

Utah Lake: A Few Considerations

LaVere B. Merritt

The following are a few observations and comments concerning Utah Lake—based on my 40 years in Utah Valley as a teacher, researcher, environmental engineer, consultant and citizen. At the end of this paper, note the short overview of water quality and pollution issues, a tabulation of the lake's water balance, and a plot of lake levels and salinity for the 1930-2007 period.

Utah Lake overview. Utah Lake is a major physical feature and unusually complex ecological system covering much of Utah Valley—The lake is integrally linked to the Valley and those living here. Attitudes towards the lake range over an interesting spectrum—from “worthless stinky pond” to “priceless natural resource.” Overall, public consensus favors persistent pollution-control efforts and continuing reasonable steps to protect the lake and its tributaries. Intense competition to use and enjoy the lake and its resources for many different purposes is confronted by its rich ecological nature that contests many use and development ideas—it seems that the use of Utah Lake resources will always feature complexity and controversy.

What is Utah Lake's natural setting? Utah Lake is a shallow, basin-bottom lake in a semi-arid climate. The lake is naturally turbid, slightly saline, and supports a very productive (eutrophic) ecosystem. In most of its physical and chemical aspects (e.g., water quality), it appears that the lake has not changed dramatically since its ecosystem stabilized after being formed as Lake Bonneville last receded about 10,000 years ago—as the climate slowly warmed in the early stages of the current cyclic global-warming period. When considered in perspective, it is sobering to realize that over hundreds of thousands of years, huge lakes have cyclically filled the Great Basin, sometimes accompanied by massive glaciers reaching down from the mountaintops—with dry valley land and habitable conditions, like we have today, occurring occasionally between these inhospitable periods.

Utah Lake exists because of geologic fault movements that cause earthquakes. The last large faulting and major earthquake(s) under Utah Lake occurred about 8,000 years ago. It deepened the main lake—making the middle part 20 feet deeper in some areas but only 3 to 10 feet deeper in most areas. An estimated 15 to 20 feet of sediments have deposited on the lake bottom since that time. This means that the lake is likely a few feet shallower overall than it was before that large faulting episode. If that fault movement had not occurred, the lake would now just be a small, shallow, swampy pond—a small fraction of its current size.

Since pioneer settlement about 150 years ago, water quality in the lake proper has probably not experienced large changes. However, land use changes, water diversions, and introduced plants and animals have caused big changes in ecosystems in and around the perimeter of the lake, as well as in and along inflowing tributaries. Concurrently, water quality in many of the lake's surface tributaries has deteriorated somewhat; however, much of this degradation is moderated by natural processes as these waters flow along their courses and out into the lake.

In the past, lake outflow was controlled by lake depth relative to a rock sill about 7 miles downstream from the lake on the Jordan River at Indian Ford Park. Had there been greater fault-movement than what occurred, the lake might not exist, or it might be much deeper, depending on the relative vertical movement of the lakebed as compared to this natural rock-sill.

This rock sill was removed over 20 years ago when the Jordan River channel was dredged to increase capacity following very high lake levels and flooding of the 1983-85 period. Now, when outlet gates are open, flowrate is determined by the lake depth and the elevation of the irrigation diversion works on the Jordan River about a mile downstream from Indian Ford. The channel dredging and sill removal increased the unimpeded outflow about 100% at compromise elevation (from about 500 to 1050 cubic feet per second (cfs) to 400% greater when the lake is one foot below compromise (from about 200 cfs to 800 cfs.) Compromise elevation (4489.04 ft) is the lakes "legal" full elevation where outlet gates must be opened so as to hopefully keep the lake from rising much higher and causing flood damage around the lake.

Why aren't there more boat launch and recreation areas in Utah Lake? Around much of the lake, particularly along the north, east and south boundaries, the near-shore bottom slope is small and drops off only about 1 to 2 feet per 1000 feet out into the lake. As a consequence, along much of the shoreline, boat access to open water is a major problem without dredged harbors and access channels since the water shoreline moves large distances with relatively small changes in depth. Thus facilities positioned at normal high-water, lake-edge locations might have to dredge channels a mile or more out into the lake to launch boats during dry cycles. And then during the peak of wet cycles, they are confronted with water several feet higher than wanted. For the foreseeable future, environmental and ecological needs, water storage rights, and ongoing wet and dry cycles will result in a continuation of depth variations about the same as in the recent past. These fluctuations will continue to pose difficult challenges to shoreline facilities.

Why does the Lake level vary so much? Many people ask: " why is lake depth allowed to fluctuate so much." Unfortunately, it is essentially impossible to keep the lake within a couple of feet of a desired depth. Most lakes have a restricted outlet; therefore, during times of relatively large inflow, lake level rises and water is temporarily stored. This later results in relatively higher outflows from the stored water as inflows drop. Under "natural" conditions, Utah Lake levels usually varied 2 to 4 feet within a given year due to the natural cycle of large spring-runoff inflows followed by drier summer and early fall conditions—note that 4 feet of water depth represents about 300,000 acre feet of water, or about one-third of the lake's full volume. Annual evaporation is also about 4 feet, most of which occurs in the June through September period. Over several-year-long wet and dry cycles, lake depth changes roughly 15 feet from its highest level to its lowest level. When at its lowest point at the end of a prolonged drought, the lake becomes much smaller, receding to the middle of the lakebed where it becomes a pond only 3 or 4 feet deep with no natural outflow. These wet and dry cycles vary in magnitude and length; recently, fairly large drought cycles seem to be occurring about every 20 to 30 years.

Starting about 150 years ago, the lake began to be used as a water storage reservoir. Also, fairly large amounts of tributary waters are diverted to other uses before they reach the lake. These two factors change annual lake levels another 2 or 3 feet—usually increasing lake level fluctuations.

Why is Utah Lake slightly salty at times? On average, about half of the lakes inflowing water evaporates; this evaporation is about 4 feet annually. Annual precipitation is about 1 foot, so net evaporation is about 3 feet—or about 230,000 acre feet a year. This is a huge amount of water; it would supply a city of about 1 million people or irrigate about 70,000 acres of farmland. Overall, evaporation nearly doubles dissolved salt (TDS) concentrations since evaporation is about half of average total annual inflow. During the peak of wet cycles, water spends about 1 year in the lake; during the bottom of dry cycles this detention time increases to about 4 years.

Numerous mineral springs also flow into the lake; these thermal, slightly salty springs—with TDS typically 1500 mg/l to 7000 mg/l (sea water is about 35,000 mg/l)—are typically associated with numerous geological faults that encircle, as well as pass under, the lake. These mineral springs supply only about 4 percent of the inflowing water but carry in about 25 percent of inflowing salts. Most of these mineral springs are small, often diffuse, scattered and many are submerged—large scale collection and transportation away from the lake to reduce salt loading is not feasible.

The net result of these factors is that average TDS in the lake is more than 2 times higher than typical inflowing waters, but still not very high. Over the years, through major wet and dry cycles, average TDS in the lake varies about fourfold, from about 500 mg/l to 2000 mg/l. Lake plant and animal communities seem well adapted to this salt range and these TDS fluctuations do not seem a significant problem to them.

Modeling simulations of TDS levels in the lake indicate that development and human activities result in average TDS levels 35% to 45% higher than for pre-settlement conditions 150 years ago. This increment of salt increase does not seem to a significant problem to the lake's ecosystem. This TDS increase is mainly due to (1) diversions of tributary waters (this reduces the amount of lake flushing) and (2) increases in TDS concentrations in tributary waters.

During average to wet periods, TDS levels are marginally acceptable for drinking water—after “conventional” treatment; but higher TDS levels during prolonged dry periods make the water unacceptable as a drinking water without salt removal or else dilution with higher quality water. Unfortunately the highest TDS levels are reached during dry cycles when the water is needed the most as other sources decrease. Biological residues also make lake waters more difficult and expensive to treat to produce drinking water. Of course, if appropriate advanced treatment is used, treated waters would be completely acceptable for domestic-use, but such treatment costs 2 to 3 times more than existing area treatment plants that traditionally treat higher quality waters. The Jordan Valley Water Conservancy District of Salt Lake County reports that costs for the most promising advanced treatment for salt removal, reverse osmosis, is expected to be about the same as costs for developing and treating large, new, high quality water sources. If these costs converge then large-scale treatment of Utah Lake water becomes more likely. However, for the time being, the cost of advanced treatment is too high for the lake to be a major source of drinking water, unless water shortages become much worse than expected.

For traditional irrigation in Utah, most soils and crops do not experience significant salt damage from “salty” irrigation water until TDS levels are above about 1,500 mg/l. The 1,200 mg/l water quality standard is occasionally exceeded in Utah Lake during prolonged droughts. In the past, during the worst part of drought cycles—1 or 2 months in late summer—TDS levels have reached 2000 mg/l or higher, making this water undesirable, or even completely unsuitable, for irrigation since TDS levels this high cause considerable damage to most crops.

Why is Utah Lake so dirty, muddy, and sometimes stinky? Utah Lake is naturally turbid due to mineral particles that chemically form (precipitate) in the lake water itself, particularly during summer and early fall. These precipitates are comprised largely of calcium carbonate mingled with smaller amounts of other minerals. Most of the lakes bottom sediments originate from this chemical precipitation. Although eroded upland sediments carried by larger tributaries are dominant near their inflow points, overall they contribute only a small portion of the total sediments deposited to the lakebed. Thus, bottom sediments contain largely precipitated minerals, relatively small amounts of sediments carried by inflowing streams and some debris from aquatic life. Bottom sediments are frequently stirred up by wind-driven waves in this shallow lake, giving it a milky gray-brown to a milky gray-brown-green appearance much of the time. On average, sedimentation is filling in the lake about 2 inches every 100 years, with the deeper part of the lake filling more rapidly than the shallows—perhaps twice as fast.

Utah Lake is very productive biologically—meaning biological growth levels in the lake are high. Growth and decay of this plant and animal life sometimes result in “swampy” conditions. Such conditions are moderate in Utah Lake (considering its biological richness) because of the lakes well-mixed, aerated nature. But at times and in certain locations, aesthetics suffer, dead zones develop and bad odors occur. These conditions are natural occurrences in the lake, but they are sometimes intensified by human-caused pollution.

Is Utah Lake polluted? Considering its basin-bottom location and its “rich” biological nature, overall water quality in Utah Lake is good; but the lake was not, is not, nor can it be, a “clear” lake. Because of its biologically rich, wave-stirred nature, the lake has excellent natural capacity for stabilizing both natural and human-caused pollutants. Its high oxygen levels, along with naturally high pH levels, are favorable for stabilizing and binding many pollutants, such as breaking down organic residue and binding heavy metals like mercury and lead. Even during the recent 40 years or so that Geneva Steel discharged its treated process waters into the lake, serious water quality deterioration was not observed, except, at times, in the vicinity of its discharges.

Most water quality data for the lake have been collected over just the last 40 years, but rather sporadically. The fact that the lake is large and has numerous tributaries, most rather small and many difficult to locate and access, makes comprehensive tributary measuring and sampling efforts difficult, time-consuming, and costly. Nevertheless, various limited studies of the lake have been completed. These studies indicate that lake water quality has not changed much over the last 40 years, and in many ways has significantly improved—remember that 50 years ago most sewage and industrial wastes flowed untreated into the lake.

Nevertheless, since the lake is downstream of most activities in Utah Valley, too frequently its tributaries are illegally used as convenient dumps for unwanted chemicals and other garbage and trash, some of which are carried into the lake. It requires constant vigilance to avoid serious pollution problems. From time-to-time new pollution issues arise that need attention—although we have cleaned up many polluting discharges via better treatment and management and have greatly reduced many pollutants, we should not think that we have completely solved the lake’s pollution problems. For example, in 2007, state agencies completed initial Polychlorinated Biphenyl (PCB) testing of fish in Utah Lake, and found some violations of allowable PCB levels in some fish species (The bottom-feeding species—carp and channel catfish). Based on this information, an advisory was issued that recommends limiting consumption of these fish caught from the lake. A 2008 intensive survey of water and bottom sediments at the mouth of main

lake tributaries did not locate any current sources—the PCBs are probably a carryover from spillage many years ago, when we did not realize the long life and polluting effect of PCBs.

Given the extremely low levels of PCBs that triggered this advisory, it might be argued that risk of injury or death is far greater in driving to the lake to fish than in eating fish caught there. However, the point to be made here is not this particular pollutant or advisory, but the fact that prevention and elimination of pollution is a wise policy, particularly the control of pollutants at their “throw-away” point of origin. For most exotic pollutants of concern today, cleanup and restoration are typically monumentally more costly than initial costs of proper waste disposal and pollution prevention at the sources.

Are algae in Utah Lake harmful? Abundant algae grow in Utah Lake. Algae are a natural and vital part (base) of aquatic food chains—they might be thought of as grass of the aquatic ecosystem. However, excessive algal growth causes water quality and habitat quality problems analogous to problems caused by tangles of plants and weeds on land. Some types of algae found seasonally in the lake, primarily the cyanobacteria (blue-greens), can be particularly troublesome and even toxic at times. When present in large amounts (blooms), algae sometimes cause dissolved oxygen depletion as a bloom dies away and decomposes; toxins given off by blue-green algae are sometimes concentrated enough to poison other organisms.

One good indicator of past conditions in a lake comes from identifying types and numbers of diatom algae (shells) deposited over time in layered bottom sediments. Studies of sediment cores taken from Utah Lake indicate that types and relative amounts of diatom algae have not changed much over the last few hundred years. Since algae types and relative numbers are quite sensitive to changes in water quality and other aquatic conditions, this consistency indicates that environmental and water quality factors have likewise been fairly constant over this time period.

Is phosphorus a pollution problem in Utah Lake? Very high levels of phosphorus, nitrogen, and other nutrients occur in Utah Lake—a significant part of them occur naturally. Phosphorus and nitrogen are not directly toxic or poisonous to man and higher animals until concentrations are many times higher than the concentrations that are of concern relative to stimulation of algal growth. Trophic state models applied to the lake indicate phosphorus and nitrogen loadings are 10 to 15 times higher than amounts sufficient to make the lake highly productive (eutrophic). This infers that removal of over 90 percent of these nutrient loadings would still not significantly reduce the amount of algae growing in the lake. Therefore, in Utah Lake relatively high nutrient levels would still occur, even if most human-caused sources were removed from tributaries and wastewater discharges,

However, the amount of these nutrients in Utah Lake is likely a moot point since overall algal growth appears to be largely limited by the lake’s natural turbidity that causes light limitation to algal growth, rather than nutrient limitation. This being the case, the high levels of phosphorus, nitrogen, and other nutrients found in the lake are of secondary concern since most of the time they probably do not stimulate significantly heavier algal growth. This is in contrast to clearer lakes where such high nutrient levels could result in widespread water quality problems from extensive algal blooms that over-abundant nutrients often cause.

Some observers have speculated that increased turbidity caused by carp might be a good thing because of more light limitation to latent algal growth. This factor is likely an insignificant one on overall algal growth since natural turbidity is widespread and persistent. In tributary waters and lake bay areas, high nutrient levels may or may not cause excessive algal growth and quality problems, depending on specific conditions found in those waters.

Another interesting point regarding nutrients is that many lakes in Utah are more nitrogen-limited than phosphorus-limited—this is likely the case with Utah Lake. Some 60 years ago, early scientific research on lake productivity was done largely in areas of the world where phosphorus was most commonly the limiting nutrient to overall algal growth, thus phosphorus concerns dominated the early literature and subsequent nutrient control efforts. More recently it has become evident that lakes in other areas, particularly in alpine, and also in arid, areas, are often nitrogen-limited. However, in most nutrient-control programs, even when nitrogen is more limiting, phosphorus reduction is usually still a key factor in reducing blooms of blue-green algae which tend to dominate in eutrophic lakes when nitrogen to phosphorus ratios are low, ie, below about 10.

Best Management Practices to control nutrients coming from agricultural sources, land erosion, and storm runoff commonly concurrently reduce levels of both nitrogen and phosphorus. But treatment systems for sewage and industrial wastewaters require specific advanced treatment processes targeted at each nutrient. Because of this situation, when nutrient(s) reductions are considered for wastewater discharges, careful field studies will be needed to specifically identify the relative importance of phosphorus and nitrogen in receiving lakes and rivers so as to target the correct nutrient(s) for more control and sometimes removal via advanced treatment.

These nutrient control effectiveness and cost issues are major issues since advanced wastewater treatment is much more expensive than the conventional wastewater treatment that has been used in the past. For example, In Utah Valley costs for advanced wastewater treatment to remove most phosphorus would be well over \$100 million for construction costs plus additional tens of millions each year in operating and maintenance costs—with total costs for wastewater treatment likely more than double current costs. If significant water quality improvements would result from these expenditures one might argue in their favor, but such is probably not the case for Utah Lake. With respect to nutrient discharges from the lake down the Jordan River, high biological activity and the chemical binding nature of the lakes sediments combine to make the lake a very effective system in reducing nutrient levels to relatively low levels in the outflowing Jordan River. Thus, any large scale reductions in Phosphorus loadings to Utah Lake would not likely reduce Phosphorus levels in the Jordan River due to the natural, very large Phosphorus removal and retention in the lake.

If Utah Lake were deeper, would it be clearer? The lake would be clearer during early spring and late fall, but probably more turbid during summer and early fall. For most of the lake, if one cuts through winter ice, clear water is found. However, in early spring when winter ice cover breaks up—during many winters a solid ice cover does not develop or lasts only a few weeks—waves stir the bottom sediments, algae begin to grow faster and turbid conditions return. If the lake were deeper, less wave energy would reach the bottom to stir up flocculent bottom sediments, thus leaving the water clearer. However, increased water clarity would trigger a major problem: sunlight, now absorbed and reflected less, would penetrate deeper into the water, triggering heavier algal blooms. This situation would result in a “pea soup” of algal growth during much of summer and early fall, and cause major

deterioration of lake quality and habitat—probably the most damaging effect would be increased episodes of oxygen loss as algal blooms die away and decompose.

What lake depth would cause stratification problems to develop? Summer stratification develops when warmer, less-dense surface water overlies colder, deeper water. Overall aesthetics, water quality and habitat deteriorate significantly with stratification, particularly in eutrophic lakes. In Utah Lake, significant summer stratification would likely occur in areas deeper than about 15 feet. Currently when full, all of the lake is shallower than 15 feet, thus Utah Lake does not experience persistent stratification—that is, the lake mixes well and escapes most oxygen-depletion problems.

In this climatic region, when fairly clear, ponded water is about 20 feet deep, or deeper, summer thermal stratification is common and often persistent—meaning that surface water does not mix with bottom waters for weeks, or even months. With this stagnation, ongoing natural decay of accumulated organic debris at the bottom often results in loss of oxygen, first at the bottom and then upward in overlying layers; water at the bottom becomes stagnant and sometimes septic and putrid. This gives rise to cesspool-like conditions that stress or kill normal aquatic organisms and sometimes even kills fish if they can't find refuge areas containing oxygen—often near the surface or near inflowing streams or springs.

Thermal stratification can occur in shallower turbid lakes since more sunlight energy (heat) is absorbed nearer the surface by the turbidity-particles—persistent summer stratification can occur in turbid lakes as shallow as about 15 feet. Therefore, in Utah Lake if any large area were dredged to depths of 15 feet or deeper, during most years persistent seasonal stratification would likely occur and trigger water quality and habitat problems that are not now common in the lake. Note that waves 2 or 3 feet high impart meaningful stirring energy down to about 12 to 13 feet. So when such waves occur, as they normally do at least each week or two on Utah Lake, stratification is broken up as mixing energy reaches the bottom.

Under ice cover, winter stratification often occurs and oxygen loss may result when enough decomposing organic debris is present. In this case, oxygen loss is most likely to occur in the most shallow areas that have little, if any, circulation or local inflows. Winterkill of fish, along with the other aquatic organisms, may occur. This problem occurs to a limited extent in some of the more stagnant bays and inlets of Utah Lake. It is not known to be a problem in the main lake, since (1) most organic debris from summer growth degrades during fall months before ice cover develops, and (2) in addition to numerous surface inflows, many small springs issue from the bed of the lake that contain oxygen and also foster circulation, largely from temperature differences.

What maximum dredged depth is acceptable for Utah Lake? For the main part of the lake, full lake depths of about 15 to 17 feet in the late spring would result in 12 to 14 foot depths during summer and fall as water levels drop. Bottom mixing energy from waves would be quite small at the deeper depths, thus turbidity would be lower in the spring and early summer and the water would be clearer. But then the lake would experience large increases in algal growth as the season progressed into the maximum algal-growth period from midsummer into midfall.

When full, the lake currently averages about 9 feet deep, its average depth (and water volume) could be increased as much as 50 percent, if most of the lake were dredged to depths of 15 to 17 feet. Deepest parts of the lake are now 13 to 14 feet deep when the lake is full. If only a relatively small area were dredged deeper, this area would still often be rather turbid since water circulating from other areas would carry fine sediments there; these would tend to fill dredged areas back in quite rapidly. In addition to these problems, large scale dredging is probably not feasible for a variety of ecological, engineering, and economic reasons. For example, dredged bottom sediments are a clayey soil—when exposed to the air to dry, they shrink, crack, and become very hard, but when wet they are swollen and mucky.

In summary, in Utah Lake with clearer water resulting from increased depth, the biggest concern would be large increases in algal blooms. Such blooms could be a major problem and increase oxygen loss and bad odor events. If dredged much deeper than about 15 feet, summer stratification would likely result in the dredged area becoming a biological dead zone. But realistically, where would one put the mucky, dredged material? If the entire Lake were dredged an average of just two feet deeper, the dredged material could cover an area 5 miles wide and 5 miles long to a depth of about 10 feet—but on a brighter side, this much material could form islands with total area of perhaps 7 square miles, requiring about 35 ft of initial fill that when settled would place them about 10 feet above the lake level.

Why are trout no longer abundant in Utah Lake? Along with other species, such as whitefish and suckers, Bonneville Cutthroat trout were abundant in Utah Lake until the late 1800s. It was a large trout, often weighing more than 10 lbs. Over-fishing, competition from introduced fish species, and interferences with stream spawning and migration cycles caused by dams and diversions for irrigation, resulted in low trout numbers by 1900. Intensified stresses hit the greatly reduced trout population during the 1930s drought when fish struggled to find cover and encountered extremely low levels of warmer and warmer water in both the lake and its tributaries. The combined stress factors eliminated the Bonneville Cutthroat. Many of these factors continue to severely challenge other remaining native species in the lake, particularly the “endangered” June Sucker.

The re-establishment of large numbers of trout in Utah Lake is very unlikely—it would require major changes in other fish species now in the lake and largely hatchery-based stocking to maintain good populations. Remember, however, that the lake has very high levels of overall fish production and supports a premier warm-water fishery. Overall, Utah Lake’s fishery is greatly underused—most of the fish species are not under the current limited-consumption advisory resulting from PCB contamination.

Since June Suckers are currently listed as an endangered species under the Federal Endangered Species Act, continuing efforts to protect and restore them are major considerations in future Utah Lake management. As part of restoration plans, projects are being developed to greatly reduce the numbers of carp. The huge carp population in the lake appears to have devastated rooted aquatic vegetation; and in several ways contribute to significant deterioration of the aquatic ecosystem, particularly in the lake’s shallows, inlets, and bays. Currently, an estimated 6 to 8 million adult carp live in the lake—they dominate in the aquatic ecosystem and are a major stressor and disruptor to the overall ecosystem.

The most feasible carp-control plan appears to be very heavy commercial harvesting for several years to greatly reduce carp numbers and bring them into a better balance with the rest of the ecosystem. A large reduction in carp would likely not result in discernable changes in water quality but should result in major improvements in the lake's ecosystem, particularly in bay and near-shore areas. Hopefully, one of the main benefits would be the re-establishment of native vegetation—many areas are now largely devoid of aquatic and shoreline vegetation.

New Invasive “problem” Plant—Phragmites. The introduced, invasive water plant, Phragmites, is a new major problem in Utah Lake. This invasive, exotic plant grows prolifically along the shoreline and in the shallows. Phragmites is a tall reed plant that chokes out other aquatic plant life and raises the ground elevation over time, thus reducing and damaging the aquatic habitat. Uncontrolled, it crowds out nearly all other aquatic plants and forms an almost impenetrable wall of growth. This plant is now spreading throughout Utah Lake. It will do great damage to the Lake ecosystem if not controlled. Initially it was largely limited to the Saratoga area—NW corner—of the lake but it is now found in many other locations. Efforts have been underway for several years to control it; elimination is unlikely. Control efforts need to be rigorous and persistent or else Phragmites will become an overwhelming problem.

Can islands be constructed in Utah Lake? The concept of constructing residential and recreational islands in the lake, perhaps linked together by a causeway or bridge across the lake, is appealing to many people. Sale of the constructed islands for residential and commercial use could provide hundreds of millions of dollars to fund island-building projects and perhaps other lake development, recreational, and enhancement projects. One or more islands reserved as wildlife refuges with some limited recreation would be great assets—rubble and rock shorelines could be developed to enhance fisheries. Lake-bottom sediments are likely stable enough to be used for most of the needed fill material; top soils would need to be added for good growth of grass, trees and other vegetation. A few years of settlement would likely be needed before beginning utility and building construction on residential islands—as mentioned above, before settling, the fill would need to be a total of 25 to 35 ft high, measured from the lake bottom, to give final elevations 10 ft, or so, above high water levels.

Could a road causeway or bridge be built across Utah Lake? Crossings could be built, but numerous and difficult environmental, engineering, and financial problems would have to be solved. Such crossings are a tremendous engineering and construction challenge and very expensive!—hundreds of millions of dollars for a major road crossing across the middle of the lake.

Long anticipated suburban growth is now occurring on the west side of the lake. This growth would accelerate if travel access to the economic hubs on the east side were better. Build a road across the lake? Can it be done? Technically, yes. Practically and economically, it would be very difficult. The bed of Utah Lake is a very poor foundation. A fill causeway would need a very wide base (several hundred feet wide) or would need to be placed on support piles. Both are very expensive; a bridge structure would cost even more. The roadway surface would need to be at least 6 to 8 feet above the highest lake level to protect it from wave action, and to also protect it from major ice-sheet movement. (Sometimes in late winter as the ice begins to break up and a strong prevailing wind develops, wind-driven ice sheets can stack up 10 to 20 feet high

along the shoreline.) However, this condition is rare and short-lived—perhaps a few hours every few years.

When loaded with the weight of a fill causeway, the lakebed under the causeway would settle several inches a year for many years—of course, the settlement rate would decrease over the years as underlying sediments compacted. Uneven settlement would likely occur and result in an undulating road surface; problems of pavement cracking and breakup would be persistent. In addition to these problems, two or three shorter bridges or many very large culverts must be placed along a fill causeway to allow for good water and aquatic biota circulation through the causeway to minimize adverse impacts on the lake's ecosystem.

If built, likely the best solution both structurally and environmentally would be a continuous bridge-type roadway built on pilings driven into the lake bottom, perhaps together with large, structural floats where the bottom is not sufficiently stable for piles to support the roadway. Engineering studies would determine how deep into the bottom piles would have to be driven, or if they could be used at all. Also, at maybe two locations, spanning bridges would be needed to allow boat passage.

A generally north-south causeway/bridge across Provo Bay would have less challenging foundation problems, since bottom layers contain more stable soils, including more sand and gravel than under the main lake. If a dike causeway were built across Provo Bay, it could perhaps also be used to control and stabilize water levels in Provo Bay. This could result in many ecological benefits. However, if a dike causeway were used to control water levels in Provo Bay at different levels than Utah Lake, the project would need a large hydrologic/hydraulic component. Flood bypass channels would have to be built for Hobble Creek, the Spanish Fork River and perhaps others, if they were behind the dike, since a pumping station large enough to pump such large water volumes over the dike in flood years, would be too costly.

Why not fill in much of Utah Lake and use it for agricultural lands, developments, or wildlife habitat? At this point in our national experience, lake and marshland areas are considered too valuable to allow further significant encroachment on them or their destruction; therefore, current environmental laws and requirements make it extremely difficult to dike or fill most shoreline and wetland areas. Though very unlikely, if at some point diking and dewatering were to be done to reclaim land, only the Provo Bay area has bottom sediments and soils somewhat suitable for farming. The rest of the lake has clayey, calcium-carbonate-type sediments that are not suitable for farming or development without large-scale and expensive stabilization and enrichment work.

Major environmental issues would arise with any construction of this type. Given current environmental requirements, stabilized water levels would probably be needed to support large marsh and wetland areas and would likely result in little, if any, additional land acreage for farming or development, as well as very little water savings from reduced evaporation. Also, diked areas might suffer up to several feet of flooding for a few months about every 30 years or so during the peak of wet cycles. This flooding would likely occur since the cost of dikes high enough to isolate diked areas from the main lake (along with the cost of standby pumping or bypass channels for tributaries to keep the diked area water levels low) would likely be excessive.

Are major improvements in the Utah Lake ecosystem feasible? This issue is very complex. Major ecosystem restorations and improvements tend to be difficult to formulate and very expensive to implement, both in direct costs and lost opportunity costs for competing uses. Many of the pressures on bird and animal populations come from factors not directly associated with water quality or the lake's existing habitat. For example, restoration of the endangered June Sucker is related more to lack of favorable spawning and brood areas in the rivers and competition from other fish than to pollution or poor water quality. Shoreline vegetation and habitat will likely benefit from current water development plans and projects of the Central Utah Project, which should reduce magnitude and frequency of extremely high and low lake levels.

With reasonable attention to ecosystem preservation and enhancement, the lake can continue to support very rich and diverse plant and animal communities; the control of Phragmites is a crucial issue. Some enhancing changes are possible, but not remaking it into a clear mountain lake. Appropriate emphasis on preserving and enhancing the ecology of Utah Lake does not preclude additional development on and near the lake, but true environmental sensitivity will be extremely important in any development and use plans.

What will Utah Lake be like in the future? Water quality in the lake is not likely to change significantly in the foreseeable future as long as wastewater treatment, agricultural pollution control, and other pollution control requirements are continued. A Total Maximum Daily Load (TMDL) water quality study, conducted by the State of Utah, is nearing completion. This study's purpose is determining whether additional pollution control is needed to protect lake beneficial uses; it targets occasional violations of the phosphorus and TDS guidelines for use classifications assigned to the lake. It is unlikely that significant new restrictions or requirements will be implemented as a result of this TMDL study since it does not appear that significant problems are associated with occasional exceedances of these two water quality parameters—TDS and Phosphorus.

Regardless, Utah Lake will be neither clear nor deep or bordered by expansive clean, sandy beaches—although some sandy beaches exist along the lake and might be expanded. It will continue to be a shallow, turbid, slightly saline, eutrophic lake that is largely bordered by marshy wetland areas. Yet, hopefully, all of us will recognize that it is an extremely valuable water, recreational, and ecological resource. Wetland protection laws, threatened native species, natural flooding and other environmental impacts will limit development near the shoreline. Causeways, bridges, or dikes will probably be built across the lake sometime, perhaps even some islands. Near-shore constraints are likely to be less restrictive on the west side than on the east since on the west side the shoreline is steeper and more stable, and fewer extensive wetlands exist. There are also zones on the east side where development conditions are somewhat favorable and fewer wetland issues exist, and a few additional residential and recreational developments will likely be built quite close to the lake, but not many.

The Utah Lake Commission that was formed recently is an authorized, recognized, representative body that can give long term continuity in addressing Utah Lake issues and hopefully will be pivotal in generating wise consensus on lake use and management issues.

Background Material:

Perspectives on water quality. Water Quality has different meanings to different people and confusion often results because of various perceptions as to what is meant by “water quality.”

Briefly, water quality and pollution as used in government water programs relate to the **official, designated, beneficial uses** of a body of water or water source (assigned by the state via professional staff evaluation and analysis, and applied via public hearings and official publication). Water quality issues typically relate to whether quality parameters used to measure quality acceptability for designated uses are being violated, and if so, how often, how persistent, etc.

Suppose a water source is designated as drinking water, but pollution-indicator bacteria persistently show up in samples. The water would then be considered polluted and of poor quality even though it may be of excellent quality for most other beneficial uses. Likewise, a water source might be of good quality for a warm water fishery but unacceptable for many other uses.

In addition to this beneficial-use orientation in defining water quality, there are also nondegradation clauses in water quality laws to help prevent pollution—they are aimed at preventing water quality deterioration when the existing quality is better than required by designated beneficial uses.

The official designated beneficial uses for Utah Lake:

| <u>Beneficial Use Designation</u> | <u>Description</u> |
|-----------------------------------|---|
| 2B | Protected for secondary contact recreation such as boating, wading, or similar uses. |
| 3B | Protected for warm water species of game fish, including the necessary aquatic organisms in their food chain. |
| 3D | Protected for other aquatic wildlife. |
| 4 | Protected for agricultural uses including irrigation of crops and stock watering. |

See the state code for more details, water classifications, and associated water quality and pollution parameters.

Total Dissolved Solids (TDS). The TDS parameter is used as a general classifying parameter in water quality management—in addition to specific limits for some beneficial uses. Typically, TDS levels increase as one goes from alpine lakes (typically 50-100 mg/l) to mountain streams, rivers, and lakes (100-400 mg/l) to lowland rivers and lakes (400-2000 mg/l) to oceans (30,000-40,000 mg/l) to salt lakes (200,000-400,000 mg/l).

TDS limits are typically near 1000 mg/l for drinking water, 1200-1500 mg/l for irrigation, and 2000-2500 mg/l for livestock watering. A healthy person could survive on water containing as much as 10,000-15,000 mg/l TDS—although it would taste rather nasty. It is at about these levels that the human body needs more water to remove the consumed salts from the body than is being drunk, and dehydration begins—drinking only this type of water would lead to death.

The current Utah TDS standard for irrigation water is 1200 mg/l. The types of crops and irrigation practices determine the TDS at which crop damage becomes a significant problem. For the crops and irrigation practices commonly used in Utah, TDS begins to cause noticeable crop damage when above about 1500 mg/l.

Phosphorus. Phosphorus is a necessary nutrient for plant growth and a major ingredient in most fertilizers. In aquatic systems, excessive phosphorus becomes a problem if it over-stimulates algae and other plants to such heavy growth that water quality and habitat problems result. In the Utah Water Quality Code, pollution indicator threshold values for phosphorus are 0.050 mg/l in flowing waters and 0.025 mg/l in ponded water. High levels of phosphorus and other nutrients are found in sewage and many other wastewaters—and somewhat high levels can even be found in natural waters in many cases, particularly in valley-bottom settings when the upstream drainage basin geology is rich in phosphorus, as is the case for some of the Utah Lake drainage. Nutrients are not removed significantly by conventional wastewater treatment plants. The addition of advanced treatment units is very expensive, often doubling or tripling overall wastewater treatment costs as various non-conventional pollutants are removed.

Nitrogen. Nitrogen is also a necessary nutrient for plant growth and the major ingredient in most fertilizers. The N/P weight ratio plants need for growth is about 10 to 1. Nitrogen levels as related to possible excessive algal or other plant growth are generally not found in water quality standards since the bioavailability of various nitrogen species in water and interaction with atmospheric nitrogen raise difficult issues on sources, controllability, and reasonable levels that elude the structuring necessary to be put into standards form. Often in lakes when nitrogen or phosphorus availability is actually limiting to algal growth, control of phosphorus is preferred since low nitrogen availability sometimes encourages the growth of “nitrogen-fixing” cyanobacteria (often referred to as blue-green algae). Cyanobacteria are more troublesome than most other algae, in that they often occur in massive blooms and produce poisonous toxins that can cause serious water quality problems. It is important to remember that if nitrogen and phosphorus are not at limiting levels, then they must become so before they have any effect on the rate of growth of algae.

LaVere B. Merritt, Ph.D., P.E., BCEE
Provo, Utah
MerrittLB@gmail.com
801-420-8112

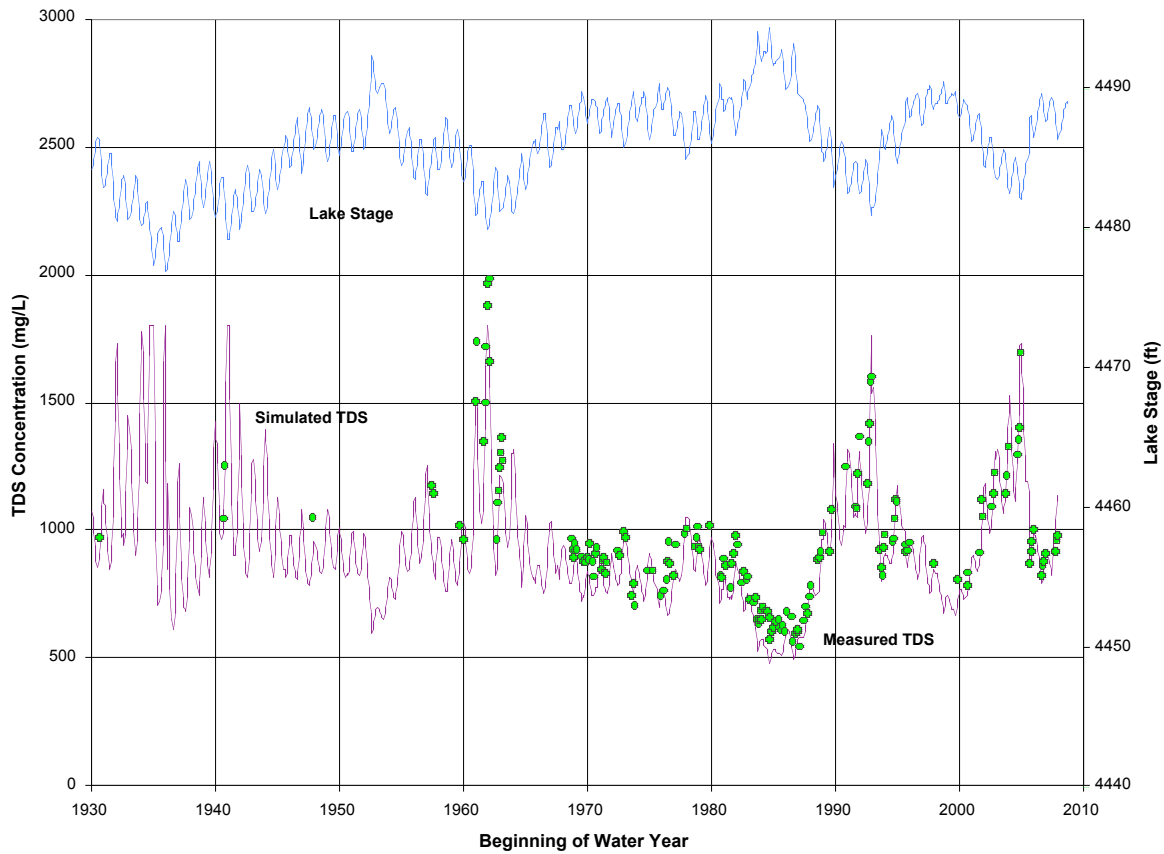
Dr. Merritt is a professor emeritus of civil & environmental engineering, Brigham Young University. His research and public service activities have included many multidisciplinary studies and evaluations of Utah Lake. He is the developer of the LKSIM model; this computer model simulates the water and salt “balances” for Utah Lake. He served as member and then chair of the Provo Metropolitan Water Board for many years. He is a consultant to both public and private entities on Utah Lake matters.

The table and figure on the following two pages are summary results from the simulation model LKSIM that tracks the water balance and salt concentrations in Utah Lake.

Table 1: Avg water & salt quantities for 1930–2007 (78 yr) UT Lk hist. simulation.

| I. INFLOW | Flow af/yr | Inflow | | Salts---Percent of the Total Input | | | | | | | | |
|--|----------------|----------------|----------------|------------------------------------|-------------|-------------|-------------|-------------|-------------|------------------|-----------------|--|
| | | % ¹ | % ² | TDS | Na | Ca | Mg | K | Cl | HCO ₃ | SO ₄ | |
| 1. Surface Inflow | | | | | | | | | | | | |
| a. Mountain Strms | 225813. | 42.4 | 35.8 | 23.2 | 11.0 | 33.0 | 27.3 | 12.6 | 8.6 | 33.9 | 20.7 | |
| b. Wastewater Trt | 25739. | 4.8 | 4.1 | 3.9 | 3.4 | 4.4 | 3.6 | 5.2 | 3.3 | 5.6 | 2.7 | |
| c. Other—Main Lake | 116744. | 21.9 | 18.5 | 21.4 | 16.5 | 21.2 | 28.6 | 22.4 | 12.2 | 26.4 | 23.4 | |
| d. Other—Provo Bay | 62332. | 11.7 | 9.9 | 10.5 | 6.5 | 13.7 | 12.0 | 8.3 | 4.6 | 13.1 | 13.5 | |
| e. Other—Goshen Bay | 6120. | 1.1 | 1.0 | 5.8 | 10.9 | 1.1 | 4.0 | 6.6 | 11.8 | 1.5 | 6.1 | |
| 1. Sub-Total | 436748. | 82.0 | 69.3 | 64.7 | 48.3 | 73.4 | 75.5 | 55.2 | 40.4 | 80.6 | 66.3 | |
| 2. Fresh Groundwater | | | | | | | | | | | | |
| a. Main Lake | 36524. | 6.9 | 5.8 | | | | | | | | | |
| b. Goshen Bay | 35462. | 6.7 | 5.6 | | | | | | | | | |
| 2. Sub-Total | 71986. | 13.5 | 11.4 | 10.1 | 8.6 | 11.0 | 13.6 | 11.6 | 8.3 | 12.7 | 10.2 | |
| 3. Thermal/Mineral GW | | | | | | | | | | | | |
| a. Main Lake | 22368. | 4.2 | 3.5 | 24.6 | 42.1 | 15.3 | 10.8 | 32.7 | 50.5 | 6.6 | 22.9 | |
| b. Goshen Bay | 1260. | 0.2 | 0.2 | 0.5 | 1.0 | 0.2 | 0.2 | 0.6 | 0.8 | 0.2 | 0.6 | |
| 3. Sub-Total | 23628. | 4.4 | 3.7 | 25.1 | 43.1 | 15.6 | 11.0 | 33.3 | 51.3 | 6.8 | 23.5 | |
| 1 + 2 + 3 Sub-Total | 532362. | 100.0 | | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | |
| 4. Precipitation | | | | | | | | | | | | |
| a. Main Lake | 66157. | | | | | | | | | | | |
| b. Provo Bay | 5465. | | | | | | | | | | | |
| c. Goshen Bay | 26315. | | | | | | | | | | | |
| 4. Sub-Total | 97936. | | 15.5 | | | | | | | | | |
| Inflow Total: | 630298. | | 100.0 | | | | | | | | | |
| <hr/> | | | | | | | | | | | | |
| II. Outflow | | | | | | | | | | | | |
| 1. Jordan River | 302418. | 48.2 | | | | | | | | | | |
| 2. Evaporation | | | | | | | | | | | | |
| a. Main Lake | 221382. | 35.2 | | | | | | | | | | |
| b. Provo Bay | 15604. | 2.5 | | | | | | | | | | |
| c. Goshen Bay | 88595. | 14.1 | | | | | | | | | | |
| 2. Sub-Total | 325581. | 51.8 | | | | | | | | | | |
| Outflow Total: | 627999. | 100.0 | | | | | | | | | | |
| Ratio: Total Salts Out/Salts In (%) | | | | 73.5 | 98.0 | 40.9 | 95.6 | 99.7 | 97.5 | 48.1 | 98.5 | |

¹Based on Total w/o precipitation, ²Based on Total Including precipitation



Total Dissolved Solids and Water Levels in Utah Lake

Figure 1