Introducing **Terminal Lakes**

Joe Eilers and Ron Larson

Study Lakes

Lakes tend to be among the more ephemeral features of the landscape and generally are formed and disappear rapidly on a geological time frame. However, to see groups of lakes disappear within a lifetime is typically not a natural phenomenon. Here in Oregon, we've witnessed the desiccation of what was formerly a 16-mile-long lake in a little over a decade. *Endorehic lakes*, commonly referred to as *terminal lakes* because they lack an outlet, are among the most vulnerable of lakes to human intervention. Because terminal lakes are usually located in arid environments where water is extremely valuable, they are the first to lose among the competing forces for water. But that doesn't have to be the case. In some respects, terminal lakes are far easier to restore than eutrophic/hypereutrophic systems. No expensive alum treatments, no dredging, no chemicals . . . just add water and life returns: but as those in West know, "Whiskey is for drinking; water is for fighting over." And fight we must.

In this issue of *LakeLine*, we describe a series of terminal lakes in the western United States starting with the least saline lake among the group, Walker Lake, and ending with Lake Winnemucca, which was desiccated in the 20th century (Figure 1). Like all lakes, each of these has a unique story to relate with different chemistry and biota. The loss of Lake Winnemucca is an informative tale, but it is not necessarily the inevitable outcome for these western terminal lakes.

There are successful templates, such as Pyramid and Mono lakes to serve as guides for how these lakes can be saved or restored. The key involves local effort to bring the problem to the attention of a wider audience and reach a solution that ensures adequate water to save the resource. And what is there to save?

Figure 1. Terminal lakes in the western United States described in this issue.

These terminal lakes are among the most productive habitats on the continent, and are especially important to waterbirds, such as avocets, gulls, stilts, and various small shorebirds like phalaropes, during migration when the birds replenish fat reserves. For waterbirds, many western terminal lakes provide food in the form of easily taken brine shrimp and alkali flies, both of which can be highly abundant. As a result, many western U.S. terminal lakes attract large numbers of shorebirds (Table 1). The Salton Sea and adjacent

Table 1. Examples of Western U.S. Terminal Lakes that are Key Shorebird Sites

Site	*Approximate Peak Shorebird Numbers in Thousands*
Great Salt Lake, UT	250-1,000
Lake Abert, OR	100-300
Salton Sea, CA	100-250
Lahontan Basin, NV	100-250
Mono Lake, CA	50-100
Goose Lake, CA & OR	30-50
Summer Lake, OR	30-50
Harney Basin Lakes, OR	30-50
Klamath Basin Lakes, CA & OR	20-30

Source: Oring et al. 2009; www.ebird.org

areas in southern California provides habitat for nearly 400 species of birds and is an important wintering site for some waterbirds. Lake Abert, a hypersaline lake in southern Oregon, hosted several hundred thousand Wilson's phalaropes, a small migratory shorebird, until the salinity got too high for its primary food, brine shrimp, in August 2013. The Great Salt Lake, one of the world's largest saline lakes, also supports an abundant bird population. Although fish are largely absent from the lake, the state of Utah derives millions of dollars in revenue annually from managing another type of "fishery" for brine shrimp cysts (eggs).

Lake Trajectories

And what happens when we fail to protect these important lakes? The story of Lake Owens describes the costs to society when the inflow to a major terminal lake is diverted to Los Angeles, leaving behind a playa that is now the single largest source of air pollution (from particulates) in the United States. Mono Lake escaped a similar fate when a group of folks intervened and halted the City of Los Angeles from desiccating this lake.

A similar approach was employed to slow the salinization of Walker Lake, NV. Lawsuits filed against the USEPA and the state of Nevada under the Clean Water Act forced the agencies to establish a TMDL for Walker Lake based on total dissolved solids (as a surrogate for salt). In both cases, the plaintiffs employed a powerful legal principle, the Public Trust Doctrine, which recognizes that government entities have a responsibility to protect resources that belong to all of us (McClurg 2005). Expect to see this legal strategy applied in upcoming conflicts involving highly flawed western water laws and protection of terminal lakes.

The current trajectory of saline lakes is largely toward desiccation (Figure 2). The combination of diversion of inflows and climate change presents two powerful forces that cause many terminal lakes to disappear. As shown in Figure 2, the longer the line and the steeper the slope the more likely the terminal lake will become a playa (dry lake bed). Even the very deep saline lakes are not immune (c.f. Walker Lake), but they do offer additional time to seek action and prevent loss.

A World-Wide Problem

Although this issue of *LakeLine* presents selected lakes from the western United States (there are dozens of others that we couldn't include in this issue), terminal lakes around the world are in jeopardy caused by diversions and changes in climate. One of the most visible and tragic cases of shrinking terminal lakes is the South Aral Sea, which is now only 25 percent of its former area. Urmia Lake, an enormous lake in Iran, is faced with similar problems, although efforts are underway to secure additional sources of freshwater for the basin (Zarghami 2011). Scores of terminal lakes in the interior of

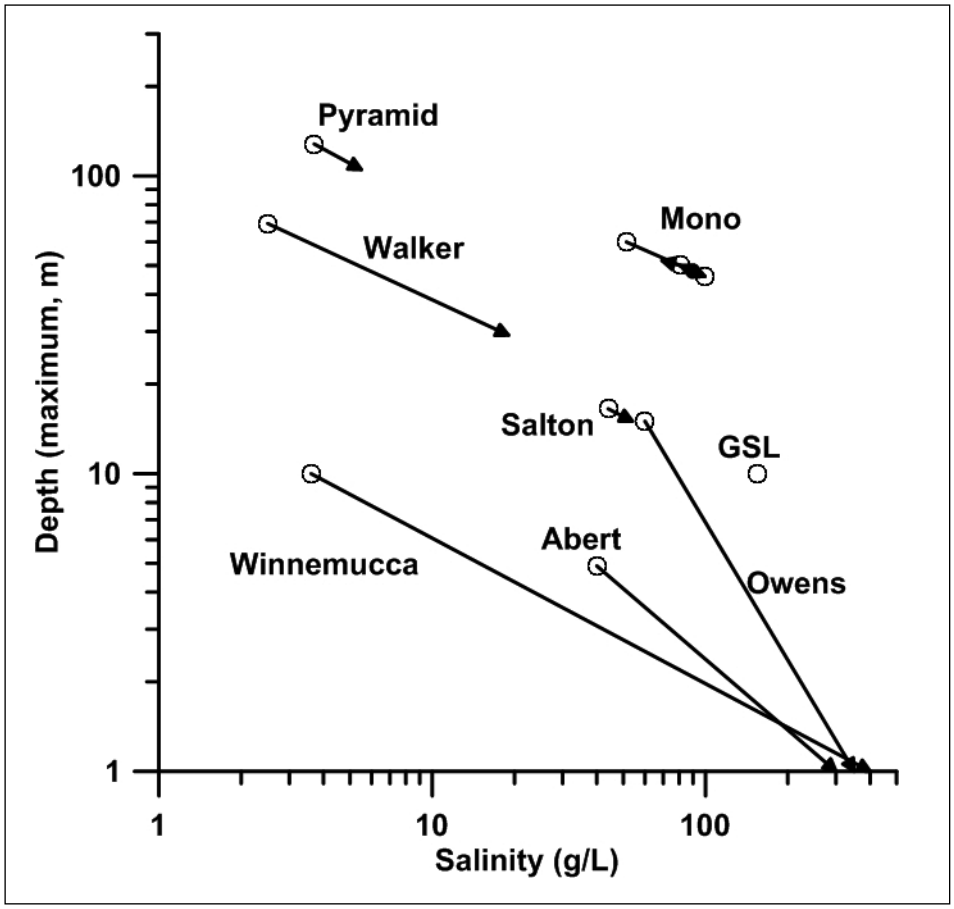

Figure 2. Vector plot of the terminal study lakes showing changes in maximum depth and salinity. The circles denote historical conditions and the arrows represent current conditions. Mono Lake with the reversing arrow is the only one of the study lakes on a path to recovery, although Pyramid Lake has stabilized. The intersection of lakes Winnemucca, Owens, and Abert with the 1 on the Y axis represents slightly different conditions for each of these lakes. Lake Winnemucca is totally dry except for transient puddles left by rainstorms. Owens Lake is dry throughout much of its former lake bed, with shallow brine ponds covering part of the lake bed, and a small remnant freshwater pool on the west side of the lake. Lake Abert, as of this writing, is nearly desiccated, with a small pool of red brine in the deepest portion of the lake. The Great Salt Lake (GSL) has shown considerable fluctuations in the last 150 years, largely associated with wet and dry periods, but no discernible trends.

China have disappeared and others are receding rapidly (Liu et al. 2013). Africa and Australia are also experiencing accelerated desertification and loss of terminal lakes (Williams 2001). Lake Chad, once the fourth-largest lake in Africa, has shrunk so rapidly in the last several decades that it has been classified as an ecological catastrophe by the United Nations. Specialized biological communities that evolved with these water bodies are jeopardized as well.

Enjoy these stories from the West and if you want to help protect or restore some of these resources, there are many avenues for you to participate, some of which are listed below.

Walker Lake.
www.walkerlakenv.org

Salton Sea
www.saltonsea.ca.gov/

Mono Lake
www.monolake.org

Great Salt Lake
http://www.fogsl.org/

Lake Abert
www.lakeabert.org

Owens Lake
http://www.ovcweb.org

Pyramid Lake
http://www.pyrimidlake.us

Lake Winnemucca
(no advocates)

For further reading (and movie) enjoyment about terminal lakes – and LA water) consider the following:

Chinatown. 1974. Movie starring Jack Nicholson, Faye Dunaway, John Huston. Roman Polanski, director. Robert Towne, screenplay. Paramount Pictures.

Hammer, U.T. 1986. "Saline Lake Ecosystems of the World." *Monographiae Biologicae* (Book 59), Dr. W. Junk Publishers. 632 pp.

Hoffman, A. 2014. *Mono Lake: From Dead Sea to Environmental Treasure*. University of New Mexico Press. Albuquerque.168 pp.

Melack, J.M., R. Jellison and D.B. Herbst (Eds). 2001. *Saline Lakes. Developments in Hydrobiology 162*. Kluwer Academic Publishers. Dordrecht. 347 pp.

Reisner, M. 1993. *Cadillac Desert: The American West and Its Disappearing Water*. Revised Edition. Penguin Books, New York. 583 pp.

Stringfellow, K. 2011. *Greetings from the Salton Sea: Folly and Intervention in the Southern California Landscape, 1905-2005.* Center for American Places, Incorporated and University of Chicago Press. Chicago. 152 pp.

References

Liu, H., Y. Yin, S. Piao, F. Zhao, M. Engelsand and P. Ciais. 2013. Disappearing lakes in semiarid northern China: drivers and environmental impact. *Environ Sci & Technol*, 47: 12107−12114.

McClurg, S. 2005. Remnants of the past: Management challenges of terminal lakes. *Western Water,* pp. 4-13.

Oring, L.W., L. Neel and K.E. Oring. 2009. Intermountain West Regional Shorebird Plan. Intermountain West Joint Venture. Missoula, Montana. 55 p.

Williams, W.D. 2001. Anthropogenic salinisation of inland waters. *Hydrobiologia*, 466:329-337.

Zarghami, M. 2011. Effective watershed management; Case study of Urmia Lake, Iran. *Lake & Reserv Mgmt*, 27:87-94.

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Ron Larson, a recently retired aquatic biologist with the U.S. Fish and Wildlife Service, is striving to bring attention to the loss of key shorebird habitat at Lake Abert, Oregon (photo credit, Kathy Larson).