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The Walker Basin, Nevada and California: Physical Environment, Hydrology, and Biology

West Shore with Rock Formations

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Cover photo, West Shore with Rock Formations, January 18, 2005, by Bonnie Rannald, Photographic Expressions, http://www.bonnierannald.com

KEY TERMS

(Horton, 2001; www.fws.gov/endangered/glossary.pdf)

Acre-Foot (or Acre-Feet) – A unit commonly used for measuring water volume; equal to the quantity of water required to cover one acre to a depth of one foot. Equivalent to 43,560 cubic feet or 325,850 gallons.

Aerobic – An environment in which oxygen is present; an organism requiring the presence of oxygen for growth; a process that occurs only in the presence of oxygen.

Anaerobic – An environment in which oxygen is absent; an organism able to grow only in the absence of oxygen; a process that occurs only in the absence of oxygen.

Andesitic – Composed of fine-grained igneous rock (volcanic origin).

Bathymetry – The measurement of water depth at various places in a body of water; information derived from such measurements.

Biodiversity – The variety of plant and animal life, and the communities and ecosystems in which they occur.

Biota – Flora and fauna.

Consumptive use – A use of water that renders it no longer available because it has been evaporated, transpired by plants, incorporated into products or crops, consumed by people or livestock, or otherwise removed from water supplies.

Decreed water rights – Water rights determined by court decree.

Desiccate – To dry out thoroughly.

Ecosystem – A community of bacteria, plants, and animals and its interrelated physical and chemical environment.

Ecotone – A habitat created by the juxtaposition of distinctly different habitats; an edge habitat; or an ecological zone or boundary where two or more ecosystems meet.

Endemic – A species or taxonomic group restricted to a particular geographic area.

Epilimnion – The warm, upper layer of a stratified lake.

Eutrophic – Of a lake or other body of water containing a rich supply of plant nutrients and characterized by periods of oxygen deficiency as a result of excessive growth of algae.

Evaporation – The process by which water from land areas, bodies, water, and all other moist surfaces is transformed into a vapor and absorbed by the atmosphere.

Evapotranspiration – The combined processes of water lost as vapor from a soil or an open water surface and water lost from the surface of a plant.

Extirpated – An organism that no longer exists within a defined portion of its range, but still lives in other areas. Removed or destroyed from a given area.

Fauna – Animals.

Federal species of concern – An informal term referring to a species that might be in need of conservation action. This may range from a need for periodic monitoring of populations and threats to the species and its habitat, to the necessity for listing as threatened or endangered. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.

Fetch – The path across a surface of water over which the wind travels; varies with wind direction.

Floodplain – The low and relatively flat area adjacent to rivers and streams. A 100-year floodplain is that area subject to a one percent or greater chance of flooding in any given year.

Flora – Plants.

Herpetofauna – Reptile and amphibian animals.

Hydrology – The science of waters of the earth; their occurrence, distribution and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.

Hypolimnion – The cold, lower layer of a stratified lake.

Infiltration – The gradual flow of water into and through the pores of a soil.

Imperiled species – A general term usually encompassing endangered, threatened, and at-risk species as well as species of concern.

Invertebrates – Creatures without a backbone or spinal column.

Ionic constituents – An electrically charged atom or group of atoms, herein referring to the major ions found in inland waters (calcium, magnesium, chloride, sodium, sulfate, bicarbonate or carbonate).

Lacustrine – Pertaining to a lake.

Limnology –The study of freshwater, the aquatic environment, and its life.

Listed species – A species or subspecies that has been added to the federal lists of endangered and threatened wildlife and plants as they appear in sections 17.11 and 17.12 of Title 50 of the Code of Federal Regulations (50 CFR 17.11 and 17.12).

Littoral – The shallow area near the shore of a non-flowing body of water.

Metalimnion or thermocline – The middle region of temperature change within a stratified lake.

Mean sea level (msl) – The level of the surface of the sea between mean high and mean low tide; used as a reference point for measuring elevations.

Paleoecology – The ecology of past environments.

Parts per million (ppm) – The concentration of a solution in grams of solute per one million grams of solution.

Phreatophyte – A plant that draws groundwater from a permanent ground supply or from the water table.

Phytoplankton – Tiny, free-floating, photosynthetic organisms in aquatic systems. They include diatoms, desmids, and dinoflagellates.

Riparian – Pertaining to the banks of a river or stream.

Riverine – Open water area occurring in the channel of a stream, intermittent stretches of streams, or dry washes.

Storage right – The authority granted by a responsible state entity to impound water in a reservoir.

Stratified – Placed in layers, such as the water column of a lake.

Supplemental right – Water rights granted for a secondary source of irrigation water.

Taxa – A species of plant or animal; a taxonomic category or group, such as a phylum, order, family, genus, or species.

Terminus lake – A lake with no outlet.

Threatened species – Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Total dissolved solids (TDS) – A measure of the amount of material dissolved in water (mostly inorganic salts), typically aggregates of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, etc. of calcium, magnesium, manganese, sodium, potassium, and other cations that form salts.

Transmissivity – The rate at which groundwater is transmitted through a unit width of an aquifer under a unit of hydraulic gradient.

Water right – A water appropriation for which a water license has been issued. May refer to either groundwater or surface water. Senior water rights are those rights that are satisfied before junior water rights, in order of their priority date. Junior water rights are those with a later priority date than senior water rights. Junior water rights are satisfied after all senior water rights are filled.

Zooplankton – The animal portion of tiny organisms such as rotifers, copepods, and krill, floating or drifting in a water body.

ACRONYMS

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
B.P.	Before present. Unit of uncalibrated age from radiocarbon dating, with 1950 being the baseline, or present, from which counting begins.
CDF&G	California Department of Fish and Game
CNDDB	California Natural Diversity Data Base
FEMA	Federal Emergency Management Agency
LCT	Lahontan cutthroat trout
mg/L	Milligrams per liter. A measurement of concentration based on one gram of a given substance dissolved in one liter of water. Generally equivalent to ppm (parts per million).
msl	Mean sea level
NDOW	Nevada Department of Wildlife
NRS	Nevada Revised Statutes
ppm	Parts per million
TDS	Total dissolved solids
USFS	United States Forest Service
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
WMA	Wildlife Management Area
WRCC	Western Regional Climate Center
WRID	Walker River Irrigation District
WRPT	Walker River Paiute Tribe

INTRODUCTION

This report describes current physical, hydrological, and biological environments of the Walker Lake Basin. The information is based on current data drawn from peer-reviewed scientific literature, agency data sets and reports, and other published sources. Acronyms and a glossary are included at the beginning of the report. We envision that this document will be used as a starting point for those interested in learning more about, or conducting research in, the Walker Basin.

The waters of the Walker Basin support agriculture, recreation, and wildlife in a number of diverse riverine, riparian, and lacustrine (lake) ecosystems. The Walker River Basin is popular for recreational activities including fishing (in the river, lake, and reservoirs), boating, and day and overnight use. Wildlife, migratory birds, and numerous terrestrial and aquatic species utilize resources in the Walker Basin. Lahontan cutthroat trout (LCT), a federally listed threatened species (Federal Register Vol. 40, p. 29863 29864), inhabit the headwaters of the Walker River and Walker Lake.

Farming is important to the economy of Lyon and Mono counties. Most irrigation water is supplied by surface water and is often supplemented with groundwater during dry periods. During an average snowpack year (when snowpack equals 100% of normal), only 84% of agricultural water rights can be satisfied; a year of 130% of normal snowpack is required to provide enough water to satisfy the full allocation of water rights to farmers in the basin. In many years, not enough water is available to simultaneously provide water for agriculture and maintain Walker Lake levels.

Of concern to many is a 149 foot drop in the level of Walker Lake during the last 125 years. The lake level dropped from an 1882 elevation of approximately 4,083 feet above mean sea level (msl) to 3,934 feet above msl in December 2007. This drop resulted in a decrease in lake volume from approximately 9.0 to 1.7 million acre-feet. This decrease is because water has been withdrawn for irrigation, not because of drought conditions (Milne, 1987; Beutel et al., 2001). Total dissolved solids (TDS) were ~16,000 ppm in December 2007. Reductions of inflow to Walker Lake and subsequent change in water quality have altered the entire ecosystem of the lake, resulting in a loss of biodiversity (a reduction in the number of species of zooplankton, invertebrates, and fishes present). The current LCT population maintained by stocking is not the original strain of LCT originally inhabiting Walker Lake. The original strain was extirpated from Walker Lake because dam construction impacted spawning runs up the river. Reproduction of tui chub, a primary food source for the LCT, may be compromised in Walker Lake. Although spawning activity occurred as of 2005, viable eggs and larvae were not observed (NDOW, 2005).

SETTING

The Walker River Basin encompasses approximately 2,658,420 acres along the eastern side of the Sierra Nevada and western portion of the Great Basin (Figure 1). Headwaters of the East and West forks of the Walker River, which ultimately feed Walker Lake, originate in the Sierra Nevada of California at elevations between 10,007 and 12,303 feet. The rivers flow through the Bridgeport, Antelope, and Smith valleys – located in California and Nevada – and join in Mason Valley, Nevada, to create the main stem of the Walker River. The main stem flows through the Mason Valley Wildlife Management Area, Walker River Paiute Reservation, and terminates at Walker Lake, near Hawthorne, Nevada.

The basin's modern climate varies from humid continental (cold winters with heavy precipitation) at high elevations to low latitude desert (arid, hot summers) at Walker Lake. The Sierra Nevada create a rain shadow to their east which decreases precipitation as storms move from west to east across the mountain range. During winter, storms generally deposit snow on the Sweetwater Mountains and Sierra Nevada, but occasional warm storms, particularly in November and December, result in rain at high elevations. These rain-on-snow events can cause flooding. During summer and fall, thunderstorms can generate runoff and flash floods, although distribution of precipitation from thunderstorms is very erratic, both in time and space. Because natural inflow into Walker Lake is dependent on climate, river and lake volume fluctuate in response to different climate regimes.

Average annual precipitation at Bridgeport, California (elevation 6,440 feet), is 9 inches (57-year record) while average annual precipitation at Hawthorne, Nevada, (elevation 4,220 feet), is less than 5 inches (51-year record) (WRCC, 2006). Substantial seasonal and diurnal temperature fluctuation, common to desert environments, occurs at the lower elevations. Temperatures at Hawthorne range from an average maximum temperature of 71˚ F to an average minimum temperature of 41˚ F. Temperatures at Bridgeport range from an average maximum temperature of 62˚ F to an average minimum temperature of 24˚ F. Bridgeport receives an average of 43 inches of snowfall per year, while Hawthorne receives 2.8 inches of snowfall. Less than half of annual precipitation occurs during the growing season (U.S. Department of the Interior, 1964). Land use includes agriculture, recreation, and military activities, as well as urban and rural housing. Most irrigated land is located in Lyon County. Land ownership and administrative control in the basin includes private, state, county, cities and towns, national forest, public domain, military lands and installations, and Indian reservations.

Lands in the Walker River Basin are under jurisdiction of the following:

- California and Nevada
- Five counties: Mono County in California, and Douglas, Lyon, Churchill, and Mineral counties in Nevada
- Municipalities
- Two National Forests: Stanislaus and Humboldt-Toiyabe
- BLM-managed public lands under jurisdiction of the Carson City Field Office
- Department of Defense lands under jurisdiction of the U.S. Army, U.S. Navy, and U.S. Marine Corps

- Three Indian reservations under jurisdiction of the Bridgeport Indian Colony, Yerington Paiute Tribe, and Walker River Paiute Tribe (Figure 1).

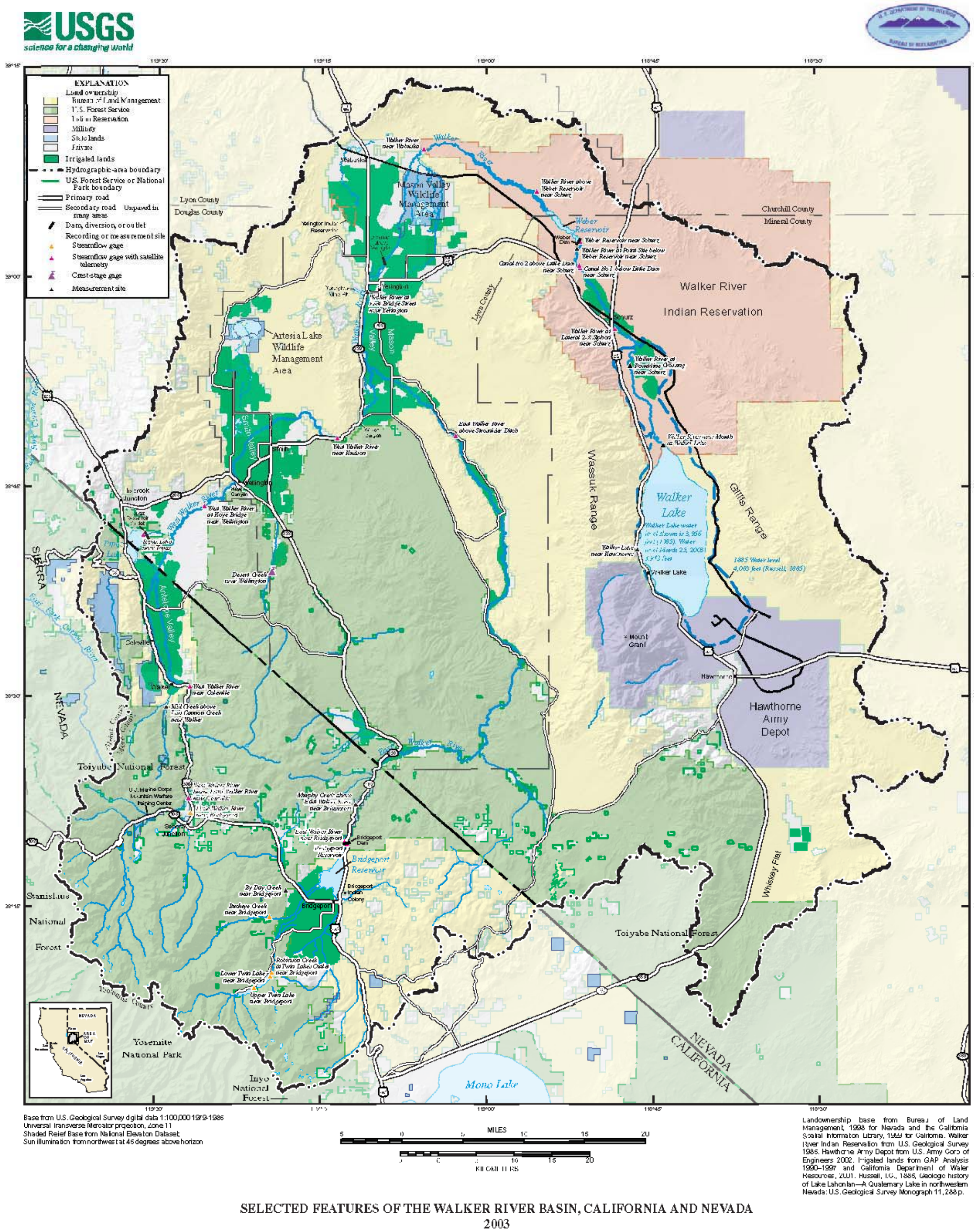

Figure 1. The Walker River Basin includes the high Sierra Nevada of California and the Great Basin Desert of Nevada (U.S. Geological Survey, 2007). To download separate 11” x 17” map, go to http://nevada.usgs.gov/walker/maps.htm.

Recreation

The Walker River Basin includes diverse recreational resources. Lake, reservoir, river, upland, mountain, and wetland areas are used for day and overnight recreational activities all year. Activities in the Walker Basin include boating, fishing, big and small game hunting, off-road vehicle use, sightseeing, hiking, kayaking, swimming, rock hounding, photography, nature study, bird watching, collecting plants, and rock climbing.

Recreational lands are private or owned and administered by USFS, California, BIA, and BLM. The USFS owns and manages the Rosaschi Ranch, which includes a seven-mile stretch of the East Walker River, renowned as a spectacular catch and release fly-fishing destination. Within the Toiyabe National Forest, Nevada, and the Inyo National Forest, California, lies the 47,937-acre Hoover Wilderness Area. Recently (2008), within the Toiyabe National Forest, the Hoover Planning Area West (49,200 acres) is recommended for addition as a wilderness area and the Hoover Planning Area East (23,500 acres) is recommended for a planning area. The USFS also administers Alum Creek campground (camping and picnicking) and Desert Creek Campground (camping, fishing, and picnicking). The BIA administers much of the land around the main stem of the Walker River. The BLM administers Wilson Canyon (picnicking and fishing), and the Nevada Highway Division administers the Wilson Canyon rest area.

The BLM, Walker River Paiute Tribe, and Hawthorne Army Depot are landowners contiguous to Walker Lake, whereas Nevada has jurisdiction of land beneath the lake. BLM campgrounds adjacent to Walker Lake, Sportsman's Beach, and Tamarack Point attract between 8,000 and 11,000 visitors every year. Special events, such as the Audubon Christmas Bird Count and the Loon Festival, attract three to five hundred visitors to the basin each year.

Boating and boat fishing, swimming, picnicking, and camping also occur at the three major reservoirs in the basin. Bridgeport Reservoir is situated at the base of the Sierra Nevada in California on the East Walker River. Topaz Lake lies on the California-Nevada border and receives West Walker River water. Weber Reservoir is located on the main stem of the Walker River on the Walker River Paiute Reservation. Public access to these areas includes land owned or administered by the USFS, BLM, private entities (Bridgeport Reservoir); private and federal (Topaz Lake); and Walker River Paiute Reservation (Weber Reservoir).

The Mason Valley Wildlife Management Area and the Alkali Lake (Artesia) Wildlife Management Area, administered by Nevada, offer hunting, bird watching, and fishing opportunities. Recreational use of the Mason Valley Wildlife Management Area (WMA) is considerable. For the period from 1991 through 2005, the area hosted an average of 38,000 visitors per year. Visitor activities include hunting, fishing, bird watching, hiking, horseback riding, berry picking, photographing, bicycling, and touring the fish hatchery.

Tribes and Colonies in the Walker River Basin

The Numa (People), as Northern Paiute groups prefer to call themselves, were hunter-gatherers prior to the arrival of Europeans. The relationship of the Paiute to their environment is evident by traditional names of the tribes—such as Agai Dicutta (Trout Eaters), Ta,boosi Tuka'du (Cyperus Eaters), Toi Dicutta, (Tule Eaters), Cui ui Dicutta (Cui cui Eaters), and Pugwi Dicutta (Fish Eaters). These names are all based on food resources requiring the presence of water. Historical accounts describe 1,500 to 2,000 Native Americans gathered at Agai Pah (Walker Lake) and Agai Hoop (Walker River) to fish during traditional fall and spring fish runs. Tui chub and LCT were dried as a staple for winter use. LCT were historically caught in the rivers from the headwaters to Walker Lake. Plants growing in the Walker River corridor—such as willow, buckberry, wild onion, and cattails— and in the upland areas—such as pinyon, juniper, and sage—were, and are, gathered for food, medicine, and household items. Deer, rabbit, and game birds—such as quail, duck and coot—also were traditionally hunted (Fowler and Liljeblad, 1986).

Acculturation and change in natural flows to Walker Lake altered hunter-gatherer traditions of the Paiute Tribes in the Walker Basin. Traditional gathering areas containing medicinal plants and food sources were permanently altered or destroyed. For example, freshwater mussels in the East Walker River, cyperus bulbs (Ta,boosi), and other small grain plants are no longer locally available. Acres of traditional foods, such as the buckberry, are regularly cleared for agricultural purposes; and other traditional foods, such as wild onion, are trampled by livestock in riparian areas. Bighorn sheep, sage grouse, antelope, and porcupine, all once common food items, have decreased in number. Northern Paiute Tribal members continue to hunt animals and gather plants when available and accessible. The Paiute tribes in the Walker Basin continue to work to preserve their reservations' natural resources and more recent agricultural way of life.

Three Indian tribes are located in the Walker Basin: the Bridgeport Indian Colony, the Yerington Paiute Tribe, and the Walker River Paiute Indian Tribe.

<u>Bridgeport Indian Colony</u>

The Bridgeport Indian Colony is a federally recognized tribe. The colony is located at the headwaters of the East Walker River within the Bridgeport Valley on 40 acres of land one mile northeast of the junction of U.S. Highway 395 and State Route 182 near Bridgeport, California. Average elevation of the reservation is about 6,500 feet, and the land is covered predominately by sagebrush, grasses, and forbs. The colony was established in 1974, and the constitution was adopted in 1977 and amended in 1994. Many Bridgeport tribal members are related to members of other tribes along the Walker River. Currently, the colony does not hold decreed water rights in the Walker Basin.

<u>Yerington Paiute Indian Tribe</u>

The Yerington Paiute Indian Tribe has historically and prehistorically utilized the entire Walker River Basin and areas beyond—such as Mono Lake, Bodie, Sweetwater, the Desert Creek area, and Aurora. The Yerington Paiute Tribe Indian Reservation was set aside in 1916. It is located 85 miles southeast of Reno, Nevada, and includes a total of approximately 1,640 acres with some of these acres in agricultural production. The Yerington Paiute Indian Tribe was recognized under the Indian Reorganization Act of June 1934, and its bylaws and constitution were approved in 1936 recognizing the tribal government. The colony, located in Yerington, includes approximately 30 acres and uses City of Yerington water and sewer services.

Decree C-125 provides water rights for the reservation and colony. The tribe owns 1061.456 acre-feet of C-125 Decree water rights. Surface water priority dates range from 1863 to 1905, with a duty of 3.2076 acre-feet/acre/year. Supplemental storage rights beginning with a decree of 1875 for both Topaz Lake and Bridgeport Reservoir are held in addition to some straight storage rights.

Walker River Paiute Indian Tribe

The Walker River Paiute Indian Tribe is known as the Agai Dicutta (Trout Eaters). Historically, LCT was a major food source, sold locally and shipped by railroad, and a major source of income for the tribe. The main stem of the Walker River flows through the reservation in a southeasterly direction for approximately 45 river miles (Figure 1). Walker Lake, the terminus of the Walker River, lies at the southern end of the reservation.

The reservation, set aside for the tribe as its homeland in 1859, includes 323,405 acres. The tribe established the constitution and bylaws of the Walker River Paiute Tribe of Nevada in 1936, and the constitution was formally accepted via a vote of the people in 1937. The town of Schurz, Nevada, is considered the hub of the reservation land, with tribal administration offices and community services located there. The overall tribal population approaches 2,000 individual members with approximately 900 tribal and non-tribal members residing on the reservation.

The Walker River Paiute Indian Reservation supports populations of mule deer, antelope, small game, waterfowl, and upland birds. Other natural resources include water, farmland, rangeland, recreational land (for hunting, fishing, hiking, camping, off-road sports), minerals, and wildlife. Weber Reservoir provides the ability to store water for use during summer months, as well as for recreational activities. The reservoir can provide habitat for bald eagles, peregrine falcons, and other wildlife. Both Weber Reservoir and Walker Lake are recognized by the tribe as important resources.

The Walker River Paiute Indian Reservation is the last area where water is diverted from the Walker River before it flows into the lake. Decree C-125 provides the reservation with the earliest priority of water rights (1859) on the entire river system. The tribe's decreed right is to 26.25 cfs to irrigate 2,100 acres on the reservation for a 180-day continuous irrigation season each year.

Agricultural Development and Consumptive Use

Individual actions undertaken by private, local and state entities during the last 150 years did not, at first, noticeably impact the hydrologic and biologic systems of the Walker River and Walker Lake. The sum of these actions during the course of multiple decades, however, has resulted in measurable changes in the basin's hydrology and biota by impacting the Walker Lake ecosystem and altering natural flows and processes in the Walker River.

As reported in Horton (1996), initial modification of the Walker River Basin hydrologic regime was in 1852, beginning with the first diversions of water from the Walker River for irrigation of agricultural lands. As irrigated agriculture proved successful in the Walker River Basin, additional water rights were filed, and irrigated agriculture expanded throughout the basin. Lands under irrigated agricultural production increased from 0 acres in 1850 to 58,000 in 1909 and approximately 103,000 acres below the Bridgeport Valley in 1919 (Horton, 1996). Presently, approximately 110,850 acres are irrigated in the Walker River Basin (Pahl, 1999).

The average yearly number of continuous frost-free days within the basin varies from a low of 51 days in Bridgeport Valley to a high of 107 in the Mason Valley area. Flow in the Walker River typically tapers off to relatively low levels by mid-July, except in very high flow years. Thus, without reservoirs, water from the Walker River is not available to support irrigated crops throughout the growing season. Reservoirs extend the irrigation season by harvesting and storing water during non-irrigation periods and allowing release of water during periods of low flow late in the irrigation season.

With construction of the two largest reservoirs in the Walker Basin, Topaz Lake (59,439 acre-feet of storage, completed in 1922) and Bridgeport Reservoir (42,455 acre-feet storage, completed in 1923), many farmers in Smith and Mason valleys were able to extend their growing season until late September and October. After Topaz Lake and Bridgeport Reservoir were completed, between 74,000 and 100,000 acres were under production in the Smith and Mason Valleys between about 1930 and 1990 (Horton, 1996).

Although reservoirs within the Walker River Basin are used to extend the irrigation season, their operation is compromised during multiple year droughts because of lack of surface water runoff into the reservoirs. Thus, during extended drought periods, reservoir volume decreases and demand exceeds supply. Plans were put forward to construct larger water-holding facilities within the basin to alleviate this problem, but with the advent of more economically efficient groundwater pumping systems along with the issuance of supplemental groundwater rights in the early 1960s, no additional reservoirs were built.

Beginning in the 1960s, supplemental groundwater rights were granted by the State of Nevada to decreed water right holders for use when Walker River flow was insufficient to satisfy the initial decreed water rights. Utilizing groundwater to supplement surface water diversions allows irrigation for the full growing season and produces a net increase in agricultural production through time. Thus, substantial increases in pumping of the shallow aquifers in Smith and Mason valleys have occurred during low-flow years since the early 1960s. Groundwater pumping in Smith and Mason valleys has depressed the aquifer’s water table, resulted in a net increase in recharge from the Walker River to the aquifer, and created a net decrease in stream flow passing the Wabuska stream gage located just upstream from the Walker River Paiute Reservation (Figure 1).

A comprehensive timeline of actions that modified the Walker River Basin’s hydrologic regime are presented in the *Walker River Basin Chronology* (Horton, 1996). Some major events are shown in Figure 2. Modifications to the Walker Basin hydrologic regime have decreased inflows to Walker Lake and changed the natural hydrograph of the Walker River. Based on flow records (period of record 1902–2005) from U. S. Geological Survey stream gage 10301500 (near Wabuska), flows have decreased from an estimated annual average of approximately 300,000 acre-feet per year prior to 1850 to an annual average of approximately 118,000 acre-feet per year. This decrease has resulted in a fairly consistent decline in the volume of water contained in Walker Lake from 8,962,000 acre-feet in 1882 to 1,710,000 acre-feet in December 2007. The volumetric decrease corresponds to an increase in total dissolved solid (TDS) concentration in Walker Lake from an estimated 2,500 parts per million (ppm) in 1882 to approximately 15,995 ppm in December 2007 (Figure 2).

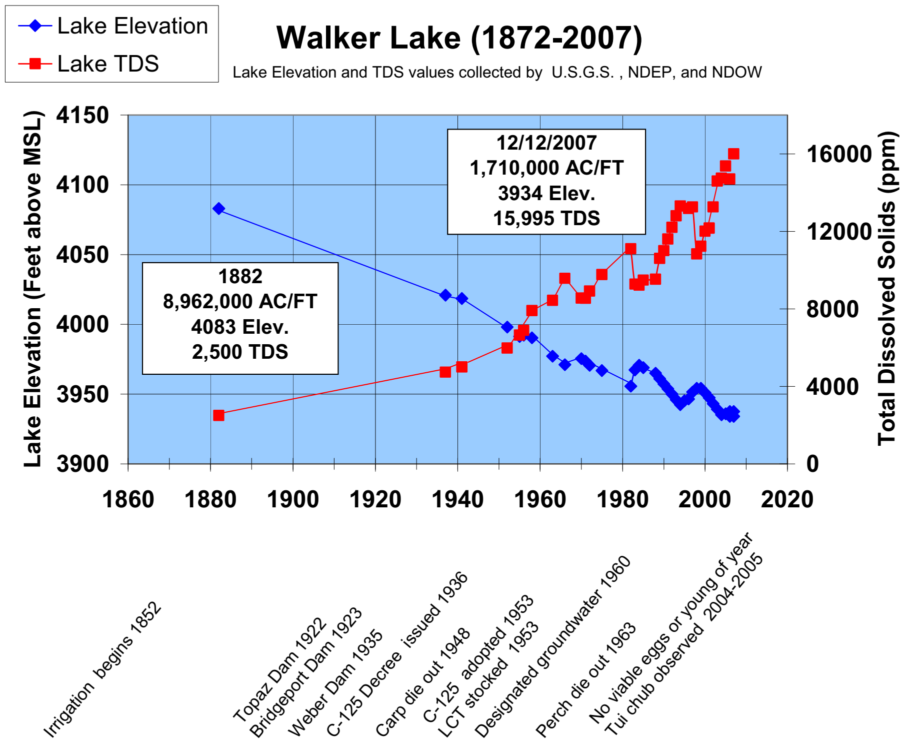

Figure 2. An abbreviated timeline of Walker Lake, including volume and TDS.

<u>Decree C-125</u>

Decree C-125 (commonly referred to as the Walker River Decree), as supplemented by various rules and regulations ordered by the Federal District Court, constitutes current adjudication of water rights in the Walker River Basin. Decree C-125 was issued in 1936, amended in 1940, and finally adopted in 1953. This decree is presently under appeal by the United States. The appeal to Decree C-125 notwithstanding, the decree includes four primary provisions:

- Rights for the Walker River Indian Reservation which were established with a priority date of 1859.
- Diversion rates for each of the other adjudicated claims—including priority, source, acreage, and place of use.
- Irrigation seasons of March 1 through September 15 in Bridgeport Valley and the upper East Walker River; as 180 consecutive days for the Walker River Paiute Indian Tribe; and as March 1 through October 31 for all other users.
- Water storage rights were defined for the Walker River, primarily Bridgeport Reservoir and Topaz Lake, as well as specified rights to refill these reservoirs under stipulated conditions.

The administration of Decree C-125 is the responsibility of the United States Board of Water Commissioners, a six-person board appointed pursuant to Federal District Court orders, which acts as the Water Master for the Walker River. Additionally, the Chief Deputy Water

Commissioner has responsibility for day-to-day operation of the Walker River system in accordance with provisions of Decree C-125.

Nevada and California Water Law

Water rights for the Walker River Basin are administered by Nevada and California. Nevada water rights are administered by the Nevada State Engineer under authority of Title 48 of the Nevada Revised Statutes. California water rights are administered by the state Water Resources Control Board and can be held under a variety of legal doctrines.

Nevada water law provides that both surface and groundwater rights in Nevada are based upon the doctrine of prior appropriation. In general, this doctrine holds that the first in time to use the water has the first priority for its continued use. Two basic types of water rights are recognized: vested rights (those with initial use pre-dating Nevada's water laws and confirmed through the judicial process) and appropriative rights (those established through the permit process of the State Engineer). The appropriative rights process is initiated when an application for a water rights permit is filed with the State Engineer to make beneficial use of some portion of the waters of the state of Nevada.

Subject to a specific process of public notification, protest, and judicial review, the Nevada State Engineer may issue a permit. The permit holder may make beneficial use of the water under such terms and conditions as the State Engineer determines appropriate. Upon submission to the State Engineer of proof that this beneficial use has been made, a water rights certificate is issued. This certificate is a permanent right that only can be lost through statutory forfeiture or abandonment procedures. It is considered real property within Nevada.

Changing the point of diversion is allowed within Decree C-125 as long as the point of diversion is within the administrative boundaries of the Walker River Irrigation District (WRID). A change in the point of diversion for decreed water rights in Nevada must be approved by the Nevada State Engineer, the U.S. Board of Water Commissioners, and is subject to judicial review by the Federal District Court. A change in the point of diversion for storage rights within the Walker River Irrigation District (WRID) must be approved by the Nevada State Engineer and the Walker River Irrigation District Board per WRID rules and regulations. A change in the point of diversion for decreed rights in California must be approved by the California State Water Resources Control Board and U.S. Board of Water Commissioners. Such changes are subject to judicial review by the Federal District Court.

California water law provides that the owner of land adjacent to a water system has a right (riparian right) to make reasonable beneficial use of that water in conjunction with other riparian right holders on that water system. The water resource is shared, no priority date is applied, and the right cannot be sold or transferred to non-riparian lands. Appropriative water rights also are recognized for non-riparian beneficial uses of water.

No statewide system for administration of groundwater rights exists in California. Groundwater use within the California portion of the Walker River Basin is unregulated, and the riparian doctrine applies, whereby the owner of any property overlying groundwater has a right to as much water as can reasonably be put to beneficial use. California neither requires permits for groundwater use, nor specifies what constitutes a beneficial use.

Interstate Compact

A California-Nevada Interstate Compact Commission was created in 1955 to negotiate an agreement to allocate waters of the Truckee River, Carson River, and the Walker River between the two states. The compact:

- Provided for equitable apportionment of water between the two states.
- Promoted interstate harmony and furthered intergovernmental cooperation.
- Protected and enhanced existing economies.
- Removed causes of present and future controversies over shared (interstate) waters.
- Permitted orderly, integrated, and comprehensive development, use, conservation, and control of waters within the Lake Tahoe, Truckee River, Carson River, and Walker River basins (Horton, 1996).

In September 1970 and March 1971, California and Nevada legislatures respectively passed legislation adopting the Compact (California Chapter 1480, California Statutes 1970, and Nevada NRS 538.600). Although both states recognize and operate under the provisions of the agreement, the Compact has never been ratified by the U.S. Congress. Because of this, the provisions are not legally binding. If this Compact, or a new one, is ratified by Congress, primary distribution of waters in the Walker River Basin will be affected.

Consumptive Water Use

Towns and urbanized areas in the Walker Basin include Bridgeport, Walker, Coleville, Topaz Lake, Wellington, Smith, Mason, Yerington, Wabuska, Schurz, and Hawthorne (Figure 1). Land use includes urban and industrial, military, cropland, rangeland, woodland, and recreation. The smaller communities generally depend on individual wells for domestic water whereas the larger communities have community water systems supplied from wells. Hawthorne’s water supply comes from both wells and streams.

The West Walker River area includes Antelope Valley and Smith Valley. Little agricultural activity occurs above Antelope Valley, however, considerable agricultural activities exist in Antelope Valley and Smith Valley. The Alkali Lake (Artesia) WMA is located at the northern end of Smith Valley. It does not include irrigated agriculture.

The East Walker River includes Bridgeport Valley and the upper and lower East Walker valleys. Bridgeport Valley, located to the south and west of Bridgeport Reservoir, is the main agricultural valley on the East Walker River. The Bridgeport Valley groundwater basin has a high water table and is recharged directly from tributaries and indirectly through irrigation. A small amount of groundwater pumping occurs in this area for municipal use. Water stored in Bridgeport Reservoir is utilized downstream in the East Walker and Mason valleys.

Mason Valley is the largest irrigated agricultural area within the Walker River Basin located in the area near the confluence of the East and West forks of the Walker River. Surface water diversions in the Mason Valley are supplemented with groundwater pumping. The Mason Valley WMA, located in the northern portion of the valley, cultivates approximately 1,200 acres. The Walker River Paiute Tribe Reservation, located downstream from Mason Valley, includes irrigated agricultural areas. The tribe owns the most senior water right in the basin and has a right to 11,500 acre-feet per year. The entire right is not diverted every year, however. Agricultural production is estimated to occur on approximately 2,100 acres. Tables 1 and 2 (from Pahl, 1997 and 1999) show sub-basins, active groundwater rights, and surface water diversion rates and acres. See Yardas (2007) for additional water rights information and discussion.

Table 1. Active groundwater rights in Nevada by manner of use (acre-feet per year). (From Pahl, 1997.)

Manner of Use	Basin No. 106 Antelope Valley	Basin No. 107 Smith Valley	Basin No. 108 Mason Valley	Basin No. 109 East Walker Area	Basin 110a Walker Lake V. Schurz Subarea	Basin 110b Walker Lake V. Lake Subarea	Basin 110c Walker Lake V. Whiskey Flat-Hawthorne Subarea	Total Active Groundwater Rights
Commercial	457.40	2,491.23	138.30	0.00	0.00	25.56	0.00	3,112.49
Domestic	4.82	36.92	16.23	0.00	1.63	0.00	1.99	61.59
Industrial	0.00	43.36	13,314.80	0.00	0.00	0.00	78.10	13,436.26
Irrigation (Including Desert Land Entry)	5,587.08	58,928.60	120,336.69	21,129.55	612.00	4.19	5,035.98	211,634.49
Mining & Milling/Dewatering	0.00	625.35	7,258.94	553.07	0.00	0.00	806.50	9,243.86
Municipal	0.00	0.00	2,369.43	0.00	0.00	0.00	10,087.89	12,457.32
Quasi-Municipal	2,200.94	182.57	961.85	0.00	0.00	2,074.41	4,666.95	10,086.72
Recreation	32.00	0.00	3,416.05	0.00	0.00	0.00	0.00	3,448.05
Stock Water	0.00	605.71	381.53	62.39	20.78	0.00	7.06	1,077.47
Wild Life	0.00	0.00	1,424.76	0.00	0.00	0.00	0.00	1,424.76
Other/Decreed	0.00	532.39	60.21	0.00	0.00	0.00	5.37	597.97
Total	8,282.24	63,446.13	149,678.79	21,745.01	634.41	2,104.16	20,689.84	266,580.58

Source: Nevada Division of Water Resources Database as of April 14, 1995. Note: The database figures for Basins 106, 109, 110A, 110B and 110C have not been checked for supplemental rights (i.e. groundwater supplemental to groundwater). As a result, the above values for these basins may be higher than actual duties.
Notes: For Smith Valley, Barrick (1994) estimated total active groundwater rights at 57,910 acre-feet per year.
Above values are for groundwater rights issued through the State Engineer's Office (permitted and certificated only). Other groundwater withdrawals such as the irrigation wells serving the Walker River Indian Reservation, and domestic wells throughout the basin are not reflected in this table.
Portions of these groundwater rights may be supplemental to other non-groundwater rights for other sources such as surface water.

Table 2. Surface water rights diversion rates and acres per decree C-125, as amended 4/24/40 (from Pahl, 1999.)

Sub-basin	Water Source	Diversion Rate (cfs)	Acres	Average Diversion Rate (cfs per acre)
Above Antelope Valley	West Walker River and Tributaries	36.1300	2,089.00	0.01730
Antelope Valley	West Walker River	247.9300	15,442.00	0.01606
	Lost Canyon/Mill/Rodriquez Creeks	8.2600	516.00	0.01601
	Subtotal – Antelope Valley	256.1900	15,958.00	0.01605
Smith Valley	North of West Walker River			
	West Walker River	40.0297	3,544.97	0.01129
	South of West Walker River			
	West Walker River	86.4040	6,261.28	0.01380
	Desert Creek	28.0800	1,754.00	0.01601
	Subtotal – South of W. Walker River	114.4840	8,015.28	0.01428
	Subtotal – Smith Valley	154.5137	11,560.25	0.01337
Bridgeport Valley	East Walker River and Tributaries (Non-WRID)	377.3700	23,768.50	0.01588
	East Walker River and Tributaries (WRID)[1]	41.9200	2,660.00	0.01576
	Subtotal – Bridgeport Valley	419.2900	26,428.50	0.01587
East Walker Area	Above Gage 10293050			
	East Walker River	19.7200	1,230.00	0.01603
	Frying Pan/Murphy Creeks	6.2400	390.00	0.01600
	Sweetwater Creek	38.0200	2,456.00	0.01548
	Subtotal – Above Gage 10293050	63.9800	4,076.00	0.01570
	Below Gage 10293050			
	East Walker River	36.7368	2,314.68	0.01587
	Bodie/Rough Creeks	19.3800	1,205.00	0.01608
	Subtotal – Below Gage 10293050	56.1168	3,519.68	0.01594
	Subtotal – East Walker Area	120.0968	7,595.68	0.01581
Mason Valley	West Walker River	49.5600	3,100.50	0.01598
	East Walker River	140.8582	10,964.22	0.01285
	Walker River	372.3982	31,055.82	0.01199
	Subtotal – Mason Valley	562.8164	45,120.54	0.01247
Walker Lake Valley	Walker River	26.2500	2,100.00	0.01250
Grand Total – Walker River Basin		1,575.2869	110,851.97	0.01421

[1]These rights are for lands submerged by Bridgeport Reservoir and are held by the Walker River Irrigation District.

SURFACE WATER RESOURCES

Surface water resources in the Walker Basin include Walker Lake, the East and West forks and main stem of the Walker River, three major reservoirs that store and release Walker River water (Bridgeport, Topaz, and Weber reservoirs), high altitude lakes in the Sierra Nevada, small water storage reservoirs, as well as ponds, marshes and streams. Surface water resources in the basin support a variety of human uses, provide habitat for wildlife populations, and are subject to both natural hydrologic process and human water management systems. At times, surface water supply is insufficient to simultaneously meet all competing needs.

Beneficial uses for the Walker River (NAC 445A.159) are as follows:

1. Irrigation
2. Watering livestock
3. Recreation involving contact with water
4. Recreation not involving contact with water
5. Industrial supply
6. Municipal or domestic supply, or both
7. Propagation of wildlife, and
8. Propagation of aquatic life and more specifically, species of major concern

Beneficial uses for Walker Lake (NAC 445A.1693) are:

1. Recreation involving contact with water
2. Recreation not involving contact with water
3. Propagation of wildlife
4. Propagation of aquatic life and, more specifically, species of major concern (tui chub, Tahoe sucker, and adult and juvenile Lahontan cutthroat trout)

Walker Lake

Walker Lake is a terminus lake. Terminus lakes have two characteristics – they are located at the end of a stream and they have no outlet. Terminus lakes abroad include the Dead Sea, Caspian Sea, Lake Eyre, Aral Sea, Lake Titicaca, Lake Baikal, and the Black Sea. Terminus lakes in the western U.S. include the Great Salt Lake, Utah; Omak and Soap lakes, Washington; Mono Lake, California; Pyramid and Walker lakes, Nevada; and Goose Lake on the Oregon-California border. Terminus lakes are fragile and subject to change through time because they occupy a low point in a basin and the end-point of a river system. As a result of these characteristics, terminus lakes form unique ecosystems with irreplaceable intrinsic values. Walker Lake is a valuable natural asset in Nevada because it supports fisheries and is a stopover point in the spring and fall for migratory birds.

Total average annual inflow from the Walker River, groundwater, local surface water, and precipitation is estimated at about 104,000 acre-feet (Thomas, 1995). Precipitation falls directly on the lake surface, annually averaging 4.9 inches per year, and is estimated to have produced between 14,000 and 17,000 acre-feet per year for the years 1960 to present (a range of values is required because the acreage of the lake surface has shrunk since 1960). Sources of inflow to the lake, reported by Thomas (1995), include:

- Walker River stream flow, estimated to average 76,000 acre-feet per year between 1939 and 1993
- Local surface water inflow, estimated to average 3,000 acre-feet per year
- Groundwater inflow, estimated to average 11,000 acre-feet per year

Because the lake has no outflow, water can only leave Walker Lake through evaporation. The evaporation rate and lake's surface area determine how much water evaporates from the lake each year. Note that as the lake's surface area decreases, the volume of water evaporated each year also decreases. The average annual volume of water lost from the lake through evaporation between 1939 and 1993 was reported to be 166,000 acre-feet per year using an average evaporation rate of 4.1 feet per year (Thomas, 1995). The USGS is recently (2008) preparing reports evaluating evaporation at the lake's surface and river flow at numerous locations throughout the Walker Lake Basin.

Since the early 1900s, annual evaporative losses have exceeded long-term average inflow to the lake for most years, which has resulted in a decline in the lake's surface elevation and volume. Milne (1987) reconstructed lake levels using historic stream flow data and by correcting for annual discharge for consumptive use (Figure 3). Milne's study showed that loss of lake inflow was caused primarily by diversion of water for irrigation and, without diversions, the 1987 level of Walker Lake would have been higher than the level in 1882. In December 2007 Walker Lake was 149 feet below the 1882 elevation of 4,083 feet msl. This corresponds to a decrease in lake volume from 8,962,000 to 1,710,000 acre-feet, a loss of approximately 7,252,000 acre-feet of water during this time period.

The decrease in water inflow to the lake has resulted in an increase in TDS in the lake water. Because Walker Lake is a terminus lake, evaporation is the major process for increasing TDS concentration by removing water from the lake. Evaporation removes water but leaves salts that the water contained behind in the remaining water body. In 1882, the Walker Lake TDS level was relatively low (2,500 ppm) and only about one tenth as salty as seawater. The lake TDS level rose to nearly 15,000 ppm in October 1995 (Pahl, 1999), while subsequent above-average precipitation years lowered this level to about 11,000 ppm in 1997. In December 2007 the TDS of Walker Lake was approximately 15,995 ppm, about half as salty as seawater.

Relatively minor contributions to TDS concentration in the lake result from salt loads in the Walker River and the interchange between salty lake sediments and the water column of the lake. Thomas (1995) estimates that between 1882 and 1994 an average of 66,000 tons of TDS were added to Walker Lake annually from the salts contained in the Walker River, groundwater inflow, and salt diffusion from lake bed sediments. Thus, at a stable lake surface elevation, salts contained in inflow sources would cause a slow increase in TDS concentration in the lake. TDS concentration in the lake would increase at a rate of approximately 20 ppm per year at the lake's current volume.

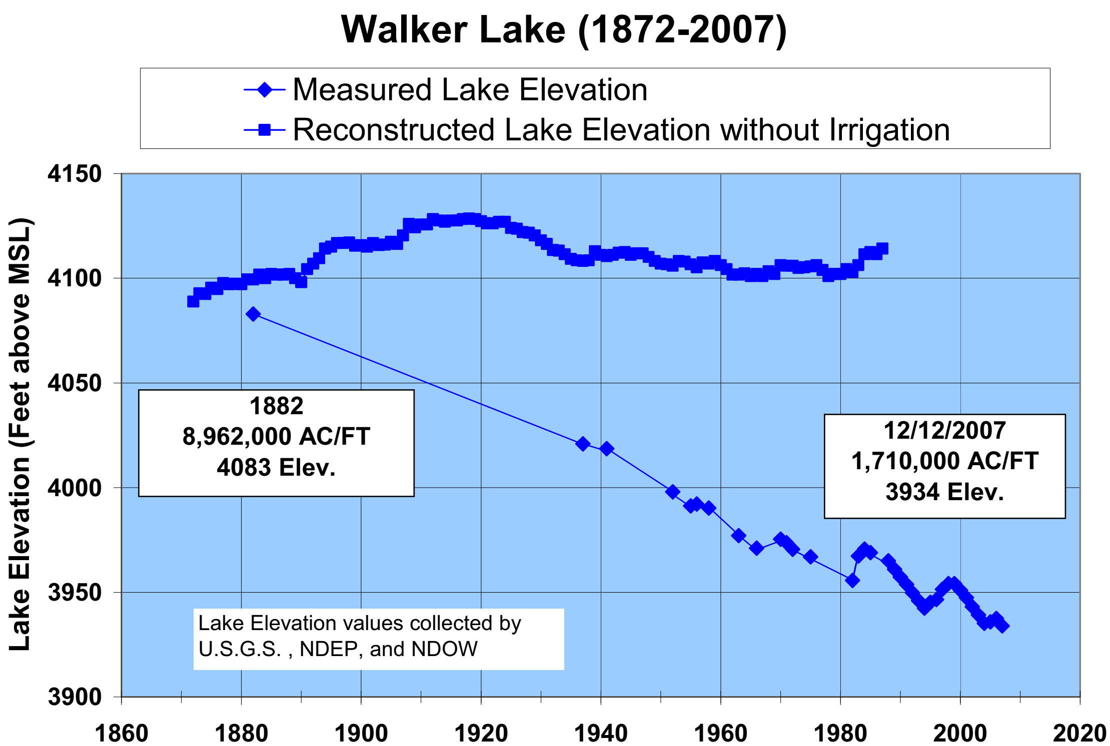

Figure 3. Historic and reconstructed (Milne, 1987) Walker Lake elevation.

Thomas (1995) calculated that if the lake were filled to an elevation of 3,964 feet msl, which would have a TDS of approximately 10,000 ppm, an additional inflow of about 47,000 acre-feet per year would be needed to stabilize the lake at this level. This additional inflow value is consistent with the evaporation rate of 150,500 acre-feet per year for a lake surface area at this lake level and water inflow values (104,000 to 107,000 acre-feet per year) given above.

Walker River

The East and West Walker rivers originate as high-elevation headwater streams in the eastern Sierra Nevada and flow generally north and east from the headwater area. The length of the Walker River from its headwaters to its terminus at Walker Lake is approximately 160 miles. River volume increases as snow melts in March and April and flow usually peaks in May or June. During years with deep snow pack, however, stream flow can reach its peak in July. During years with shallow snow pack, flow can dramatically decrease in July and remain low throughout the rest of the year. Flows are typically the lowest from November through February.

Floodplains occur along the Walker River. These areas are typically flat and become covered with water during large floods. The floodplain serves an important role in spreading floodwaters, decreasing flow velocities, and accumulating sediments and debris. These functions help to decrease severity of flooding downstream, as well as provide fertile soil adjacent to the river. The Federal Emergency Management Agency (FEMA) has delineated floodplains along the West and East Walker rivers and along the main Walker River up to the boundary of the Walker River Paiute Reservation.

Natural flow in most of the river reaches is affected by agricultural diversions per California and Nevada water rights law and operation of the C-125 decree. Average annual surface water budgets for the East, West, and main stem of the Walker River are provided in Table 3 (Pahl, 2000). Note that Pahl's data are for 1926–1995. Values in text are for 1939–1993. Differences in values underscore the importance of which time periods are selected to calculate average values.

Table 3. Average annual surface water budget for East Walker, West Walker, and Walker Rivers, 1926-95 (all values in acre-feet per year). (From Pahl, 2000.)

Item	Upper West Walker River Area – West Walker River and Tributaries	Antelope Valley – West Walker River	Smith Valley – West Walker River	Bridgeport Valley – East Walker River and Tributaries	East Walker Area – East Walker River	Mason Valley – East Walker, West Walker, Walker Rivers	Schurz Area – Walker River	Entire Walker River Basin above Walker Lake	Walker Lake Area – Walker Lake
Inflows									
River Inflows		191,200	176,100	130,600	103,900	235,400	121,200	326,300	69,900
Net Local Inflow	195,700	55,800	23,900	28,100	21,800	22,300	See "Net Local Outflow"	126,100	14,000
Total	195,700	247,000	200,000	158,700	125,700	257,700	121,200	452,400	83,900
Outflows									
River Outflows	191,200	176,100	130,100	103,900	105,300	121,200	69,900	69,900	---
Irrigation Diversions	4,500	64,700	69,900	50,000	20,400	136,500	23,000	369,000	---
Net Lake/Reservoir Evaporation	---	5,800	---	4,300	---	---	2,500	12,600	160,300
Change in Lake/Reservoir Storage	---	400	---	500	---	---	---	900	-76,400
Net Local Outflow	---	---	---	---	---	---	25,800	See "Net Local Inflow"	---
Total	195,700	247,000	200,000	158,700	125,700	257,700	121,200	452,400	83,900
Change in River Flow Through Sub-basin = River Outflow – River Inflow	Not Determined	-15,100	-46,000	-26,700	1,400	-114,200	-51,300	-256,400	Not Determined

Some of the annual values used to calculate these statistics were estimated by Nevada Division of Water Planning.

West Walker River

A number of tributaries meet and form the main channel of the West Walker River upstream from the town of Walker, California. USGS flow monitoring gage 10296000 (Walker River below Little Walker River, upstream of Walker, California) is located just below this confluence (Figure 4). This gage has the longest continuous period of record on the West Walker River and documented an average annual flow of 185,000 acre-feet per year between 1939 and 1993. The main channel of the West Walker River flows through Antelope Valley. A USGS flow monitoring gage where the West Walker River enters Antelope Valley (10296500: West Walker River near Walker, California), has an average annual flow of 195,000 acre-feet per year for 1939 to 1993 (Thomas, 1995). The flow entering Antelope Valley is subject to large annual variations depending on the amount of snowfall that occurs in mountains upstream of Antelope Valley.

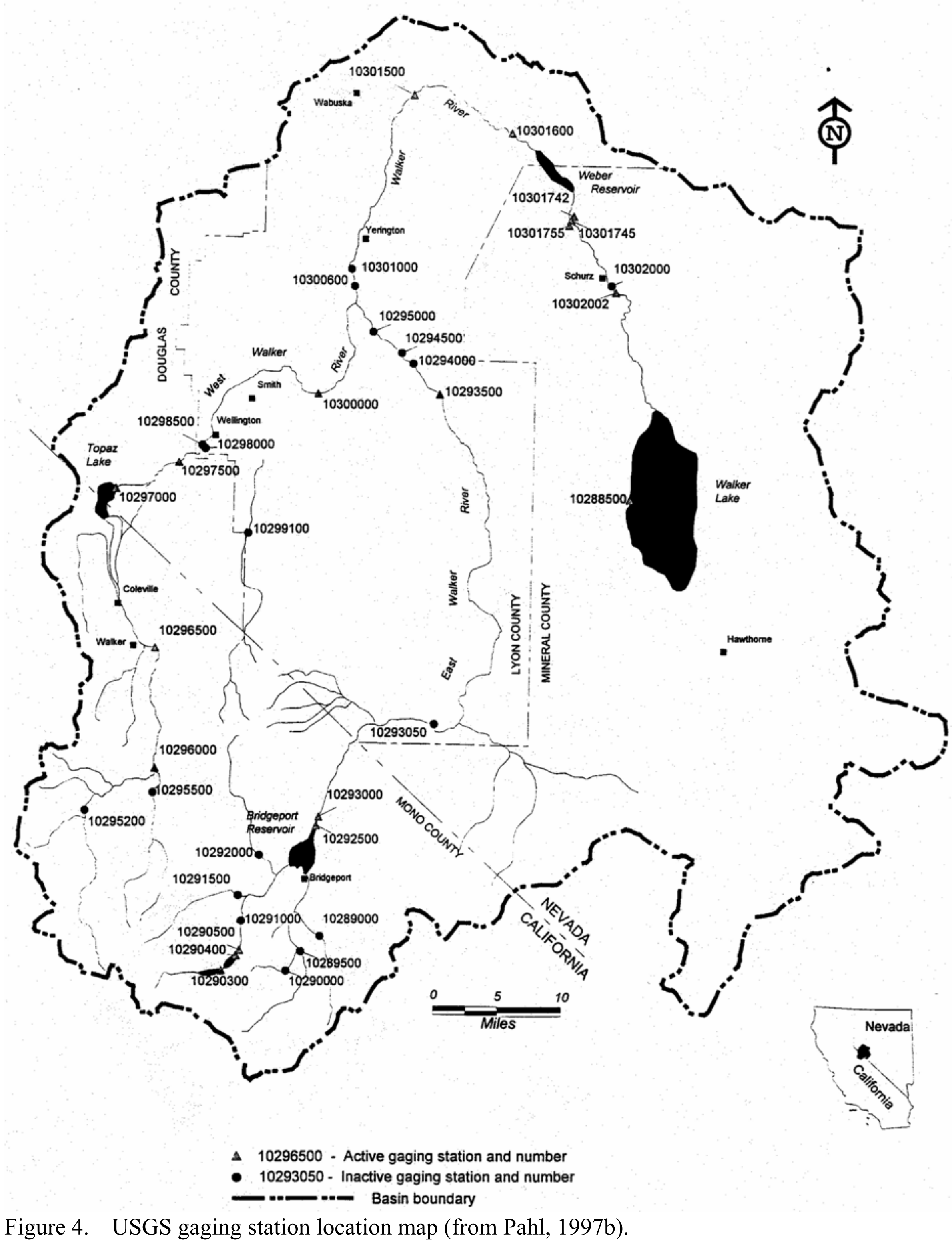

Figure 4. USGS gaging station location map (from Pahl, 1997b).

In Antelope Valley, the West Walker River passes several miles to the east of Topaz Lake and continues downstream to Smith Valley (Figure 1). Topaz Lake is a reservoir that is off stream; that is, water is diverted from the West Walker River to Topaz Lake but the river channel passes to the east of the reservoir. USGS gage 10297500 (West Walker River at Hoye Bridge, near Wellington, Nevada) is located below Topaz Lake inflow near the outlet of Antelope Valley and at the upstream end of Smith Valley (Figure 4). This site has a measured average annual flow rate of 180,000 acre-feet per year between 1939 and 1993. All diversions are used for irrigation within the basin. Diversions to the Colony Ditch do not return any flow to the West Walker River. Irrigation return flows and flood flows in this area discharge to the Alkali (Artesia) Lake WMA (Figure 1).

Total dissolved solids in the West Walker River ranged between 24 and 314 ppm from May 1998 to March 1999 (Humberstone, 1999). These values remained well below the 500 ppm annual average maximum limit for uses of water supply, irrigation, and livestock set by the Nevada Administrative Code (NAC 455A.118 to 445A.225) in this river reach. The higher values Humberstone recorded are still below the single value $\leq$ 425 mg/L TDS requirement to maintain existing higher quality water set forth in NAC 455A.118 to 445A.225 above the confluence with the East Walker River at Nordyke Road in Mason Valley. Minimum values of TDS tend to be in the headwaters and gradually increase downstream. TDS also varies with seasonal stream flow changes, generally decreasing with increasing flows. According to Humberstone (1999), TDS levels increase during irrigation season with maximum levels typically occurring in September.

Water temperature behaves in a manner similar to TDS and varies in space and time. Water temperature is generally lowest near headwater streams and gradually increases downstream. Water temperatures in the West Walker River range from as low as 32˚ F in the upstream areas in winter to as high as 75˚ F in the downstream areas, measured in August 1998 (Humberstone, 1999). Between May 1998 and March 1999, dissolved oxygen levels in the West Walker River ranged between 6.3 and 13.7 mg/L. Between May 1994 and June 1995 levels ranged between 5.2 and 11.3 mg/L. Trout prefer oxygen levels above 5 mg/L; the ideal dissolved oxygen level for fish is between 7 and 9 mg/L (Humberstone, 1999; Koch et al., 1979).

<u>East Walker River</u>

Headwaters of the East Walker River originate from several creeks in the eastern Sierra Nevada upstream of Bridgeport Valley, California. The largest of these tributaries include Buckeye, Green, Robinson, Virginia, Swauger, and Sumners creeks. The average annual combined inflow of these tributaries into the Bridgeport Valley between 1939 and 1993 was 132,000 acre-feet per year, as estimated by Thomas (1995) using data from USGS stream gages. Inflow values are subject to large annual variations depending on the amount of snowfall in the mountains above Bridgeport Valley.

Downstream of Bridgeport Valley and Bridgeport Reservoir are the areas referred to as the Upper East and Lower East Walker valleys. USGS gage 10293000 (East Walker River near Bridgeport, California) is located just below Bridgeport Reservoir (Figure 4). The average annual flow of the river at this gage was 107,000 acre-feet per year between 1939 and 1993 (Thomas, 1995).

As with the West Walker River, East Walker River solutes vary depending on seasonal stream flow. From May 1998 to March 1999, TDS ranged between 54 ppm in July near Bridgeport Reservoir to 139 ppm in October at Minister Road (Humberstone, 1999). These values remained well below the 500 ppm annual average maximum limit for uses of water supply, irrigation, and livestock and the single maximum value of $\leq$ 390 mg/L to maintain existing higher quality water set by the Nevada Administrative Code (NAC 455A.118 to 445A.225) in this river reach. Water temperature ranges from 32˚ F upstream in the winter to approximately 72˚ F downstream in summer months. Dissolved oxygen ranged between 7.1 and 12.3 mg/L from May 1998 to March 1999 (Humberstone, 1999).

Main Stem Walker River

The East and West forks of the Walker River converge in Mason Valley to form the main stem of the Walker River (Figure 1). Mason Valley is the largest irrigated agricultural area within the Walker River Basin. It includes irrigated areas along the West, East, and main Walker rivers. Average annual inflow to Mason Valley from the East and West Walker rivers is measured at USGS gages 1030000 (West Walker River near Hudson, Nevada) and 10293500 (East Walker River above Strosnider Ditch, near Mason, Nevada) (Figure 4). Between 1939 and 1993, the combined average annual flow at these two stations was 238,000 acre-feet per year (Thomas, 1995). The downstream boundary of Mason Valley is located near Wabuska at USGS gaging station 10301500 (Walker River near Wabuska, Nevada). The annual average stream flow out of Mason Valley at this location between 1939 and 1993 was estimated to be 128,000 acre-feet per year (Thomas, 1995).

The Schurz area lies between Wabuska and Walker Lake (Figure 1). Stream flow and diversion records for this part of the Walker Basin only recently have been re-established in October 1994. Flow in the Walker River near Schurz, Nevada (USGS gage 10302000, Walker River at Schurz, Nevada) was measured from about 1915 to 1932 with the exception of two years during this period. Annual average flow for this time period (not normalized to the flow at the USGS gage 10296000 West Walker River below Little Walker River near Coleville, California) was 86,000 acre-feet per year. Annual average flow for the recently established USGS gage 10302002 (Walker River at Lateral 2-A Siphon near Schurz, Nevada, for the 12-year period from October 1994 to September 2006) averaged 124,000 acre-feet per year. When this period was normalized to flow at the USGS gage 10296000 West Walker River below Little Walker River near Coleville, California, average annual flow was 91,000 acre-feet per year.

TDS and water temperature values in the main Walker River are similar to trends in the East and West Walker rivers. TDS was 70 ppm at an upstream site in July 1998 and 289 ppm near Schurz in October 1998 (Humberstone, 1999). Water temperature ranged from approximately 32˚ to 76˚ F during this same period. Dissolved oxygen ranged between 6.4 and 14.0 mg/L between May 1998 and March 1999 (Humberstone, 1999).

Wildlife Management Areas

Mason Valley Wildlife Management Area

The Mason Valley WMA includes 13,375 acres and has decreed water rights from the Walker River. In the 13-year period between 1989 and 2001, the Mason Valley WMA received between 4,476 to 17,085 acre-feet of decree water per year, depending upon availability of water in the Walker River, with an average diversion from the river of about 10,335 acre-feet per year. In 1983, a water right was granted to the Nevada Department of Wildlife with a priority date of 1970 for 575,850 acre-feet per year of surplus water in the Walker River below Schurz that can only be used to deliver flows to Walker Lake. Other minor sources of water for the Management Area include about 800 acre-feet per year from Sierra Pacific Power Company's Fort Churchill power plant and about 500 acre-feet per year from treated effluent from the city of Yerington. In 2004, approximately 3,550 acre-feet of water (measured at the Siphon gage near Schurz) were transferred to Walker Lake through the process of securing a permit to temporarily change the place of use of a portion of NDOW's decree. Waters are used for maintenance of wetlands and ponds, and no surface water flows from the Mason Valley WMA into the Walker River (Elmer Bull, Nevada Division of Wildlife, personal communication, 2001).

Alkali Lake (Artesia) Wildlife Management Area

In 1969, a habitat management plan was written for the Alkali Lake (Artesia) Management Area. Alkali Lake is a wintering and resting area for a variety of waterfowl, as well as many other birds throughout the year when water is present. The Alkali Lake WMA in northwest Smith Valley receives surface water only from drainage of irrigated fields and has no Walker River water rights (Elmer Bull, Nevada Department of Wildlife, personal communication, 2001). The Nevada Department of Wildlife (NDOW) does, however, maintain water rights on the Dave and George Wilson (DGW) drainage channel (permit number 47450) that entitles NDOW to 4,747 acre-feet per year (10 cfs) (Myers, 2001). During wet years, this irrigation return flow amount may be reached, but during dry or normal years that follow a dry year, almost no irrigation return flows reach the wildlife management area (Myers, 2001). Surface water is occasionally available in the form of runoff from the Pine Nut Mountains during wet years. In recent years, the lakebed is commonly a playa, particularly in years of low precipitation, when surplus water is not available from neighboring farmlands.

Reservoirs

Several reservoirs have been constructed along the East, West, and main Walker Rivers. The three main reservoirs—Bridgeport, Topaz, and Weber—were constructed to supply water for agriculture, but all are used for recreation and all support wildlife. Bridgeport Reservoir (storage capacity 42,400 acre-feet, and a refill right of almost 15,000 acre-feet), completed in 1923 (Horton, 1996), is located at the downstream end of Bridgeport Valley. The Walker Irrigation District is responsible for day-to-day operation of Bridgeport Reservoir and directs the Federal Water Master to release water from the reservoir to serve agricultural needs in the East Walker River Basin below the reservoir and in Mason Valley (Figure 1). The California State Water Resources Control Board has regulatory interest of the reservoir since it is located in the state of California.

Near the downstream end of Antelope Valley lies Topaz Lake (storage capacity 59,439 acre-feet), which was built as a water storage reservoir in 1922 (Horton, 1996), and is filled by diversion of the West Walker River (Figure 1). The reservoir is not on the river, but is several miles to the west of the main channel. The reservoir is owned and operated by the Walker River Irrigation District, which has about 50,000 acre-feet of decreed water rights to fill the reservoir and an additional 35,000 acre-feet to refill the reservoir if water is available. Water releases from the reservoir serve agricultural needs in Smith and Mason valleys.

Below gage 10301500 (Walker River near Wabuska, Nevada) is the Schurz area (Figures 1 and 4) on the Walker River Paiute Reservation which includes irrigated agricultural land and Weber Reservoir. Weber Reservoir was completed in 1935. It is owned and operated by the BIA. In 1989, as part of the BIA Dam Safety Maintenance and Repair Program, the dam was given a high hazard rating and poor overall safety rating. An EIS was completed in 2005 for Weber Dam Repair and Modification. The repair and modification plan for the dam also includes a design for a fish passage (fishway) around the dam. A ground-breaking ceremony for the new dam was held in early 2007, however it remains unclear if funds exist to build the fish passage.

Small water storage facilities exist on both the West and East Walker rivers in California. Those on the West Walker River include:

- Black (Junction) Reservoir, with a storage right of 350 acre-feet, a priority date of 1907, and a decreed place of use of stored waters in the Sonora Junction area.
- Lobdell Lake, with a storage right of 500 acre-feet, a priority date of 1864, and a decreed place of use of stored waters in the south end of Smith Valley.
- Poore Lake, with a storage right of 1,200 acre-feet, a priority date of 1901, and a decreed place of use of stored waters in the Antelope Valley area.

Those on the East Walker River include:

- Green Lakes (East Lake, West Lake, and Green Lake) with a collective storage right of 400 acre-feet, a priority date of 1895, and a decreed place of use of stored waters in the Bridgeport Valley area.
- Upper Twin Lake, with a storage right of 2,050 acre-feet, priority dates of 1905 and 1906, and a decreed place of use of stored waters in the Bridgeport Valley area.
- Lower Twin Lake, with a storage right of 4,050 acre-feet, priority dates of 1888 and 1905, and a decreed place of use of stored waters in the Bridgeport Valley area.

GROUNDWATER RESOURCES

Most of the groundwater in the Walker River Basin is derived from surface water. Surface water infiltrates alluvial sediments by direct seepage from the river channel to alluvial aquifers and by infiltration of surface water applied to irrigate crops. Estimates of surface water infiltration for Mason Valley [70,000 acre-feet per year (Huxel and Harris, 1969)], Smith Valley [47,000 acre-feet per year (Rush and Schroer, 1976)], and the Schurz/Walker River Paiute Reservation area [13,800 acre-feet per year (Schaefer, 1980)] total 131,000 acre-feet per year of Walker River recharge to the alluvial aquifers. This total does not include surface water recharge from the West and East Walker rivers in Antelope Valley, Bridgeport Valley, and the East Walker River drainage area. Myers (2001) showed that the amount of surface water infiltration in valleys within the Walker River Basin is highly dependent upon the amount of flow in Walker River and the amount of groundwater pumping in the valleys. In comparison to groundwater recharge from Walker River water (131,000 acre-feet per year), an estimated 80,500 acre-feet per year of precipitation recharges alluvial aquifers along the Walker River from headwater areas to Walker Lake (Resource Concepts Inc., 2000).

Antelope Valley, California (modified from (Glancy, 1971)

Groundwater in Antelope Valley comes primarily from old and young alluvial aquifers within the basin. The younger alluvium is mainly unconsolidated lenses of gravel, sand, silt and clay, whereas the older alluvium is unconsolidated to consolidated deposits of boulders, gravel, sand, silt and clay. The alluvial aquifers are bounded by consolidated rock that forms no-flow boundaries to the alluvial aquifers because the consolidated rock transmits little water. Hydraulic properties of the alluvial aquifers are not available, however similar alluvial aquifers in Smith and Mason valleys and the Schurz/Walker River Paiute Reservation area generally have transmissivities that range from 50,000 to 200,000 gallons per day per foot. Similar transmissivities are likely for the alluvial aquifers in Antelope Valley, because the aquifers contain similar materials to those in the other basins. Glancy (1971) estimated that groundwater in storage exceeds 350,000 acre-feet in the top 100 feet of saturated sediment in Antelope Valley.

A major source of recharge to the Antelope Valley alluvial aquifers is recharge from the West Walker River, both directly from the river and indirectly from irrigation infiltration. The quantity of surface water recharge is not known in Antelope Valley. Recharge to the alluvial aquifers from precipitation in mountains surrounding Antelope Valley is estimated to be 18,000 acre-feet per year. Groundwater inflow to alluvial aquifers in the valley is estimated at 1,000 acre-feet per year, and outflow to Smith Valley is estimated to be 200 acre-feet per year (Glancy, 1971).

Smith Valley, Nevada (modified from Rush and Schroer, 1976 and Myers, 2001)

Groundwater development in Smith Valley is from alluvial aquifers within the basin. Alluvium in the valley consists of older and younger alluvium and playa (dry lakebed) deposits (Rush and Schroer, 1976). The older and younger alluvium consists of unconsolidated gravel, sand, silt, and clay, with the older alluvial deposits generally being more consolidated than the younger deposits. Sediments in Artesia Lake, a playa in the northwest part of the valley, consist primarily of silt, clay, and evaporate salts and minerals. Like most of the other basins in the Walker River flow system, low-permeability consolidated rocks underlie and bound the alluvial aquifers such that little groundwater enters or leaves Smith Valley. In general, transmissivity of the alluvial aquifers ranges from less than 50,000 to greater than 100,000 gallons per day per foot for the top 500 feet of valley-fill deposits (Rush and Schroer, 1976). These values correspond to a range in hydraulic conductivity of about 10 to 60 feet per day. A more detailed description of hydraulic properties and their distribution is given by Myers (2001).

Myers (2001) reported generally greater transmissivities in the south and southwest areas of the valley near Hoye, Red, and Burbank canyons and generally lower transmissivities in the middle part of the valley. The average storage coefficient for most of the alluvial aquifers is 0.15, which means that the valley-fill deposits will release 0.15 cubic feet of water from each square foot of material for each one-foot drop in water level. Using an area of 100,000 acres for the alluvial aquifers, Smith Valley contains an estimated 1,500,000 acre-feet of water stored in the top 100 feet of saturated alluvium (Rush and Schroer, 1976). A water budget developed by Rush and Schroer (1976) had inflows and outflows that balanced within 1,000 acre-feet per year when changes in storage were included in the calculation. Thus, potential groundwater outflow from the basin is assumed to be minimal.

The main source of recharge to alluvial aquifers in Smith Valley is from percolation of irrigation water derived primarily from diversions of the Walker River (Rush and Schroer, 1976). The amount of Walker River water that recharges alluvial aquifers in Smith Valley depends on flows in the Walker River and the amount of water level decline in the alluvial aquifers (Myers, 2001). Rush and Schroer (1976) estimated that 47,000 acre-feet per year of diverted Walker River water recharges the alluvial aquifers. Recharge to Smith Valley from precipitation in the surrounding mountains is estimated to be 17,000 acre-feet per year. Most of this recharge, 16,000 acre-feet per year, is from the Pine Nut and Sweetwater mountains to the west and southwest and the Wellington Hills to the south (Rush and Schroer, 1976).

Local precipitation on the valley floor, at altitudes less than 6,000 feet, is assumed to contribute no recharge to the alluvial aquifers. Little, if any, ponded water on the Artesia Lake playa recharges the alluvial aquifers. Groundwater outflow from Smith Valley is small (Rush and Schroer, 1976), but no estimate of this small amount of potential groundwater outflow has been made. In a study of Mason Valley (Huxel and Harris, 1969), an estimated 500 acre-feet per year of groundwater enters Mason Valley in alluvial deposits beneath the East and West Walker rivers. They did not estimate how much of the 500 acre-feet per year can be attributed to inflow from Smith Valley. Glancy (1971) estimated that 150 acre-feet per year of groundwater flows into Mason Valley from alluvial aquifers beneath the East Walker River, however, thus an estimated 350 acre-feet per year of groundwater inflow to Mason Valley would be attributed to Smith Valley outflow.

Bridgeport Valley, California

The Bridgeport Valley groundwater basin has a shallow water table and is recharged from streams, tributaries, and irrigation water spread on land in the basin, as well as groundwater inflow from recharge derived as precipitation in the Sierra Nevada. The amount of groundwater recharge from these sources has not been quantified. Groundwater used in the basin is likely pumped from alluvial aquifers similar to the other valleys in the Walker River drainage, but no studies have been published that identify and quantify groundwater resources in Bridgeport Valley.

East Walker River Area (modified from Glancy, 1971)

The East Walker River Area is located in the drainage basin between the outlet of Bridgeport Reservoir and Mason Valley, where groundwater development is primarily from alluvial aquifers within the basin. The alluvial aquifers consist of younger and older alluvium. The younger alluvium is mainly unconsolidated lenses of gravel, sand, silt, and clay, whereas the older alluvium is unconsolidated to consolidated deposits of boulders, gravel, sand, silt, and clay.

Alluvial aquifers in the East Walker River area form three distinct aquifer systems: Sweetwater Flat, the Rough Creek area, and the area tributary to the East Walker River in the downstream part of the drainage basin. The alluvial aquifers are underlain and bounded by consolidated rock. This rock forms no-flow boundaries to the alluvial aquifers because it transmits little water. Hydraulic properties of the alluvial aquifers are not presented in Glancy (1971); however, similar alluvial aquifers in Smith and Mason valleys and the Schurz/Walker River Paiute Reservation area generally have transmissivities that range from 50,000 to 200,000 gallons per day per foot. Similar transmissivities are likely for the alluvial aquifers in the East Walker River area because they are similar aquifers to those in these other basins. An estimated 800,000 acre-feet of water is stored in the top 100 feet of saturated sediment in the East Walker River area (Glancy, 1971).

A major source of recharge to alluvial aquifers in the East Walker River area is recharge from East Walker River water. Recharge from precipitation in mountains surrounding alluvial aquifers in the East Walker River area is estimated to be 31,000 acre-feet per year. Groundwater inflow from Bridgeport Valley is estimated to be 200 acre-feet per year, and outflow to Mason Valley is estimated to be 150 acre-feet per year (Glancy, 1971). Glancy (1971) also notes that of the estimated 18,000 acre-feet per year of recharge from precipitation to the Rough Creek drainage area alluvial aquifers, only 500 acre-feet per year are removed by evapotranspiration. He suggests that a substantial amount of the remaining 17,500 acre-feet of groundwater may be flowing out of the East Walker River drainage area south toward Mono Valley.

Mason Valley, Nevada (modified from Huxel and Harris, 1969 and Myers, 2001)

Groundwater development in Mason Valley is from alluvial aquifers within the basin. The alluvium in the valley consists of unconsolidated gravel, sand, silt, and clay (Huxel and Harris, 1969). Surrounding bedrock has low hydraulic conductivity compared to valley-fill deposits, thus the alluvial aquifers may be considered to be an isolated unit within the valley with little groundwater flowing out of the valley in consolidated rock. The Walker River has reworked the valley-fill deposits near the river and created well sorted beds of clay, silt, sand, and gravel, as is typical in valleys with perennial streams (Plume, 1996). Transmissivity of the alluvial aquifers ranges from 50,000 to 200,000 gallons per day per foot for the top 100 feet of valley-fill deposits (Huxel and Harris, 1969). These values correspond to a range in hydraulic conductivity of 5 to 80 feet per day. The average storage coefficient is 0.2, which means that the valley-fill deposits will release 0.2 cubic feet of water from each square foot of material for each one-foot drop in water level. Assuming an area of approximately 100 square miles for the alluvial aquifers, Mason Valley contains an estimated 1,300,000 acre-feet of water stored in the top 100 feet of saturated alluvium (Huxel and Harris, 1969).

Percolation of irrigation water derived primarily from diversions of the Walker River is the main source of recharge to the alluvial aquifers in Mason Valley. Myers (2001) estimated that 70,000 acre-feet of Walker River water annually recharge alluvial aquifers in Mason Valley. Huxel and Harris (1969) estimated recharge to Mason Valley from precipitation in the surrounding mountains to be 2,000 acre-feet per year. Local precipitation on the valley floor is assumed to contribute no recharge to the alluvial aquifers. Groundwater inflow in alluvial deposits beneath the East and West Walker rivers is estimated to be 500 acre-feet per year (Huxel and Harris, 1969). An estimated 1,550 acre-feet per year of groundwater flows out of Mason Valley (Huxel and Harris, 1969). An estimated 700 acre-feet per year flow through Walker Gap and 700 acre-feet per year flow through Parker Gap toward the Schurz area. In addition, an estimated 150 acre-feet per year of groundwater flow through Adrian Gap to the Carson River Basin.

Schurz and Walker River Paiute Reservation Area, Nevada (modified from (Schaefer, 1980)

Groundwater from alluvial aquifers is used in the Schurz and Walker River Paiute Reservation areas. Consolidated rocks underlie alluvial and playa deposits and surround valley-fill deposits in this area. The consolidated rocks are mainly volcanic, quartz monzonite, and granodiorite and are considered not to be water bearing (Schaefer, 1980). The valley-fill sediments are alluvial deposits consisting mainly of sand, silt, and clay (Everett and Rush, 1967).

Geophysical techniques were used to determine that the alluvial deposits range from 600 to about 1,500 feet in thickness (Schaefer, 1980). Several dry playas also exist in this area. The playas are primarily clay with lesser amounts of silt and sand, and they do not contain significant amounts of groundwater that can be extracted for use. Irrigation wells completed in alluvial aquifers yield as much as 2,500 gallons per minute indicating that alluvial aquifers are generally quite permeable and a potential source of groundwater (Schaefer, 1980). Transmissivity values for the alluvial aquifer, from analysis of limited aquifer test information, range from 13,000 to 153,000 gallons per day per foot, with an average value of 97,000 gallons per day per foot (Kleinfelder, 1995). The storage coefficient of the alluvial aquifer ranges from 0.002 to 0.042 (Kleinfelder, 1995). An estimated 1,500,000 acre-feet of groundwater is stored in the top 100 feet of saturated alluvial deposits in the Schurz area (Resource Concepts Inc., 2000).

Groundwater in the alluvial aquifers is derived primarily from seepage of Walker River water into the aquifers. Additional sources of groundwater in the area include precipitation in the surrounding mountains, subsurface inflow, and recharge from excess irrigation. Schaefer (1980) estimated that between the Wabuska gage site—where the Walker River enters the Schurz/Walker River Paiute Reservation area—and Walker Lake, an average of 13,800 acre-feet per year seep from the Walker River into underlying alluvial aquifers. Everett and Rush (1967) estimated recharge to the alluvial aquifers from precipitation within the basin to be about 650 acre-feet per year. Huxel and Harris (1969) estimated that inflow to this basin from Mason Valley through Walker and Parker gaps to be a total of 1,400 acre-feet per year (700 acre-feet per year through each gap). An estimated 11,000 acre-feet per year of groundwater are assumed to flow into Walker Lake from the Walker River Paiute Reservation area (Schaefer, 1980).

HABITAT

The largest acreage of the Walker River watershed is located primarily in the Great Basin, the largest desert ecosystem in North America and the only cold desert on the continent (Mares, 1999). The Great Basin ecoregion, as defined by Bailey (1995), has a high number of endemic species and the second highest number of imperiled species of all U.S. ecoregions (Forbis et al., 2006). Perhaps the most recognizable characteristic of the Great Basin is shrub-steppe vegetation, which includes salt desert and sagebrush communities. These semi-arid vegetation communities occur in the rain shadow of the Sierra Nevada and receive as much as 60% of their annual precipitation as snow (Baldwin et al., 2003). In contrast, headwaters of the Walker River are located in montane and alpine ecosystems. The aquatic habitat in the basin includes alpine lakes; high, moderate, and low gradient streams; reservoirs; and a desert terminus lake (U.S. Fish and Wildlife Service, 2003).

Wildlife in the Walker Basin is associated with specific types of habitats, although habitat use may be seasonal. Migratory birds, for example, may visit Walker Lake during specific times of the year while sage grouse are year-round residents in the sagebrush community. While fauna are typically considered users of habitat or having habitat association, flora also may be associated with specific habitat types. The relationship between a species and its habitat is called a habitat relationship. Morrison et al. (1992) define habitat as “an area with the combination of resources (food, cover, water) and environmental conditions (temperature, precipitation, presence or absence of predators and competitors) that promote occupancy by individuals of a given species (or population) and allows those individuals to survive and reproduce.” Therefore both fauna and flora have habitat associations.

The list of flora and fauna in the Walker Basin is extensive, because of both the large physical size of the area and variability in terrestrial habitat. The Walker Basin uplands (non-water dominated) include the alpine environment above tree line, subalpine and montane forests, pinyon-juniper woodlands, sagebrush scrub, and alkali sink (Smith, 2000). Identifying an exact and complete species list of flora and fauna of the Walker is difficult for a number of reasons. Point locations (with recorded geographic coordinates) of common or abundant species are neither recorded regularly nor stored centrally. Because the boundary of the Walker Basin crosses two states, different state agencies are responsible for maintaining species lists and cataloging occurrences. Therefore, the list of species and their associated habitats presented here represent the best available data and information but should be expected to change as new data are collected.

Generating complete species lists for areas crossing political boundaries requires extensive data mining. The level of detail and ease of access to data differ between California and Nevada. Some species have special designation, but there is not a universally accepted or adopted hierarchy, so lists maintained by different entities do not necessarily cross-reference in terms of species status or inclusion. Numerous entities maintain data on rare, threatened, endangered, watch-list, species of concern, or at-risk species, and each entity has its own list type and definitions.

Within the Walker Basin, federal and state agencies own and/or manage wildlife habitat. The USFS and BLM are charged with managing wildlife habitat on their lands, yet other government agencies maintain data on wildlife that are not directly tied to a physical parcel of land, including Nevada Department of Wildlife and the U.S. Fish and Wildlife Service. The Nevada Natural Heritage Program (http://heritage.nv.gov) falls under the Nevada

Department of Conservation and Natural Resources and is charged with maintaining comprehensive information on locations, biology and conservation status of all endangered, threatened, sensitive, and at-risk species in Nevada. Internet access to spatial data is limited to protect the actual location of known listed species and because complete surveys rarely, if ever, exist. Links are listed on the Nevada Natural Heritage's Web site to other databases maintained by the respective agency or entity. The California Department of Fish and Game, for example, has a readily accessible database of rare plants and animals in California. It is important to note that accuracy and completeness of any database is dependent on field surveys.

Common species are not typically surveyed because there is a limited pool of funds for wildlife, and listed species take priority due to their special status. Listed species are not often well studied because they can be difficult to find and generally do not occur in large numbers. The list of species with special designations continues to grow but complete knowledge of the distribution and life history of each simply does not exist. Furthermore, precise locations may not be released to the public in an effort to protect those individuals that remain. Based on records provided by the Nevada Natural Heritage Program, the U.S. Fish and Wildlife Service, the Nevada Department of Wildlife, the California Department of Fish and Game, the Mason Valley Wildlife Management Area, Cornell Lab of Ornithology (online) and NatureServe.org, wildlife species and their associated (observed or expected) habitat of the Walker River Basin are listed in Table 4.

Table 4. Wildlife Species of the Walker River Basin and associated habitat type.

SPECIES	HABITATS	SPECIES	HABITATS
BIRDS		BIRDS	
Common Loon	Lake	Sharp-shinned Hawk	River, Farm, Upland
Horned Grebe	Lake	Coopers Hawk	River, Farm, Upland
Eared Grebe	Lake	Northern Harrier	Farm, Upland
Western Grebe	Lake, River	Red-tailed Hawk	River, Farm, Upland
Clark's Grebe	Lake, River	Swainson's Hawk	River, Farm, Upland
Pied Billed Grebe	River	Rough-legged Hawk	River, Farm, Uplands
Double-crested Cormorant	Lake, River	Ferruginous Hawk	River, Farm, Uplands
Great Blue Heron	Lake, River, Farm	Golden Eagle	Uplands
Green Heron	Lake, River	Bald Eagle	Lake, River, Farm
Cattle Egret	Lake, River, Farm	Osprey	Lake, River
Snowy Egret	Lake, River, Farm	Prairie Falcon	Farm, Uplands
Black-crowned Night Heron	Lake, River, Farm	Peregrine Falcon	All
Western Least Bittern	River	Merlin	River, Farm, Uplands
American Bittern	Lake, River	American Kestrel	All
White-faced Ibis	River, Farm	Ring-necked Pheasant	River, Farm, Upland
Tundra Swan	Lake, Farm	California Quail	River, Farm, Upland
Canada Goose	All	Virginia Rail	River, Lake
Greater White-fronted Goose	Lake, River, Farm	Sora	River, Lake
Snow Goose	Lake, River, Farm	Sandhill Crane	Farm
Ross's Goose	Lake, River, Farm	American Coot	Lake, River
Mallard	Lake, River, Farm	Semi-palmated Plover	Lake, River, Farm
Gadwall	Lake, River, Farm	Snowy Plover	Lake
Northern Pintail	Lake, River, Farm	Killdeer	All
Green-wing Teal	Lake, River, Farm	Mountain Plover	Lake, Farm
Blue-wing Teal	Lake, River, Farm	Black-bellied Plover	Lake, Farm
Cinnamon Teal	Lake, River, Farm	American Avocet	Lake
American Wigeon	Lake, River, Farm	Black-necked Stilt	Lake
Northern Shoveler	Lake, River, Farm	Mountain Plover	Lake, Farm, Upland

Table 4. Wildlife Species of the Walker River Basin and associated habitat type (continued).

SPECIES	HABITATS	SPECIES	HABITATS
BIRDS		BIRDS	
Wood Duck	Lake, River, Farm	Common Snipe	Lake, River
Redhead	Lake, River	Long-billed Curlew	Lake
Ring-necked Duck	Lake, River	Spotted Sandpiper	Lake, River, Farm
Greater Scaup	Lake, River	Solitary Sandpiper	Lake, River, Farm
Lesser Scaup	Lake, River	Greater Yellowlegs	Lake, River, Farm
Cmn. Goldeneye	Lake, River	Lesser Yellowlegs	Lake
Barrow's Goldeneye	Lake, River	Willet	Lake
Canvasback	Lake, River	W. Sandpiper	Lake, Farm
Bufflehead	Lake, River	Least Sandpiper	Lake
Ruddy Duck	Lake, River	Dowitcher sp.	Lake
Hooded Merganser	River, Lake	Marbled Godwit	Lake
Cmn. Merganser	River, Lake	Dunlin	Lake
Red-breasted Merganser	River, Lake	Sanderling	Lake
N. Goshawk	River, Farm, Upland	Wilson's Phalarope	River, Farm
Red-naped sapsucker	River, Upland	Red-necked Phalarope	River, Farm
Williamson's Sapsucker	Upland	Herring Gull	Lake, Farm
Red-breasted sapsucker	River, Upland	California Gull	Lake, Farm
Northern Flicker	River, Farm, Upland	Ring-billed Gull	Lake, Farm
Western Kingbird	River, Farm, Upland	Franklin's Gull	Lake
Ash-throated Flycatcher	River, Farm, Uplands	Bonaparte's Gull	Lake
Say's Phoebe	River, Upland	Caspian Tern	Lake
Black Phoebe	River, Farm, Upland	Forster's Tern	River
Western Flycatcher	Farm, River, Upland	Black Tern	Lake
Dusky Flycatcher	River, Upland	Steller's Jay	Upland
Gray Flycatcher	River, Upland	Scrub Jay	River, Farm, Upland
Willow Flycatcher	River, Farm, Upland	Common Raven	All
Ash-throated flycatcher	River, Upland	Black-billed Magpie	All
Hammond's Flycatcher	River, Upland	Tree Swallow	River, Farm
W. Wood-Pewee	River, Upland	Violet-green Swallow	Upland
Olive-sided Flycatcher	River, Farm, Upland	Bank Swallow	River, Upland
N. Shrike	River, Farm, Upland	N. R.W. Swallow	Farm, Upland
Loggerhead Shrike	Farm, Upland	Horned Lark	Farm, Upland
Hutton's Vireo	Farm, Upland	Barn Swallow	River, Farm, Upland
Warbling Vireo	River, Farm, Upland	Cliff Swallow	River, Farm
Cassin's Vireo	River, Upland	Yellow-billed Cuckoo	River, Farm, Upland
Plumbeous Vireo	River, Upland	Mourning Dove	Farm, Upland
Barn Owl	River, Farm, Upland	Juniper Titmouse	Upland
W. Screech Owl	River, Farm, Upland	Bushtit	River, Farm, Upland
Great Horned Owl	River, Farm, Upland	W.-brst. Nuthatch	Upland
Flammulated Owl	Upland	R.-brst. Nuthatch	Upland
Long-eared Owl	River, Farm, Upland	Pygmy Nuthatch	Upland
Short-eared Owl	Farm, Upland	Brown Creeper	Upland
N. Saw-whet Owl	Upland	Canyon Wren	Upland
N. Pygmy Owl	Upland	Rock Wren	Upland
Great Gray Owl	Farm, Upland	House Wren	River, Farm, Upland
Spotted Owl	Upland	Marsh Wren	Lake, River
Burrowing Owl	Farm, Upland	Blue-gray Gnatcatcher	River, Upland
Common Poorwill	Farm, Upland	Am. Robin	River, Farm, Upland
Common Nighthawk	River, Farm, Upland	Hermit Thrush	Upland
Vaux's Swift	River, Farm, Upland	Townsends Solitaire	Upland
White-throated Swift	Farm, Upland	Western Blue Bird	Upland
Bl-ch. Hummingbird	River, Farm, Upland	Mountain Bluebird	Upland
Broad-tailed Hummingbird	River, Upland	N. Mockingbird	River, Farm, Upland
Rufs. Hummingbird	River, Upland	Sage Thrasher	Upland
Call. Hummingbird	River, Farm, Upland	European Starling	River, Farm, Upland
Orng-crnd Warbler	River, Upland	Cedar Waxwing	River, Farm, Upland

Table 4. Wildlife Species of the Walker River Basin and associated habitat type (continued).

SPECIES	HABITATS	SPECIES	HABITATS
BIRDS		BIRDS	
Yellow Warbler	River, Farm	Brewer's Blackbird	Farm
Virginia Warbler	River, Upland	Brn-hd. Cowbird	Farm, Upland
Yllw-rmpd. Warbler	Upland	Ylw-hd. Blackbird	River, Farm
Blk-thr.Gray warbler	River, Upland	Rd-wng. Blackbird	River, Farm
MacGillvry. Warbler	River, Upland	Tricolor Blackbird	River, Farm
Cmn. Yellowthroat	River, Upland	Bullock's Oriole	River, Upland
Western Tanager	Upland	W. Meadowlark	Farm, Upland
Spotted Towhee	Upland	House Finch	River, Farm, Upland
Savannah Sparrow	Farm, Upland	Lesser Goldfinch	River, Farm, Upland
Brewer's Sparrow	Farm, Upland	Sage grouse	Upland
Blk-hd. Grosbeak	Upland	Rio Grande Turkey	Upland
Lazuli Bunting	River, Farm, Upland	Tree Sparrow	Farm, Upland
Wh.-crn. Sparrow	Farm	Dark-eyed Junco	Farm, Upland
Song Sparrow	River, Farm, Upland	White pelican	Lake
Chipping Sparrow	River, Farm, Upland		
MAMMALS		MAMMALS	
Broad-tailed Mole	Upland	Muskrat	River
Broad-footed Mole	Upland	Grasshopper Mouse	Farm, Upland
Merriam's Shrew	Upland	Pinyon Mouse	Upland
Vagrant Shrew	River, Upland	Deer Mouse	River, Farm, Upland
Inyo Shrew	River, Upland	Broad footed mole	Farm, Upland
Montane Shrew	River, Upland	Desert Woodrat	River, Upland
Mt. Lyell Shrew	Upland	Bushy tailed woodrat	Upland
Water Shrew	River	Long eared woodrat	Upland
Northern flying squirrel	Upland	Pinyon mouse	Upland
Little Brown Bat	River, Upland	Western Harvest Mouse	Farm, Upland
W. Small-footed Myotis	River, Upland	Brush mouse	River, Upland
Long-legged Myotis	River, Upland	Pocket Mouse	Upland
W. Red bat	River, Upland	Canyon mouse	Upland
Yuma Myotis	River, Upland	Least Chipmunk	River, Upland
Silver-haired Bat	River, Upland	Y.pine Chipmunk	Upland
W. Pipistrelle	River, Upland	Panamint chipmunk	Upland
Big Brown Bat	River, Farm, Upland	Allen's chipmunk	Upland
Hoary Bat	River, Upland	Lodgepole chipmunk	Upland
Spotted Bat	River, Upland	Long eared chipmunk	Upland
Townsend's Big-eared Bat	River, Farm, Upland	Merriam's chipmunk	Upland
Pallid Bat	River, Upland	Montane Vole	River, Farm, Upland
Brazillian Free-tailed bat	River, Upland	Long-tailed Vole	River, Upland
California Myotis	River, Upland	Sagebrush Vole	Upland
W. small footed myotis	River, Upland	W. heather vole	Upland
Long-eared myotis	River, Upland	Black Rat	River, Farm
Beaver	River	House Mouse	River, Farm
Raccoon	River, Farm, Upland	Kangaroo Mouse	Upland
Short-tailed Weasel	River, Farm, Upland	Kangaroo Rat	Upland
Long-tailed Weasel	River, Farm, Upland	Mountain Pocket Gopher	Upland
Mink	River	Northern Pocket Gopher	River, Farm, Upland
River Otter	River	Botta's Pocket Gopher	Farm, Upland
Spotted Skunk	Farm, Upland	Townsend's Pocket Gopher	Farm, Upland
Striped Skunk	Farm, Upland	California Ground Squirrel	Farm, Upland
Badger	Farm, Upland	Belding's Ground Squirrel	Upland
Ermine	Upland	Black Bear	Upland
Kit Fox	Upland	Antelope Ground Squirrel	Farm, Upland

Table 4. Wildlife Species of the Walker River Basin and associated habitat type (continued).

SPECIES	HABITATS	SPECIES	HABITATS
MAMMALS		MAMMALS	
Red Fox	River, Farm, Upland	Golden Mantled Ground Squirrel	Upland
Gray Fox	River, Farm, Upland	Piute Ground Squirrel	Upland
Coyote	River, Farm, Upland	Yellow-bellied Marmot	Upland
Cougar	Upland	White-tailed Jackrabbit	Farm, Upland
Bobcat	Farm, Upland	Black-tailed Jackrabbit	Farm, Upland
Sierra Nevada Mountain Beaver	River, Upland	Nuttall's Cottontail	River, Farm, Upland
American Marten	Upland	Desert Cottontail	Upland
Porcupine	River, Farm, Upland	Mountain Cottontail	Upland
Snowshoe Hare	Upland	Western Jumping Mouse	Farm, Upland
Nutria	River	Long-tailed pocket mouse	Farm, Upland
Western gray squirrel	Upland	Desert kangaroo rat	Upland
Douglas squirrel	Upland	Chisel-toothed kangaroo rat	Upland
Mule Deer	River, Farm, Upland	Ord's kangaroo rat	Upland
Pronghorn	Upland	Panamint Kangaroo rat	Upland
Bighorn Sheep	Upland	Pale kangaroo mouse	Upland
Pygmy rabbit	Upland	Great Basin pocket mouse	Upland
Pacific Fisher	Upland	Pika	Upland
Mountain Lion	Farm, Upland		
FISH		FISH	
Lahontan Cutthroat Trout	Lake, River	Yellow Perch	Reservoir
Rainbow Trout	River	Black Crappie	Reservoir
Brown Trout	River	White Crappie	Reservoir
Lahontan Tui Chub	Lake, River	Bullhead (black and brown)	Reservoir
Lahontan Redside Shiner	River	Channel Catfish	Reservoir
Tahoe Sucker	River	White Catfish	Reservoir
Mountain Sucker	River	Bluegill	Reservoir
Paiute Sculpin	River	Green Sunfish	Reservoir
Mosquitofish	River	Asiatic Carp	Reservoir
Speckled Dace	River	Mountain Whitefish	River
Common Carp	River	Largemouth bass	River, Reservoir
Sacramento Perch	River	Smallmouth bass	River, Reservoir
REPTILES & AMPHIBIANS		REPTILES & AMPHIBIANS	
Zebra-tailed Lizard	Upland	Great Basin Spadefoot Toad	Farm, upland
Desert Collared Lizard	Upland	Western Diamondback Rattlesnake	Upland
Leopard Lizard	Upland	Night Snake	River, Upland
Desert Spiny Lizard	Upland	Western Ground Snake	Upland
Western Fence Lizard	Farm, upland	Western Terrestrial Garter Snake	Farm, Upland
Sagebrush Lizard	Upland	Common Garter Snake	Farm, Upland
Side-botched Lizard	Upland	Long-nosed Snake	Farm, Upland
Desert Horned Lizard	Upland	California King Snake	Farm, Upland
Western Skink	Farm, Upland	Great Basin Gopher Snake	Farm, Upland
Western Whiptail	Farm, Upland	Western Patch-nosed Snake	Upland
Pacific Treefrog	River, Farm, Upland	Striped Whipsnake	Upland
Western Toad	Upland	Coachwhip	Farm, Upland
Rubber Boa	Farm, Upland	Western Yellow-bellied Racer	River, Farm, Upland

Data compiled from government agency inventories and online servers. Lake = lake habitat; River = River plus riparian habitat; Farm = agriculture, grazing, and other habitats including water sources or ponds associated with farming; Uplands = all other non-water dominant habitat.

The habitat of the Walker Basin can be characterized in a number of different ways that are meaningful from an ecological or biological perspective. Water is used here as a primary feature to define habitats. The Walker watershed can be delineated into four very general habitat types: (1) lacustrine; (2) riverine, riparian, and wetlands; (3) upland or non-water-dominated; and (4) farmlands and associated agricultural production areas. These four habitat types have water associated with them to different degrees and in varying temporal scale. Quality of the habitat is not intrinsic in the definition and therefore changes through time.

Lacustrine

Lakes and reservoirs host many different environments. The water environment includes shallow near-shore areas; deep, mid-lake areas; and a vertical component from the lake surface to sediments on the lake bottom. Physical characteristics of these environments change diurnally, seasonally, and through centuries. Shoreline, from the edge of the lake upslope, and the lake surface are other habitats associated with lacustrine bodies of water. This section discusses Walker Lake's habitat and processes, paleoecology, and potential future scenarios with increasing TDS. Shoreline, lake surface, and reservoir habitats in the Walker Basin also are discussed.

<u>Walker Lake</u>

Physical, geochemical, and biotic processes in Walker Lake are important because they dictate the environment that supports particular biota. Hydrologic change through time affects these processes which alter the occurrence and abundance of Walker Lake taxa. Physical processes include changes in water temperature and water column stratification. Geochemical processes include changes in TDS and ionic constituents. Biotic processes influence light penetration, dissolved oxygen content, and amounts of nitrogen, ammonia, and phosphorus.

The decrease in lake volume and depth has changed the entire lake ecosystem—physically, chemically, and biologically. Increased TDS, increased water temperature, and decreased dissolved oxygen concentration have played a role in altering nutrient cycling, changing biotic communities, and affecting the extent and quality of fish habitat, particularly in summer months. As a result, Walker Lake is experiencing eutrophication, a degradation of lake water quality.

Because of limited freshwater inflow to Walker Lake, the lake is nitrogen-limited (Cooper and Koch, 1984; Horne et al., 1994) meaning that biological productivity such as algal growth is limited by the availability of nitrogen in the lake environment. Phytoplankton deplete nitrogen that exists in the form of ammonia and nitrate. As is common in arid climates, Walker Lake is rich in phosphorus (Beutel and Horne, 1997; Horne et al., 1994). Another feature of Walker Lake is that it has a naturally low capacity to hold dissolved oxygen due to its high elevation of ~ 4,000 feet (Horne et al., 1994). In 1992–93, peak oxygen concentration reached only 10.4 mg/L whereas typical values for lakes at sea level are around 15 mg/L during peak algae blooms (Horne et al., 1994).

Presently Walker Lake is a monomictic lake that is stratified in the summer and mixes completely in the fall or winter season. Beginning in April or May, the lake stratifies: waters are arranged in layers of different temperatures and densities. The uppermost water layer, the epilimnion, is relatively warm and oxygen-rich (aerobic). This layer contains enough oxygen for LCT in the summer, but the water temperature is too warm, 68˚ to 75˚ F, to sustain LCT for more than a short period of time. The bottom layer of the water column, the hypolimnion, ranges in temperature from 50˚ to 54˚ F (Beutel and Horne, 1997). While this temperature range may support LCT, the hypolimnion is oxygen-depleted (anaerobic), a result of algal decomposition, so it is not available as fish habitat. The metalimnion is a narrow zone between the top and bottom layers. It is this narrow zone that is the most hospitable area for LCT when the lake is stratified. The thickness of the epilimnion and hypolimnion zones fluctuate widely throughout the warmer months of the year, often dramatically compressing the fish-tolerant metalimnion. As the lake overturns in the fall or winter, oxygen-rich surface water and anoxic (without oxygen) bottom water mix.

The lake's eutrophication has resulted in a substantial increase in blue-green algae (cyanobacteria), *Nodularia spumigena* (Horne et al., 1994). This algae currently dominates the phytoplankton community in summer months, thus reducing phytoplankton and zooplankton diversity. These algae are responding to an increased rate of ammonia recycling from bottom sediments due to decreased lake volume and not from increases of nitrogen and phosphorus from fertilizer (Horne et al., 1994; Beutel and Horne, 1997). During summertime peak blooms of algae, dissolved oxygen increases in the epilimnion as a result of photosynthesis. During this same time period, consumption of oxygen by bacteria and decomposing algae cause anoxic conditions in the hypolimnion significantly affecting the habitat available for LCT.

Reduction of the lake's water quality has directly affected the health and vitality of Lahontan cutthroat trout (*Onchorhynchus clarki henshawi*) and its primary prey species, tui chub (*Gila bicolor*). The LCT population is currently maintained in Walker Lake through fish hatchery plantings by Nevada Department of Wildlife (NDOW) and the U.S. Fish and Wildlife Service (USFWS). The LCT strain that exists in Walker Lake today is not the original native strain. Stocking of non-native Lahontan cutthroat trout began in 1953, undertaken because the construction of dams prevented upstream migration for spawning (see Beutel, 2001). The Lahontan tui chub is the most abundant fish species at present and is a key food source for both the lake's LCT population and migratory fish-eating birds such as the common loon (*Gaver immer*) and white pelican (*Pelecanus erythrophynchos*). In 2005, TDS was > 15,000 ppm; and, although tui chub spawned with vigor, no larvae or viable eggs were observed (NDOW, 2005). It is possible that if water quality continues to decline, neither LCT nor tui chub will be able to survive in Walker Lake. Desert Research and University of Nevada, Reno, scientists are preparing reports on the current state of Walker Lake based on field research conducted in 2007 and 2008.

Lake Paleoecology

Histories of lake levels, hydrology, and climate are important because they provide a link from the past into the present and also can be used to infer potential future conditions. Sediment cores taken from Walker Lake by the USGS during the 1970s and 1980s provided biotic (diatom, ostracode, brine shrimp, and pollen) and abiotic (sediment structure, composition, pore water, stable isotope, and geochemical) material used to reconstruct the paleolimnology of Walker Lake. This paleoenvironmental record indicates that the hydrology of Walker Lake changed dramatically through time, although the timing and duration of lake high- or low-stand events are not well defined. Lake levels were influenced by climate and changes in the course of the Walker River. During the past 30,000 years, Walker Lake fluctuated from fresh and deep to very shallow and saline. Conflicting evidence exists as to whether and when the lake completely desiccated.

Researchers generally agree that the lake was low or possibly dry from prior to 13,000 to about 4,800 yr B.P. and then filled quickly beginning about 4,700 yr B.P. (Benson, 1988; Bradbury et al., 1989). This rapid increase in lake volume may have occurred because the physical course of Walker River changed, flowing into the Walker Lake basin instead of the Carson basin, or it may reflect a change to a much wetter climate. Adams (2007) reports four lake highstands during the last 3,500 years ranging between 4,084 and 4,117 msl. He also reports low or fluctuating lake levels during this time period, possibly when the Walker River flowed into the Carson Sink through Adrian Gap. According to his analysis, lake elevation fluctuated about 180 feet during the last ~3,500 years. Yuan et al. (2006) also report lake high- and lowstands during the last ~2,700 years.

The important point to note from these records is that the lake can change relatively rapidly in volume and from one ecosystem to another. Analysis of biota in lake core sediments also suggests that Walker Lake TDS dropped below 1,000 ppm several times in the last 5,000 years (at approximately 4,700, 4,300, 1,100 yr B.P.), and TDS may have averaged as low as 500 ppm during these times. On the other hand, Walker Lake was very saline at about 5,000 and 2,100 yr B.P., with TDS ranging between 60,000 and 100,000 ppm as evidenced by the recovery of *Artemia* (brine shrimp) pellets. Periods of fresh water supported certain species, while more saline periods supported different species.

Calculations (J.M. Thomas, personal communication, 2003) using lake volume and TDS indicate that if TDS in a low-volume Walker Lake were as high as 100,000 ppm during the last 5,000 years, the lake did not need to desiccate and have salts removed by wind during this time span to reach a high-volume lake with TDS of 2,500 ppm in the late 1880s. Rather, TDS levels could have been reduced entirely by increased inflow. This also implies continued stream input during the last 5,000 years, as known groundwater input is not enough to support a standing body of water in the Walker Lake basin (R.M. Forester, U.S. Geological Survey, personal communication, 2001). Therefore, the low stands may be evidence for severe droughts unlike any we have experienced in historic time.

The record during the last 30,000 years shows that many species enter and leave the lake ecosystem with regularity. This suggests that species die off when conditions are unfavorable and colonize when conditions are favorable. The record also shows that taxa in the lake are dependent on each other in terms of the food web and utilization of ecological niches within the lake ecosystem. A breakdown in any one part of this biotic chain affects all other aspects of the ecosystem.

A listing of selected taxa from published literature is shown in Table 5. Taxa are included in this table if they were found at other times in the record or if they were an important paleoenvironmental indicator. If a species drops from the record in Table 5, it could mean that (1) it was not abundant, therefore, not recorded; (2) it was extirpated; (3) it was not preserved in the record; or (4) the sampling design was not intended to collect that particular taxon. Therefore, when a particular species drops out of the record, we cannot be sure if it were really absent at that particular time or if it were just not present in that sample. Also the taxa in Table 5 are from published peer-reviewed literature only, so Table 5 does not represent other times in the lake's history or other studies. Additionally, the 5,000 yr B.P. to 1885 column encompasses all taxa from high to very low lake levels occurring during this time. These taxa did not all exist at once in the lake. They are included so that a presence-absence comparison may be made with more recent years.

Table 5. Selected Walker Lake taxa through time.

TIME PERIOD	4800 yr B.P. to 1885*[1]	1885-1910[2]	Pre-1950[3]	Pre-1963[4]	1975-1977[5]	1992-1994[6]
Dominant Phytoplankton						
Bluegreen Algae						
Nodularia spumigena					X	X
new observed species						X
Green Algae						
Cladophora glomerata					X	X
Botryococcus sp.	X				X	
Diatoms						
Cyclotella kutzingiana					X	X
Chaetoceros elmorei	X	?			X	X
Navicula sp.	X				X	X
Cocconeis placentula					X	X
Cymbella sp.					X	X
Stephanodiscus excentricus	X	?			X	
Surirella nevadensis	X					
Cyclotella quillensis	X	?			X	
Cyclotella meneghiniana	X	?				
Stephanodiscus rotula	X	?				
Cyclotella ocellata	X	?				
Stephanodiscus niagarae	X	?				
Anomoeoneis costata						
Zooplankton						
Copepods						
Ceriodaphnia quadrangular		probably	X	X	absent	
Diaphanosoma leuchtenbergianum		probably	X	X	absent	
Leptodiaptomus (Diaptomus) sicilis		?	?	X	X abundant	X
Acanthocyclops (Cyclops) vernalis		?	?	X	X rare	absent
Rotifers						
Hexarthra					not	X
Brachionus					not	X
Cladoceran						
Moina hutchinsoni				X	X abundant	X
Ostracodes						
Limnocythere ceriotuberosa	X				X	
Candona caudata	X	X		X ?		
Limnocythere sappaensis	X					
Candona sp.	X					
Brine Shrimp						
Artemia	X					
Mollusks						
Helisoma newberryi	X	?				
Anodonta sp.	X	?				
Helisoma trivolvus	X	?				
Physella sp.	X	?				
Gyraulus parvus	X	?				
Pisidium sp.	X	?				
Pyrgulopsis nevadensis	X	?				

Table 5. Selected Walker Lake taxa through time (continued).

TIME PERIOD	4800 yr B.P. to 1885*[1]	1885-1910[2]	Pre-1950[3]	Pre-1963[4]	1975-1977[5]	1992-1994[6]
Fish						
Cyprinus carpio (common carp)**		X	X	absent		
Archoplites interruptus (Sacramento perch)**		X	X	absent		
Oncorhynchus clarki henshawi (LCT)		X			stocked	stocked
Catostomus tahoensis (Tahoe sucker)		X			X	absent/low
Gila Bicolor (tui chub)		X			X	X
Rhinichthys osculus (speckled dace)		X			absent	absent/low
Lake Parameters (from Horne et al. 1994)						
Mean depth (feet)		130			66	61
Area (Acres)		69,000			36,600	35,000
Length (miles)		25			25	13
Breadth (miles)		7			9	5.3
Fetch (miles)		25			?	13
Salinity (total dissolved solids)		2,500			10,650	12,500
Watershed area (km^2)		10,400			10,400	10,400
Watershed: lake area ratio		37				74
Surface elevation (feet)		4086			3,960	3946

X indicates taxa in lake at that time.
? indicates this species may have inhabited the lake at this time, but data are non-existent or inconclusive.
*not all species present consistently through entire time period.
**introduced. Other fish taxa are native.
[1]Bradbury et al., 1989; S.E. Sharpe, unpublished data.
[2]Bradbury et al., 1989; Brussard et al., 1996; Cooper and Koch, 1984; Horne et al., 1994.
[3]Brussard et al., 1996; Cooper and Koch, 1984.
[4]Bradbury et al., 1989.
[5]Cooper and Koch, 1984; Bradbury et al., 1989; Horne et al., 1994.
[6]Horne et al., 1994; Brussard et al., 1996.

The composition of algae in Walker Lake has changed through time. The only taxon with a record earlier than 1975 is *Botryococcus*, a green algae. This is a predominately freshwater algae found during some periods throughout the last 5,000 years. It also was recorded in 1975–1977 by Cooper and Koch (1984) but is absent or rare in Walker Lake today. In 1975–1977, blue-green algae and diatoms comprised more than 99% of the total phytoplankton sampled, and blue-green algae alone made up 97% of this sample (Cooper and Koch, 1984). The cyanobacteria, *Nodularia spumigena*, has dominated the blue-green algae assemblage for the last 25 years although it appears that the total number of blue-green algae and mass of chlorophyll-a have increased substantially during this timeframe. Additionally, Horne et al. (1994) report a new species of blue green algae.

Diatoms often are well preserved in lake sediments, so a record exists for diatom assemblages from 30,000 years ago until present. Diatoms recovered from lake sediments representing the last 5,000 years also found in the lake today include *Chaetoceros elmorei*, *Navicula* sp., *Stephanodiscus excentricus*, and *Cyclotella quillensis* (Cooper and Koch, 1984; Bradbury et al., 1989). In Pyramid Lake, *Chaetoceros elmorei* and *Stephanodiscus excentricus* are replaced by blue-green algae at higher salinities, and the relative scarcity of diatoms in Walker Lake today may be due to its rising salinity (Bradbury et al., 1989).

Zooplankton diversity has decreased since the mid-1970s. Two species of copepods—*Leptodiaptomus (Diaptomus) sicilis* and *Acanthocyclops (Cyclops) vernalis* and one cladoceran, *Moina hutchinsoni*—were recorded in 1975–1977 by Cooper and Koch (1984) although *Acanthocyclops* was rare. When Horne sampled in 1992–1994, *Acanthocyclops* was not found, and it most likely is extirpated or exists in very small numbers. *Leptodiaptomus* declined 50–70% in abundance between 1977 and 1994. Claderceran *Moina* has been stable for the last 40 years, but we do not know if it inhabited the system prior to the 1960s because no studies were conducted for this taxon. It was as abundant in 1992–1994 as in 1975–1977. Rotifers *Hexarthra* and *Brachionus*, were not found in 1975–1977 but were found in 1992–1994 (Horne et al., 1994). *Ceriodaphnia quadrangula* and *Diaphanosoma leuchtenbergianum* were lost from Walker Lake by the late 1970s due to elevated TDS (Dickerson and Vinyard, 1999).

Communities of ostracodes, brine shrimp, amphipods, and mollusks also have changed through time. *Limnocythere ceriotuberosa* is the only abundant ostracode living in the lake sediment today. It inhabited the lake at various times during the last 5,000 years (Bradbury et al., 1989). *Candona caudata* also lived in the lake at various times during the last 5,000 years and historically prior to lake drawdown (Bradbury et al., 1989). Pellets from the brine shrimp, *Artemia*, are recorded frequently between approximately 24,000 and 14,500 years ago and at about 5,000 and 2,100 years ago. This implies a very saline lake during these times, possibly as much as 100,000 ppm. Scuds (amphipods) disappeared from the lake in 2003 or 2004 (NDOW, 2005). Mollusks once lived in Walker Lake, but the lake does not support mollusks today. Gastropods *Planorbella newberryi*, *Planorbella trivolvus*, *Physella* sp., and *Pyrgulopsis nevadensis*—and bivalves, *Pisidium* sp. and *Anodonta* sp., once living in Walker Lake—are taxa found in relatively freshwater today (S.E. Sharpe, unpublished data).

Historically, four native species of fish inhabited Walker Lake: the Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), tui chub (*Gila bicolor*), speckled dace (*Rhinichthys osculus*), and Tahoe sucker (*Catostomus tahoensis*) (Sigler and Sigler, 1987; LaRivers, 1962; Brussard et al., 1996). Presently, Tahoe sucker and speckled dace are either extirpated or present in very low numbers (Brussard et al., 1996). Two non-native fish species, the common carp (*Cyprinus carpio*) and the Sacramento perch (*Archoplites interruptus*) were extirpated from the lake by about 1963 (Cooper and Koch, 1984). Speckled dace were absent by the middle 1970s (Cooper and Koch, 1984). Page and Burr (1991) report that Lahontan redside (*Richardsonian egregius*), a native fish, inhabited the lake in the early 1990s. Tui chub is the only native fish (defined as the strain that evolved in Walker Lake) remaining in Walker Lake. LCT are native to Walker Lake, however, the stocked fish are not the original Walker Lake native strain and, so, are considered by many not native.

Projected changes to lake habitat if TDS continues to increase

By investigating changes in past ecology and similar lake systems, different future scenarios for Walker Lake may be inferred. For example, influxes of fresh water or continued evaporation leading to higher TDS will alter the timing and seasonal pattern of physical and geochemical processes in Walker Lake. Thermal stability may change and change in wind strength or patterns or temperature could cause the lake to turn over more readily. If the lake decreases in volume resulting in a substantial increase in TDS and then receives a large influx of freshwater, however, the lake may not overturn because of the salinity difference. This could alter primary production and the food chain as occurred at Mono Lake during 1984–88 (Jellison and Melack, 1999).

Presently, maximum dissolved oxygen concentrations occur during most intensive blooms of *Nodularia spumigena,* and the lowest dissolved oxygen is in bottom waters during summer. If TDS increases, low dissolved oxygen may begin to limit zooplankton distribution patterns as it presently does with fishes. If TDS decreases so that *Nodularia spumigena* is no longer dominant, the pattern of dissolved oxygen may shift. Light penetration may change with a change in algae. Presently, maximum light penetration occurs in the fall and winter because *Nodularia* blooms reduce light transmission in spring.

Ionic composition of the water column changes with increased freshwater or continuing evaporation. Presently, Walker Lake is a sodium chloride dominated system with sodium chloride, sulfates, and bicarbonates making up 97% of total ionic content. Change in ionic composition also may affect occurrence and distribution of taxa.

As TDS levels fluctuate, nutrient cycling may be altered. Presently, nitrate is higher on the water surface in the winter, which is associated with lake mixing. Spring and late summer show decreased nitrate, which is associated with increased biological production. Increases in nitrate during June and July are associated with *Nodularia* blooms. Nutrient cycling in the bottom waters are affected by changes in stratification and algal production.

Past ecology of the lake also can be used to answer the following commonly-asked questions. *What if Walker Lake TDS increases and then drops?* The paleoenvironmental record indicates that phytoplankton, zooplankton, ostracodes, brine shrimp, mollusks, and fishes are effective in moving back into a system where they have previously been rare or extirpated. Recolonization mechanisms for these taxa include transport by wind or waterfowl, persisting in refugia such as at a groundwater discharge site within the lake or migrating to refugia upstream or by hatching of dormant (resting) eggs in the sediments.

For example, based on ostracodes recovered from sediment cores, Walker Lake probably dropped below 1,000 ppm TDS at least three times during the last 5,000 years. It may have averaged as low as 500 ppm during these highstands (R.M. Forester, personal communication). Depletion in $\delta^{18}O$ values (Benson et al., 1991) at approximately 4,330 and 1,090 yr B.P. support rapid rises in lake levels (hence decreasing and lowered TDS) during these periods. This interpretation is also consistent with interpretation of lake core unrecrystallized carbonates (Benson et al., 1991) and mollusks collected from sediments. On the other hand, brine shrimp, *Artemia*, found in the record at about 5,000 and 2,100 yr B.P., imply a lake with 60,000–100,000 ppm TDS. This is supported by other lake core data such as pollen assemblages and diatoms.

Biologic and geochemical evidence from the USGS Walker Lake sediment cores indicate that lake TDS ranged from 500 to 100,000 ppm in the past and taxa moved in and out of this system as TDS and lake processes changed. It is likely that many of the taxa listed in Table 5 will recolonize Walker Lake should the TDS rise or fall from the present concentration. In other words, if a 16,000–20,000 ppm TDS threshold is crossed, many of the present taxa will be lost, but new taxa will colonize. Should TDS then decrease to 10,000 or 11,000 ppm, it is likely that many of the taxa previously thriving at these levels will once again inhabit Walker Lake.

The crucial things that we do not know about this process include:

- The length of time for recolonization of species and groups of species; it could be years, decades, or longer.

- If fishes will need to be restocked. If fish can migrate upstream, the chances for recolonization are much better than if they are not able to migrate.
- The financial burden to help re-establish the ecosystem. What are the associated financial, ecological, and economic costs?

What if Walker Lake TDS continue to increase? Ten years ago, when TDS was about 13,000 ppm, Brussard et al. (1996) proposed a scenario based on dry conditions and average agricultural usage resulting in further increased TDS. The proposed scenario is proving to be correct. Survival statistics show that an inverse correlation exists between TDS and LCT survival. As TDS increases, fewer LCT are surviving (1) the shock of placement into the salty water (even though the release involves two-phases to reduce shock) and (2) the cumulative stress of high TDS levels. For those LCT that survive elevated TDS, food availability will become limited. This is because tui chub will stop reproducing when TDS reaches approximately 16,000 ppm.

In 2005, TDS were ~16,000 ppm and although tui chub spawned with vigor, no larvae were observed (NDOW, 2005). Without this primary food source, LCT will not be able to survive, so stocking the lake with LCT would result in complete mortality from either the initial shock of stocking, cumulative stress from the water, or ultimately lack of food. Therefore, the existing LCT population would decline because the population that exists in Walker Lake is non-reproducing.

Concomitant with LCT decline, tui chub populations will become older and larger, and no offspring will be produced. Because larger tui chub eat more littoral invertebrates and less pelagic zooplankton than small chub, biotic diversity of the lake will shift with a shift in the tui chub age and size. Increased pelagic zooplankton could decrease the number of planktonic algae and bacteria. This could increase water clarity, but *Nodularia* might simultaneously increase in number, as is already happening, and this would further deplete the hypolimnic oxygen. At the same time it also is possible that the insect population would increase and tui chub would feed off the insects and not *Nodularia*. This would produce little change in water clarity or *Nodularia* abundance.

As TDS continue to increase, the fish will die off, and the present invertebrate fauna will disappear. Since vertebrate predation will be decreased, filter-feeding fairy shrimp, clam shrimp, cladocerans, copepods, tadpole shrimp, and insects will be able to colonize Walker Lake because these taxa are intolerant of vertebrate predation and thrive in ephemeral saline lakes. With ever-increasing TDS, Walker Lake may move to an ecosystem like Mono Lake (which is currently at about 80,000 ppm TDS) hosting brine flies and brine shrimp.

<u>Shoreline and Lake Surface</u>

Terrestrial habitat exists along the shore of Walker Lake. A freshwater marsh at the southernmost end of the lake is dominated by cottonwood (*Populus fremontii*) and cattails (*Typha latifolia*). These plants grow well in the boggy, wet substrate. Cottonwood, tamarisk (*Tamarix ramosissima*), coyote willow (*Salix exigua*), Russian olive (*Elaeagnus angustifolia*), and saltgrass (*Distichlis spicata*) occur in the riparian area that is associated with nearby freshwater springs. Here, the soil is predominately sand (Espinoza and Tracy, 1999).

Herpetofauna (reptiles and amphibians) find an abundance of habitat in boulders and tufa formations on Walker Lake's southwestern shore (Espinoza and Tracy, 1999). Western toads (*Bufo boreas*) and Great Basin spadefoot toads (*Spea intermontana*) occur on the southwestern shore of Walker Lake. Western toads also occur on other areas of the shoreline

(Espinoza and Tracy, 1999). Other herpetofauna found within relatively short distances from the lake include the Great Basin collared lizard (*Crotaphytus bicintores*), western whiptail (*Cnemidophorus tigris*), the common kingsnake (*Lampropeltis getula*), long-nosed leopard lizard (*Gambelia wislizenii*), side-blotched lizard (*Uta stansburiana*), desert horned lizard (*Phrynosoma platyrhinos*), and the zebra-tailed lizard (*Callisaurus draconoides*). Birds also use non-lacustrine habitat associated with, but not directly part of, the lake. The snowy plover, for example, relies on the dry lakebed to the east of Walker Lake for breeding (Stockwell, 1994).

Walker Lake also provides habitat for a changing array of migratory birds throughout the year. In general terms, seasonal avian use of Walker Lake can be described as follows:

- *Spring* – shorebirds, waterfowl and other water birds stop at Walker Lake for food and/or rest during their northward migration to breeding areas. The duration of their stay depends on food availability, weather patterns, and distance to the breeding grounds. Food resources of the lake provide important pre-nesting protein and nutrients.
- *Summer* – limited use of the lake and lakeshore by waterfowl and shorebirds for breeding and brood rearing. The marshlands at the mouth of the Walker River support a more diverse mix of numerous waterfowl, water birds, and shorebirds.
- *Fall* – this is the reverse of the spring migration, with waterfowl, shorebirds, and water birds again utilizing Walker Lake for food and/or rest.
- *Winter* – small populations of the hardier waterfowl (such as mallard or Canada goose) may remain in milder years, but no true resident lake-living bird species is known.

<u>Reservoirs</u>

Reservoirs are similar to lakes – they are predominantly aquatic systems with a varying extent and composition of shoreline vegetation, and they support habitats for various animals at different times throughout the year. Natural lake levels fluctuate because of external environmental and climatic conditions, whereas reservoir levels fluctuate based on human use. Disjunct wetland communities may occur when water levels drop for extended time periods and can exist intermittently depending on fluctuating water levels. Discharge from reservoirs is regulated and controlled to accommodate downstream water requirements and reservoir holding capacities. For this reason, reservoirs tend to be more unstable environments than lakes, particularly in terms of shoreline habitat.

Bridgeport Reservoir

Rainbow trout (*Oncorhynchus mykiss*) are stocked in Bridgeport reservoir (Figure 5) by the California Department of Fish and Game (CDF&G). Brown trout (*Salmo trutta*) also inhabit the reservoir. Pelicans (*Pelicanus sp.*), gulls (*Larus sp.*), egrets, and herons are common. The reservoir also is used as a stopover for migrating waterfowl. Species associated with the irrigated pasture and meadows adjacent to the reservoir occur where shoreline habitat provides adequate cover, foraging, or hunting conditions.

Topaz Lake

In 2006, Topaz Lake was stocked with rainbow and tiger trout by the NDOW. Brown trout, rainbow/cutthroat hybrids (also called bowcutts), and bullhead catfish (*Ictalurus nebulosus*) also occur there (Sigler and Sigler, 1987). Wetland habitat exists in the area where the Walker River is diverted into the reservoir and provides habitat for a variety of water birds such as egrets, herons, and wading shorebirds. Pelicans and gulls are also common. The reservoir is used as a stopover for migrating waterfowl. Other riparian species and species associated with irrigated pasture habitat may be found near the reservoir or nearby. Bats, for example, forage over the reservoir and along the shore. Species associated with the irrigated pasture and meadows adjacent to the reservoir occur where shoreline habitat provides adequate cover, foraging, or hunting conditions.

Figure 5. Bridgeport Reservoir looking southwest. Photo: Mary E. Cablk.

Weber Reservoir

Weber Reservoir (Figure 6) is located on the Walker River Paiute Reservation. Carp, channel catfish (*Ictalurus punctatus*), crappie (*Pomoxis sp*.), and largemouth bass (*Micropterus salmoides*) occur here. Shorebirds and migrating waterfowl are common.

Figure 6. Weber Reservoir. Photo: Mary E. Cablk.

Twin Lakes

Twin Lakes lie at 7,726 feet elevation in the Toiyabe National Forest, just below the Hoover Wilderness in Mono County, California (Figure 7). The lakes and surrounding area are used extensively for recreation. Privately owned residences as well as motels and cabins are located near the lakes. A large campground at the west end of the lakes and a trailhead for foot and stock access to the high Sierra backcountry are used by visitors. The lakes drain via Robinson Creek into an extensive wetland that is both natural and receives water from ditch irrigation. Although LCT no longer inhabit Twin Lakes, the USFWS reported that Twin Lakes was the only lacustrine habitat in the Walker River Basin, other than Walker Lake, where LCT occurred (U.S. Fish and Wildlife Service, 1994). Rainbow trout are stocked in Twin Lakes by the CDF&G. The Bridgeport Inn in Bridgeport, California, reports that Kokanee salmon (*Oncorhynchus nerta*) inhabit Twin Lakes and brown trout also occur in Twin Lakes as well.

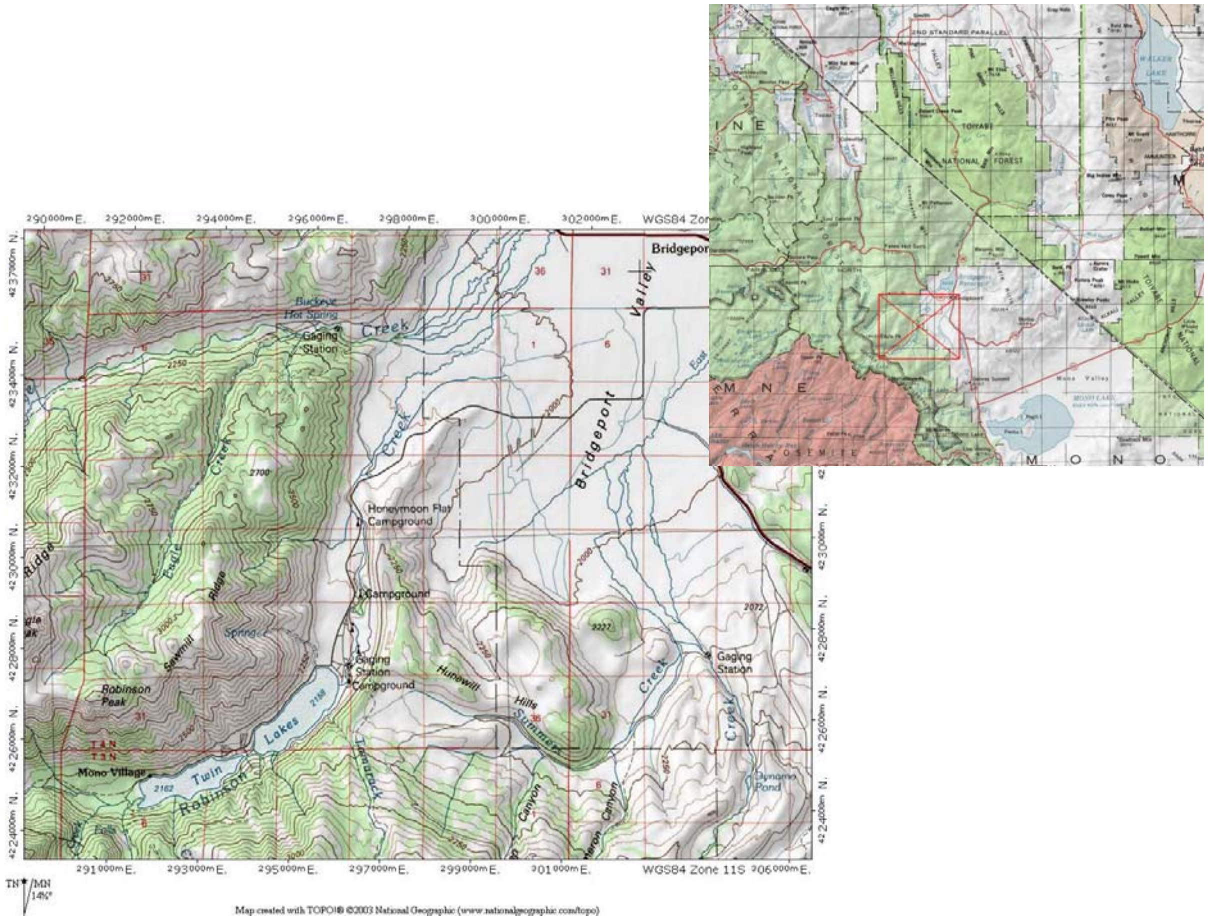

Figure 7. Location of Twin Lakes relative to Walker Lake. The East Walker River originates to the east and flows north into Bridgeport Reservoir. The red box in the upper right graphic corresponds with the larger view in the lower left.

Riverine, Riparian, and Wetlands

In general, the entire Walker River riparian zone plays a critical role in maintaining physical characteristics and function of the river. For example, the riparian zone moderates river temperatures, traps sediment, and adds resiliency to the river channel during floods. For the riparian zone to function in these restorative and regenerative capacities, enough water must be available with appropriate frequency and duration. Water must be available for the germination and survival of seeds from riparian and wetland plants, and these plants, in turn, provide critical functions that maintain the integrity of the river. Desert Research and University of Nevada, Reno, scientists are preparing reports on the current state of the Walker River based on field research conducted in 2007 and 2008.

Riparian zones affect in-stream habitat and quality by converting, diluting, and flushing accumulated pollutants and redistributing sediment. Rejuvenation of coarse and fine-grained habitat patches is essential for maintaining aquatic organisms. The riparian zone vegetation of the Walker includes native and non-native species. Although tamarisk and Russian olive (*Elaegnus angustifolia)* have invaded the Great Basin, native Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.) still line reaches of the Walker River. Cattail (*Typha* spp.) and hardstem bulrush (*Scirpus acuta*) as well as grasses, sedges (*Carex* spp.), and rushes

(*Juncus* spp.) are abundant in riparian zone wetlands associated with the Walker River. Wetlands can form in oxbows or in areas of the river where flow is slow. Inundated land can host submergent plant communities dominated by pondweeds (*Potomogeton* spp.), widgeon grass (*Ruppia maritime)*, flatsedges (*Cyperus* spp.), and spikerushes (*Eliochrus* spp.).

On a broader scale, Great Basin wetlands—such as riparian zones along the Walker River, the pasturelands outside of Bridgeport, and pasture in the Walker Valley adjacent to Topaz Lake—are important habitat for migrating birds. In general, for the Great Basin, such wetland areas provide critical stopover habitat.

Walker River West Fork

Headwaters of the West Walker originate east of the Sierra crest just south of Sonora Pass, California, from Kirkwood and Tower Lakes. Three of the four remaining LCT populations that occur in the Walker River are found in West Walker River tributaries of Slinkard Creek, Silver Creek, and Wolf Creek. Leavitt Meadows, a high alpine valley, and Pickel Meadows remain undeveloped and contribute to the clarity and high water quality of the upper reaches of the West Walker River. Thirty or more species of wildflowers may be found in these mountain meadows including paintbrush (*Castilleja miniata*), lupine (*Lupinus polyphyllus*), and shooting stars (*Dodecatheon alpinum*). Where the ground remains fairly wet, grasses, rushes, and sedges dominate (Howald, 2000). At the same time, where microtopography dictates, sagebrush and other more xeric plant species occur.

Plant communities that comprise the riparian zone of the West Walker River host diverse assemblages of mammals, amphibians, birds, and insects, as well as aquatic invertebrates. California spotted owls (*Strix occidentalis occidentalis*) may occur along the Walker River headwaters in dense, old-growth, multi-layered mixed conifer forests of the Sierra Nevada to 7,600 feet elevation. They feed on a variety of small mammals, birds, and large arthropods and are thought to require a permanent water source. The Mono checkerspot butterfly (*Euphydryas editha moensis*) is a rare subspecies of the Editha butterfly. It occurs in foothills and high elevations in mountains, with the center of its range being Mono County. They also are found in wet meadows and pine forests.

Native fish species occurring in the West Walker River include mountain whitefish (*Prosopium williamsoni*), Lahontan redside (*Richardsonius egregious)*, Lahontan speckled dace (*Rhinichthys osculus robustus)*, Tahoe sucker (*Catostomus tahoensis)*, Lahontan mountain sucker (*Catostomus platyrhynchus*), and Lahontan tui chub (*Gila biocolor obesus)*. Common carp (*Cyprinus carpio)* and largemouth bass (*Micropterus salmoides)* occur here, and brown trout (S*almo trutta*) and rainbow trout (*Oncorhynchus mykiss*) are stocked (NDOW 1997; Sada, 2000). Paiute sculpins (*Cottus beldingi*) were reported by Stockwell (1994) above Topaz Lake. LCT inhabit streams feeding into the upper reaches of the West Fork, and LCT have been stocked in the West Fork. In 1997, brown trout were the most common sport fish in the West Walker River (NDOW, 1997). Benthic macro-invertebrates were sampled in 1996 by NDOW at two locations. Hydrazoa, Oligochaeta, and Insecta were recovered during this survey (NDOW, 1997).

South of the town of Walker, the river channel becomes a network of boulders in the constraints of the Walker River canyon and, thus, is popular with anglers. Ponderosa pine (*Pinus ponderosa*) is common on the shores of the river here. From here, the West Walker flows into Antelope Valley and is flanked by irrigated pasture and alfalfa fields. Water is diverted from the main river channel downstream into Topaz Lake; this location is the upstream extent of Paiute sculpins (Stockwell, 1994). From Topaz, the West Walker River flows through Smith Valley, Wilson Canyon, and Mason Valley, through predominantly sagebrush shrub-scrub and irrigated agriculture fields. The two forks of the Walker, West and East, join in Mason Valley to form the main stem of the Walker River (California Department of Water Resources, 1992).

Walker River East Fork

The East Walker River headwaters originate in the Sierra Nevada above Twin Lakes outside of Bridgeport, California. LCT occur in By-Day Creek above Bridgeport Reservoir. This meadow-like environment is grazed by cattle and supports a variety of wetland associated avifauna. Grasses and sedges dominate this pastureland, although some sagebrush occurs where microtopography permits drainage or where the ground is alkaline. The short river stretch above the grazed pasturelands in the Twin Lakes vicinity is montane riparian woodland, characterized by quaking aspen (*Populus tremuloides*), mountain alder (*Alnus tenuifolia*), and black cottonwood (*Populus balsamifera*) as well as willows (*Salix sp*.) and creek dogwood (*Cornus stolinifera*) (Howald, 2000). Rainbow trout (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*) from the Mason Valley Fish Hatchery are stocked in the East Walker River. Brown trout are the most common sport fish except where rainbow trout are stocked. In 2004, wild rainbow trout and mountain whitefish (*Prosopium williamsoni)* were uncommon in the river, although mountain whitefish occurred at Rosachi Ranch (NDOW, 2004).

Below Bridgeport Reservoir, the river takes on characteristics more typical of a below-dam water course (Figure 8). The lower stretches are considered high desert riparian woodlands. Woody vegetation in the riparian zone includes species such as the arroyo willow (*Salix lasiolepis*), cottonwood (*Populus* spp*.*), birch (*Betula occidentalis*), and interior wild rose (*Rosa woodsii*) (Howald, 2000). Fish species include rainbow trout, mountain whitefish, Lahontan redside, speckled dace, Tahoe sucker, Lahontan mountain sucker, tui chub, common carp, and brown trout (Sada, 2000). Both brown and rainbow trout are actively stocked in the East Walker River (Stockwell, 1994). Stockwell (1994) reported that a remnant population of LCT in the East Walker River was used to establish populations elsewhere in the east and west forks of the Walker. These fish species feed on the abundant mayflies, stoneflies, caddis, and midges. Amphipods, snails, and minnows are also abundant throughout the east and west forks of the Walker River.

Shortly after the East Walker crosses the California and Nevada border, it enters Pine Grove Hills. The riparian vegetation between Bridgeport Reservoir and the southern end of Mason Valley is similar to the riparian community below Bridgeport Reservoir. This vegetation provides cover for a variety of birds and small mammals. In Mason Valley, the East Walker runs through open sagebrush and irrigated agriculture country.

Figure 8. The East Walker River as it flows from Bridgeport Reservoir. Photo: Mary E. Cablk.

Walker River Main Stem

The main stretch of the Walker River, below the point at which the east and west forks converge, is dominated by cottonwood, willow, and, in places, tamarisk. Tamarisk, commonly known as salt cedar, was introduced to the river basin in 1837. The river slows down relative to its flow rate in the constrained canyons upstream after it enters the relatively flat sagebrush and agricultural countryside. As a result, the river changes character, losing its boulder and cobble substrate and pronounced pools and riffles. Water is lost to phreatophyte use (deep-rooted plants that obtain water from the water table or the layer of soil just above it), particularly downstream from the Wabuska gage (Figure 4; Humberstone, 1999).

Cooper and Koch (1984) reported that LCT and Tahoe suckers no longer spawn in the Walker River. NDOW (2004) reports Tahoe sucker at Rosachi Ranch and Raccoon Beach but does not report that spawning was observed. Stockwell (1994) reports rainbow trout, mountain whitefish, Lahontan redside, speckled dace, Lahontan Mountain sucker, tui chub, common carp, and brown trout are found in the Walker River. Other fish species that occur here include largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus nebulosis*), white catfish (*Ameirus catus*), bullhead catfish (*Ictalusus nebulosis*) and bluegill sunfish (*Lepomus macrochirus*).

Wildlife Management Areas

Mason Valley

The Mason Valley WMA, managed by the Nevada Department of Wildlife, provides critical habitat for a variety of species, particularly waterfowl. The primary management charter of Nevada Wildlife Management Areas is to provide for preservation, protection, management, and restoration of wildlife and wildlife habitats on state-owned lands (NRS 501.105, 501, 181). Mason Valley WMA was initially purchased for its wildlife values with Federal Aid in Wildlife Restoration Act funds. By Federal Aid regulation, the property must continue to serve the purpose for which it was acquired. The Nevada Board of Wildlife Commissioners adopted Commission Policy #66 in 1998 which directs priority management on state-owned wildlife management areas toward wetland development and waterfowl activities including use of the area as a public hunting ground.

Within the Mason Valley WMA, 2,000–2,500 acres of wetlands occur out of a total of 13,375 acres. More than 30 impoundments exist in Mason Valley WMA, but not all are always filled. Wetlands and impoundments are maintained primarily from the Walker River (Figure 9) using both decreed water and storage water originating at Topaz and Bridgeport reservoirs. Storage allotments during wet years may be as much as 2,400 acre-feet per season. During dry years, these storage water allotments may be as low as 800 acre-feet per season. Other water sources include groundwater supplied by the Mason Valley fish hatchery and wells owned by Mason Valley WMA. The stretch of Walker River that flows through the refuge is maintained in as natural a state as possible, allowing for vegetation colonization and streambed meandering (Elmer Bull, Nevada Division of Wildlife, personal communication, 2007).

Figure 9. Walker River as it flows through Mason Valley Wildlife Management Area. Photo: Mary E. Cablk.

Approximately 1,200 acres of the WMA are irrigated for production of alfalfa, other cereal grains such as winter wheat, and corn with the specific intent for use by wildlife for forage and cover. The non-economic value, or importance, of these crops is very high for certain game species of wildlife such as mule deer, turkeys, Canada geese, and ducks. Alfalfa, in particular, provides forage for deer, turkeys, and ducks, and some nesting habitat for turkeys and ducks. Harvesting practices for crops within the Mason Valley WMA are very different from commercial production farms, which do not follow practices to maintain crop habitat for wildlife (Elmer Bull, Nevada Division of Wildlife, personal communication, 2001). Table 6 lists the species of concern to the U.S. Fish and Wildlife Service in Mason Valley WMA.

Table 6. Fauna of Mason Valley Wildlife Management Area of concern to the U.S. Fish and Wildlife Service.

Birds	**Mammals**	**Reptiles/Amphibians**	**Fish**
Pacific loon	Long-legged myotis	Northern sagebrush lizard	Lahontan cutthroat trout
Least bittern	Small-footed myotis		
White-faced ibis	Yuma myotis		
Northern goshawk	Spotted bat		
Ferruginous hawk	Townsend's big-eared bat		
Bald eagle			
Mountain plover			
Black tern			
Burrowing owl			
Tri-colored blackbird			

Alkali Lake (Artesia)

The Alkali Lake WMA includes 3,447 acres of high desert land. It is owned by the U.S. Bureau of Reclamation and managed by the Nevada Department of Wildlife. There are no water rights associated with Artesia, and it is fed almost entirely from agricultural runoff—with minimal water input from runoff out of the Pine Nut Mountains. During wet years, however, the alkali flat becomes a shallow wetland and is heavily used by waterfowl and shorebird species. Agricultural runoff is not enough to maintain Artesia as a wetland during dry years. When there is no water, habitat is not available to wetland-associated wildlife. When flooded, however, this playa hosts a complement of species including birds, mammals, and herpetofauna.

Alkali lakes of the Great Basin and Mojave deserts are harsh environments that support few plant species due in part to their highly saline soils. Flora that occur in Nevada Great Basin alkali sink scrub environments and potentially in Artesia include species such as alkali pink (*Nitrophila occidentalis*), greasewood (*Sarcobatus vermiculatus*), alkali birds beak (*Cordylanthus maritimus*), Nevada saltbush (*Atriplex lentiformis torreyi*), and saltgrass (*Distichlis spicata*). A private parcel of land on the south end of the alkali lake harbors ponds and sloughs. It is not known what flora and fauna occur here.

Upland Areas or Non-Water-Dominated

Most of the Walker Basin is upland habitat dominated by sagebrush, commonly big sagebrush (*Artemesia tridentata*). Antelope bitterbrush (*Purshia tridentata*), desert peach (*Prunus andersonii*), and spiny hopsage (*Grayia spinosa*) are other common sagebrush associates. Pure stands of sagebrush may occur over large areas and provide habitat for mammals. Pygmy rabbits (*Brachylaus idahoensis*), a federal species of concern, are found in sagebrush communities but also use bitterbrush and pinyon-juniper habitats (Green and Flinders, 1980; Orr, 1940; Severaid, 1950). Numerous bat species occur in the Walker upland habitat. Birds of prey likewise are commonly associated with big sagebrush.

Upland conifer woodlands (5,000–9,000 feet) include pinyon pine (*Pinus monophylla*), juniper (*Juniperus* spp.), birch (*Betula occidentalis*), manzanita (*Arctostaphylos* spp*.)*, buckbrush (*Ceanothus* spp*.)*, oak *(Quercus* spp.), currant (*Ribes* spp.), ponderosa pine *(Pinus ponderosa*), curleaf mountain mahogany *(Cercocarpus ledifolius),* and aspen *(Populus tremuloides)*; (Howald, 2000; Mares, 1999). Understory vegetation in pinyon-juniper woodlands is similar to those species found in sagebrush scrub communities. Sage grouse (*Centrocercus urophasianus*) is the most common species of grouse in Nevada, although the Nevada Department of Wildlife reports populations have been in decline since 1978. Healthy sage grouse populations are considered indicators of a healthy sagebrush ecosystem, and these birds are regarded as a keystone species for the sagebrush-steppe ecosystem.

In pinyon-juniper woodlands, mammals such as mule deer, mountain lion, ground squirrels, and bobcat are common. The pinyon jay (*Gymnorhinus cyanocephalus)* is an obligate species in pinyon-juniper woodlands and the primary seed disseminator for pinyon pine trees. The ferruginous hawk, a species of concern, uses mature Utah juniper for nesting.

The other dominant shrub-scrub community in the Nevada Walker Basin is shadscale shrub. Shadscale shrub (*Atriplex confertifolia*) is a close associate of ubiquitous sagebrush. It is a short, spiny saltbush found on alkaline basins and playas. Other species of sage and saltbush are found here, as well as a myriad of shrubs such as spiny hopsage (*Grayia spinosa)*, winterfat (*Eurotia lanata*), greasewood (*Sarcobatus vermiculatus*), rabbit brush (*Chrysothamnus* spp.), glasswort (*Salicornia* spp.), pickleweed (*Allenrolfea occidentalis*), desert teas (*Ephedra*), and gray molly (*Kochia vestita*).

In California, the Walker Basin is located on the eastern slope of the Sierra Nevada where coniferous forest dominates. Ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi),* white fir *(Abies concolor*), red fir (*Abies magnifica*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*), and mountain hemlock *(Tsuga mertensiana*) comprise the forest along an elevational gradient. At the highest elevations in the subalpine zone, whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) occur. Mountain meadows in the high Sierras of the westernmost extent of the Walker Basin are comprised of dense, lush, low-growing sedges, rushes, grasses, and wildflowers. Eastern Sierra riparian woodlands occur along the reaches of creeks above Twin Lakes and above Pickel Meadows and include very dense deciduous broad-leaved trees and shrubs such as dogwood (*Cornus* spp.), mountain alder (*Alnus* spp.), quaking aspen (*Populus tremuloides*), and willow (*Salix* spp.); (Smith, 2000).

Farmlands and Associated Areas

Lacustrine and riverine-associated habitats are water-dominated continuously throughout the year while farmlands have a water association only during discrete times of the year. Irrigation for agriculture and pasture in the Walker watershed has created habitats that support important elements of biodiversity. Irrigation has expanded the extent of riparian and wetland habitat in the Smith and Mason valleys in a number of ways, both directly and indirectly. Figure 10 shows the extent of vegetation along a diversion channel that runs adjacent to the East Walker in Nevada, just above the east and west fork confluences. Before the land was channelized and irrigated, only a fraction of these valleys supported riparian and wetland habitat.

Figure 10. Diversion ditch and native vegetation along the Walker River. Photo: Mary E. Cablk.

Earthen ditches may be colonized by plants able to take advantage of available water. In ditches that have only seasonal water availability, true wetland flora cannot establish; but where ditches provide consistent and substantial flow, plants may become established. Earthen ditches are not impervious and therefore allow water to infiltrate back into the ground, creating a zone of subsurface water (Figure 11). Flood irrigation creates temporary wetland-like environments with an ephemeral life. Where the land is low, water may accumulate long enough to support a wetland-like environment for short time periods. Swainson's hawks nest in islands of cottonwood trees that are allowed to remain along fields and prey on rodents that take advantage of vegetation established along fence rows.

Pasturelands provide habitat for a number of faunal species. Deer and other herbivores graze among cattle on these lands. In addition to providing forage, irrigated pasturelands may support a prey base of small mammals and insects for predators, including birds such as prairie falcons, ferruginous hawks, and rough-legged hawks. Tricolored blackbirds (*Agelaius tricolor*) use farmlands and associated habitats (primarily pasture) for feeding. They forage on the ground in croplands, grassy fields, flooded land, and along edges of ponds. These birds require emergent freshwater wetlands for other life requirements where wetland vegetation such as cattails (*Typha* sp.), tule (*Scirpus* sp.), and shrubs are available.

Figure 11. Irrigation ditches allow water recharge into the ground. Photo: Mary E. Cablk.

Ferruginous hawks (*Athene cunicularia hypugea*) may be found where a mosaic of open grasslands, sagebrush flats, desert scrub, low foothills surrounding valleys, and fringes of pinyon-juniper habitats occur. These hawks hunt for small mammals, especially rabbits, by gliding low above open treeless areas, hovering, or perching on high mounds. Mountain plover occur in the Mason Valley WMA. Because this species inhabits shortgrass plains, plowed fields with little vegetation, and open sagebrush areas, it likely uses habitat outside of the Mason Valley WMA as well. It is insectivorous and for this reason also would be associated with irrigated grass for pasture or alfalfa where insects may be common.

Black terns (*Chlidonias niger*), least bittern (*Ixobrychus exilis hesperis*), and white-faced ibis (*Plegadis chichi*) may be found in irrigated habitats as well, particularly where emergent wetlands are maintained with fresh water. The black tern catches insects by hovering above fresh emergent wetlands, lakes, ponds, moist grasslands, and agricultural fields. The least bittern is a stalking predator and requires similar habitat to the black tern but with increased vegetation cover and often is found near freshwater pools. Least bitterns inhabit the Mason Valley WMA but also may occur in freshwater ponds associated with private irrigation lands to the south of the Artesia WMA. The white-faced ibis occurs in fresh water emergent wetlands, shallow lacustrine waters, and the muddy ground of wet meadows and irrigated, or flooded, pastures and croplands. Its prey includes earthworms, insects, crustaceans, amphibians, small fishes, and miscellaneous invertebrates (Zeiner et al., 1990a). Western burrowing owls (*Athene cunicularia hypugea*) are common throughout the lower Walker Basin. Although primarily associated with sagebrush habitat, they use irrigated agricultural areas for hunting.

Irrigated pasturelands outside of Bridgeport (Figure 12) are perhaps the most diverse and productive of the irrigated systems for a number of reasons. First, these lands support wetland environments that are, in and of themselves, highly productive systems. Second, this area lies at an ecotone, where the Sierra Nevada and Great Basin meet, or merge. Here, species' ranges from each ecosystem may occur and overlap. This meadow-like area (Figure 12) is also part of the migration flyway for numerous bird species. Bridgeport Reservoir provides a relatively stable permanent water source, even though reservoir levels fluctuate. Although grazing alters the dynamics of a natural ecological system, this area is not planted and harvested like other agricultural areas in the lower Walker Basin. Therefore, the system is relatively stable compared to many other agricultural areas in terms of available habitat through time.

Figure 12. Bridgeport Valley pasturelands. Photo: Mary E. Cablk.

Threatened, Endangered and Sensitive Species

Numerous agencies and organizations maintain lists of "special" animals and plants that have their own designations and corresponding definitions. In California, the California Natural Diversity Data Base (CNDDB) ranks species using the "Heritage Methodology," and codes were developed to correspond with the California Endangered Species Act (CESA). The California Department of Fish and Game also maintains a list of "Species of Special Concern" and a list of "Fully Protected" species. The USFWS uses a list of codes that are part of the federal endangered species act (ESA) and developed a "Birds of Conservation Concern" list in 2002. The IUCN maintains and uses red list categories. The American Fisheries Society categorizes risk for marine, estuarine, and diadromous fish stocks. The Audubon Society has a

Watch List for species that focuses on birds. BLM has its own designations for species as does the California Department of Forestry and Fire Protection. Corresponding online links to these resource lists are provided in Table 7.

Specialty groups exist as well, such as the American Bird Conservancy that maintains a "Green List" for birds, and the United States Bird Conservation Watch List that focuses on birds. Both of these lists are coordinated with Partners in Flight. The Western Bat Working Group designates bat species as "High Priority." This is not an exhaustive list of species with special designation. Within the Walker Basin, there are numerous groups and organizations dedicated to Walker Lake and the biota in and around the Walker Basin.

Table 7. Some of the online data bases that provide species lists with different levels of concern and different ranking systems.

Database	Web Site
California Natural Diversity Data Base	www.dfg.ca.gov/bdb/html/cnddb.html
California Department of Fish and Game	www.dfg.ca.gov/hcpb/species/ssc/ssc.shtml
US Fish and Wildlife Service Birds of Conservation Concern	www.fws.gov/migratorybirds/reports/BCC2002.pdf
International Union Conservation of Nature and Natural Resources	www.redlist.org
Audubon Society	www.audubon.org/bird/watchlist/index.html
For other sources	www.dfg.ca.gov/bdb/pdfs/SPanimals.pdf

In summary, there are many species that have some special designation on one or more list; however, the criteria used to designate a species by any group vary with the charge and priority of the group. For the purposes of this report, we include only those species that were identified by the USFWS as having a USFWS listing or are a species of concern within the Walker River Basin, California, and Nevada. This information was provided directly by the USFWS. Those species that occur in California were cross-verified with the January 2007 CDFG CNDDB list of state and federally listed endangered, threatened, and rare plants of California, the January 2007 CDFG list of special concern plants (California Department of Fish and Game, 2007), and the February 2006 CDFG CNDDB Special Animals lists. A list of these species is provided in Table 8.

Table 8. Species listed as federally threatened or endangered and their occurrence in the Walker River Basin.

Status[†]	Species	Y[‡]	U
T	Bald Eagle	X	
T	Lahontan cutthroat trout	X	
PT	Mountain plover		X
C	Sierra Nevada mountain beaver		X
C	Pygmy rabbit		
C	Pale Townsend's big-eared bat	X	
C	Pacific Townsend's big-eared bat		X
C	Spotted bat	X	
C	Greater western mastiff-bat	X	
C	California wolverine	X	
C	Pacific fisher		X

Table 8. Species listed as federally threatened or endangered and their occurrence in the Walker River Basin (continued).

Status†	Species	Y‡	U
C	Fletcher dark kangaroo mouse	X	
C	Small-footed myotis	X	
C	Long-eared myotis	X	
C	Fringed myotis	X	
C	Long-legged myotis	X	
C	Yuma myotis	X	
C	Sierra Nevada red fox		X
C	Northern Goshawk	X	
C	Tri-colored blackbird	X	
C	Western burrowing owl	X	
C	Ferruginous hawk	X	
C	Black tern	X	
C	Least bittern	X	
C	White-faced ibis	X	
C	California spotted owl	X	
C	Mountain yellow-legged frog		X
PE	Yosemite Toad		X
C	Northern sagebrush lizard	X	
C	Mono checkerspot butterfly	X	
C	Travertine band-thigh diving beetle	X	
C	Carson Valley silverspot butterfly	X	
C	Bodie Hills rockcress	X	
C	Lavin's milkvetch	X	
C	Bodie Hills draba	X	
C	Pine Nut mountains ivesia	X	
C	Webber's Ivesia	X	
C	Nevada oryctes	X	
C	Mono phacelia	X	
C	Crowded combleaf		X
C	Combleaf	X	
C	Masonic mountain jewelflower	X	

†T = federally threatened, PT = proposed federally threatened, PE = proposed federally endangered C = federal species of concern
‡Y = occurs within study area, U = unknown or possible occurrence in study area

Flora

Upland habitats support populations of plant species listed by the USFWS as threatened, proposed threatened, and species of concern. The Bodie Hills rockcress (*Arabis bodiensis*) is found in pinyon-juniper communities on rolling to steep topography in andesitic soils at elevations of 7,500–9,500 feet. Bodie Hills draba (*Cusickiella quadricostata*) occurs in communities of low sagebrush, bitterbrush, and mountain mahogany usually on open, level slopes and ridges in well-drained soils of granitic origin at elevations between 7,200 and 8,400 feet.

Masonic mountain jewelflower (*Streptanthus oliganthus*) is found on rocky slopes in pinyon-juniper communities at elevations between 6,500 and 8,500 feet. Each of the above three species is listed as a plant of special concern by the state of California and occurs in the Walker Basin. Lavins milkvetch or eggvetch (*Astragalus oophorus* var. *lavinii*) is a perennial herb in the legume family, a California special concern plant, and a USFWS species of concern. This milkvetch occurs in open, dry, relatively barren gravel and clay slopes, knolls, badlands, or outcrops that are derived from volcanic ash or carbonate, in openings in the pinyon-juniper or sagebrush zones between 5,700 and 7,467 feet elevation.

Aquatic or wetland habitats support federal species of concern. The Pine Nut Mountain ivesia (*Ivesia pityocharis*), which is in the rose family, is endemic to the Pine Nut Mountains. Unlike Webbers ivesia (*Ivesia webberi*), which is a candidate for federal listing and is ”recommended for full protection” in Nevada (http://heritage.nv.gov/atlas/ivesiwebbe.pdf) in the Pine Nut Mountains, this ivesia species is dependent on aquatic or wetland habitats between 6,990 and 8,550 feet elevation. It is associated with springs, moist drainages, or ephemeral ponds and is typically found on flats or gentle northwest to northeast exposures. Williams combleaf (*Polyctenium williamsiae*) is a perennial herb which is considered wetland dependent. It is a California special concern species, a fully protected Nevada state plant, and a federal species of concern. Williams combleaf is found between 5,670 and 8,930 feet elevation in relatively barren sandy to sandy-clay or mud margins and bottoms of non-alkaline seasonal lakes perched over volcanic bedrock in the sagebrush, pinyon-juniper, and mountain sagebrush zones.

Fauna

The Lahontan cutthroat trout is the largest species of cutthroat trout and is native to the Walker River Basin from Twin Lakes near Bridgeport to Walker Lake. It was originally federally listed as endangered in 1970 and later reclassified threatened by the USFWS to allow for sport fishing. Within its former native range, the LCT now occupies less than one-half of one percent of its former lake habitat and only 11% of its former stream habitat (U.S. Fish and Wildlife Service, 1994). Beginning in the mid-1800s, as water was diverted for agricultural purposes in the Smith and Mason valleys, stream flows decreased and resulted in diminished LCT spawning runs. In 1933, construction of Weber Dam eliminated spawning runs upstream from Walker Lake (Dickerson and Vinyard, 1999). Approximately 70,000 LCT are stocked annually by NDOW and USFWS. The LCT recovery plan (U.S. Fish and Wildlife Service, 1995) cites numerous factors as principal threats for recovery in the Walker Basin. Water diversions and poor water quality are specifically cited.

Three amphibian species potentially occur in the Walker watershed as well as in the high Sierra of California in Mono County according to USFWS. The Mount Lyell salamander (*Hydromantes platycephalus*) may occur within the Walker watershed above Twin Lakes north to near Sonora Pass and has a CNDDB rank of G3S3 (rare). The populations are discontinuously distributed in isolated patches of suitable habitat. These salamanders are active on the surface only when water in the form of seeps, drips, or spray is available between 4,000 and 11,600 feet elevation. Habitat includes massive rock areas in mixed conifer, red fir, lodgepole pine, and subalpine habitats that include a water source, such as higher elevations in the westernmost extent of the watershed. The Yosemite toad (*Bufo canorus*) is a candidate for federal listing as endangered (Federal Register 60607 vol. 65, no. 198, 50 CFR Part 17; 67 FR 75834) and is a CDFG species of concern. It would have very limited occurrence due to elevation constraints (6,400 to 11,300 feet). The Yosemite toad is restricted to vicinities of wet meadows in the central high Sierra from El Dorado County south to near Kaiser Pass in Fresno County. This toad primarily occurs in montane wet meadows as well as seasonal ponds associated with lodgepole pine and subalpine conifer forests. Habitat could include montane meadows of the upper west fork of the Walker River and near the headwaters of the east fork

Walker and Twin Lakes Reservoir (Zeiner et al., 1989). The yellow-legged frog (*Rana muscosa*) is federally listed as endangered and is a CDFG species of concern. Its habitat is restricted to high elevation water bodies including streams, lakes, ponds, and wet meadows (U.S. Fish and Wildlife Service, 2005). Known distribution of this species is dramatically reduced from its historical range. It has all but disappeared from Yosemite, but because of the proximity of Yosemite to the western edge of the Walker Basin, there is the possibility that the mountain yellow-legged frog may occur in the Walker Basin as well.

The travertine band-thigh diving beetle (*Hygrotus foninalis*) occurs only in Travertine Hot Springs, outside of Bridgeport, California. It is a California endangered species and was identified by USFWS as a listed species in 2001; however it is not listed in the USFWS database as of 2007. This species does not occur outside of Travertine Hot Springs in the Bridgeport Valley, and its status is unknown due to conflicting reports.

The Northern sagebrush lizard (*Sceloporus graciosus graciosus*) is listed CNDDB G5T5S3 (having restricted range in the state). This terrestrial lizard inhabits a variety of upland habitats in the Walker watershed, including desert sage-scrub, mountain slopes, forested slopes, and open flatlands. They prefer sagebrush areas and occur mainly on fine gravel soils, sandy soils, and rocky soils that are adjacent to water.

The California wolverine (*Gulo gulo luteus*) is listed by the state of California as threatened. It is a relatively secretive mammal associated with areas undisturbed by humans in mixed forests up to 7,300 feet elevation. It feeds primarily on small mammals and carrion in open areas, returning to cover for resting and reproduction. California bighorn sheep (*Ovis canadensis californiana*), listed as endangered in California and at the federal level, may or may not occur in the Walker watershed in the high Sierra. These large herbivorous mammals graze and browse on a wide variety of plant species and require steep, rocky terrain for predator avoidance and resting. Sierra Nevada red fox (*Vulpes vulpes necator*) is listed by the state of California as threatened. Populations may be found in a variety of habitats, including alpine dwarf-shrub, wet meadow, subalpine conifer, lodgepole pine, red fir, aspen, montane chaparral, montane riparian, mixed conifer, ponderosa pine, Jeffrey pine, eastside pine, and montane hardwood-conifer. This species would be expected to occur in headwater areas of either fork of the Walker River, although more likely near the high meadows of the West Walker, where forests are interspersed with meadows or alpine fell-fields (Zeiner et al., 1990b).

Northern goshawks (*Accipiter gentilis*) are CNDDB rank G5S3 (restricted range in state) and occur in mature and old growth stands of conifers and deciduous habitats. This species nests near water and could be expected to occur throughout the Walker watershed where appropriate nesting habitat occurs. Northern goshawks hunt in forested areas feeding primarily on smaller birds and small mammals (Zeiner et al., 1990a). Western burrowing owls (*Athene cunicularia hypugea*) are common throughout the lower Walker Basin. Although primarily associated with sagebrush habitat, they use irrigated agricultural areas for hunting. California spotted owls (*Strix occidentalis occidentalis*) are federally listed as threatened and would be expected to occur only in dense, old-growth, multi-layered mixed conifer forests of the Sierra Nevada to 7,600 feet elevation. They feed on a variety of small mammals, birds, and large arthropods and are thought to require a permanent water source. For this reason, they may occur near the headwaters of the east and west forks of the Walker River.

Noxious Weeds

Noxious weeds occurring throughout the Great Basin ecosystem also are found in the Walker watershed. Tall whitetop (*Lepidium latifolium*) is a particularly harmful weed that has invaded stretches of the Walker River in Douglas and Lyon counties. It is of particular concern because flood irrigation carries tall whitetop into and throughout hay meadows, pastures, and other irrigated lands making agricultural areas in the basin particularly susceptible to invasion. Yellow starthistle (*Centaurea solstitialis*), which is extremely toxic to livestock, also has invaded Douglas, Lyon, and Churchill counties. The Bureau of Land Management identified invasive and non-native weeds for irrigated agricultural areas and pasturelands in Nevada (Table 9).

Table 9. Invasive and non-native weeds for irrigated agricultural areas and pasturelands.

Dyers Woad	*Isatis tinctoria*
Diffuse knapweed	*Centaurea diffusa*
Russian knapweed	*Centaurea repens*
Tall whitetop	*Lepidium latifolium*
Puncture vine	*Tribulus terrestris*
Rush skeletonweed	*Chondrilla juncea*
Yellow starthistle	*Centaurea solstitialis*
Iberian starthistle	*Centaurea iberica*
Musk thistle	*Carduus nutans*
Scotch thistle	*Omopordum acanthium*
Yellow toadflax	*Linaria vulgaris*

Nevada statute 555.090 states that the Walker River weed control district was created to control designated noxious weeds within prescribed boundaries. Table 10 lists weeds to be controlled.

Table 10. Weeds to be controlled in the Walker River weed control district.

(a) Whitetop (*Cardaria* spp., *Lepidium* spp.)	(e) Scotch thistle (*Onopordum* spp.)
(b) Knapweed (*Centaurea* spp.)	(f) Yellow star thistle (*Centaurea* spp.)
(c) Canada thistle (*Cirsium* spp.)	(g) Puncture vine (*Tribulus* spp.)
(d) Musk thistle (*Carduus* spp.)	(h) Licorice (*Glycyrrhiza* spp.)

CONCLUSION

The Walker Basin is unique in many respects. Its upper reaches begin high in the Sierra Nevada above 10,000 feet in mountain meadows lush with low-growing sedges, rushes, grasses, and wildflowers. The East and West forks of the Walker River wind their way down high-gradient stretches and across boulder and cobble substrate with pronounced pools and riffles. The rivers flow down through montane riparian woodlands, ponderosa pine stands, pinyon-juniper communities, and eventually through open sagebrush and irrigated agriculture fields. Shadscale shrub, common to alkaline basins and playas in many areas of Nevada, is common in the lower part of the basin at Hawthorne, elevation 4220 feet msl. Walker Lake, located in the lower portion of the basin, along with Pyramid Lake in northern Nevada, are the only two terminus lakes in Nevada. Streams, reservoirs, lakes, wetlands, irrigation ditches, montane forests, uplands, agricultural fields, and pasture land host numerous species of wildlife, fishes, reptiles, insects, and amphibians. Migrating and resident birds are also common throughout this diverse elevational gradient.

The Walker Basin is unique because it spans two states, Nevada and California. Federal agencies–USFS, BLM, and DoD–and the States of California and Nevada, as well as three Indian reservations, one with the most senior water rights in the entire Walker Basin, own or manage land in the Walker Basin. One of the conundrums of the Walker Basin is that while most of the precipitation needed to support wildlife and the economy occurs in California, a large amount of the water is used in Nevada to irrigate agricultural crops. Irrigation management is the responsibility of the United States Board of Water Commissioners. The Chief Deputy Water Commissioner acts on their behalf and is responsible for day-to-day operation of the Walker River system in accordance with provisions of Decree C-125.

People have occupied the Walker Basin for at least 8,000 years. The first inhabitants utilized the Basin to hunt and fish; today's residents practice agriculture, own businesses, and work in service and mining industries. Recreational opportunities abound in the Walker Basin – from activities centered in the mountains, to fly fishing on the river, to boating on Walker Lake. No doubt all who have spent time in the Walker Basin marvel at its beauty and diversity.

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