Water and the

In this driest of North American landscapes, water is not obvious, and perhaps not expected.

BY LAWRENCE R. WALKER AND FREDERICK H. LANDAU

The Mojave Desert is, by definition, a dry place. But much of the desert’s appearance today can be explained by both the absence and occurrence of water, past and present. The presence of seashells and fossils on top of desert mountain ranges provides evidence of a time when the Mojave Desert lay under the sea. Water-blasted canyons, playas, and underground rivers speak of a time in the more recent past when the Mojave Desert supported rivers and lakes, and the life those waterways maintained. To take liberties with a line from a Bob Dylan song, *Visions of Johanna*, the ghost of water howls in the bones of the landscape. The severe desert architecture that encloses canyons, especially slot canyons, has its watery past written all over it—the smoothly sensuous sandstone walls with their carved-out sockets like owl eyes are evidence of running water. And water still fashions the landscape—gradually, from gentle rains; catastrophically, from floods; permanently, from rivers, riparian zones, springs, and seeps; and ephemerally, from tinajas and playas.

About 11,000 years ago, water was abundant on this landscape, with an extensive drainage system of rivers and large lakes fed from retreating glaciers, snowmelt, and rainwaters of the mountains that ring the Mojave and Great Basin Deserts.

Three drainages, the Owens, Mojave, and Amargosa Rivers, all flowed at one point into Death Valley and its enormous Lake Manly—no longer extant, but once ninety miles long, eleven miles wide, and said to be 600 feet deep. It was fed by snowmelt and, indirectly, from the melting glaciers during the Pleistocene epoch. As one basin overflowed into another, a chain of lakes was created across what is now the desert.

In the northwest, the Owens River drainage starts on
the eastern slope of the Sierra Nevada Mountains. Owens Lake once spilled over into a basin to the south that became China Lake; then the water flowed east, creating Searles Lake and Panamint Lake before finally draining into Lake Manly. From the northeast, the Amargosa River drains the western side of the Spring Mountains from its origins on Pahute Mesa. Once there were two lakes flowing northward on this southwest drainage: Tecopa and Pahrump Lakes.

Finally, from the southwest, the Mojave River flows east out of the San Bernardino Mountains and used to feed Harper Lake, Lake Manix, and Mojave Lake. At that time, Lake Manix extended eighty-three square miles, covering present-day Afton Canyon, Troy and Coyote lake beds, and Cronese Basin. When Lake Manix spilled over, it created Afton Canyon. Rushing water, full of sediment, drained eastward and carved through the surrounding granite hills. This event likely happened more than once during the past 500,000 years. Continued extensions of this drainage eventually filled the basin that became Lake Mojave, just northeast of Lake Manix, in present-day Soda Lake and Silver Lake playas near Baker, CA. Today, under exceptionally wet weather conditions, Silver Lake is the end point of the Mojave River. However, in Pleistocene times, the Mojave River drainage joined with the Amargosa River drainage and terminated further north in Lake Manly at present-day Badwater, Death Valley. The proximity of these two drainage systems is apparent from the Salt Creek Hills Area of Critical Environmental Concern. Just to the north of Salt Creek Hills are the Dumont Dunes and the visible southern extension of an Amargosa tributary, as it trickles across the approach to the dunes. To its south is Silver Lake. The few miles in between are separated only by a slight rise in elevation. There is also speculation that the ancient Mojave lakes may have drained into the Colorado River via a chain of lakes to the southeast.

Today, there are three major river systems within the Mojave Desert—the Mojave, Colorado, and Amargosa Rivers—although none actually begins in the desert. Each has its headwaters in a region of water surplus where rains are intercepted and snows accumulate. The rivers then flow through the arid desert, often disappearing in low-lying areas. Such rivers are often called exotic rivers. There are two important tributaries of the Colorado River, the Mud-
The headwaters of the Mojave River begin high in the San Bernardino Mountains, where annual precipitation—primarily as snow, but also as rain—is forty inches or more. Spring and summer meltwaters supply the Mojave River with perennial water that flows north to the Barstow, CA area, before heading northeast to its terminus at Soda Lake. For most of its 110-mile run, the Mojave River flows underground, its surface waters lost to coarse and porous sands along its ancient course. Today, water flow is controlled by release from Cedar Springs Dam, that created Silverwood Lake. The Mojave River emerges permanently on the surface at a few points, most notably in Afton Canyon, by the railroad trestle bridge, and in Victorville—because of impermeable granitic structures. It occasionally becomes visible after intense rainstorms near Barstow, and at the internal basin of Soda Lake, where it adds to the lake bed’s shallow groundwater.

The Mojave River and its drainage system now provide the water supply (surface and ground water) to much of the western portion of the Mojave Desert, including Barstow, Victorville, and Hesperia. The river basin covers approximately 3,400 square miles. Because the river’s surface water is for most of its length only intermittently present, the residential and agricultural communities depend principally on ground water. This reliance has had a large impact on the underground storage system and resulted in overdrafts, or water that is “mined” at a faster rate than it is being replenished. The net result is a lowered water table and less surface water because the two are hydrologically connected.

The Colorado River enters the Mojave Desert from northwestern Arizona and runs south along the border separating Arizona and Nevada, in the easternmost Mojave Desert, before largely disappearing prior to reaching its natural outlet in the upper end of the Gulf of California. The river had only a marginal influence on the pre-human natural history of the Mojave Desert due to its location near the far edge of the eastern border of the desert, but it has had a huge influence on human activity in the American Southwest. The river’s corridor was the site of much of the indigenous habitation and activity within the Mojave Desert, providing resources to sustain permanent, sedentary cultures, rather than the semimigratory patterns of other tribes that were located farther from a large, permanent water source.

The Amargosa River—the river of bitter waters, as its name suggests in Spanish—resembles the Mojave River as a river of intermittent surface flow. Its 185-mile serpentine course begins near Pahute Mesa, then drains south from the Spring Mountains, the Nevada National Nuclear Security Site, and the Amargosa Valley, before disappearing to the north, below the salt pan of Badwater Lake in Death Valley. The drainage area also includes the thermal springs near Shoshone and Tecopa. The river basin covers about 5,500 square miles, part of the larger Death Valley Regional Flow System (17,000 square miles), and it includes small rural communities, mining operations, agricultural areas, Ash Meadows National Wildlife Refuge, Death Valley National Park, and the Amargosa Opera House in Death Valley Junction. The riverbed is mostly dry, but there are short reaches that flow seasonally, such as at Beatty, Amargosa Valley, and Tecopa. It is most notably manifest in the fragmented surface waters of Ash Meadows. The bitter waters of the Amargosa River refer to the alkali left behind by evaporation of the river and the suspended salts still found in the remnant pools left behind by the drying climate. The region is predominantly calcareous (calcium-rich), with limestone and dolomite outcroppings, and the waters and soils are largely saline.
The Amargosa River is an ancient river with evidence of indigenous habitation that goes back ten thousand years. We do not know precisely what impact ancient native populations had on the river, but we can infer from artifacts that the people were hunter-gatherers with the likelihood of limited agriculture, featuring corn, beans, squash, and sunflowers that were irrigated by nearby spring waters. The people also managed and harvested the dense mesquite stands for their pods and wood. Anthropological speculation suggests that native use was unobtrusive and its impact minimal. The first major impacts on the environment of the area were mining—clay from 1916–1940 and peat in the 1960s—in the Carson Slough, a tributary of the Amargosa River and the primary drainage in the Ash Meadows National Wildlife Refuge ecosystem.

Ash Meadows is an anomaly because it is a rare wetland in a very dry place and, consequently, hosts many organisms. Fish, such as the Devils Hole pupfish, *Cyprinodon diabolis*, and invertebrates, including the Devil’s Hole Warm Spring riffle beetle, *Stenelmis calida ssp. calida*, once occupied a broad range of waterways within the region, when the basin was lush and rivers and lakes supported an abundance of life. In the subsequent warming and drying climate of the past ten thousand years, these waterways began to dry up, and those species that did not go extinct became stranded in small, isolated pools and springs.

Over the course of hundreds or thousands of years, such species as the Devils Hole pupfish adapted to their unique habitat and began to diverge genetically and morphologically from their ancestral stock. Although there are about 120 species of pupfish (thirty in the southwestern United States alone) the Devils Hole pupfish lives in a very restricted fragment of its former range. Small populations
are generally subject to a high likelihood of extinction due to a number of factors, including low genetic diversity and the introduction of novel diseases, making them less able to adapt to a changing environment. In addition, such a restricted environment can be highly vulnerable to disturbances, such as floods, earthquakes, droughts, lowered water table, and to introductions of nonnative, invasive species. These disturbances have the potential to kill off the entire population of organisms and, in these cases, an entire species. For example, one individual of the invasive American bullfrog was removed from a spring in Ash Meadows with eight native Amargosa pupfish in its stomach. Similar scenarios play out elsewhere in the Mojave Desert with other species. Harsh, isolated environments can be breeding grounds for species that are genetically unique, restricted in habitat, and live nowhere else. Ash Meadows is home to thirty endemic organisms, including vascular plants, invertebrates, fish, and one mammal, the Ash Meadows montane vole, *Microtus montanus nevadensis*. Another vole, the Amargosa vole, *Microtus californicus scirpensis*, is endemic to the fragmented wetlands in the Tecopa area of the Amargosa drainage.

The Muddy and Virgin Rivers, tributaries to the Colorado River, also support many endemic species. The Muddy River in Moapa Valley begins in White Pine County in northern Nevada and, since the construction of the Boulder Dam, drains into Lake Mead, an impoundment of the Colorado River. Like the Mojave and Amargosa Rivers, the Muddy River is part of a discontinuous waterway—138 miles long—that has pockets of isolated springs and flows along its course. The Virgin River—162 miles long—begins in southern Utah and also drains into Lake Mead and the Colorado River. It flows through dramatic canyons in both Zion National Park and the Virgin Narrows; the Old Spanish Trail once followed part of it. There are also springs along the Virgin River, but there is generally more consistent water flow in the Virgin than in the Muddy River. The Muddy and Virgin River drainages are home to a variety of rare and endangered species, including the minnow-like Moapa dace, *Moapa coriacea*, and the slightly larger Virgin River chub, *Gila seminuda*. Because these species and habitats are already vulnerable, they face constant pressure from further depletions of the water table for agriculture, power stations, resorts, and other diversions.

It would be a mistake to think of these rivers and wetlands only as fragmented remnants of a once larger system that has contracted and left behind isolated species in a series of lonely traps. In fact, these riparian areas have
mostly done the opposite: they have enabled humans and other animals to migrate across inhospitable stretches of the desert that may have otherwise been inaccessible. The rivers are also corridors for plant migration, because many riparian plants disperse their pollen and seed via wind or moving water. Ash Meadows, for example, is not only a refuge for endangered fish, but an extensive marshland surrounded by surface and near-surface water. It gets its name from the scattered ash trees that line these waterways, fed from the nearby groundwater.

Riparian zones occupy the moist transition between wet, aquatic environments such as rivers and dry upland zones. Viewed from above, riparian strips provide a narrow green ribbon, dramatically distinct in vegetation and wildlife from the surrounding upland terrain. Riparian zones support a conspicuous assemblage of plants and animals, which may include cottonwood, willow, seep willow, mesquite, common reeds, and a wide variety of other woody and nonwoody species. In this sense, we often “see” water in the desert indirectly, being first alerted to it by its associated vegetation.

Water is the most limiting factor to the survival of organisms in the desert, and riparian corridors are often referred to as “ribbons of life” because of their biodiversity and the vegetation that the waters can sustain. Riparian zones ameliorate the privations of the dry upland with dense vegetation that provides protective cover and shade, lower surface temperatures, breeding and nesting sites, food sources, and shelter against predation. These zones, including wetlands such as marshes, also act as buffers against flooding. The riparian zone slows down the velocity of runoff that enters the river, thereby reducing erosion and stimulating riparian vegetation rather than scouring it off. Riparian zones make up less than 1 percent of the land in the western United States, and only 0.4 percent of arid lands, yet they support the greatest density of plant and animal populations in the arid lands. Because of the favorable habitat that permanent water creates, plant structures need not be limited to the constraints that the desert ordinarily imposes. It might be said, then, that riparian zones represent the desert when it is most unlike itself.

Riparian zones are not limited to areas with permanent flowing water; they also include “dry riparian” zones, or arroyos. Although surface water in these channels is contingent upon recent precipitation, soil moisture in dry riparian zones is nevertheless higher than in the adjacent desert upland areas, and this moisture supports a flora and fauna distinct from the adjacent drier area. Species such as desert willow, catclaw acacia, cheesebush, rabbitbrush, and many others are characteristic of desert arroyos. Because of their unique characteristics and their distinct flora and fauna, riparian zones may be considered ecological islands.

Watering holes, or springs and seeps, were precisely mapped by indigenous people, who occasionally sang of them as part of a song cycle, a mental map of the elaborate network among water locations. Springs form where the underground aquifer pushes to the surface due to impermeable layers below that inhibit further infiltration. These upwellings of groundwater often occur in fractured, unconsolidated rock layers or faults. It is the peculiar geology of the western United States that causes the greatest concentration of springs to occur there, as compared to the geology of the country’s eastern and midwestern areas. Springs vary from small, low-volume seeps near rocky escarpments to large flows of underground rivers. There are many such springs throughout the Mojave Desert.

Hot or thermal springs—where the water has been warmed by contact with hot magma rocks far below the surface and may have a high percentage of dissolved minerals and carbon dioxide—can be an oasis for thermophiles, or extremophiles, that can typically survive in water that is 113°F to 176°F. There is often an abundance of bacteria and algae.
Springs can also be the last remaining refuge, or paleorefugia, for such rare species as pupfish, dace, and poolfish.

Tinajas are surface depressions in bedrock that has been carved out by gravel-laden water flowing from springs or rainwater coming off rock escarpments. In Spanish, the word tinaja refers to an earthenware jar, and tinajas are rock basins that capture fresh surface water. They are important sources of hydration for local wildlife, such as desert bighorn sheep, coyotes, bees, and dragonflies. Although they range in size and can be very small, there may be hundreds of tinajas in a given mountain range, providing thousands of gallons of water. These water holes are also important to the life cycle of some desert crustaceans, such as tadpole shrimp, water fleas, copepods, and microscopic rotifers—all collectively considered zooplankton. Standing water in this climate lasts for only a short time after a rare rain. Therefore, these invertebrates exist as dry embryos that can persist in a dormant state for years, waiting out the absence of water. When the right circumstances arrive, they become active and go through their life cycle in a matter of days. This ability to go dormant for long periods is a very opportune adaptation to a climate of unpredictable rainfall. In fact, if water were present all the time the zooplankton would not survive because they would be eaten by other organisms. Additionally, in the dry state of dormancy, embryos are readily distributed to new sites by wind or by attaching to the bodies of visiting wildlife.

Playas—Spanish for “beaches”—are striking features of the desert landscape, especially when viewed from above. They are dry lake beds that periodically fill with water. They also are areas with a high water table, and therefore store water in an arid land with few permanent rivers and lakes. Playas are vast, empty, flat places that contrast conspicuously with the more varied topography of the surrounding desert. In fact, they are some of the flattest natural topographical features on Earth. Playas are terminal, undrained basins of rivers and floodwaters, or the remnants of lakes and marshes of the last glacial period. They have become the repository of the fine silts, salts, and clay sediments that were left behind from evaporating lakes and from rainwater flowing down from higher elevations. High temperatures lead to high evaporation rates. Consequently, the accumulated fine particles and minerals are full of soluble salts and create soils that are compact, with little percolation, low oxygen levels, and extremely high salt concentrations. Playa soils are generally basic, with a pH of 9–11, poorly aerated, and saline, with concentrations of salt up to 35,000 parts per million (3.5 percent).

Playas are integral feeding and resting places for birds. Diversity in many of these lake beds is high, with migrating and winter residential birds. At Owens Lake alone, more than 100 bird species and over 45,000 individual birds have been recorded, including many species of ducks, geese, and shorebirds. Soda Lake also hosts significant numbers of waterfowl, herons, egrets, sandpipers, owls, warblers, sparrows, and orioles.

The crystallized evaporites (alkali salts) that sprinkle the playa surface with white give the impression of a snowfield in 100°F-plus weather. The evaporites are most developed on playas with a high water table, due, in part, to a consolidated basin floor with little leakage to the groundwater below, and poor drainage. In summer months, when the evaporative pull of the atmosphere is greatest, the resistant salts remain behind on the lake bed surface. If you walk out on these playas, you might lose your boots to the great sucking power of the wet, adhesive soil below. Soda Lake, and similar playas such as Searles and Bristol Lakes, typify this slurpy, salt-encrusted playa.

There is another kind of playa that is more solid, drier, and perhaps less dramatic-looking because it lacks a saline frosting. Playas such as Silver Lake and Ivanpah Lake have
significant ruptures in their basin floors, allowing accumulated water to drain below, recharge the aquifer, and lower the water table. The subsoils of these playas are comparatively dry and compacted. However, all playas are former lake beds and with a period of rain can get wet and become more difficult to traverse.

Another characteristic of playas is the relative absence of vegetation, even within a desert known for its scarcity of vegetation. As with other playas in the Mojave Desert, Soda Lake is fringed by a specialized band of vegetation, characterized by plants known collectively as halophytes that are adapted to grow in saline areas. The drier playas, however, generally have a different community of plants. Rather than salt tolerance, plants on the playa floor are more adapted to drought tolerance, and the interior of the lake is without vegetation. Salinity increases from the margins of the playa to its interior, and salt accumulations, toxic to most plants, are generally thought to be second only to drought in limiting the activities and distribution of desert plants. There is often a corresponding decrease in particle size from the margins of the lake bed to its interior, with increasing accumulations of small particles in the interior. These smaller particles reduce the ability of water to flush salts below the root zone, as occurs in the sandier, more porous soils at the playa’s edge.

But even these relatively barren interiors are not devoid of life. Clays swell when wetted and refuse to absorb more water. Additional water, having nowhere to go, pools. When rainwaters come to these lake beds, the playa reinvents its Pleistocene past and becomes a real lake again, a shimmering sheet of shallow water. And as we saw earlier with tinajas, this apparently lifeless spot comes alive again with many zooplankton.

Contributing to plant distributions on playas is cold air drainage, which occurs when cold air masses flow downslope at night and displace warmer air upward onto the slopes. When the cold air drops into a basin, especially a closed basin ringed by mountains, it creates a temperature inversion. It is not unusual to find cold-sensitive plants (ordinarily found at low elevations) higher up in the surrounding slopes and cold-hardy plants (ordinarily found at higher elevations) on the playa surface. Playa vegetation must, therefore, survive relatively high levels of salinity, low oxygen levels, and temperature inversions to persist in a basin environment.

As a closing observation, the future of the natural resources of the Mojave Desert is hard to predict. Certainly, challenges lie ahead as the region likely becomes hotter and drier but possibly sees more frequent summer rains. Depending on their intensity and duration, these monsoonal rains might lead to increased erosion. Organisms that can move rapidly enough will move north, or to higher elevations. Whatever conditions prevail, we hope that as many as possible of the myriad desert organisms and their ecosystems remain intact. The Mojave Desert is a spare place. The land will not support the people, animals, and plants that other lands can. But it is a place where one can breathe deeply and be unhurried. As Joseph Wood Krutch has written, deserts are a place where one kind of scarcity is compatible with, and maybe necessary for, another kind of plenty.

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Lawrence R. Walker is a professor of plant ecology at the University of Nevada, Las Vegas. He is the (co)author or (co)editor of nine previous books, including The Biology of Disturbed Habitats. Frederick H. Landau is a research associate at the University of Nevada, Las Vegas.