also* Heath, at 6; Price, at 10–11. If a well is drilled through the impermeable upper layer of the aquifer, the confining or hydraulic pressure within the confined aquifer propels water through the well toward the surface. *See Shurbet*, 242 F. Supp. at 741; *see also* Fetter, at 110. The water may rise a considerable distance above the top of the aquifer and may spout above the ground surface. *See* Fetter, at 110.

As an example, consider a U-shaped tube filled with water. If one were to attach a vertical pipe (or "well") in the center of the tube between the two raised arms, water would be propelled upward into the vertical pipe at the point where it is attached. The water in the pipe would rise as a result of the pressure until it reached a point where the hydraulic pressure equals atmospheric pressure.

Where a well is drilled into a confined aquifer, the well acts as a partial relief valve for the confining pressure in the aquifer. Water in the well will rise until the hydraulic pressure equals atmospheric pressure. If the water level in the well rises and spouts above the ground surface, the well is called a *flowing artesian well*. *See* Heath, at 6.

Despite their name, confined aquifers are not devoid of any connection to surface water or other water resources. *See* Bouwer, at 4–5 (relating that confined aquifers may transmit water vertically to surface waters, and vice versa, through an aquitard—a layer of strata less permeable than the aquifer, but not totally impermeable). Such aquifers must have a water source and often are recharged through lateral flow of water from recharge zones located at distant higher elevations, such as mountains or high plateaus, where the aquifer crops out on the land surface. *See* Bouwer, at 5. In addition, confined aquifers can themselves discharge into rivers and lakes at lower elevations. *See* Bouwer, at 6 (noting that "[h]illside seeps and springs occur where the aquifer and its lower impermeable boundary are exposed to the atmosphere at hillsides, canyons, etc.").

c. Nonrecharging Aquifer

Aquifers that receive little or no recharge can be described as nonrecharging aquifers. *Cf.* Fetter, at 288. The water in such aquifers is typically stagnant, with little if any flow. In most cases, these aquifers contain very old groundwater that has been trapped in a geologic formation for centuries or eons because the aquifer is physically isolated from sources of recharge, the surrounding formations are impermeable, or there is a paucity of recharge in an arid region. *See* Bouwer, at 7; Fetter, at 364.

Often found in arid and semiarid climates, other nonrecharging aquifers are important sources of water for many parts of the United States. The Ogallala Aquifer in the central United States is an example of an unconfined aquifer with relatively limited recharge. Located at depths ranging from a few meters to hundreds of meters below the surface, the water in this aquifer is estimated to be thousands to millions of years old. *See* Manjula V. Guru & James E. Horne, The Kerr Center for Sustainable Agriculture, *The Ogallala Aquifer* (2000), *available at* www.kerrcenter.com/publications/ogallala_aquifer.pdf. While the overlying strata are still relatively permeable, present-day recharge rates range from miniscule to nil. Buchanan et al., at 2, 5.

2. Water Table

The term "water table" generally refers to the upper limit of a saturated geologic formation (see Figure 1). *See Shurbet*, 242 F. Supp. at 740; *see also* Winter et al., at 6. This definition, however, is more applicable to unconfined aquifers. (See "unconfined aquifer" above.) A water table is more correctly described as the level in the saturated zone of a saturated geologic formation in which the hydraulic pressure is equal to atmospheric pressure. *See* Heath, at 4; *see also* 30 Tex. Admin. Code § 330.3(176) (describing the water table in the context of municipal solid waste as "[t]he upper surface of the zone of saturation at which water pressure is equal to atmospheric pressure, except where that surface is formed by a confining unit"). Thus, in an unconfined aquifer, the water table is represented by the top of the saturated zone of the geologic formation. In a confined aquifer (see "confined aquifer" above), however, the water table is evidenced by the level to which the water naturally rises in an unused well.

3. Functioning of an Aquifer

The "functioning" of an aquifer refers to how a particular aquifer works or operates as an aquifer. Aquifers typically store and transport water and dilute wastes and other contaminants; provide a habitat for aquatic biota; and serve as a source of fresh water and nutrients to aquifer-dependent ecosystems. Some aquifers even provide geothermal heat. Each of these is a function of an aquifer. All functions are dependent on the particular aquifer's hydrostatic pressure, hydraulic conductiveness, and mineralogical, biological, and chemical attributes. Moreover, those functions may be interdependent to the extent that the aquifer's continued operation depends on the continuation of the particular function or series of functions. *See generally* Heath, at 14–15 (describing the basic "functions" of groundwater systems).

4. Groundwater Flow

Aquifers and groundwater are sometimes mistakenly perceived as underground lakes or rivers. In reality, they are neither. In most aquifers, water is rarely stagnant (except in aquifers with no recharge) and tends to flow toward natural discharge sites, such as springs, rivers, lakes, lagoons, swamps, or the sea. *See* Bouwer, at 36 (asserting that "[u]ndergroundwater is almost always in motion"); Heath, at 20. Water in an aquifer resides in the pore spaces of a geologic formation similar to water in a sponge, where the water fills all the small holes. The material found in a geologic formation, though, is far less elastic or pliable than that of a sponge. Accordingly, water flowing through an aquifer does so by seeping through the available pore spaces.

One notable consequence of this water flow process is that the rate or velocity of flow is typically far slower than any water flow perceived on the land surface, such as in rivers and streams. Groundwater velocities commonly range from one meter per day to one meter per year. *See* W. Kenneth Hamblin & Eric H. Christiansen, *Earth's Dynamic Systems* 325 (Prentice Hall 10th ed. 2001); *see also* Heath, at 25 (noting that "[t]he rate of movement of groundwater is greatly overestimated by many people, including those who think in terms of groundwater moving through 'veins' and underground rivers at the rates commonly observed in surface streams. . . . It would be more appropriate to compare the rate of movement of groundwater to the movement of water in the middle of a very large lake being drained by a very small stream."). Although water generally flows at low velocity underground, an exception can occur in karst aquifers, such as the Edwards Aquifer. Karst aquifers generally consist of limestone. Because of the chemical composition of limestone (calcium carbonate), such aquifers are more prone to having their matrix dissolved by the water, which results in the formation of larger pores and cavities through which the water can flow at much faster rates. See Chapter 17 of this book regarding the Edwards Aquifer Authority.

The rate at which water flows in an aquifer is a function of hydraulic potential. *See* Heath, at 25. Hydraulic potential is the ability of an aquifer to transmit water. Hydraulic potential of surface water is primarily a function of gravity and the slope of the land surface. Although gravity plays a central role in determining the hydraulic potential of groundwater, aquifer porosity and permeability (the ability of the aquifer to transmit water), the gradient or slope of the groundwater table (or the hydraulic gradient in the case of a confined aquifer), and temperature also play a significant role in determining the rate at which water will flow through the geologic formation. *See* Heath, at 20–25. Although the rate of percolation into the subsurface and the flow of groundwater within aquifers are considerably slower than surface water flow, they are relatively consistent processes. *See* Price, at 17.

5. Aquifer Recharge

Aquifers may recharge from precipitation-soaked ground, from lakes and streams, and, to some extent, from other aquifers. *See* Bouwer, at 4–6 (explaining that seepage and draining from rivers and lakes connect unconfined aquifers to surface bodies of water and that water in confined aquifers is derived mostly from rainfall in higher elevations where the aquifer is exposed to the surface); Fetter, at 512 (noting that confined aquifers may recharge from other aquifers). A recharge zone is the area from which a body of water is recharged. Freeze & Cherry, at 194; *see* 30 Tex. Admin. Code § 285.2(22) (defining "recharge zone" in the context of the Edwards Aquifer as "[t]hat area where the stratigraphic units constituting the Edwards Aquifer crop out, including the outcrops of other geologic formations in proximity to the Edwards Aquifer, where caves, sinkholes, faults, fractures, or other permeable features would create a potential for recharge of surface waters into the Edwards Aquifer. The recharge zone is identified as a geographic area delineated on official maps located in the agency's central office and in the appropriate regional office, or as amended by Chapter 213 of this title."); 30 Tex. Admin. Code § 213.3(27). Significantly, certain human activities, such as irrigation operations, dike and canal building, and damming projects, may also recharge aquifers. *See* Winter et al., at 57, 68. Aquifer recharge is a function of both gravity and the permeability of the strata lying between the aquifer and the source of the recharge. As a result, aquifers can transmit to and serve as a source of water for lakes, streams, and other aquifers.

6. Aquifer Discharge

Most aquifers have natural discharge points that allow their water to exit the aquifer. Such natural discharge zones include springs, rivers, lakes, lagoons, swamps, and the sea. *See* Bouwer, at 293. Aquifers, however, may also be discharged artificially. A well, for example, is an artificial means of aquifer discharge.

a. Cone of Depression

Water from water wells is usually produced by the use of a pump intake lowered into a water well. *See* Heath, at 30 (relaying that the pump-intake action causes the water level of the well to fall). As a result of the pumping action, a pumping water well typically generates a flow of groundwater in the immediate vicinity of the well. The water converges radially from all directions on the well's intake pipe, resulting in a *cone of depression*—a curved, funnel-shaped depression in the water levels—centered at the pumping well. The largest drop in the groundwater level occurs in the center of the "funnel," that is, at the pumping well, and diminishes with distance from the pumping well. The shape and dimensions of the cone of depression—the amount of drop in the groundwater table at any given point around the pumping well—depend on the permeability of the aquifer material and the rate of pumping. *See* Heath, at 30–32.

b. Radius of Influence

The radial distance from a pumping well at which the drop in the groundwater table declines to nil is the *radius of influence* or the *radius of the cone of depression* for that particular water well at the specified rate of production. *See* Heath, at 30 (explaining that "because water must converge on the well from all directions and because the area through which the flow occurs decreases toward the well, the hydraulic gradient must get steeper toward the well"). Water outside the radius of influence (beyond the influence of the pumping well) does not flow toward the pump intake but rather in its normal flow pattern.

C. Surface and Groundwater Interaction

Surface water and groundwater are interrelated parts of a larger system and can interact in a range of ways. Water does not flow in only one direction; therefore, surface water can contribute to groundwater, and vice versa. As discussed above, groundwater and surface water are fundamentally interconnected in the hydrologic cycle. Understanding a water resource is incomplete without realizing the relationship between the surface and subsurface waters. Surface water percolates down into the ground to become groundwater. This water then flows laterally and eventually returns to the surface at a spring, the ocean, or other low-lying areas.

One of the more common routes of interaction is through streams. Streams can gain or lose water to the subsurface, or do both. This direction of flow is affected by many factors, including season, altitude, storm events, or local pumping. William M. Alley et al., *Sustainability of Ground-Water Resources*, U.S. Geological Survey Circular 1186, 30 (1999) [hereinafter Alley et al.], *available at* http://pubs.usgs.gov/circ/circ1186/pdf/circ1186.pdf. Lakes, wetlands, and reservoirs can have similar relationships with groundwater. Groundwater also discharges into the ocean in regions where there are low scarps and terraces and where surface and groundwater mix in the tidal zones. Winter et al., at 42. Estuaries, which are common in Texas, create an interface between the ocean and discharges of fresh water. The addition of fresh water from rivers and groundwater is important to the maintenance and health of an estuary. Larry McKinney, *Why Bays Matter*, *Texas Parks & Wildlife* 24–25 (July 2003) [hereinafter McKinney, *Why Bays Matter*], *available at* www.tpwmagazine.com/archive/2003/jul/ed_2/.

Relationships between surface and groundwater resources can vary in time and space. Price, at 10–11, 16. A river, for example, may discharge water into a related aquifer at one point of its course and receive water from groundwater at another, or a given stretch of a river may discharge into an aquifer during the autumn season and receive water in the spring. Understanding this association is important in water planning and anticipating water quantity and protecting water quality.

The interaction of water above and below ground extends beyond the movement between bodies of water. Groundwater flows laterally to areas of lower elevation before eventually discharging at the surface. Although this discharge can be into surface water bodies, it can also be in the form of springs or seeps. Springs occur where the water table intersects with the surface or where water from a confined aquifer is forced to the surface through fissures or fractures. Alley et al., at 43; William F. Guyton & Assoc., Texas Department of Water Resources Report 234: *Geohydrology of Comal, San Marcos, and Hueco Springs* 20 (June 1979), *available at* www.twdb.texas.gov/publications/reports/numbered_reports/doc/R234/r234.pdf. This means that a change in the water table or hydrostatic pressure can influence spring flow. If the water table drops below the surface, or if the hydrostatic pressure drops sufficiently, water in the spring ceases to flow. Springs often form the headwaters for rivers and can be an important water source as well as a cultural feature, especially in Texas. McKinney, *The State of Springs*. Therefore, their protection is intrinsic to the understanding and security of groundwater resources. See Chapter 5 of this book regarding conjunctive management and use.

1. Chemical and Physical Interaction

As water flows in both directions between the surface and the subsurface, chemical elements move with it. This transfer affects the supply of carbon, oxygen, nutrients, and other chemicals that enhance biogeochemical processes on both sides of the interface. When water enters the land surface, the chemistry of the soil is affected. The organic matter in the soil starts to degrade, lowering the pH of the water. Depending on the amount of time the groundwater remains in the ground, a range of chemical changes can take place. Winter et al., at 22–23. Groundwater chemistry cannot be separated between a surface water body and its interrelated groundwater.

Because of this interaction, contaminants can also be transported from one water resource to another, damaging the quality of both. This problem is exacerbated in a gaining stream (see definition below) when groundwater reductions decrease the surface water flow, thus further concentrating contamination in the stream. Alley et al., at 62. Almost all human activity can be a source of contamination. For example, agricultural fertilizers and pesticides can be as harmful to water quality as industrial discharges and by-products. Alley et al., at 60–61. Therefore, protection of water quality must take all related bodies into consideration.

2. Influent and Effluent Relationship

One of the primary ways that groundwater and surface water interact is through streams. Although this interaction can transpire in various landscapes, it occurs in three basic ways: (1) the stream can gain water from the groundwater, (2) the stream can lose water to groundwater, or (3) both can happen. Surface water resources hydraulically linked to an aquifer are often described as *influent* or *effluent* bodies of water, depending on the direction the water is flowing. *See* Fetter, at 58–59.

Water generally flows from higher elevation to lower elevation. An *influent*, or *losing*, stream or lake (see Figure 2) occurs when the groundwater table is below the bottom of a surface body of water and the soil is relatively permeable. In this situation, water percolates from the surface water body downward and recharges the underlying aquifer. Winter et al., at 9. In contrast, an *effluent*, or *gaining*, stream or lake (see Figure 2) results where the groundwater table is at an elevation higher than the intersected stream channel or lake and recharges the surface water resource. *See* Fetter, at 58–59. It is also possible that a stream can gain in some parts and lose in others. *See* Fetter, at 58–59.

This differentiation is important, especially in the context of water quality and contamination. For example, a polluted river that is effluent will not contaminate the related groundwater on either side of the river because it does not contribute water to the aquifer. Likewise, polluted groundwater on one side of an effluent river will contaminate the river, but will likely not affect the quality of the groundwater on the other side of the river.

Although seemingly straightforward, the relationship between rivers and groundwater can become complex. As explained, rivers that hydraulically link to an aquifer can be influent at one point of the river and effluent at another point with the same or a different aquifer. Winter et al., at 9. Moreover, a river that is influent during normal climatic conditions may temporarily become effluent during heavy rains and flooding, when the ground becomes saturated and the water table rises above the intersected river. Alley et al., at 30. Such changes can also be very localized—for example, where one side of a river is effluent and the other side is influent. Such conditions might occur as a result of heavy groundwater pumping on the second side of the river resulting in a localized lowering of the water table. Whether a river is influent or effluent at any particular point is dependent on various factors such as topography, amount and rate of precipitation, soil permeability, and hydraulic conductivity of the soil underlying the river, as well as human intervention. Alley et al., at 30.

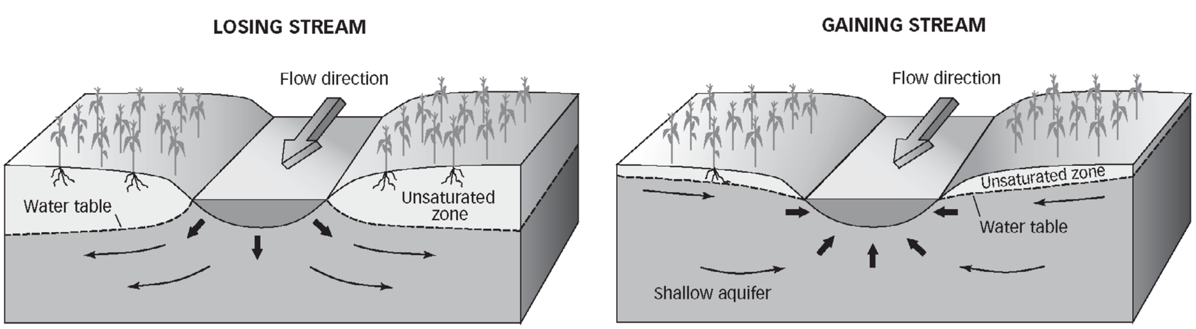

Figure 2. Aquifer-stream relationships showing an influent, or losing, stream at left and an effluent, or gaining, stream at right. Thomas C. Winter et al., *Ground Water and Surface Water, A Single Resource*, 1139 U.S. Geological Survey Circular 9 (1998), *available at* http://pubs.usgs.gov/circ/circ1139.

Groundwater can also interact with the surface water in lakes or reservoirs. A lake can receive groundwater inflow through its entire lake bed or through portions of the lake bed, or it can lose water to the subsurface through infiltration. Winter et al., at 18. Although this is similar to the stream dynamic, it is also different in several ways. Because the quantity of water in a lake is larger than in a stream, more water can be lost through evaporation than from infiltration, especially in arid climates. Also, deposits on lake bottoms and wetlands are different from those found on stream beds. This can affect water's ability to permeate the surface. Generally, lake sediments are not fine grained, particularly around their perimeters where wave motions remove fine particles, thus allowing water to flow freely between the surface and subsurface. Wetlands often have finer grained deposits and rooted vegetation, which inhibit water flow. Winter et al., at 21. Reservoirs are usually sited in stream beds so the water characteristics mirror those of rivers rather than lakes; however, over time, reservoirs can behave more like lakes. Winter et al., at 21.

D. Water Measurements

Water is measured using different units depending on the purpose of the measurement. For example, water can be measured for its rate of flow or storage capacity. The unit of measure typically used to measure the rate of water flow is *cubic feet per second* (cfs). A cubic foot of water contains 7.48 gallons. The cfs is computed by measuring the number of cubic feet of water that pass a given location in a second. Thus, a flow of 1 cfs over a 24-hour period produces approximately 1.98 acre-feet, or 646,317 gallons of water. The cfs measurement is typically used for assessing water flow rates in rivers, pipelines, canals, and other water conduits. A. Dan Tarlock et al., *Water Resources Management: A Casebook in Law and Public Policy* 6, 1037 (Foundation Press 5th ed. 2002) [hereinafter Tarlock et al.]; Joseph L. Sax et al., *Legal Control of Water Resources*, 18–19 (West 3d ed. 2000) [hereinafter Sax et al.].

Storage capacity for large water resources (such as reservoirs, aqueducts, canals, and rivers) is typically measured in acre-feet. An acre-foot is the amount of water that covers 1 acre of surface area to a depth of 1 foot. One acre is roughly the size of a football field, and 1 acre-foot of water is equivalent to approximately 325,851 gallons, or 43,560 cubic feet of water. It is also roughly the quantity of water used by an average family of five in a year at a rate of 180 gallons of water per person per day. Tarlock et al., at 6; Sax et al., at 18–19.

One notable exception to the use of acre-feet as a measurement is with large quantities of fresh water, such as the amounts provided by municipal water suppliers. Such supplies are often measured in million or billion gallons per day (mgd or bgd). Tarlock et al., at 6; Sax et al., at 18–19.

Table of Common Water Measurements and Equivalents		
1 gallon	=	8.34 pounds or 0.134 cubic feet
1 million gallons	=	3.07 acre-feet
1 million gallons per day	=	1.55 cfs or 3.07 acre-feet per day
1 cubic foot	=	7.48 gallons
1 cubic foot per second (cfs)	=	646,317 gallons or 1.98 acre-feet per day
1 acre-foot	=	325,851 gallons or 43,560 cubic feet

E. Effects of Human Activity

Human activity can severely affect the distribution, quantity, and quality of water resources both above and below ground. These impacts can be short term or long term and on a range of scales. Increased pumping, pesticide usage, and urban runoff can damage the water relationship above and below the earth's surface. Winter et al., at 54. This is most easily seen where excessive withdrawal depletes the water resource. For example, well pumping near an effluent stream can lower the water table in the immediate area around a well and thereby shift the stream-aquifer relationship to an influent relationship. *See* Heath, at 32–33 (describing the response of the groundwater systems to withdrawals from wells). The converse is also possible. Extensive dewatering of an aquifer can reduce or potentially stop spring flow, stream flow, or flow into a wetland. Alley et al., at 31; Votteler, at 845.

The impact of pumping on spring flow is especially important in Texas. Many springs in North and West Texas have disappeared due to aquifer dewatering. Springs in Central Texas such as Comal Springs and San Marcos Springs are a major source of municipal water, provide habitat to several threatened and endangered species, and offer a cultural tradition. The flow in these springs is directly related to the water level in the Edwards Aquifer, which creates a complex situation in which human pumping must be carefully monitored. *See* Votteler, at 845. See Chapter 17 of this book regarding the Edwards Aquifer Authority.

Texas has more than 350 miles of coastline. Texas State Historical Association, *Texas Almanac*, www.texasalmanac.com/topics/environment/environment. Coastal areas are an interface between the continents and the ocean. Alley et al., at 44. The health of the bays and estuaries can depend on water that emanates from underground. Maintaining spring and surface water flow protects the wildlife found at the coast, which is sometimes miles away from the headwaters. McKinney, *Why Bays Matter*, at 24–25.

Another significant impact of human activity is increased evaporation. This occurs in a number of ways, but primarily through the construction of reservoirs. Micheal Overman, *Water: Solutions to a Problem of Supply and Demand* 45 (Doubleday 1969) [hereinafter Overman]. In lakes or reservoirs, up to 25 percent of the water can be lost to the atmosphere, particularly in hot climates like Texas. Overman, at 45. Widespread pumping of groundwater for irrigation purposes also increases evaporation from the increased soil moisture. Any water gained by the atmosphere is water lost in another part of the hydrologic cycle, such as stream flow or aquifer storage.

Urban construction also affects water and its relationships. Increased impervious cover can greatly reduce groundwater recharge. Overman, at 51. Precipitation falling in municipal areas is generally channeled as runoff and treated as wastewater, preventing it from adding to ground or surface water resources as it would under natural conditions. In addition, pumping and piping of water from one basin to another or inland from the sea to meet water needs alter the natural system in an area. The extent to which society allows water resources to be affected by its actions depends on the importance placed on those resources.

V. The Value of Water

The following two sections offer a perspective on the value and ethics of water as a means of encouraging cooperation over the sound management of fresh water resources. Both sections rely heavily on Gabriel Eckstein, *Precious, Worthless, or Incalculable: The Value and Ethic of Water,* 38 Tex. Tech L. Rev. 963 (2006) [hereinafter Eckstein]. Although these are not legal or scientific principles, familiarity with these concepts is critical to the water professional who must daily make decisions about writing water legislation, drafting rules, issuing permits, entering water contracts, and dealing with a myriad of other water issues.

A. Valuing Water

The value of water is often expressed in terms of its numerical or economic worth. See Chapter 29 of this book regarding the economics of water. In 2009, for example, in addition to a base charge tied to the size of the water meter, the average Lubbock, Texas, homeowner paid $2.67 per 1000 gallons of water. Water Rate Ordinance No. 2009-O0018, City Council of the City of Lubbock, TX, adopted Mar. 9, 2009. Thus, Lubbock homeowners valued water at $2.09 per 1000 gallons of water (plus the base charge). Similarly, in 2004 in Medina and Uvalde counties, which overlie the Edwards Aquifer, irrigated cropland sold for between $3000 and $4000 per acre when water rights were included, while dry cropland without water rights sold for between $700 and $1200 per acre. Charles E. Gilliland et al., *Water Power, 11, No. 4 Tierra Grande,* Journal of the Real Estate Center at Texas A&M University (Oct. 2004), *available at* http://recenter.tamu.edu/pdf/1691.pdf. Here, landowners placed an $1800- to $3300-per-acre premium on the value of water. In both cases, water was treated as a marketable commodity and assigned an economic value.

Water, however, often defies such commodification efforts. The value of water can permeate the social fabric of peoples and communities and includes factors and characteristics that cannot easily be appraised. For example, the valuation of water may be related to the desire to maintain soil moisture levels, spring flows, and base flows in rivers and streams; a personal assessment of water's importance to human and nonhuman life; an exercise of belief related to faith or history; or the need to preserve a cultural heritage or way of life. Although not a comprehensive list of valuation methodologies, the process of valuing water is highly dependent on how the one conducting the valuation perceives water. Factors that can influence how water is perceived, and therefore valued, may include perspectives on life and the value of life itself; social and economic ideals; cultural, religious, and societal backgrounds and proclivities; and even politics. Ultimately, it must be recognized that the scales used to assess the price homeowners and landowners may be willing to pay for fresh water and those used for noneconomic valuation are often incongruous. Accordingly, to ensure that all perspectives are given their due regard, these disparate assessments must be reconciled to find some basis on which to fairly and justly allocate this singular resource.

1. Economic Valuation of Water

As noted above, in an entrepreneurial society, people tend to look at water as an economic good. Under this perspective, water is considered and valued in terms of its economic potential. It is deemed a commodity—a "thing" or good that is subject to market forces, that can be bought, sold, and owned, and whose value depends on supply and demand. Thus, in places where fresh water resources are plentiful and easily accessible, water should be inexpensive. Conversely, where water is scarce, the value of water should be directly related to what the market will bear. In its purest form, the commodification of water would be available only to those who could pay for it and only in quantities that they could afford. Accordingly, this valuation methodology may be most in harmony with capitalist-based societies, which prevail in much of the world. *See generally* Andrew Morriss, *Real People, Real Resources, and Real Choices: The Case for Market Valuation of Water*, 38 Tex. Tech L. Rev. 973 (2006).

2. Noneconomic Valuation of Water

a. Anthropocentric Valuation of Water

Under the anthropocentric perspective, the value of water is directly related to its irreplaceability as a fundamental component of life. Proponents of this perspective believe water has an intrinsic value that is incalculable and therefore it is beyond valuation. This position is grounded in the belief that life itself, at least human life, is sacrosanct and that the valuation of life is inappropriate, if not completely impossible. Just as the buying and selling of people is regarded by most as an inconceivable evil, under this perspective, so is the valuation of the substance that is so necessary for creating and sustaining life. The anthropocentric perspective is often at the base of arguments for the human right to water. *See generally* Salman M. A. Salman & Siobhan McInerney-Lankford, *The Human Right to Water* (World Bank Publications 2004) [hereinafter Salman & McInerney-Lankford]; Amy Hardberger, *Life, Liberty, and the Pursuit of Water: Evaluating Water as a Human Right and the Duties and Obligations It Creates,* 4 Nw. U. J. Int'l Hum. Rts. 331 (2005) [hereinafter Hardberger], *available at* http://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1037&context=njihr.

b. Ecocentric Valuation of Water

In a similar vein, water is regarded by some as an intrinsic component of the natural environment with a value that is incalculable. In contrast with the anthropocentric notion of the inviolability of human life, the value of water to the environment is grounded in an ecocentric perspective of life in which humanity is but a component of the natural environment. In this view, the life of all creatures, including but not limited to humans, is inviolable. Moreover, because water is a principal source of sustenance for all life, it is likewise regarded as sacrosanct and incapable of valuation. *See generally* Kerry Turner et al., *Chapter 5 Conclusions*, *in Economic Valuation of Water Resources in Agriculture: From the Sectoral to a Functional Perspective of Natural Resource Management* (U.N. Food & Agricultural Organization 2004), *available at* www.fao.org/docrep/007/y5582e/y5582e09.htm; Captain Paul Watson, Clarification on Where Director Paul Watson Stands on Various Issues, http://www.ecospherics.net/pages/wonw.htm.

c. Cultural or Traditional Perspective on the Valuation of Water

The cultural or traditional perspective of water valuation is dependent on individual or collective beliefs that water has a value more significant than that based on personal enrichment or sustenance. This distinct notion of valuation is typically related to a system of beliefs based on cultural, social, religious, or historical custom. The value of water becomes incalculable, at least in the economic sense, by its very nature of being abstract and ethereal and built on a foundation of tradition, social norms, or faith. Moreover, water is incapable of valuation because it is regarded as a blessing rather than a commodity. In some communities, water is considered the lifeblood of the earth, which should not be exploited or extracted to excess lest the earth be injured or killed. In other communities, water is sacrosanct to the extent that it is a gift of the creator, a gift that cannot be withheld from anyone in need. In still others, water defines the culture to the extent that it characterizes a people's identity, religious beliefs, ceremonial practices, and daily life. In most of these cases, water is regarded as an absolute necessity, not merely to maintain individual life but as a means of maintaining the life of the people. *See generally* Katosha Nakai, *Water: It Always Has Been; It Is; It Will Be—A Cultural Perspective on the Valuation of Water*, 38 Tex. Tech L. Rev. 1027 (2006); William Greenway, *Dominion and Domination: Living Life and Living Earth*, *in Symposium Proceedings: Precious, Worthless, or Immeasurable: The Value and Ethic of Water*, Center for Water Law & Policy and International Center for Arid & Semi-Arid Land Studies, Texas Tech University (A.C. Corrêa & Gabriel Eckstein eds. 2006).

B. Overcoming Valuation Differences

To a great extent, the above perspectives are described in absolute terms. Reality, however, is rarely based on absolutes, and perspectives often are combined to form unique viewpoints. For example, many environmentalists have adopted a combination of the ecocentric and economic approaches to valuation and created the hybrids of environmental and ecological economics. *See, e.g.*, James Boyd, *Procurement of Water's Ecosystem Services: An Economic and Ecological Perspective*, *in Symposium Proceedings: Precious, Worthless, or Immeasurable: The Value and Ethic of Water*, Center for Water Law & Policy and International Center for Arid & Semi-Arid Land Studies, Texas Tech University (A.C. Corrêa & Gabriel Eckstein eds. 2006). Although none of these perspectives can claim to be definitive, it is evident that they employ disparate and often contradictory methodologies that have the potential for fomenting conflict among the proponents of the respective approaches. This is particularly likely when the water resources assessed are inadequate to meet everyone's wants or needs.

A current controversy in West Texas, for example, over the possible sale of Ogallala Aquifer water to Dallas, San Antonio, and El Paso provides a clear illustration of disparate perspectives and value systems leading to friction among stakeholders, as described in Suzanne Schwartz, *Whiskey Is for Drinking, Water Is for Fighting: A Texas Perspective on the Issues and Pressures Relating to Conflicts Over Water*, 38 Tex. Tech L. Rev. 1011, 1021–22 (2006); Jerry Needham, *Water Offers Pour In to San Antonio*, *San Antonio Express-News*, June 22, 2004. In this controversy, economic values clashed over West Texas community sensibilities and environmental perspectives. Similarly, in the Klamath Basin of Oregon, where environmentalists and Native Americans have long challenged farmers, irrigators, and the government for greater instream flows, traditional and cultural valuation notions were at odds with environmental perspectives, and both conflicted with economic valuation ideals. *See* Jeff Barnard, *Fishermen, Farmers Divided on How to Share Water*, *Seattle Times*, Aug. 4, 2003, at B2.

Overcoming these fundamental and often ingrained viewpoints and methodologies is clearly not an easy proposition. Such perspectives are often at the core of disputes and greatly depend on personal perspectives; national interests; social and economic ideals; cultural, religious, and societal backgrounds; and politics. Moreover, they often serve as the basis for legislative and regulatory action and business decision making, as well as the justifications for aggravating controversies over limited fresh water resources. Common ground may be inconceivable, but it may be found in the ethics of water.

VI. The Ethics of Water

Ethics are fundamental to human existence. They are at the core of societal decision making and define what people and communities consider important as well as how people interact with one another. Ethics are the tacit rules of behavior and consequences that regulate people's lives, activities, and decision making. One author described ethics "as a socially accepted moral standard as to what you can do and what you cannot do (behaviour ethics) and/or a standard as what damage, pain, loss, poverty, thirst, etc. can be inflicted upon your fellow human beings (consequence ethics)." Poul Harremoës, *Water Ethics—A Substitute for Over-Regulation of a Scarce Resource*, Stockholm Water Symposium, Aug. 16, 2001, at 5.

In a sense, ethics are a structured system of principles, codes of conduct, or prime directives that aid humanity in determining appropriate conduct. To some extent, ethics can be both elective and prescriptive in that they direct people's actions toward what they should or ought to do and which values they should or ought to hold. To the extent that civil society can identify fundamental ethical bases related to fresh water, it can then begin constructing laws and policies that best reflect society's collective ideals of right and wrong.

A. Water Ethics in History

Water has been the focus of ethics in every corner of the world for millennia. Irrigation and other water management practices, for example, were the developmental cornerstone of numerous communities in the Americas, Asia, Africa, the Middle East, and elsewhere thousands of years before the Industrial Revolution. *See* Fekri A Hassan, *A Historical Perspective*, *in Water and Ethics* 11–15 (UNESCO 2004) [hereinafter Hassan], *available at* http://unesdoc.unesco.org/images/0013/001363/136341e.pdf. These communities formulated strict rules of behavior that governed the use and management of fresh water. *See* Hassan, at 47–49 (discussing principles of distribution, use, upkeep, and overall management dating back to the Code of Hammurabi 3,700 years ago). Cultures in arid parts of the world, such as Muslim communities, are especially noteworthy for developing allocation priorities for limited water resources. *See, e.g.*, Melanne Andromecca Civic, *A Comparative Analysis of the Israeli and Arab Water Law Traditions and Insights for Modern Water Sharing Agreements*, 26 Denv. J. Int'l L. & Pol'y 437 (1998). Considered collectively, water ethics have served as the foundation upon which every aspect of a society's management of fresh water resources is structured.

Water ethics reflect the relative importance water plays in people's lives and provide guidance in decision making related to the use, management, allocation, and protection of fresh water resources. Even the concept and the act of valuation, regardless of methodology, are fundamentally based on notions of good and bad, right and wrong. For example, communities that apportion fresh water based on historical use hold a water ethic that values prior and existing uses. In contrast, those that apportion water based on ownership rules value the property aspects of water. But both communities value water in relation to what they define as morally appropriate and correct. Thus, the valuation of water is but a function of water ethics in that valuation reflects the evaluator's belief of how water should be managed.

B. Identifying Universal Water Ethics

Ethics generally focus on individual conduct, yet they are profoundly influenced by societal norms and beliefs. Writing about the related notion of a "land ethic," noted philosopher Aldo Leopold explained that "[a]ll ethics rest upon a single premise: that the individual is a member of a community of interdependent parts." Aldo Leopold, *The Land Ethic*, *in A Sand County Almanac* (Oxford Univ. Press 1949). The extent to which that interdependence is taken lies at the core of the question of whether an ethic can be said to cut across diverse cultural, political, economic, religious, and national beliefs and proclivities. Yet, any effort to identify one or more universal water ethics is not an easy task. In fact, recent cases suggest that different societies have distinct viewpoints related to water management issues. For example, in 1992 the International Conference on Water and the Environment formulated a number of recommendations, including principle four, which states that "[w]ater has an economic value in all its competing uses and should be recognized as an economic good." *The Dublin Statement on Water and Sustainable Development*, International Conference on Water and the Environment (Jan. 1992), *available at* www.wmo.int/pages/prog/hwrp/documents/english/icwedece.html. This portrayal of water as an economic good generated considerable concerns in Islamic countries, which regard water as the source of all life and a free gift of God that could not be bought or sold. *See* Jerome Delli Priscoli et al., *Overview*, *in Water and Ethics* 8–9 (UNESCO 2004) [hereinafter Priscoli et al.], *available at* http://unesdoc.unesco.org/images/0013/001363/136343e.pdf.

One starting point in seeking universal water ethics, however, may be the fact that all individuals, communities, nations, and societies value water. The specific reasons that different societies treasure fresh water may be particularly significant because if common justification can be identified, it may serve as a basis for articulating shared ethical bases for water valuation. This in turn could evolve into a foundation for further cooperation on managing fresh water resources—especially in a transboundary context.

1. Life as a Water Ethic

Possibly the simplest and most obvious universal factor in valuing water is the value of water for human life. Water is absolutely fundamental to human life. It nourishes people in a way that sodas and dairy drinks cannot and facilitates health and well-being. In fact, the adult human body is composed of up to 60 percent water, while a human brain is more than 70 percent water and human lungs are about 83 percent water. *See* U.S. Geological Survey, *The Water in You*, *in The USGS Water Science School*, http://ga.water.usgs.gov/edu/propertyyou.html. Accordingly, it is easy to concede that water is universally valued for its life-giving and life-sustaining qualities. Combined with the broadly accepted notion that human life is invaluable and should be protected, a water ethic emerges: All human beings should have water in a quantity and quality that ensures and sustains life. The practical consequence of such an ethic would mandate that, regardless of any other objective, water for human life should be ensured and guaranteed in the quantity and quality necessary to maintain that life. *See* Eckstein, at 969.

It is noteworthy that this particular water ethic is basic and does not address the mechanisms for its realization. Rather, it is a simple statement designed to capture the fundamental and universal notion that everyone—regardless of cultural, religious, political, economic, or other background—values fresh water for sustaining human life. Whether there exists another identifiable water ethic related to the *provision* of water, however, is a separate matter. Such is the position argued by those who espouse the human right to water. *See* Salman & McInerney-Lankford; Hardberger.

2. Participation as a Water Ethic

Participation in institutions and the decision-making process is one of the fundamental rights upheld in most democracies. Thus, in a democracy and in the context of water management, such a right comprises an ethic to the extent that all stakeholders are afforded the opportunity to become involved in assessing a given situation and determining how fresh water resources might be managed and allocated. *See* Priscoli et al., at 16. Accordingly, it is important that the ethic of participation in water issues be substantial and applied at all levels of involvement. Moreover, it especially should be ensured and protected for those in society who are least able to assert their rights and interests and for whom water is vital to their fulfillment as humans. *See* Priscoli et al., at 16.

3. Equality as a Water Ethic

Equality is at the heart of the American experience and is enshrined in many of its constituent documents, including the Declaration of Independence. It is a notion that appeals to the near primordial sense of fairness and justice that most people harbor and that is at the core of civil society. The antithesis of discrimination, it is a principle intended and designed to apply to all people with regard to rights, opportunities, and the application of law. In this respect, in America, the ethic of equality applies to all aspects of fresh water and suggests that everyone is equally entitled to the water due them. In practical terms, the ethic of equality refers to the actual allocation of water as well as opportunities related to water, such as access to water, decision making affecting fresh water resources, and commercial and other prospects related to water. *See* Priscoli et al., at 16.

4. Stewardship as a Water Ethic

The ethical principle of stewardship reflects the understanding of a moral responsibility for creation. It both teaches respect for creation and establishes an obligation to use wisely all components of creation. Moreover, it offers a reminder that absent sound stewardship, the ability to achieve the full human potential, now and in the future, will likely be compromised. Without good water management, human potential and human dignity are diminished for all and denied for some. The practical consequence of such an ethic challenges people to consider and respect all interests and perspectives in the efforts to manage fresh water resources. It also binds people to formulate management schemes that ensure and promote the human potential of current generations without compromising those of future generations. *See* Priscoli et al., at 16.

C. Ethical Base for Water Law and Policy

The purpose of the above discussion is to encourage the sound management of fresh water resources by balancing and ensuring adequate water supplies for all stakeholders. Although different peoples, communities, and stakeholders often have disparate objectives for limited water resources, they often possess common ethical beliefs and values related to fresh water on which they can agree. And although the use of ethics is but one method for analyzing how fresh water resources are managed, it is a lens that, unlike other approaches, allows a more direct view of the social, environmental, cultural, and other values that are so important to stakeholder groups and people in general. By pursuing such commonalities, disputes can be replaced by cooperation.

Under this ethical lens, when considering how to pursue a water permit, a bulk water sales agreement, new water legislation, or a lawsuit challenging or defending a client's water rights, lawyers would endeavor to incorporate considerations of ethics and values into the decision-making process. Examples of questions and issues to consider might include:

- Who will the decision or planned action affect and how? Have those who may be affected been offered a voice in the decision-making process? Do they even know about the pending decision or action?
- What are all of the economic and noneconomic values involved in the decision or planned action? Have they been integrated into the cost-benefit analysis of the deal? Have they been given equal treatment?
- What are the consequences of the decision or planned action for the water resource? Will it leave adequate fresh water resources for future generations?

The integration of such ethics and values into the decision-making process offers a unique opportunity to seek common ground and to pursue compromise. Moreover, it permits the creation of a foundation on which to construct rules and regulations and business and court decisions that are inclusive and just, as well as principled.

VII. Conclusion

The field of water law is today an established and growing specialization whose importance is well recognized around the country. The reasons are quite clear: Water is critical, not only to human survival but also for other human interests and endeavors, including development, the environment, and recreation. Moreover, there is now a greater appreciation that while our water needs continue to expand, our water resources are finite. Accordingly, the sound management and regulation of terrestrial water resources are critical to ensuring both our present and our future. Without water, nothing is possible.

Water law, however, is a complex subject matter and requires a broad understanding of not only the law but also the science of water as well as people's relationship to this critical resource. Accordingly, water law today is an interdisciplinary practice encompassing a broad perspective that incorporates individual and community rights, environmental issues, commerce and economics, and other societal and legal concerns. Moreover, it is interdisciplinary in the sense that it requires a firm understanding of the science of water, including knowledge of the hydrologic cycle, groundwater flow regimes, agricultural practices, ground and surface water interaction, wetlands and dependent ecosystems, and much more.

Ultimately, the application of water law is a means to advance societal values and goals related to terrestrial water resources. It is a tool for bridging the gap between our societal water needs and the actual availability and distribution of the resource. The challenge we as water lawyers face is to practice water law in a manner that will ensure our clients' interests as well as those of society's in this precious and irreplaceable resource.