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Climate Data Manipulation and the Use of Water to Build Political Power in the Southwest United States

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CLIMATE DATA MANIPULATION AND THE USE OF WATER TO BUILD POLITICAL POWER IN THE SOUTHWEST UNITED STATES

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Over the past four years, two landmark articles dealing with climate change and future water scarcity in the Southwest United States have been published in Science magazine. In "Stationarity is Dead: Whither Water Management?" Milly et al. (2008) stated that "Anthropogenic climate warming appears to be driving a poleward expansion of the subtropical dry zone, thereby reducing runoff in some regions" (1). The authors showed that 8 of the 12 climate models utilized by the Intergovernmental Panel on Climate Change indicate that the adverse effect of climate change on runoff volume would be greater in the Southwest United States by the middle of the 21st century, compared with 1900-70, than would be the case for any other region in the Western Hemisphere. Runoff volume is projected to decline by 10-20 percent in Colorado, Utah, New Mexico, and California. Extreme runoff decline of 20-40 percent is projected for Arizona and Nevada. In addition, it was emphasized that "Modeling should be used to synthesize observations; it can never replace them. . . In a nonstationary world, continuity of observations is critical" (1).

In "Dry Times Ahead" (2010), Jonathan Overpeck and Bradley Udall elaborated on the climatic causes of water scarcity. Although no precipitation data were presented, the authors contended that "climate changes in western North America, particularly the Southwest, have outstripped change elsewhere on the continent, save perhaps in the Arctic . . . According to climate models, global warming should lead to a continued progressive drying out of the region as it warms up and winter storm tracks shift north...recent climate change in the West matches these projections. Warming is bad enough, but when it is coupled to a continued reduction in winter snow and rainfall, the situation will only get worse" (2).

In line with this, the authors emphasized the inadequacy of Colorado River water supplies to meet the coming needs of Los Angeles, San Diego, and Phoenix, as well as agricultural areas in southern California and Arizona. Metropolitan Las Vegas was curiously omitted. The 50 percent volume loss in Lake Powell and Lake Mead between 1999 and 2004 with "no substantial recovery since" due to "the most severe drought observed since 1900," rising temperatures, and the northward retreat of winter storm tracks was cited as evidence of regional vulnerability. This was highlighted with a photograph of Lake Mead showing the drop in water level that "may be a sign of things to come as climate change takes hold in western North America" (2).

There are four problems with the contentions advanced in "Dry Times Ahead," the first of which is the unprecedented and largely uniform absence of precipitation data in 2005-09 for 18 of the 21 National Weather Service stations in southern Arizona that are within 80 miles of the international border. Only the international airports at Yuma, Tucson, and Douglas have complete precipitation records for 2005-09.

For the 18 southern Arizona borderlands weather stations, including the primary station at the University of Arizona, there was a total of three missing months for the six-year drought period 1999-2004 (3). For the subsequent five-year period 2005-09, there were 281 missing months with 198 of these months (70 percent) being identical for all 18 stations (3). Precipitation data were uniformly absent for June and November 2005, April through November 2006, and March 2008 (Table 1).

The pattern of uniformly missing precipitation data was changed in 2012 from what it had been in 2010. Although the patterns for 2005 and 2006 were the same in 2010 and 2012, precipitation data were missing in 2010 for all 18 stations for January, March and November of 2007. For 2008, data were uniformly missing for April and July, as well as March.

The traditional summer monsoon months (July-September) accounted for 75 (27 percent) of the missing months. The number of missing months was virtually identical for each of the three months. There were 25 missing months in July, 26 in August, and 24 in September.

In 2008, the National Weather Service revised the official beginning of the summer monsoon season in the Southwest from early July to June 15, despite the fact that June is a very dry month. Forty-three of the missing months (15 percent) occurred in June.

For the four eastern borderlands stations with complete precipitation records for the 60-year period 1950-2009, i.e. the Tucson and Douglas airports and Animas and Lordsburg in southwestern New Mexico, average total summer monsoon precipitation was 6.52 inches. The average for June was 0.42 inches or six percent of the total. July (2.42 inches) was the wettest month. September (1.32 inches) was the third wettest month. On average, June precipitation exceeded 1.32 inches once every 14 years. The much higher incidence of missing months in June appears to be an effort to obscure the comparative insignificance of June precipitation for the summer monsoon season.

In the Southwest, high elevation winter snowstorms and low elevation winter rains begin in early November and continue through March. In addition, the November-March winter season in the Southwest is defined by the absence of evaporative water loss data for the 53 high elevation pan evaporation stations throughout the region. Sub-freezing temperatures in November and March prevent accurate measurement (4). Ninety-four of the missing months (33 percent) occurred in winter. November (46 missing months) and March (19 missing months) accounted for 69 percent of the total. The marked absence of complete winter precipitation data for the 18 stations weighs particularly heavily against the contention that winter storm tracks have shifted to the north. If the winter precipitation data from the borderlands stations supported that contention, why were the data deleted? The likelihood that the missing data for 2005-09 was the result of a bizarre technical accident that was unexplained and uncorrected for three years is less than miniscule.

In contrast to southernmost Arizona, there was a total of 15 missing months in 2005-09 for the five borderlands stations in California (San Diego, Chula Vista, Alpine, El Centro, and Calexico). For the two in southwestern New Mexico (Animas and Lordsburg), there were none.

Although less egregious than the situation for the southern Arizona borderlands, northern areas were not immune from the problem of apparent manipulation of recent precipitation data. For the National Weather Service stations at the Chico Experiment Station in northern California and Steamboat Springs and Glenwood Springs in northwestern Colorado, the comparatively massive amount of missing and underreported precipitation data (i.e. individual months with more than five missing days) in 1999-2009 precluded their use for long-term regional comparisons. For the three weather stations collectively, only eight of the 33 years for 1999-2009 had complete precipitation records (3). For the 49-year period 1950-98, average annual precipitation at Chico (26.40 inches) was the third highest in northern California. Steamboat Springs (24.04 inches) was the wettest weather station along the western slope of the Rocky Mountains, while Glenwood Springs #2 (17.03 inches) was the third wettest. None of the other weather stations south of the 41st parallel (the northern border of Colorado and northeastern Utah) with long-term precipitation records exhibited this extreme lack of precipitation data.

The accuracy of climate models is impoverished by the very recent absence of continuity for weather station observations in southern Arizona, northern California, and northwestern Colorado.

The second problem is the contention that the recent drought that began in 1999 is the "worst drought since 1900." The precipitation record for southwestern North America during the first half of the 20th century is distinctly limited. Only 18 reasonably dispersed weather stations have continuous precipitation records covering the 90-year period 1920-2009. Even fewer extend back to 1900, rendering the conclusion concerning the relative importance of the recent drought open to question.

The network of regional weather stations for the last half of the 20th century and the present century provides a vastly more accurate basis for assessing drought severity. For the region south of the 41st parallel and west of the continental divide, there are 59 National Weather Service stations, at least 30 miles distant from one another, with continuous precipitation records for the 60-year period 1950-2009 (Figure 1).

Annual Precipitation Change

Based on the precipitation records from the 59 stations, the recent drought is the most severe of the past 60 years (3). Average annual precipitation for the 11-year period 1999-2009 was 10.09 inches, slightly less than the annual average of 10.20 inches for the 11-year period 1950-60. However, the 1999-2009 precipitation deficit was due entirely to much drier conditions in western California and central and eastern Arizona in 1999-2009 than in 1950-60. With the exception of Fort Bragg 5 N on the northwest coast, all of the California stations west of the Sierra Nevada from Eureka in the north to San Diego in the south were drier in 1999-2009 than in 1950-60. For the ten weather stations in western California, average annual precipitation in 1999-2009 was 17.34 inches, four percent less than the average of 18.14 inches for 1950-60 (Table 2). All of the Arizona stations from Prescott and Phoenix in the west to Saint Johns and Douglas in the east were drier in 1999-2009 than in 1950-60. Williams and Springerville were nonconforming outliers slightly to the northwest and northeast. For the 15 weather stations in central and eastern Arizona, average annual precipitation in 1999-2009 was 12.20 inches, eight percent less than the average of 13.21 inches for 1950-60 (Table 2).

For the 34 weather stations in the more arid interior Southwest that lie to the west, north, and east of central and eastern Arizona, 1950-60 was much drier than 1999-2009.

Average annual precipitation in 1950-60 was 6.54 inches, seven percent less than the average of 7.03 inches for 1999-2009 (Table 3). Twenty-four of the 34 stations (71 percent) were drier in 1950-60 than in 1999-2009. Of the nine weather stations located between western California and central and eastern Arizona, only Needles and Blythe on the Colorado River were drier in 1999-2009. For the nine stations, average annual precipitation in 1950-60 was 3.18 inches, six percent less than the average of 3.37 inches for 1999-2009.

Although 1999-2009 was the driest 11-year period in western California and central and eastern Arizona, and the second driest period in the surrounding interior Southwest, this is not at all indicative of a climate change trend. The National Oceanic and Atmospheric Administration's National Climatic Data Center uses 30-year averages to determine climatic conditions for cities in the United States and its territories. The data in Tables 2 and 3 indicate a distinct upward trend in annual precipitation throughout the Southwest. 1980-98 was by far the wettest period for all three regions. In western California, average annual precipitation in 1980-98 was 19.59 inches, seven percent greater than the 60-year average of 18.35 inches. For central and eastern Arizona, 1980-98 was 11 percent higher than the 60-year average (i.e. 15.75 versus 14.18 inches). For the surrounding interior Southwest, 1980-98 was 12 percent greater (i.e. 8.49 versus 7.56 inches).

For the 30-year periods 1950-79 and 1980-2009, average annual precipitation in western California increased by five percent from 17.93 inches to 18.76 inches. For central and eastern Arizona, annual precipitation increased by four percent from 13.92 inches in 1950-79 to 14.45 inches in 1980-2009. The increase in annual precipitation in the surrounding interior Southwest was considerably more pronounced. Average annual precipitation in 1950-79 was 7.17 inches versus 7.95 inches in 1980-2009, an eleven percent increase. The very dry conditions in 1999-2009 in the Southwest appear to have been a downward climatic adjustment from the very wet conditions of 1980-98.

The 1999-2009 Drought: Regional Comparisons for 1999-2004 and 2005-09

While the 1999-2009 drought in the Southwest was the most severe of the past 60 years, there were major regional differences between 1999-2004 and 2005-09. In 1999-2004, regional drought effects progressively intensified from western California to the northern interior, and from the northern interior to the southern interior. In 2005-09, annual precipitation continued to decline in western California, but increased sharply in the northern interior and only modestly in the southern interior.

For the ten western California weather stations, drought severity during the first six years was comparatively moderate. Average annual precipitation in 1999-2004 was 17.78 inches, three percent less than the 60-year average of 18.35 inches (Table 4). In 2005-09, annual precipitation declined by five percent to 16.82 inches, eight percent below the 60-year average. Seven of the stations were drier in 2005-09 than in 1999-2004. Fresno, Redlands, and San Diego were slightly wetter in 2005-09.

For the 49 weather stations between the Sierra Nevada and the continental divide, average annual precipitation in 1999-2004 was 8.34 inches, 13 percent less than the 60-year average of 9.59 inches. In 2005-09, precipitation increased by seven percent to 8.94 inches, but there were stark contrasts between the 22 stations in the northern interior, i.e.

eastern California, northern and central Nevada, Utah, and western Colorado and the 27 stations in the southern interior, i.e. southeastern California, southern Nevada, Arizona, and western New Mexico. In addition, contrasts within the southern region were particularly pronounced.

For the 22 northern interior stations, average annual precipitation increased by 12 percent from 7.77 inches in 1999-2004 to 8.72 inches in 2005-09 (Table 4). 1999-2004 was ten percent below the 60-year average of 8.65 inches, while 2005-09 was slightly above the average. Nineteen of the stations (86 percent), including nine of the ten Upper Colorado River Basin stations, were wetter in 2005-09 than in 1999-2004. Battle Mountain and Caliente, Nevada and Castle Dale, Utah were drier in 2005-09 and were widely dispersed. The three-station average was only five percent lower than in 1999-2004. For the ten Upper Colorado River Basin stations, average annual precipitation increased from 8.72 inches in 1999-2004 to 9.79 inches in 2005-09, an identical 12 percent increase.

For the 27 southern interior stations, average annual precipitation increased by only four percent from 8.80 inches in 1999-2004 to 9.13 inches in 2005-09, due to the presence of two extremely anomalous concentrations (Table 4).

All six stations in the central corridor (Las Vegas, Needles, Gila Bend, Phoenix, Safford, and Tucson) were drier in 2005-09 than in 1999-2004. Average annual precipitation for the six stations declined by 11 percent from 6.29 inches in 1999-2004 to 5.58 inches in 2005-09.

The three stations on the Little Colorado River in northeastern Arizona (Saint Johns, Holbrook, and Winslow) that flows into the Colorado River upstream from Lake Mead were also drier in 2005-09 than in 1999-2004. Average annual precipitation declined by 20 percent from 7.38 inches in 1999-2004 to 5.92 inches in 2005-09. The average for the three stations in 2005-09 was only a third of an inch greater than the average for the six stations in the central corridor.

In 1999-2004, average annual precipitation for the nine stations in the Colorado River water supply and demand areas of the southern interior was 6.65 inches, 13 percent less than the 60-year average of 7.61 inches. In 2005-09, precipitation declined by 14 percent to 5.70 inches, 25 percent below the 60-year average.

Of the 18 remaining stations in the southern interior, only Inyokern in southeastern California was drier in 2005-09 than in 1999-2004. Average annual precipitation for the 18 stations was 10 percent greater in 2005-09 than in 1999-2004 (i.e. 10.84 inches versus 9.87 inches), but there were major regional differences for these stations as well.

For the nine stations in the western and eastern extremities of the southern interior, average annual precipitation increased by 18 percent from 4.66 inches in 1999-2004 to 5.50 inches in 2005-09 (Table 4). Despite the fact that average annual precipitation in western New Mexico was 3.26 times greater than the average for the extremely arid desert in the west, the percentage increases in 2005-09 were identical. Average annual precipitation for Chaco Canyon, Lordsburg, and Animas increased from 8.67 inches in 1999-2004 to 10.24 inches in 2005-09. Average annual precipitation for Inyokern, Trona, Blythe, Calexico, Parker, and Yuma increased from 2.66 inches in 1999-2004 to 3.13 inches in 2005-09.

While all nine remaining Arizona stations to the east of the central corridor were wetter in 2005-09, the increase was much more modest. Average annual precipitation for the nine northern and eastern Arizona stations, excluding the three on the Little Colorado River, increased by seven percent from 15.08 inches in 1999-2004 to 16.19 inches in 2005-09 (Table 4).

Climate change patterns in the southern interior during the 1999-2009 drought were an extreme departure from the comparatively consistent conditions that prevailed in western California and the northern interior. The radical annual precipitation deficits in 2005-09 in the upstream water supply and downstream high demand areas for the Colorado River defy meteorological explanation. The deletion of precipitation data in 2005-09 along the southern Arizona borderlands compounds the regional problem.

Winter Precipitation Change in the Colorado River Basin, upstream from Lake Mead, and the Lower Southwest

For the Colorado River Basin above Lake Mead and the lower Southwest, 1977-80 was one of the wettest three-year winter precipitation sequences on record, a fact that was reflected in the rapid rise of water levels in Lake Mead. Winter precipitation and Lake Mead water levels remained high until the end of the 1990s. Inflows to Lake Mead increased and Colorado River water demand in the lower Southwest decreased as a result of the very wet conditions.

The winter precipitation records for the 36 weather stations in this region show that winter storm tracks shifted to the south, rather than the north, over the 60-year period 1950-2010 (3). Winter storm tracks were at their most northerly position in 1950-61. Average winter (November-March) precipitation was 3.67 inches (Table 5). In 1961-77, winter storm tracks began shifting south. Average winter precipitation increased to 3.95 inches, eight percent greater than in 1950-61. Winter storm tracks plummeted to the south in 1977-99. Average winter precipitation was 5.44 inches, 48 percent greater than in 1950-61. In 1999-2010, winter storm tracks retreated to the north, but winter precipitation was 4.02 inches, slightly greater than in 1961-77 and ten percent higher than in 1950-61.Only seven of the 36 stations (19 percent) were drier in 1999-2010 than in 1950-61. Six were in central and eastern Arizona. For the six stations, 1999-2010 was nine percent drier than 1950-61 (i.e. 4.27 versus 4.67 inches).

For the 17 weather stations within or adjacent to the Colorado River Basin, upstream from Lake Mead, period-to-period increases in winter precipitation were comparatively subdued. 1961-77 was one percent wetter than 1950-61, while 1977-99 was 34 percent wetter. 1999-2010 was nine percent wetter than 1950-61.

Period-to-period increases were considerably greater in the lower Southwest. 1961-77 was 13 percent greater than 1950-61, while 1977-99 was 59 percent greater. 1999-2010 was ten percent greater than 1950-61. The contention in “Dry Times Ahead” that winter storm tracks have recently shifted to the north is valid only in comparison with 1977-99, when winter storm tracks were at their most southerly position of the past 60 years.

Since 1950, there has been a marked increase in annual and winter precipitation in the Southwest United States, although it is not certain that the 60-year trends have been the result of global warming. Climate models indicating the opposing trends are contradicted by the observations.

The evidence presented in the discussion that follows strongly suggests that climate change is being used to divert attention away from the continued building of an extraordinarily water consumptive political power base that has been underway for more than half a century.

Central and Eastern Arizona

Since the end of World War II, Arizona's population growth has been seven times greater than that of neighboring New Mexico, despite the extreme aridity of western Arizona where, with the exception of cities along the Colorado River, the settlement landscape has remained unchanged. In 1950, Arizona and New Mexico had two seats each in the United States House of Representatives. By 2010, Arizona had gained seven seats (5). New Mexico added only one. The phenomenal growth that has occurred in southern Nevada and along Colorado's Front Range resulted in Nevada and Colorado gaining only three seats each over the past 60 years.

Arizona's massively greater growth of population and political power has been achieved primarily through the promotion of water-lavish urban landscapes. Arizona has abundant water resources within its borders, but their capacity for sustaining water-driven population growth has long since been exceeded.

The deletion of precipitation data along the southern Arizona borderlands in 2005-09 and the recent concentration of meteorologically inexplicable annual and winter precipitation anomalies in central and eastern Arizona suggest a need to provide an alternative explanation for escalating demand-driven water scarcity. Climate models indicating a sharp increase in aridity and consequent runoff reduction fulfill this need, but are supported solely by the anomalies. For annual precipitation, 13 of the 15 weather stations in central and eastern Arizona were drier in 1999-2009 than in 1950-60. Only ten of the 34 stations in the surrounding interior Southwest were drier in 1999-2009. Three were in eastern California, two in Nevada, three in Utah, and one each in western Colorado and New Mexico. Nine of the 13 stations that were drier in 2005-09 than in 1999-2004 were in the Las Vegas-Phoenix-Tucson growth corridor and along the Little Colorado River. Seven were in central and eastern Arizona. For winter precipitation, seven of the 36 stations in the Upper Colorado River Basin and lower Southwest were drier in 1999-2010 than in 1950-61. Six were in central and eastern Arizona.

A continuing increase in Arizona's political power can only be attained through the federally supported acquisition of additional water resources. Were it not for the belief that climate change is the cause of diminished water availability, political opposition on the part of states losing Congressional representation would block Arizona's water accumulating efforts. The on-going pursuit of political power is indicated in the 2011 projection by Arizona State University's Morrison Institute for Public Policy. The population of the promotionally re-named Phoenix-Tucson "Sun Corridor" is estimated to increase by more than 3.5 million over the 30-year period 2000-2030. The 82.5 percent increase far exceeds that of the nine other megapolitan areas in the United States identified in the study (6).

Central and eastern Arizona is a climatically and topographically unique region, the northern portion of which is water-rich. Fifty percent of the annual precipitation for 1950-2009 occurred during the summer and fall months (July-October). July and August accounted for 65 percent of the summer and fall precipitation. October was 16 percent wetter than November. In addition, summer and fall precipitation was remarkably stable over the 60-year period. In sharp contrast to western California where winter precipitation was 80 percent of the annual total, winter precipitation accounted for 41 percent of annual precipitation. The spring months (April-June) were very dry. June (0.37 inches) was the driest month of the year.

Because of the dominance of orographically enhanced summer and fall precipitation, northern Arizona is arguably the wettest sub-region east of the Sierra Nevada. The elevations of the ten weather stations in this 200-mile long sub-region range between 3,400 feet and 7,300 feet. The average elevation is 5,705 feet. Average annual precipitation for the 60-year period 1950-2009 was 16.37 inches, 71 percent greater than the average of 9.59 inches for the 49 stations in the interior region (3). Summer and fall precipitation accounted for 7.91 inches, 48 percent of the total (Table 6).

Of the 39 other weather stations east of the Sierra Nevada, only Mesa Verde National Park (elevation 7,000 feet) exceeded the annual average for northern Arizona. Average annual precipitation at Mesa Verde for 1950-2009 was 17.84 inches. Four of the weather stations in northern Arizona were much wetter than Mesa Verde. Average annual precipitation at Williams, Flagstaff, and Payson exceeded 21 inches. McNary 2 N (26.36 inches) was the wettest station east of the Sierra Nevada. As noted previously, for the 49-year period 1950-98, Steamboat Springs, Colorado (24.04 inches) was the wettest station along the western slope of the Rocky Mountains.

Average summer and fall precipitation in northern Arizona was 46 percent greater than it was for the five southern Arizona stations with complete precipitation records for 1950-2009. In absolute terms, northern Arizona received nearly two and a half inches more summer and fall precipitation than southern Arizona, i.e. 7.91 inches versus 5.43 inches (Table 6). Douglas airport was the only station in the south that exceeded the average for the northern stations. The average elevation for the five southern stations is 2,404 feet, 3,301 feet lower than the average for the northern stations. Douglas airport (4,154 feet) is the only southern station with an elevation exceeding 3,000 feet. Phoenix Sky Harbor airport (1,135 feet) is the lowest station. For the 15 stations, summer and fall precipitation was unchanged over the 60-year period. Average precipitation in 1950-79 was 7.08 inches versus 7.09 inches in 1980-2009.

Because of the comparatively high annual precipitation across the 200-mile long sub-region immediately to the north, metropolitan Phoenix possesses a hydrologic resource unmatched by any other metropolitan area in the Southwest. Summer and fall runoff, as well as spring snowmelt, is stored in dozens of small reservoirs throughout the highland. Outflow from these reservoirs is, in turn, stored in nine major reservoirs lying to the north and east of the metropolitan area (7).

For metropolitan Phoenix particularly, water conservation has never been a priority, although myriad token gestures toward that end have been made in recent years. The water supply from the surrounding reservoirs is delivered throughout the metropolitan area in Venetian style canals, despite the high rate of evaporative water loss in this hot and very arid lowland. Water from Lake Havasu on the Colorado River is also transported to Phoenix in an open canal that crosses one of the hottest and driest 100-mile stretches in the Southwest. Average annual evaporative water loss for the five pan evaporation stations within the metropolitan canal network with complete data for 1950-2005 (Bartlett Dam, Stewart Mountain, Mesa, Sacaton, and Roosevelt 1 WNW) was 104.41 inches or 8.70 feet (4). Data from the pan evaporation station at Arizona State University (Tempe) were not used since the annual average was 30 inches less than the average for the five other stations. There are no data for any of the more than 300 pan evaporation stations in the western United States after 2005, despite the fact that these data are critical in determining the hydrologic effect of global warming.

Metropolitan Phoenix's abundant water supply supports many more golf courses than all of the rest of the state combined, i.e. 121 versus 87 (7). The lush fairways of the golf courses typify the urban landscape that resembles that of a city in the humid eastern United States, without which Phoenix would not be the magnet for immigration that it has become over the past several decades. The environmental liability of intense summer heat is offset by the ubiquity of backyard swimming pools.

In the lower Southwest, the proliferation of municipal and private golf courses has been a major factor contributing to the high rate of population growth. In Nevada and Arizona, golf courses have been classified as industrial water use, along with mining and manufacturing, for over forty years despite the fact that they produce nothing (8, 9). This has masked their considerable impact on municipal water demand, thereby making municipal water use appear to be much less than it actually is.

The Impending Colorado River Crisis

The final and most critical issue is the threat to Colorado River water supplies imposed by recent population growth in the lower interior Southwest. The severity of the problem is demonstrated by an examination of the history of water levels in Lake Mead following the construction of Hoover Dam in the early 1930s.

From 1935 to 1939, Lake Mead's elevation rose to 1,172 feet and remained generally at that level through 1952 (10). In 1953-57, when the demand for water from the Colorado River was far less than it has been in recent decades, the average elevation fell to 1,124 feet due to the aforementioned drought. Lake Mead's average elevation rebounded to 1,174 in 1958-62, after which upstream water began to be stored behind Glen Canyon Dam. Lake Mead's average elevation declined to 1,138 feet in 1963-72 while Lake Powell was being filled.

From 1973 through 1977, Lake Mead's average elevation rose to 1,179 feet due to increased inflow from Lake Powell, but this was followed by a rapid 24-foot increase that occurred from 1978 through 1980 (1,203 feet) as a result of the sharp increase in winter precipitation in the upstream Colorado River Basin and reduced demand in the lower Southwest.

For the 20-year period 1981-2000, Lake Mead's average elevation was 1,197 feet, 25 feet higher than 1939-52 and 18 feet higher than 1973-77 as a result of continuing very wet conditions during the 1980s and '90s. 1983 (1,215 feet) and 1998 (1,214 feet) were the two highest years in the history of the reservoir. Field inspection by the author in October 2012 confirmed that the high water mark shown in the photograph of Lake Mead in "Dry Times Ahead" is from this 20-year wet period.

By 2010, Lake Mead's elevation had plummeted to 1,091 feet, the lowest year on record dating back to 1939 and perilously close to the minimum elevation (1,083 feet) of the active joint use pool that supplies water for municipal use, industrial use, irrigation, and power generation (10, 11). Three simultaneous factors were responsible for the 112-foot decline that occurred between 2000 (1,203 feet) and 2010.

Drought in the upper Colorado River Basin during the six-year period 1999-2004 was the most severe of the past 60 years. Average inflows to Lake Mead in 2000-04 were only 50 percent of the long-term average (12). The reservoir's average elevation fell to 1,156 feet in 2001-04, 41 feet below the 1981-2000 average (10).

In 2005-09, average inflows increased to 88 percent of the long-term average. 2005 (105 percent), 2008 (102 percent), and 2009 (90 percent) were the three highest years (12). In contrast to the 50-foot recovery that occurred in 1958-62, Lake Mead's average elevation fell to 1,114 feet in 2005-10, an additional 42 feet below the 2001-04 level and ten feet lower than in 1953-57.

The tremendous increase in Colorado River water demand in central Arizona and southern Nevada was a major factor in the 2005-10 decline. From April 1, 2000 through July 1, 2009, there was a 33 percent increase in the population of Maricopa, Pinal, and Pima counties in central and southern Arizona and Clark County in southern Nevada. The four-county total population increased by 1,816,000 over the nine-year period (13). The three Arizona counties along the Phoenix-Tucson corridor accounted for 71 percent of the population growth (1,289,000) with 80 percent of that growth being concentrated in metropolitan Phoenix and adjacent Casa Grande. For political reasons particularly, draw down of Lake Mead's water supply to meet the increasing demands of the residential and commercial real estate boom in the Phoenix-Tucson corridor and metropolitan Las Vegas was the utmost priority. Rapid population growth resulted in increased Congressional representation in 2010.

The third factor imperiling Lake Mead's water storage was the emergence of water banking in the late 1990s in response to accelerating population growth. From 1999 through 2008, the Arizona Water Banking Authority and the Southern Nevada Water Authority stored over 4.2 million acre-feet of previously unused Colorado River and secondary tributary river allocations as groundwater to compensate for future surface water shortage (12, 14). This is enough water to meet the demands of a city of three million people for approximately seven years. Seventy-nine percent of the water (3.3 million acre-feet) was stored along the Phoenix-Tucson growth corridor (14).

The impending Colorado River crisis is the product of a region living far beyond its hydrologic means, rather than climate change. The critical decline of Lake Mead's elevation from 2005 through 2010 was the result primarily of the addition of nearly two million more water consumers in central and southern Arizona and southern Nevada over the last eleven years and simultaneous water banking. Arizona and Nevada each gained a seat in the United States House of Representatives as a result of the 2010 federal census, but at hazardous hydrologic cost.

If the increase in annual and winter precipitation that has occurred over the past 60 years has been the result of global warming, continued warming will increase potential water storage in Lake Mead. The projected addition of 2.2 million more water consumers in Arizona's Sun Corridor over the next 20 years will far exceed the possible climatic benefit, just as water-driven population growth in metropolitan Phoenix outstripped northern Arizona's abundant water supply.

The Water Resource Future for the Lower Interior Southwest

In 2001, average daily per capita water use for Phoenix and Las Vegas was 285 gallons, 60 percent greater than the average of 178 gallons for Tucson, Albuquerque, and El Paso (15). While a number of Southwestern cities have made substantial progress in conserving their water resources, Alamogordo, New Mexico (population 41,000) stands out as a model for what can be accomplished. In 2005, Alamogordo was one of only two cities in the United States to receive the U. S. Conference of Mayors Municipal Water Conservation Achievement Award.

In 1992, Alamogordo's water use, including its golf course, was 261 gallons per person per day, about the same as that of Phoenix, excluding the golf courses. By 2004, the city reduced water use to 121 gallons per person per day (15). All water use, including reclaimed water, is metered. The 54 percent reduction was accomplished primarily through two measures.

The city greatly reduced its freshwater consumption by developing a reclaimed waste water system (16.2 miles of pipeline and two booster stations). Reclaimed water is used exclusively for parks, athletic fields, cemeteries, city landscaping, construction site dust suppression, and the city's golf course. In 2004, the city produced 1,592 million gallons of water from its two water filtration plants and wells. Thirty-one percent (499 million gallons) was reclaimed and reused (15).

Secondly, Alamogordo implemented a five-tiered water rate structure in which progressively higher rates are charged for those consuming greater amounts of water. In addition, a surcharge is imposed for water waste during drought. This reduced water consumption by 49 gallons per person per day from 2000 through 2002 (15).

Although average annual temperature is eleven degrees F. cooler than Phoenix, the problem of high evaporative water loss was solved by covering the city's three freshwater reservoirs and two reclaimed water reservoirs. In addition, a city ordinance was passed requiring that all swimming pools be covered when not in use (15).

Arizona's present water management policies that stimulate population growth, increased Congressional representation, and political power at the expense of other states are unsustainable in the long term. When all of the water used for irrigating agricultural land is expropriated for municipal and "industrial" use in coming decades, water-lavish urban landscapes will be next in line. The water management plan recently implemented by the Southern Nevada Water Authority, in which residents have been paid for removal of lawns from their property (12), foretells the future for the lower interior Southwest. Urban landscapes with progressively diminished lawns, gardens, and golf courses will neutralize the immigration magnet. Graveled yards and rock gardens with interspersed cacti and other desert plants have a decidedly limited appeal. Heat-relieving swimming pools will also become hydrologic relics. Population growth along Arizona's Sun Corridor will gradually grind to a halt.

Continuing depletion of dwindling groundwater resources, on which most of Arizona is dependent, will coincide with and exacerbate the problem of increasing surface water scarcity. Recent Arizona legislation has been designed to prevent both knowledge of the severity of groundwater depletion and implementation of remedial measures, as these would impede population growth.

In 2007, the state legislature addressed the issue of groundwater depletion in southeastern Arizona's Sierra Vista Sub-watershed. House Bill 2300 created the Upper San Pedro Water District, the boundaries of which were identical to those of the Sub-watershed. HB 2300 expressly prohibited the Water District's Board of Directors from (1) "requiring water measuring devices [i.e. water meters] for wells in the District," (2) "imposing mandatory conservation requirements," and (3) "regulating use of water within the District." In lieu of these measures that would have reduced groundwater depletion and possibly eliminated groundwater overdrafts, the Water District's Board of Directors was authorized to "issue revenue bonds [and] impose and collect fees related to revenue bonds to acquire water supplies and water rights for water deliveries [from the] Colorado River" (16).

HB 2300 was approved by 55 of the 60 members of the Arizona House of Representatives and 22 of the 30 members of the Senate and was signed into law by then Governor Janet Napolitano, pending final approval by a majority of the registered voters in the Water District (17). HB 2300 was defeated in the November 2010 general election largely because of high cost for Water District residents, even with federal assistance.

Conclusion

By obscuring precipitation, evaporation, and other water data, and relying on climate models that are radical departures from reality, it may be possible to garner unwitting Congressional support for federally funded water augmentation projects, such as the importation of desalinated water from the Gulf of California, but this will only delay the inevitable at very high cost. Sequential exhaustion of groundwater supplies for cities to the north, east, and west of the Sun Corridor, increasing consumption of surface water, and increasing evaporative water loss due to global warming ensure that immigration will ultimately cease and emigration will ensue. The end result, in the latter half of the century or possibly sooner, will dwarf the "Dust Bowl" emigration of the 1930s when Nebraska, Kansas, and Oklahoma each lost a seat in the United States House of Representatives as a result of the 1940 federal census (5).

The counterproductive futility of Arizona's obsession with building political power through water-driven population growth will be demonstrated when its groundwater resources are exhausted and shortsighted political gains are relinquished.

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