Short-Term Action Plan for Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*) in the Truckee River Basin

Photo courtesy of Becky Smith collection

Developed by the
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TABLE OF CONTENTS **Page**

APPENDICES

FIGURES

TABLES

MAPS

I. INTRODUCTION

Lahontan cutthroat trout (LCT) (*Oncorhynchus clarki henshawi*) was listed as an endangered species in 1970 (Federal Register Vol. 35, p.13520). In 1975, under the Endangered Species Act of 1973 as amended (ESA), LCT was reclassified as threatened to facilitate management and to allow for regulated angling (Federal Register Vol. 40, p.29864). In 1995, the U.S. Fish and Wildlife Service (USFWS) released its recovery plan for LCT, encompassing six river basins within LCT historic range, including the Truckee River basin. The Lahontan Cutthroat Trout Recovery Plan (USFWS 1995) identified the need to develop ecosystem plans for the Truckee and Walker River Basins.

The 1970 Federal Register notice identified two primary listing factors that related directly to LCT: 1) Present or threatened destruction, modification, or curtailment of habitat or range; and 2) natural or manmade factors affecting the species continued existence. Three additional ESA listing factors that were considered in the reclassification of LCT and not addressed as having a direct impact were: 1) Over-utilization of the species for commercial, scientific, or education purposes; 2) disease or predation; and 3) inadequacy of existing regulations.

The Recovery Plan (USFWS 1995) specified five additional conditions contributing to decline and affecting the potential for recovery of LCT in the Truckee River basin: 1) Reduction and alteration of stream flow and discharge; 2) alteration of stream channels and morphology; 3) degradation of water quality; 4) reduction of Pyramid Lake elevation and concentration of chemical components; and 5) introductions of non-native fish species.

This Action Plan and the tasks identified herein are intended to eliminate or minimize threats that impacted LCT and through continued implementation of this process ensure the long-term persistence of the species in the Truckee River basin.

II. THE PLANNING PROCESS

To address the complexity of issues related to recovery of LCT, USFWS determined that basin-specific interagency and interdisciplinary teams, as well as public stakeholder participation, would be beneficial for developing LCT recovery efforts. In 1998, USFWS organized a Management Oversight Group (MOG) to address LCT recovery range wide. In 1998, the Truckee River Basin Recovery Implementation Team (TRIT) was organized to develop a strategy for LCT restoration and recovery efforts in the Truckee

River basin (Figure 1). Public stakeholder involvement began in 1998. As a result TRIT developed a short-term action plan to assist in recovery of the species.

Affiliations Represented on the TRIT

- California Department of Fish and Game (CDFG)
- University of Nevada, Reno (UNR)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Forest Service (USFS)
- U.S. Geological Survey, Biological Resources Division (USGS)
- Pyramid Lake Paiute Tribe
- Otis-Bay Ecological Consultants
- Bureau of Indian Affairs (BIA)
- Bureau of Reclamation (BOR)
- Bureau of Land Management (BLM)

Additional Entities who provided input to the TRIT Process

- Truckee Watershed Council
- Trout Unlimited
- University of California, Berkeley
- Tahoe Research Group

Figure 1. Entities participating in TRIT process

USFWS guidelines require that recovery plans incorporate scientific methods and analyses that are subject to review. Therefore, members of the TRIT have technical experience associated with fishery biology, geomorphology, hydrology, restoration ecology, population viability analysis, and genetics and are familiar with resources of the Truckee River basin. Through a collaborative effort spanning over three years, TRIT developed short-term actions they believe are necessary to develop information on lacustrine and fluvial LCT life history requirements and address threats to the species' persistence.

During plan formulation, the list of short-term actions being considered by TRIT was twice presented to public stakeholders. Several issues were identified by the public as important: economic impacts to local communities; fish management; recreational fishery impacts; habitat restoration; instream flow requirements for fish and recreation; water management; land management along the riparian zone; water quality; and the genetic basis for LCT recovery. Recommendations from the public have been considered in the design of short-term actions.

The recovery of LCT will be a long-term effort and require coordination among the United States, States of Nevada and California, Tribes, and the public. Administrative and funding priorities will be given to partnerships that maximize the potential for recovery and avoid adverse impacts to existing recreation and ecological resources. This initial short-term strategy is focused on gathering information about habitat requirements and implementing demonstration projects and research that will further our understanding to restore and protect an interconnected network of LCT populations within the Truckee River basin.

Development of a comprehensive recovery effort for Truckee River basin LCT was based on the following assumptions:

- The Truckee River basin is significantly fragmented due to water and human development.
- The historic use of the Truckee River basin by LCT has been, and currently is, compromised.
- Recovery of LCT will be a long-term effort that will require monitoring, review and evaluation.
- Water quality and quantity, especially temperature, significantly limits the habitat for LCT in portions of the Truckee River system.
- The State of California has initiated some recovery efforts in selected areas of the Truckee River basin.
- The Pyramid Lake Paiute Tribe has management and jurisdictional authority of the Truckee River and Pyramid Lake within the exterior boundaries of the Pyramid Lake Indian Reservation.
- Habitat degradation and presence of non-native fish species in the Truckee River basin currently limits the potential success for recovery of LCT.
- Non-native salmonid fisheries are an important recreational use in the Truckee River basin.
- Historically LCT in the Truckee River basin functioned as a networked population where different life stages and year classes of fish utilized different habitats and repopulation of extirpated areas occurred from other locations within the river system.

State, Federal and Tribal entities provide the primary infrastructure for implementing tasks identified in the plan and will, to the extent possible, collaborate and integrate their efforts. These entities will share technical data and recommendations for action. In addition, stakeholder meetings will provide periodic public review of the short-term tasks and accomplishments, providing information on local and regional opportunities, and assisting in the review and refinement of the annual work plans.

Recovery Goals, Criteria and Timeline

The objective of the 1995 plan is to remove LCT from the List of Threatened and Endangered Wildlife and Plants consistent with ESA.

The following criteria were recommended by TRIT as being necessary to assist in the recovery of LCT in the Western Distinct Population Segment (DPS). These recovery criteria may be periodically revised through an adaptive management program as new information is acquired.

Recovery Criteria

1. A self-sustaining, networked LCT population is established, composed of wild, indigenous strains, in streams, lakes, mainstem and tributaries of the Truckee River basin.

2. Physical connectivity exists between spawning and rearing habitats in lakes, mainstem and tributaries of the Truckee River basin to support natural LCT reproduction and recruitment and restore self-sustaining lacustrine LCT in the Truckee River basin.

3. A self-sustaining lacustrine population shall be considered to be naturally reproducing with a stable age-class structure consisting of at least four year classes and a stable or increasing population size with documented reproduction and recruitment. These conditions must be demonstrated to have been met for a minimum period of 20 years.

4. Water is obtained through water right purchases or other means to protect and secure a stable Pyramid Lake ecosystem and meet life history and habitat requirements of LCT.

5. A flow regime for the Truckee River is implemented which facilitates LCT migration, life history and habitat requirements.

6. A commitment is secured to develop and maintain opportunities for fish passage within the basin in a manner that facilitates migration and reproductive behavior of LCT.

7. Threats to LCT and its habitat have been reduced or modified to a point where they no longer represent a threat of extinction or irreversible population decline.

Adaptive Management

> *Adaptive management is an approach and process that incorporates monitoring, research and evaluation to allow projects and activities, including projects designed to produce environmental benefits, to go forward in the face of some uncertainty regarding consequences (Holling1978; Walters 1986).*

Until a long-term recovery strategy for LCT in the Truckee River basin is developed, MOG and TRIT agreed to adopt an adaptive management approach within a stepwise framework composed of short term actions.

Short-term actions will be evaluated periodically, with subsequent management decisions and actions implemented to achieve the objectives. An adaptive management program will include stakeholder participation. Adaptive management recognizes that science, management and stakeholder coordination are essential to the overall accomplishment of program objectives.

General features of adaptive management are:

- Development of clear, measurable objectives for recovery actions that relate directly to the risk, uncertainty, or the problem being addressed;
- Selection of indicators to measure success, failure, or general performance that are practical to use and capable of signaling change at a level needed to meet recovery objectives;
- A clear assignment of responsibility for responses when triggers, thresholds, or standards are exceeded, as demonstrated through monitoring;
- A fair, objective, and well understood program for collecting, managing, and interpreting information for monitoring and research projects; and,
- Provisions to deal with disputes over interpretation of information.

A structured and documented review process of the short-term actions and results will be integrated into the recovery effort. Short-term actions will be implemented through a cooperative approach that utilizes agency expertise and capability. TRIT will provide the primary technical expertise with individual actions coordinated through the appropriate agency, Tribe or organization. USFWS will retain the primary responsibility initially for information and data consolidation and management.

Actions that will assist with restoration of ecosystem functions upon which the LCT depends include: seasonally increasing river flow to Pyramid Lake; improving instream water quality; revising and implementing biocriteria standards; modifiying or removing barriers that impede fish movement; restoring riparian habitat; improving water management to mimic natural flow regimes and geomorphic processes; and managing wild populations believed to be indigenous to the Truckee River basin.

The short-term tasks outlined in this plan for LCT recovery in the Truckee River basin are developed to focuses on three components:

1. Developing a thorough understanding of the issues and management of the Truckee River basin.
2. Gaining information for refining a future recovery strategy for LCT in the Truckee River basin.
3. Implementing a scientifically based Adaptive Management Program.

III. HISTORICAL CONDITIONS OF THE TRUCKEE RIVER BASIN

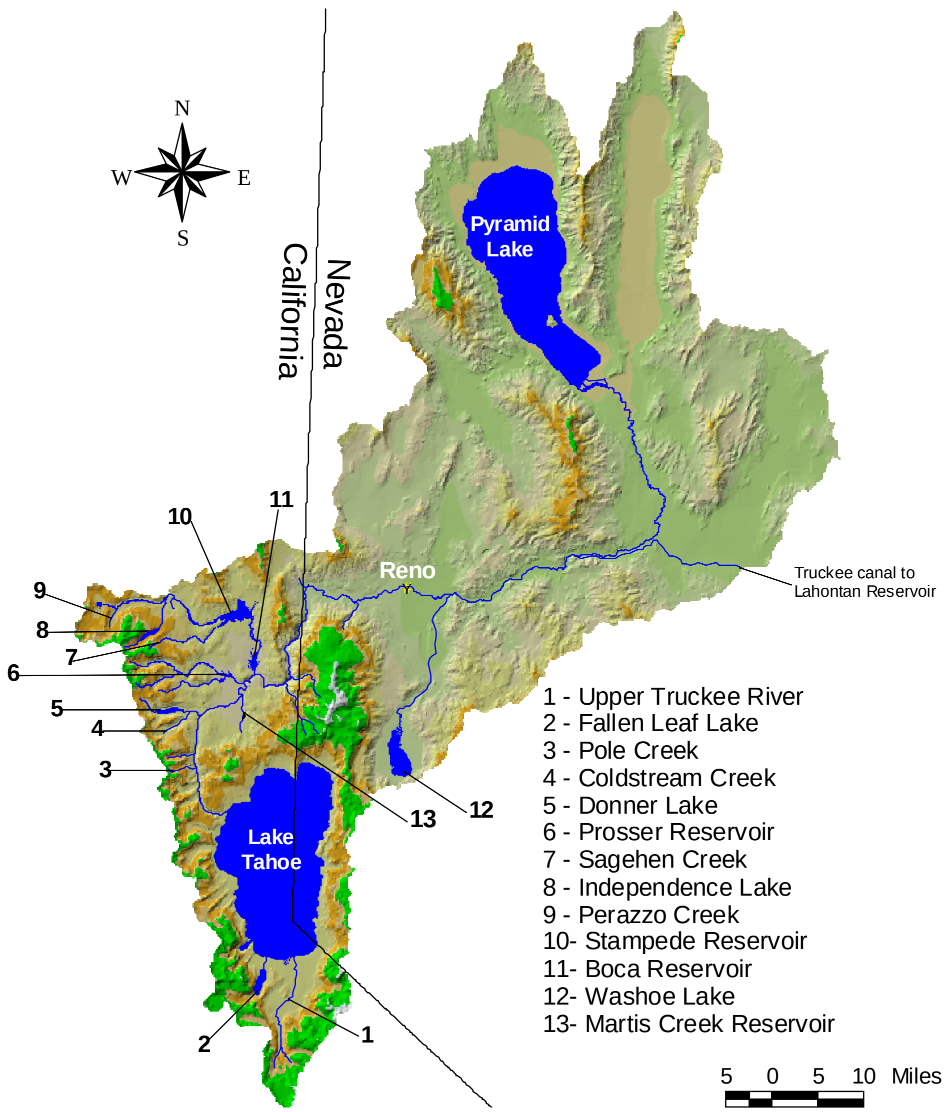
The Truckee River originates at an elevation of approximately 9,000 feet in the Tahoe basin of the Sierra Nevada Mountain range and terminates at Pyramid Lake (3810 feet). The Upper Truckee River, in combination with Trout, Taylor, Ward and Blackwood Creeks, provide the primary water sources to Lake Tahoe**.** These streams historically provided spawning habitat for Lake Tahoe LCT. Lake Tahoe was created in late Tertiary Age when a lava flow blocked the glacially formed lake basin and allowed it to fill with water. In 1870 a supplementary dam was built at the Truckee River outlet that allowed the natural level of Lake Tahoe to be raised an additional six feet. The dam provided water control for downstream logging, irrigation and hydroelectric power generation.

At the northwest end of Lake Tahoe the Truckee River exits and continues its journey downstream. The upper portion of the Truckee River basin resembles a funnel capturing water and transporting it eastward towards Nevada (Houghton 1994). The Truckee River watershed below Lake Tahoe is composed of 790 square miles in California and 1,340 square miles in Nevada. The Truckee River flows 105 miles from Lake Tahoe to Pyramid Lake. It turns east at Truckee, California, and emerges from its steep canyon environment immediately west of Reno, Nevada. Near Reno the Truckee River enters the Great Basin section of the Basin and Range physiographic province. After flowing through Reno and Sparks, formerly a low meadow area of about 10,000 acres and collectively known as the Truckee Meadows, the river flows through the Vista reefs and enters the Truckee Canyon. The Truckee Canyon is geologically composed of volcanic rock and lacustrine deposits. Near Wadsworth, Nevada, the Truckee River turns northward and flows through a broad alluvial valley that is bounded by Quaternary Age lacustrine deposits of Lake Lahontan and Tertiary Age volcanic rocks. The Truckee River cuts through the lacustrine deposits and enters Pyramid Lake.

Pyramid Lake, the terminus of the Truckee River, is a remnant of Pleistocene Era Lake Lahontan, which historically covered an area of over 8,665 square miles, the size of present day Lake Ontario. Pyramid Lake represents the last remnant of Lake Lahontan. Today Pyramid Lake is over 30 miles long and ranges from 4 to 11 miles wide and is situated between the Lake Range on the east and the Virginia Mountains to the west. Historically ephemeral Lake Winnemucca, located east of Pyramid Lake and the Lake Mountain Range, were connected. Lake Winnemucca dried up in 1938 (Sumner 1939) as the flows of the Truckee River were reduced by upstream diversions. The lands surrounding Pyramid Lake are those of the Pyramid Lake Paiute Tribe (PLPT). Pyramid Lake is located in a sedimentary basin, which influences the natural water quality and limnological dynamics of the water body. From 1981 to 1990 the maximum depth of Pyramid Lake varied from 320 to 355 feet. The average annual evaporation loss is approximately 440,000 acre-feet, which equates to a vertical loss of approximately four feet per year. The majority of the evaporation occurs during the summer period.

The Truckee River basin has included human habitation for at least 11,000 years. Archeological research and the oral histories of the Paiute, Shoshone, and Washoe Tribes indicate that the people in the Truckee River basin have always subsisted upon aquatic life found in the Truckee River and Pyramid Lake (Houghton 1994).

TRUCKEE RIVER BASIN



Map 1. Truckee River Basin

Lake Tahoe

In 1844, trapper and explorer John C. Fremont became the first person of European descent to see Lake Tahoe. Prior to 1844, the Washoe Tribe lived in the area and sustained itself on the rich biological and physical resources. In 1870, Colonel A.W. Von Schmidt built a dam at the Truckee River outlet of Lake Tahoe and eventually raised the lake level six feet. In 1915, the Federal Government gained legal control of the top six feet of Lake Tahoe through a court decree which dictated that a Federal Water Master be responsible for jurisdiction over downstream water releases into the Truckee River system. After European discovery, Lake Tahoe and the Truckee River system became known for its abundant timber and mineral resources. Homes, hotels, roads, stores and railroads were built around Lake Tahoe to support the logging industry. By 1859 numerous lumber mills directly discharged sawdust and other logging mill debris into the Truckee River, choking the rivers banks and beds, and creating fish passage problems due to sawdust bars at the rivers terminus at Pyramid Lake. Silt loading from timber clear-cutting and erosion runoff significantly degraded the river's water quality. As logging continued, the amount of easily available timber decreased to a point where the milling operations began to shut down (Houghton 1994). Each spring (March through July), thousands of adult LCT migrated from Lake Tahoe into the surrounding tributaries in the basin to spawn (Shebley 1929).

Market fishermen established permanent fish traps on the major tributaries and used gill nets and seines to capture additional fish. By the 1880's the combined effects of over-fishing, damage to the spawning tributaries, logging and diversions downstream had negatively impacted the LCT fishery. Biologically the LCT were being negatively influenced by the addition of non-native lake trout (*Salvelinus namaycush*), rainbow trout (*Oncorhynchus mykiss*), and brown trout (*Salmo trutta*) to Lake Tahoe.

The combination of physical and biological modifications reduced the ability of the LCT to sustain itself in Lake Tahoe. Although commercial LCT fishing was banned on Lake Tahoe in 1917, by 1938 the last spawning LCT from Lake Tahoe was observed in the tributaries (Curtis 1938; Scott 1957; Cordone and Frantz 1966). The State of California conducted an egg-taking and propagation program for Lake Tahoe LCT from 1889 to 1938 (Leitritz 1961) but was not successful with sustaining the population.

Mainstem Truckee River and Pyramid Lake

John C. Fremont discovered the Truckee River in January 1844, as he explored the lands West of Pyramid Lake (Townley 1980). Fremont originally called the Truckee River the Salmon Trout River due to its abundant and large sized fish. The 1850's brought the first diversion of water from the Truckee River to agricultural lands. In 1861, the Cochrane and Pioneer ditches were completed, diverting Truckee River water for irrigation in the Truckee Meadows ranchlands (Horton 1997). Extensive diversion of the Truckee River followed and became the focus of evolving water rights and needs issues in Nevada.

To satisfy the need for better water control and development potential, Congress, in 1903, approved the Newlands Project, the first of hundreds of reclamation projects in the West. The Newlands Project authorized the construction of a new weir at Lake Tahoe; Derby Dam on the lower Truckee River; Truckee canal - an inter-basin transfer canal from the Truckee River to the Carson River; and Lahontan Reservoir on the Carson River, to support irrigation demand in the Carson River basin (CDWR 1991; Horton 1997; USDOI 1998). The Truckee-Carson Irrigation District (TCID) manages the water delivery for the Newlands Project.

In 1944, a court action, called the Orr Decree, defined the amount of water to be distributed downstream (Horton 1997; USDOI 1998). In the late 1960's, the Pyramid Lake Paiute Tribe, concerned over the shrinking amount of water in Pyramid Lake, litigated the government to evaluate reducing the amount of water diverted from the Truckee River by TCID. Today the Federal government continues to negotiate between the States, publics and the Pyramid Lake Paiute Tribe to determine an equitable solution to the Truckee River allocation issues.

IV. Existing Ecosystem Conditions in the Truckee River Basin

The Truckee River basin has undergone a variety of channel modifications that have led to reduced instream habitat complexity and degradation of the riparian zone. Flood control projects, completed by the Army Corps of Engineers in the 1960s and 1970s in the Reno/Sparks area, included channel modifications of the Truckee River (WET 1990). Realignment and bank protection of the Truckee River was performed downstream from Reno, in conjunction with the installation and maintenance of Interstate 80 and railroad line (WET 1991). In the Truckee Meadows area, various types of channel bank revetments (such as gabions, riprap, and concrete floodwalls) now exist. The slope of the Truckee River has remained relatively fixed in this reach since 1946 (WET 1990). Along the lower

Truckee River, the Bureau of Reclamation initiated channel clearing, embankment repair, and bank stabilization projects after the winter floods of 1964/65 (USACOE 1995; WET 1991). Rock riprap, rock groins, and gabion groins have been constructed for bank protection along the lower river (WET 1991).

Between 1905 and 1966, the base level for the Truckee River lowered as the elevation of Pyramid Lake decreased due to diversions associated with the Newlands Project. The mouth of the Truckee River incised, as it adjusted its profile to the new base level. This channel incision migrated through the unstable bank sediments upstream, destabilizing the channel and associated riparian area between Pyramid Lake and Numana Dam (USACOE 1998). Channel incision caused erosion and increased sediment loads in the lower Truckee River, which led to the development of an expanded delta at Pyramid Lake. The Truckee River delta has been a major barrier for the listed fishes of Pyramid Lake and was a critical factor in the decline of these species.

The construction of Marble Bluff Dam, in 1976, established grade control for the lower river, halting further upstream channel incision. Upstream of Marble Bluff Dam, channel incision is less severe due in part to the dam and in part to the presence of erosion-resistant geologic features (WET 1991).

Fish Passage Barriers

The Truckee River basin has in excess of 40 potential barriers to fish migration (Appendix D). Barriers have impeded LCT migration to historic spawning and rearing habitats. Certain structures are complete obstructions to upstream migration while others are only partial barriers. When access is limited, fish may be forced to utilize sub-optimal habitats, which exposes them to potential predation and competition from nonnative fish. All life stages may be entrained in diversion canals, impinged on screens, or delayed in migration. The combined effect of disrupted migration is reduced productivity for LCT. In 2002, Bureau of Reclamation constructed a fish passage channel around Derby Dam.

Hydrology and Water Management

The natural hydrology of the Truckee River is dominated by spring snowmelt peaks of low to moderate magnitude that typically occurs in May. Intense rain and rain-on-snow events can also produce occasional high-magnitude, short-duration peaks at various times throughout the year, although they rarely occur between July and September.
Truckee River runoff is normally highest during April, May, and June and lowest during August through October. During very dry years, sections of the Truckee River are dewatered for extended periods of time: six gages in the system have had mean daily discharges of 1 cubic-feet-per-second (cfs) or less during the period of record from 1901 – 1997 (Otis Bay Riverine Consultants 2002).

Native riverine species have been exposed to flow regimes that varied with seasonal and across-year weather fluctuations. In the Truckee River, this natural variation ranges across thousands of cfs on a relatively regular basis between heavy snowmelt events and drought cycles. Native biota such as fish, invertebrates, amphibians, and riparian plants, have therefore presumably adapted to such variation in flow regimes. In fact, important processes responsible for sustaining native species may even depend on the river's natural variability in flows, as for example, the process of recruiting riparian vegetation. Recent evidence even suggests that artificially constant flow regimes favor exotic species, such as salt cedar (*Tamarix ramossissima*), over native species that are tolerant of greater fluctuations in instream flows, such as Fremont cottonwood (*Populus fremontii*). Thus, to sustain and perpetuate the native aquatic and riparian ecosystem, a managed flow regime would mimic natural patterns of variation in streamflow, seasonally and across years, as closely as possible.

In California, dams on tributaries of the Truckee River have significant impacts on Truckee River discharge. Prominent dams include Lake Tahoe Dam, Donner Creek Dam, Martis Creek and Prosser Creek Dams, Stampede and Boca Dams and Independence Lake Dam (Table 1). Although a number of flood storage facilities exist in the Truckee River's upper reaches, their actual influence on flood magnitude is unclear.

Analysis of historic flood records at the USGS gage at Farad indicate that there is no difference in the magnitude of flooding prior to and following the year 1962, despite the construction of Prosser Creek (1962), Stampede

Table 1. Major reservoirs in the upper Truckee River basin, including dam completion dates, storage capacities, owners, and primary purposes for stored water (compiled from Horton 1997 and USDOI 1998).

Reservoir	Date of Completion	Capacity (Acre-feet)	Owner	Primary Purpose
Lake Tahoe	1913	744,600	BOR	Orr Ditch
Donner Lake	1930s	9,500	SPPC/TCID	M&I
Martis Creek Reservoir	1971	20,400	ACOE	Flood control
Prosser Creek Reservoir	1962	29,800	BOR	Tahoe/Prosser Exhcange
Independence Lake	1939	17,500	SPPC	M&I
Stampede Reservoir	1970	226,000	BOR	Fishes of Pyramid Lake
Boca Reservoir	1937	40,800	BOR Washoe County Conservation District	Orr Ditch Flood control

(1970), and Martis Creek (1971) dams. Human modifications of the river channel (including channelization and channel incision) have significantly increased flood magnitude in the river's downstream reaches. Although the presence of dams and reservoirs alters the magnitude, duration, and frequency of flow events, management of Stampede Reservoir and uncommitted water in Prosser Reservoir will provide the opportunity to implement instream flows that resemble the natural flow regimes.

The USFWS funded research that would lead to the development of variable instream flow recommendations for the Truckee River. Flow management that varies across seasons and across years appears to be the only solution for meeting all ecosystem needs in a naturally variable riverine system with variable availability of water for environmental flows. Four flow management regimes recommended by the Nature Conservancy for the lower Truckee River in 1995 were designed for variable flow management based on water availability and existing knowledge about biological flow requirements and physical processes that sustain the system. These flows were managed for by the USFWS from 1995 through 1999 and resulted in substantial improvement in the riparian forest below

Derby Dam and in other sites throughout the mainstem Truckee River, where appropriate substrate and bank slope occurred.

Water availability is determined by four principle factors, amount of water in the snowpack, reservoir storage levels, expected river flows below Derby Dam without environmental supplements, and expected reservoir flood surcharge. Once water availability for the year in question is determined (high, fair, moderate, or poor), decisions regarding the priorities in ecosystem management need to be made. For this, we currently recognize six basic issues, Lahontan cutthroat trout recruitment, riparian woodland recruitment and maintenance, cui-ui recruitment and population maintenance, invertebrate community maintenance, and maintenance of the riverine environment (temperature, oxbow wetland maintenance, sediment transport). Other priorities for ecosystem management may arise as more scientific knowledge is acquired about the system.

Table 2 lists some of the primary Truckee River diversions from the Nevada stateline downstream to Pyramid Lake. Most diversions supply water for irrigation and municipal needs, except three diversions which supply water for hydroelectric or power generation. A more comprehensive list of diversions within the Truckee River basin is presented in Appendix D.

Where water diversions lead to lower instream flows, LCT habitat is affected by increased water temperature, limited access to aquatic habitats and increased opportunity for competition between fish species. Natural low flows, caused by droughts, have occurred historically in the Truckee River system, and are now exacerbated by flow diversions. Dewatering of the stream channel during the irrigation season may result in the stranding of fish, exposure and desiccation of spawning redds and nursery habitat, and disruption of LCT and cui-ui migratory patterns.

Total diversions at Derby Dam represent about 32 percent of the average annual flow of the Truckee River measured at the Farad gauging station near the California-Nevada state line. The average amount of flow diverted at Derby Dam has declined over time, primarily due to the development of Operating Criteria and Procedures (OCAP) for the Newlands Project, and further refinement of OCAP in 1998 under the Adjusted OCAP (USFWS 1992).

Table 2. Lower Truckee River diversions from Nevada stateline downstream to Pyramid Lake.

Diversion	Use	Return Flow
Steamboat Ditch	Irrigation	Through Steamboat Ck
Verdi Power Diversion and Coldron Ditch	Power generation, irrigation	Through Verdi Powerhouse
Washoe Power Diversion and Highland Ditch	Power generation, municipal	Washoe Power through Mogul Powerhouse. None from Highland
Last Chance Ditch	Irrigation and Municipal	Through Steamboat Ck
Lake Ditch	Irrigation and municipal	Through Steamboat Ck
Orr Ditch	Irrigation	Through N.Truckee Drain
Cochrane Ditch	Municipal	No
Glendale Treatment Plant	Municipal	No
Pioneer Ditch	Irrigation	Through Steamboat Ck
Largomarsino-Murphy Ditch	Irrigation	To Truckee River
McCarran Ditch	Irrigation	No
Tracy Power Plant	Power generation	To Truckee River via cooling ponds
Derby Dam/Truckee Canal	Interbasin transfer Lahontan Res.	Partial to Truckee River
Numana Dam	Irrigation	No

The effects of flow depletion at Derby Dam are apparent in virtually every type of hydrologic analysis. For example, substantial changes after completion of the dam are evident in (1) discharge versus area relations, (2) mean monthly discharge, (3) frequent high-flow magnitude, (4) flow duration relations, (5) base flows, and (6) water volume (USACOE 1995). Based on its historic record of operation, Derby Dam probably imposes the single largest hydrologic disruption of the Truckee River in Nevada. Dams and diversions have been a key cause of habitat degradation because they affect seasonal flow variability and flood magnitude.

Pyramid Lake

Pyramid Lake is an alkaline lake with no outflow, hence terminal, and represents an intact remnant of pluvial Lake Lahontan. Historically water levels in Pyramid Lake fluctuated in response to climatically driven dry and wet hydrologic cycles. At a lake elevation of 3,862 feet, water from Pyramid Lake would overflow into Winnemucca Lake. At this elevation, the surface area of Pyramid Lake covered nearly 140,000 acres and had a storage capacity of approximately 30 million acre-feet. Elevations of both Winnemucca Lake and Pyramid Lake remained relatively stable until the early 1900's. Today Winnemucca Lake is a dry lakebed as a result of reductions in inflow from the Truckee River and a concomitant decrease in the elevation of Pyramid Lake.
Since construction of Derby Dam in 1905, Truckee River discharge into Pyramid Lake has dramatically decreased (U.S. Geological Survey water data reports, as cited in USDI 1998). Increasing urbanization also decreases water flow into Pyramid Lake. This flow reduction significantly impacts the character of the lower Truckee River ecosystem and of Pyramid Lake, which declined 26 m (85 ft) in surface elevation between 1910 and 1965 (USACOE 1998). The result has been a periodic disconnect between the lake and the river for migrating fish. Under current conditions the lake fluctuates around a highly altered hydrograph. The level of Pyramid Lake reached a historic minimum of approximately 1154 m (3787 feet) in 1966, after which time it has risen to about 1163 m (3818 feet) in 2000. In June 2003, Pyramid Lake elevation was 1161 m (3810 feet).

Water Quality

Water quality in the Truckee River and Pyramid Lake influences ecosystem processes. Temperature, dissolved oxygen, total dissolved solids (TDS), alkalinity, and nutrient supply are important parameters that affect aquatic biota and ecosystem function. Detailed descriptions of Truckee River and Pyramid Lake water quality can be found in the following sources:

- Goldman et al. (1974)
- Chatto (1979)
- Horne and Galat (1985)
- Galat (1986, 1990)
- USFWS (1992)
- Lebo et al. (1994a, 1994b)
- USACOE (1995)

Total dissolved solids (TDS) concentration in Pyramid Lake is inversely related to volume. As discharge decreases and lake volume declines, TDS increases (Galat 1986 and 1990; Lebo et al. 1994a and 1994b). Alkalinity is a constituent of TDS that most impacts the ecosystem (Wright et al. 1993; Wilkie et al. 1993 and 1994). Since 1905, TDS in Pyramid Lake increased over 30 percent (USFWS 1992). The substantial increase in TDS has caused significant degradation of the lake food chain (USFWS 1992). The result is that Pyramid Lake habitat has been degraded by a combination of reduced volume, higher water temperature and increased TDS.

Point and non-point sources of pollutants impact the Truckee River system. Non-point sources are primarily irrigation return flows, sediment runoff from development, erosion of the surrounding watershed, and urban stormwater runoff (Lebo et al. 1994b). For example Steamboat Creek is a contributor of nutrients and suspended sediments and has been classified as the largest nonpoint source of pollution to the Truckee River (NDEP 1994 as cited by Codega 2000). A major point source is treated wastewater effluent. The result is that Pyramid Lake habitat has been degraded by a combination of lowered surface level and concomitant reduced volume, higher water temperatures, and increased TDS and organic nutrients (Galat 1990; Meyers et al. 1998).

Riparian Ecosystems

Healthy, intact riparian zones are important to ecologically functioning stream systems, providing bank stability, wildlife habitat, nutrient cycling, lower water temperatures, and a reduced potential for colonization by non-native species such as saltcedar (or tamarisk, *Tamarix ramosissima*) (WET 1991). In the Truckee River basin, three primary types of riparian plant communities exist: (1) wetlands, (2) cottonwood forests and (3) riparian shrubs (USFWS, 1993). Much of the existing riparian area is dominated by Perennial pepperweed (or Tall whitetop, *Lepidium latifolium*), an invasive species that out-competes native riparian plants. Two other invasive species, Purple loosestrife (*Lythrum salicaria*) and Eurasian watermilfoil (*Myriophyllum spicatum*), are also becoming established in the Lower Truckee River clogging wetlands and waterways, and may overtake riparian areas if left unchecked (Eiswerth et al. 2000). Areas of potential direct impact of human development to the Truckee River system include, a general depletion of stream sediment input, an increase in turbid sediment pulses and the reduced input of large woody debris. Woody debris in streams increases the amount and quality of hydraulic habitat types, increases sediment storage, improves nutrient cycling and provides refugia from predators and high flow events (Robison and Beschta 1990).
In the lower Truckee River basin, riparian cottonwood communities have been highly impacted by human modifications of the floodplain, as well as

channel incision (Otis Bay Riverine Consultants 2002). Before construction of dams and diversions, overbank flooding was more frequent, providing riparian seed dispersal and conditions necessary for seed germination. Much of the Truckee River's historic flood plain has been converted to agriculture, urban and industrial uses and therefore compromised as sustainable riparian habitat. Channelization of the Truckee River from Reno to Vista has de-watered many wetland areas, and confined the river to a narrow corridor (USACOE 1995). The resulting river channel has limited riparian and aquatic cover, reduced channel complexity and limited ability to sustain a viable LCT fishery.

Channel incision along the lower Truckee River has affected riparian communities when the historic floodplains become disconnected from the river, resulting in terraces that are physically separated from river processes. Existing mature cottonwoods remaining on terraces are able to reach the water table; however, regeneration of cottonwood seedlings will not occur without the return of ecosystem dependent floods (Cordes et al. 1997; Scott et al. 1997; Rood and Mahoney 2000; Bovee and Scott 2002; Otis Bay Riverine Consultants 2002).

The Lower Truckee River riparian forest has substantially declined since settlement in the 1800s. Between 1938 and 2000 the riparian forest downstream of Vista, Nevada to Pyramid Lake was reduced from 2067 acres to 628 acres, representing a 70 % loss of cottonwood-willow forest in this time period (Table 3). Furthermore, by 1938 the Truckee River had experienced decades of negative impact from extreme grazing pressure and the hydrologic influence of Derby Dam. Willow thickets reported in the 1800's by Robert Ridgeway and others are not observed in the 1938 aerial photos and patches of immature cottonwoods are also lacking (USACOE in press 2003. The loss of the cottonwood canopy has led to other ecological problems; for example, higher stream temperatures resulted from diminished forest canopy which caused lethal conditions for several aquatic organisms (USACOE 1998).

Table 3. Riparian cottonwood forest decline from 1939 to 2000 (Otis Bay Ecological Consultants 2003)

Segment Name	Riparian Forest Acreage in 2000	Riparian Forest Acreage in 1939	Acres of Lost Forest Between 1939 and 2000
Vista	0.4	10.2	-9.8
Upper Lockwood	6.2	15.6	-9.4
Lower Lockwood	2.0	16.8	-14.8
Mustang	4.3	67.2	-62.9
Upper McCarran	6.4	21.7	-15.3
Lower McCarran	6.0	48.9	-42.9
Granite Pit	0	2.8	-2.8
Tracey Power Plant	1.6	55.4	-53.8
102 Ranch	21.0	81.4	-60.4
Eagle Pitcher	4.4	78.9	-74.5
Derby	4.4	46.1	-41.7
Ferretto Ranch	7.7	20.9	-13.2
Railroad Cut	14.6	42.0	-27.4
I-80 Rest Stop	24.3	82.8	-58.5
Above I-80 Bridge	59.0	111.6	-52.6
Wadsworth	36.2	67.9	-31.7
Numana Hatchery	241.2	742.9	-501.7
Dead Ox	8.9	26.6	-17.7
Above Nixon Bridge	82.8	239.8	-157.0
Below Nixon Bridge	94.3	256.7	-162.4
Marble Bluff	2.7	30.7	-28.0
Total Acreage	**628.4**	**2066.9**	**-1438.5**
% Change			**70%**

V. Instream Flow Needs to Support Ecosystem Processes

Instream flow requirements for managed rivers have traditionally been determined using Instream Flow Incremental Methodology (IFIM). This method entails modeling flows that maximize what is considered the optimal aquatic habitat for a target fish or other organism (Stalnaker et al. 1995). However, several important limitations of IFIM led Otis Bay Ecological Consultants under contract with the USFWS to develop an alternative method for determining instream flows, which are proposed to be implemented on the Truckee River.

The primary limitation of IFIM lies in its inability to simulate the dynamic nature of a fluvial system and the variable flow needs of organisms that have evolved in variable flow regimes. Moreover, IFIM fails to address the need to maintain fluvial processes such as sediment entrainment and transport, which continually shapes the physical environment, including riffle-pool development, channel geometry, and channel migration. In conclusion, IFIM is neither designed nor intended to simulate variable natural flow regimes. Thus, recommendations based solely on IFIM methodology may lead to artificial flow regimes with potentially grave shortcomings over those methods that approximate the natural hydrograph. While IFIM provides insight into specific flow needs of a single species and should thus continue to be used for this purpose, a more comprehensive approach to instream, or ecosystem flow management is presented to sustain the natural riverine ecosystem and its native biota.

A method pursued by Otis Bay Ecological Consultants and the USFWS to determine ecosystem flow requirements contained several features: (1) it evaluates the entire range of natural flow conditions; (2) it integrates the needs of multiple biota such as fish, invertebrates, and riparian vegetation; and (3) it addresses the sediment transport processes that control channel geometry and perpetuate a dynamic riverine system. Flow regime recommendations derived form this methodology will mimic the natural hydrologic patterns that sustain the riverine ecosystem and its native species.

The method for developing ecosystem flows for the Truckee River was based on the assumption that organisms living in the riverine environment have adapted to and depend on a flow pattern that varies across seasons and across years. For example, organisms such as the cui-ui are stimulated by high, turbid flow to congregate, ready to spawn, at the mouth of the Truckee River in Pyramid Lake. Furthermore, spring-time high flows also create conditions needed for cui-ui migration, maintain lower water temperatures needed for cui-ui and LCT egg incubation, and expand shallow habitats for spawning as gravel bars are flooded. Likewise, other organisms such as cottonwood trees and willows have similar requirements for naturally variable flows. For example, high flows are needed to scour existing vegetation to reduce competition and recharge riparian aquifers to supply water for survival and growth. Declining flows, or declining river stage, encourage deep root growth and support plant survival as roots grow down to the capillary-rise zone of the seasonally low-level water table. Late-summer-early-fall low flows supply water to maintain seedlings and prevent drought stress in mature trees (as well as create conditions to support diverse invertebrate and fish communities).

Variability across years is also important. For example, high flows during one year might dynamically alter the riverine environment creating suitable geomorphic surfaces for riparian forest regeneration in following years (Everitt 1968; Rood and Gourley 1996).

Variable Ecosystem Development

Truckee River flow regimes were evaluated by subjecting river-flow gage records to a variety of analytical procedures: Log-Pearson Type III flood frequency estimates, flow duration relations, monthly mean discharges, flood peak magnitude-timing evaluation, as well as a literature review and summary of past Truckee River instream flow studies. In the following analysis of flow variability five key characteristics are discussed and evaluated: (1) *magnitude,* (2) *frequency*, (3) *duration*, (4) *timing*, and (5) *rate of change*.

Relationship of Native Species to Natural Flow Variability

Native riverine species were, in their recent evolutionary history, exposed to flow regimes that varied with seasonal and across-year weather fluctuations. In the case of the Truckee River, this natural flow variation ranges across thousands of cfs on a regular basis between winter-spring and late summer-fall, within a year, and between wet, average, and dry climatic periods between different years (Figure 2). Native biota, such as fish, invertebrates, amphibians, riparian plants, have therefore presumably adapted to such variation in flow regimes, at least since the past ice age. In fact, important processes responsible for sustaining native species, for example the process of recruiting riparian vegetation, depends on the river's natural variability in flows (Mahoney and Rood 1993). Recent evidence suggests that artificially created un-natural flow regimes may even favor exotic species, such as saltcedar, over native species. Thus, to sustain and perpetuate the native aquatic and riparian ecosystem, a managed flow regime would ideally mimic the natural variation in stream flow both seasonally and across years.

Human Impacts on Flow Variability of the Truckee River

<u>Channelization and Storage Reservoirs</u>
In the early 1960's, USACOE implemented a large-scale flood control project along the middle and lower Truckee River, which channelized the natural river channel and removed a large section of Vista Reef (Vista Reef was a bedrock outcrop that presented a natural grade control at the river's outflow from Truckee Meadows). The purpose of these activities was to convey greater flow volumes during flood peaks to reduce the flooding.

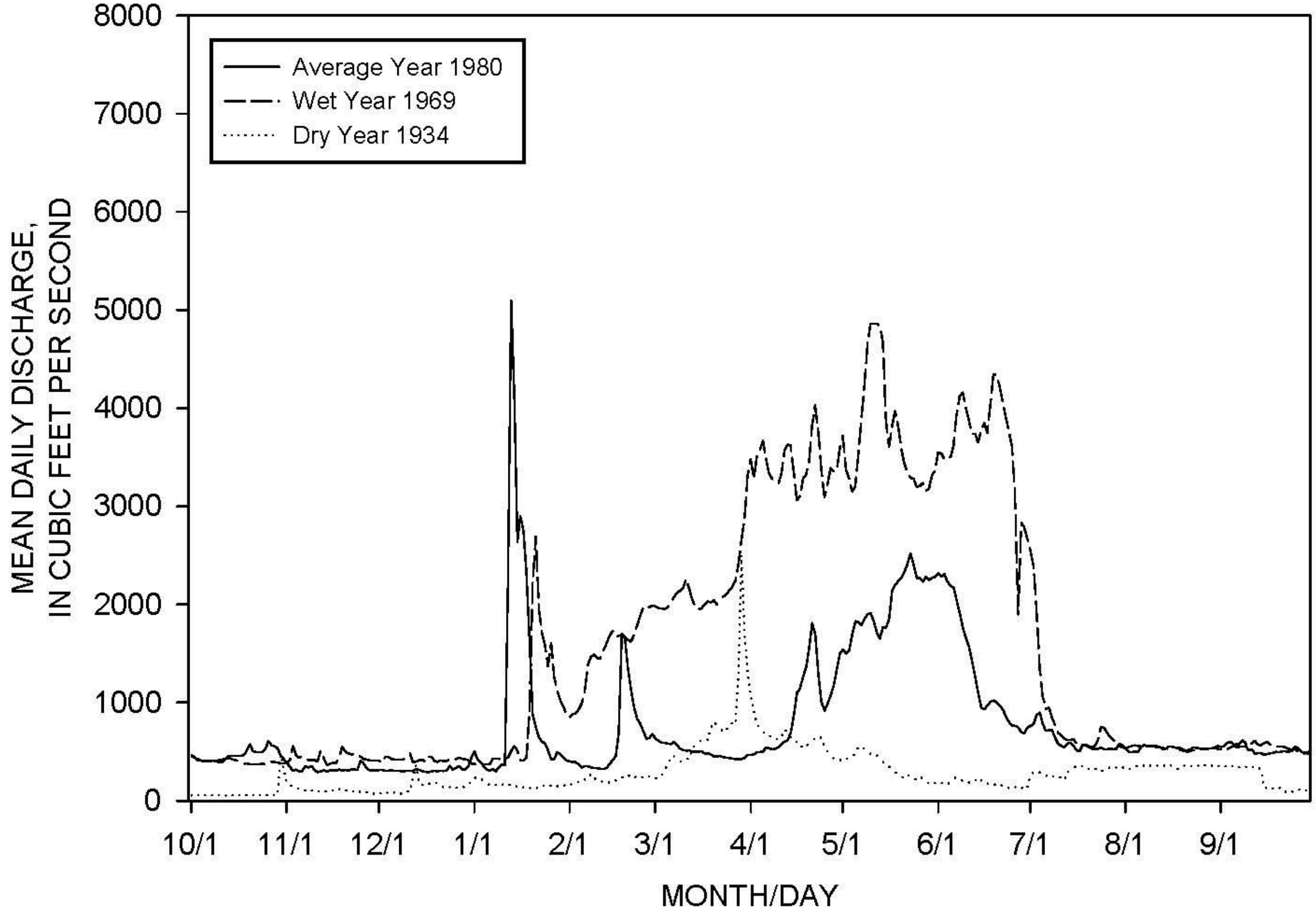


Figure 2. Plot of hydrographs recorded at the USGS Farad station from selected years: average year (1980), wet year (1969), and dry year (1934).

hazard to urban areas in the Truckee Meadows and other areas along the river. However, channelization and lowering Vista Reef significantly increased flood magnitude in downstream reaches, which probably resulted in channel incision and entrenchment during the post-construction period.

The construction of several reservoirs in the upper watershed also had a substantial impact on river flows. Their impact is greatest on low to moderate peak flows and base flow magnitudes; however, they seem to have negligible influence on the largest historic flood peaks (Otis Bay Riverine Consultants 2002).

Diversions for Agricultural and Municipal Purposes

Streamflow of the Truckee River is also influenced by many small dams and diversions that exist throughout its length. Although their net effect on the five key flow characteristics may be substantial, it is difficult to quantify their cumulative effects. The construction and operation of Derby Dam, however, provided a significant hydrologic impact to the flows of the Truckee River.

Non-Dimensional Flow Duration Curves

Flows in the Truckee River have been altered to some degree for all of the period of record, making determination of the natural regimes directly from the flow gage records difficult. Therefore, to more accurately decipher the natural flow characteristics gage records from nine streams in the same climatic region as the Truckee River were analyzed. These surrogate streams were located in areas with similar geomorphologic and topographic characteristics

Analysis of the flow duration characteristics of the nine streams gage records with minimal hydrologic alteration produced the series of flow duration relations illustrated in Figure 3. In this form, it is difficult to use these curves to estimate an appropriate range of flows for the Truckee River, due to the wide scatter that is created by differences in drainage basin size and annual discharge. However, when these curves are nondimensionalized by dividing by the mean annual discharge for each stream, the curves create an “envelope” that shows remarkable consistency in variability from stream to stream despite the differences in basin size (Figure 4).

These dimensionless curves define the natural range of variability for streams in the area, and can be used to estimate the range of flows that likely would have occurred in the Truckee River if human impacts were not present. When Figure 4 is combined with a similar plot of dimensionless

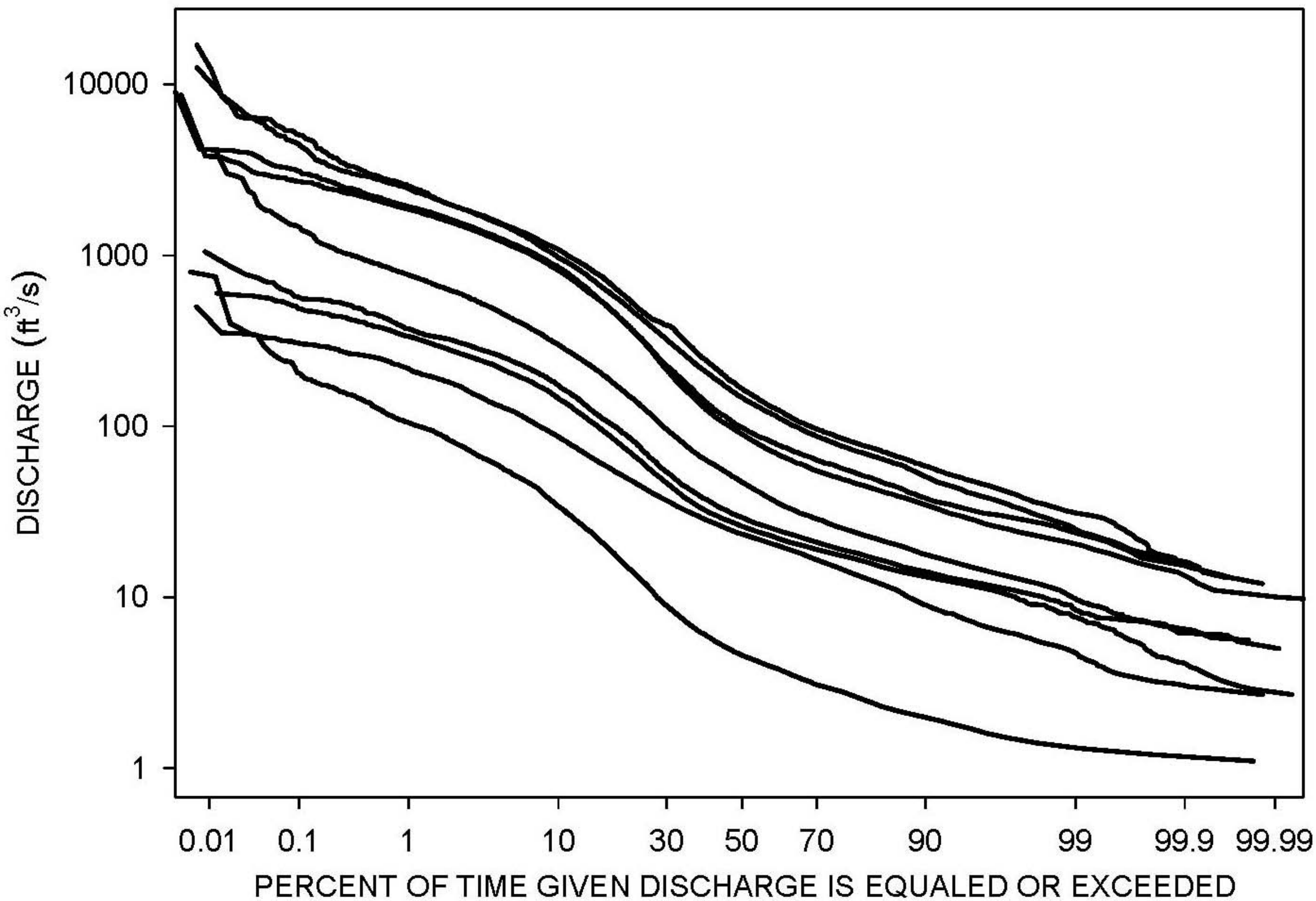


Figure 3. Plot of flow duration relations for nine area streams that have little hydrologic alteration.

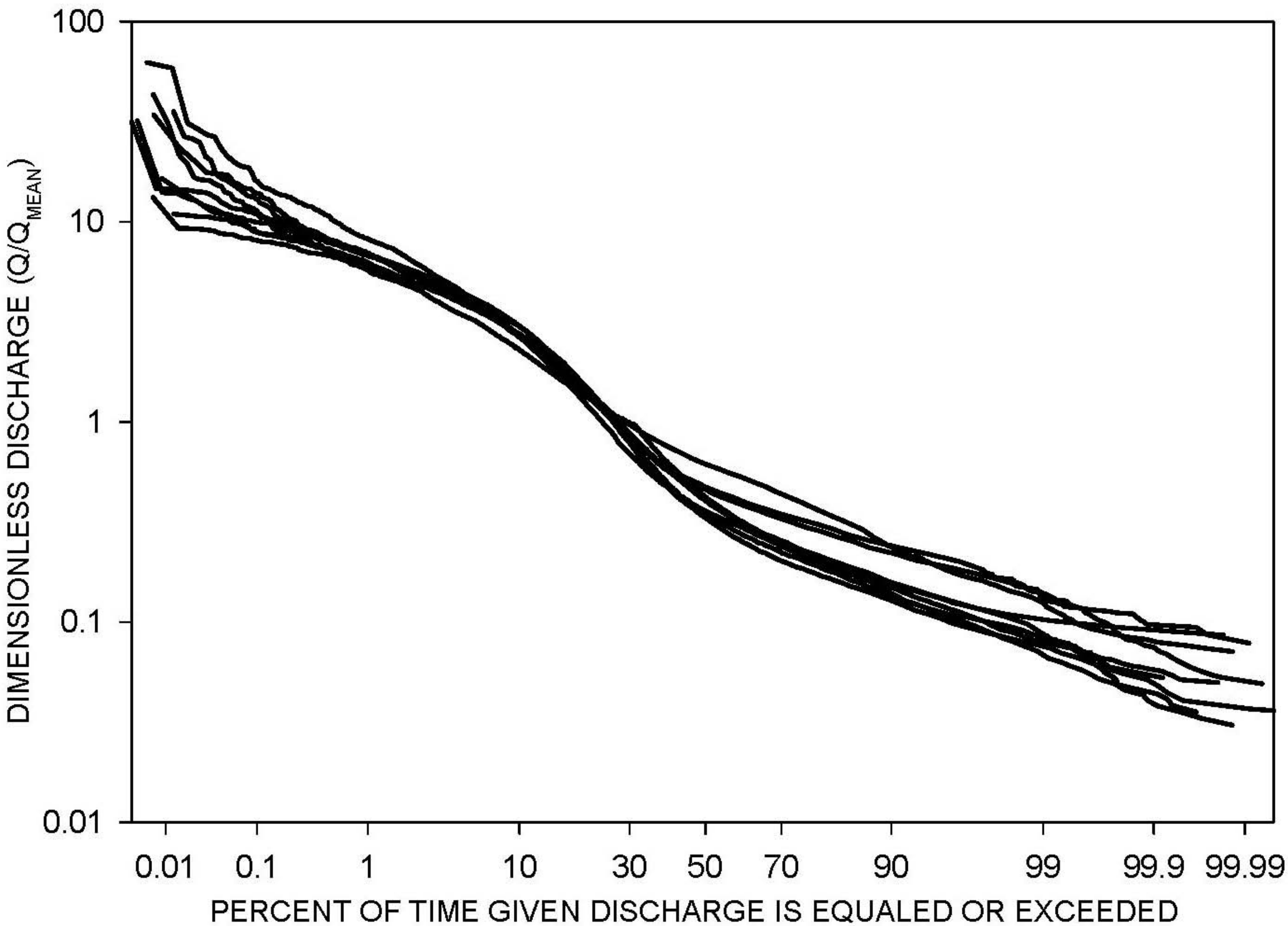


Figure 4. Plot of dimensionless flow duration relations for nine area streams that have little hydrologic alteration.

discharge for Truckee River gages, the streamflow problems on the Truckee River become readily apparent as deviations from the “envelope” of natural streamflow variability illustrated by the unaltered streams (Figure 5). Truckee River stream flow at the Farad and Vista gages actually mimics the natural flow variability reasonably well. However, stream flow at Reno, Sparks, and sites below Derby Dam, all show substantial deviation from a more natural stream flow pattern.

Using data from Figure 4, a table of the dimensionless discharge for each 10 percent exceedance increment of each month was tabulated (Table 4a). The values listed in the table are the median values from the nine streams included in the analysis. This table captures the variability present during each month of the year, for streams in the same climatic and geomorphic area as the Truckee River. Table 4a can thus be used to estimate the appropriate stream flow variability of the Truckee River by multiplying the values in the table by the mean annual discharge of the Truckee River. This was done using the mean annual discharge at the Vista gage (Table 4b) and gives insight into the natural monthly range of variability for the Truckee River in relation to water year percentile.

Natural flow, quantity and variability are the most suitable flow regimen for ecosystem processes; however, human demands for water resources remove the natural regimen as a management strategy. For the Truckee River, a finite quantity of flow, which varies depending on the annual water supply, is available for ecological purposes. Thus, river operators must make difficult decisions regarding water allocation for the environment.

The dimensionless-flow-duration analysis (Figure 5) shows that high flows in the Lower Truckee do not significantly vary from natural conditions, but base flows are substantially altered. This realization is a grave concern because base flows are essential to sustain the aquatic and riparian ecosystem. Therefore, the formulation of ecological flow regimes focuses primarily on base flows for the Truckee River, with the exception of periodic management of the declining limb of the hydrograph to create conditions suitable for cottonwood and willow recruitment.

The dimensionless-flow-duration analysis for nine streams gage records with minimal hydrologic alteration indicates that base flows ranging between 320 and 165 cfs for the 80% exceedance, and between 180 and 100 cfs for the 95% exceedance are more suitable for an ecosystem adapted to the natural flow regimes of the lower Truckee River than current post-Derby Dam flows. Using this information as a guide, resource planners developed environmental flow regimes for water years that vary from *very wet* to *extreme dry* (Table 5). Table 5 can therefore be used as a management

Table 4a. Median monthly dimensionless discharges from nine unaltered streams located in the same climatic and geomorphic area as the Truckee River (Figure 4), at 10 percent exceedance increments. Values below can be multiplied by mean annual Truckee River discharge to estimate stream flow variability.

Dimensionless Curves											
Dimensionless Discharge											
Water Year Percentile											
Month	**Min**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Max**
Jan	0.124	0.160	0.191	0.223	0.259	0.310	0.370	0.461	0.574	0.910	3.181
Feb	0.142	0.209	0.239	0.279	0.309	0.352	0.412	0.523	0.694	0.975	1.815
Mar	0.173	0.265	0.374	0.419	0.493	0.567	0.643	0.791	1.007	1.274	2.245
April	0.415	0.595	0.713	0.854	0.969	1.103	1.294	1.419	1.485	1.942	2.246
May	0.505	1.134	1.563	1.970	2.324	2.626	3.018	3.318	3.720	4.309	6.172
June	0.370	0.691	1.044	1.637	2.074	2.615	3.281	3.604	3.956	4.733	7.623
July	0.159	0.255	0.336	0.443	0.630	1.054	1.358	1.669	2.079	2.583	4.966
Aug	0.090	0.152	0.194	0.234	0.320	0.363	0.526	0.630	0.826	1.169	1.983
Sep	0.062	0.109	0.136	0.165	0.209	0.248	0.276	0.308	0.390	0.505	1.029
Oct	0.079	0.122	0.142	0.161	0.199	0.215	0.241	0.273	0.314	0.374	0.929
Nov	0.116	0.151	0.176	0.195	0.218	0.253	0.277	0.334	0.418	0.581	1.613
Dec	0.116	0.146	0.177	0.199	0.227	0.253	0.295	0.373	0.441	0.682	1.793

Table 4b. Median monthly dimensionless discharge estimates, redimensionalized for the Truckee River.

Dimensionless Discharge – Converted for Vista Gage											
Redimensionlized Discharge, in cfs											
Water Year Percentile											
Month	**Min**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Max**
Jan	103	132	158	184	214	256	305	381	474	752	2628
Feb	117	173	198	230	155	291	340	432	573	805	1499
Mar	143	219	309	346	408	468	531	653	832	1053	1854
April	343	492	589	706	800	911	1069	1172	1227	1604	1856
May	417	937	1291	1627	1920	2169	2493	2741	3073	3559	5098
June	306	571	863	1352	1713	2160	2710	2977	3268	3910	6297
July	131	211	278	366	521	871	1122	1379	1717	2134	4102
Aug	75	126	160	193	264	300	435	521	682	966	1638
Sep	51	90	112	136	173	205	228	254	322	417	850
Oct	66	101	117	133	164	177	199	226	259	309	767
Nov	95	124	145	161	180	209	229	276	345	480	1332
Dec	95	121	146	165	188	209	244	308	364	563	1481

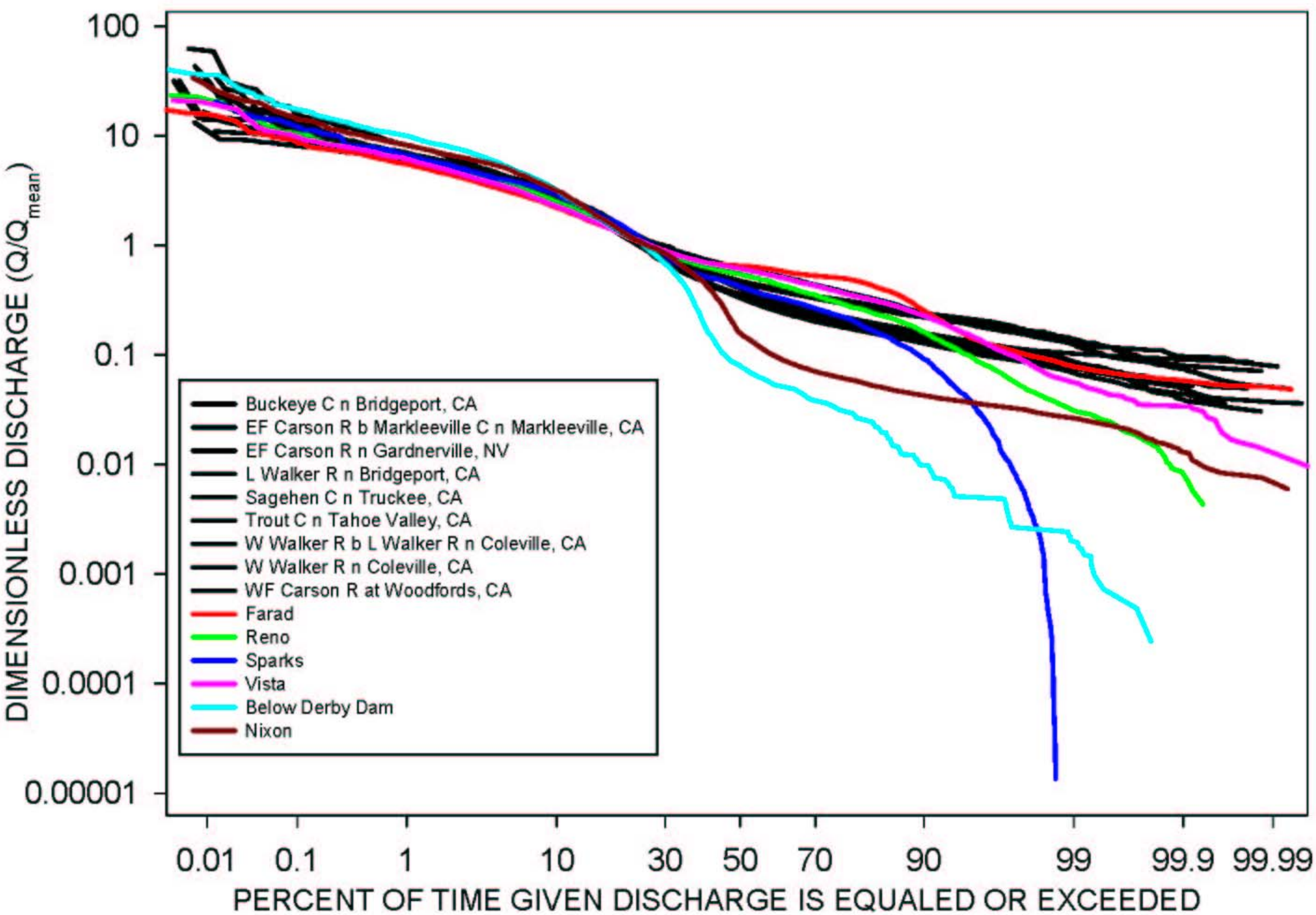


Figure 5. Plot of dimensionless flow duration relations for Truckee River gages compared to nine area streams that have little hydrologic alteration.

tool to guide decision makers toward instream flows that more closely resemble natural flow conditions with an emphasis toward maintaining essential base flows.

Table 5. Truckee River ecosystem flow regime recommendation

Month	Very Wet	Wet	Above Average	Average	Below Average	Dry	Very Dry	Extreme Dry
Regime No.	**WET 1**	**WET 2**	**1**	**2**	**3**	**4**	**5**	**6**
January	>200	>200	160	150	120	110	100	90
February	>200	>200	160	150	120	110	100	90
March	>450	>350	290	220	200	160	160	140
April	>1000	>800	590	490	420	350	300	200
May	>3000	>2700	>1000	800	600	530	400	300
June	>3500	>3000	800	600	500	400	270	170
July	>1700	>1000	300	210	300	200	150	120
August	>300	>300	200	170	200	200	150	110
September	>300	>300	170	170	110	110	120	100
October	>200	>200	160	150	120	110	100	100
November	>200	>200	160	150	120	110	100	90
December	>200	>200	160	150	120	110	100	90
Acre-Feet	>680,000	>570,000	>249,000	211,800	176,400	150,000	121,000	96,000

Cottonwood Recruitment Flows
Flow decline not to exceed 1 inch per day once high flows drop below 2000 cfs

Effective Discharge

While high magnitude flows individually entrain and transport more sediment than any lower magnitude single event, they do not transport the bulk of sediment moving through the system. In fact, those flows that are responsible for most of the river’s sediment transport, or work, are the moderate magnitude annual peaks that occur frequently (i.e., between a 1 and 5 year return interval). These frequently-occurring peak flows that are responsible for doing the bulk of work in the system are called the dominant or effective discharge.

Maintaining effective discharge is important for the riverine ecosystem, as these flows shape the channel, control channel geometry, maintain diverse hydraulic habitats, and impose dynamics in the system. Changes or disruption of these flows almost always result in dramatic changes in the river morphology and ecology. We have identified the effective discharge as an important component of any ecosystem flow regime.

To determine the effective discharge, the Parker bedload function is integrated with a streamflow duration relation using computed hydraulic radius relations and the particle size distribution for a segment to calculate average annual bedload flux for the given river segment. The results of this transport calculation are in the form of an average annual sediment flux for each particle size fraction, transported by each discrete increment of discharge. The procedure provides an estimate of the average annual bedload flux through each segment, under existing conditions, and it also provides an estimate of the geomorphically effective discharge if one exists for the site. An example of such calculations is displayed in Figure 6, where effective discharge is approximately 3000 cfs.

These effective discharge calculations were completed for multiple segments of the lower Truckee River with similar results, in most segments, as the example given in Figure 6. Therefore, 3000 cfs is a good approximation for Truckee River effective discharge between Vista and Derby Dam, but the effective discharge is approximately 2,000 cfs below Derby Dam as a result of large volume of water diverted into the Truckee Canal at Derby. These results are incorporated into ecosystem flow recommendations.

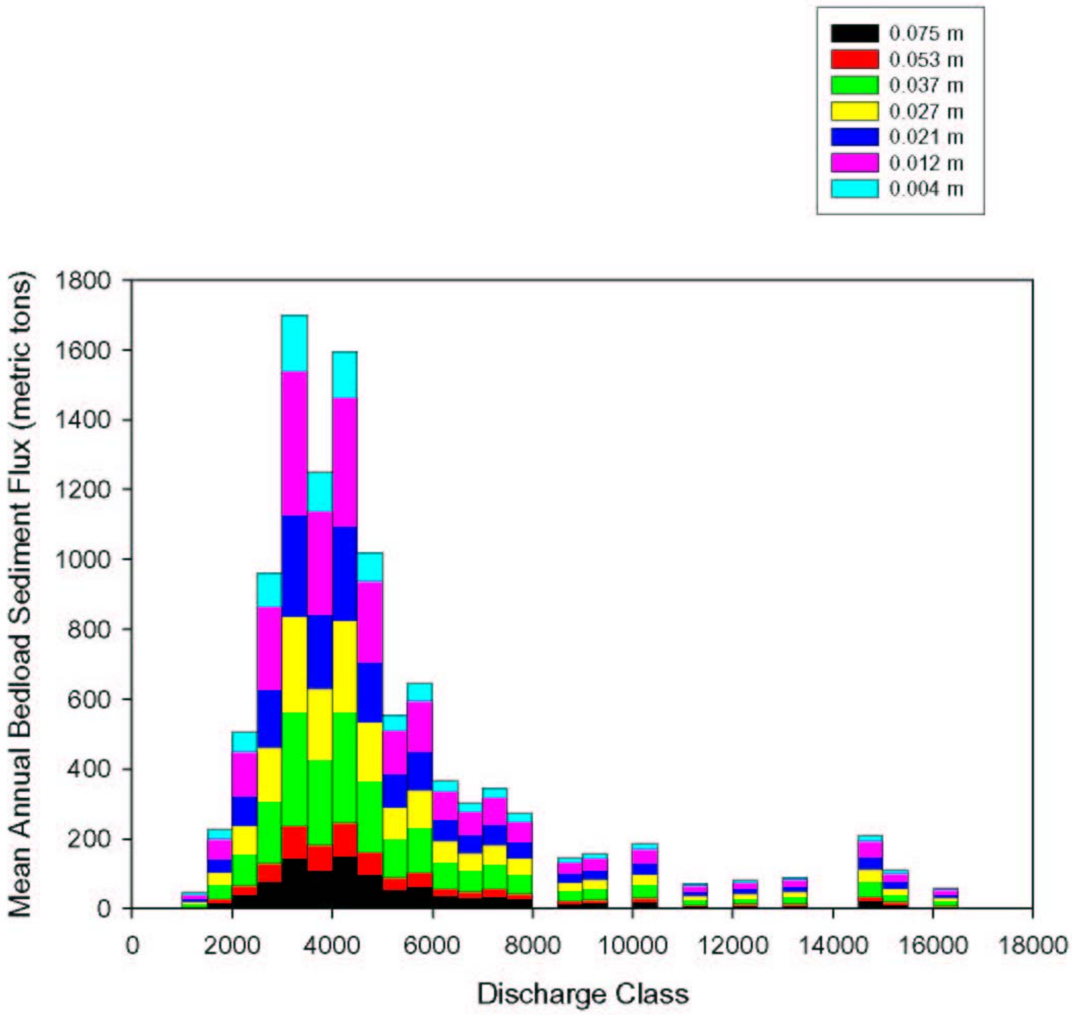


Figure 6. An example of a plot of mean annual bedload sediment flux using the Parker bedload function (Station 480B1, segment 20).

Flows for the Cottonwood Forest

Several studies suggest that once Derby Dam went into full operation extensive recruitment of cottonwoods along the Lower Truckee River cannot be detected in aerial photography from 1938 to the 1980's and the riparian forest was in a state of constant decline (Lang et al.1990; Rood et al. 2002; USACOE in press 2003). However, in 1987 extensive bands of cottonwood trees and willows were recruited primarily as a result of managed flow for cui-ui spawning. This discovery gave river mangers an indication that alteration of Truckee River flow management would be necessary to promote cottonwood forest restoration. Starting in 1995, USFWS working with Dr. Steward Rood, the Nature Conservancy, and the Federal Watermaster's office, began to show positive results as they experimented with new flow management to promote recruitment for cottonwoods and willows. These managed flow regimes were based, in part, on the flow characteristics of the 1987 cui-ui spawning flow releases, which resulted in significant cottonwood recruitment.

In October 1995, application of a general ecological model, developed for several other rivers by several different researchers (Rood and Mahoney 1990; Mahoney and Rood 1993; Segelquist et al. 1993), was investigated using conditions of the lower Truckee River. Upon completion of this study, the findings validated application of the general model to the Truckee River.

After validation of the general model, flow management recommendations were developed to increase the probability of cottonwood recruitment. Four sources of information were used to develop these flow recommendations: (1) the characteristics of the cui-ui instream flow spawning regime of 1987; (2) average relative elevation of the tree band above base flow; (3) hydrology data from the Truckee River and surrogate streams; and (4) a stage-discharge relationship for the lower Truckee, with specific emphasis on rate of flow decline on the falling limb of the hydrograph (Rood et al. 2002).

According to the general ecological model, which relates flows to cottonwood and willow recruitment, the cottonwood and willow seed release is timed to occur during the falling limb of the spring-early summer high-flow hydrograph. Shortly after the seeds disperse and land on moist soils (2 to 4 days), they germinate and quickly grow roots down to the top of the groundwater surface. Near the river where the seeds usually germinate, the ground water surface is approximately the same level as the river stage and as the river stage declines so does the ground water level. Chasing the falling ground water surface, the cottonwood seedlings grow roots up to an inch per day, but if the rate of water table decline significantly exceeds the biological potential for the rate of root growth (1 inch per day) then the seedlings will suffer a high mortality level.

The validation phase of this investigation determined that cui-ui spawning flows in 1987, the year of extensive cottonwood tree and willow recruitment, were hypothetically suitable (i.e., on average, flow decline did not exceed one inch per day). Hence the general ecological model was tested with flow management timed to cottonwood root growth for five consecutive years (1995 to 2000). This and another study (Klotz 1997; Klotz and Swanson 1997) validated the applicability of the general ecological model to the Truckee River with some refinements.

One suggested refinement was that riparian forest recruitment might be possible with average flow declines greater than one inch per day. Slowly declining flows were deemed one of the key factors in successful cottonwood tree and willow recruitment. Stage-discharge relationships developed from several river channel cross-sections measured along the lower Truckee River were used to generate recommendations for maximum daily flow reduction. The rates of stage-discharge decline measured at the Numana Hatchery (powerline site) generally matched those measured at other sites and are reported in Table 6. These recommended rates were successfully used as experimental flows to facilitate cottonwood recruitment in subsequent years. Other hydrologic characteristics important for cottonwood\willow recruitment and perpetuation, in addition to the rate of flow decline, include the timing and magnitude of peak flows, timing of declining flows, and sufficient minimum flows.

The following is a summary of the flow characteristics currently recognized as the most important for cottonwood recruitment and maintenance:

1. *Gradual flow decline* promotes seedling survival by allowing root growth to remain in contact with the declining water table. The maximum rate of decline, as determined by experimental Truckee River flows and from the scientific literature, is approximately one inch/day (Mahoney and Rood, 1991; McBride et al. 1988; Segelquist et al. 1993).

2. *Peak flows* drive geomorphic processes associated with dynamic river meandering and the creation of geomorphic surfaces that are suitable for cottonwood establishment (recruitment surfaces are principally point bars on meander lobes). Peak flows also remove competing vegetation, deposit new soils, wet surface soils, disperse seed, and recharge riparian aquifers.

3. *Declining flows*, timed during seed release, expose saturated and barren sites that are suitable for seed germination.

4. *Sufficient minimum flows* are needed through the hot, dry summer period to support seedlings and prevent drought stress in saplings and mature trees.

River managers should also recognize that cottonwood tree recruitment does not naturally occur every year. Based on natural cottonwood recruitment rates, managing flows toward successful cottonwood recruitment may only be needed once every three to five years on average.

Table 6. Rate of managed flow decline (1 inch/day) needed to enhance conditions for cottonwood tree recruitment (as determined at a site near Numana Hatchery).

Range of Discharge (cfs)	Maximum Daily Flow Reduction (cfs)	Acre-Feet Expended to Maintain Flow (6 day period)
3,500 - 2,700	140	37,000
2,700 - 2,000	110	28,200
2,000 - 1,600	80	21,400
1,600 - 1,200	65	16,200
1,200 – 900	50	12,100
900 – 600	40	8,800
600 – 400	30	6,100
400 – 250	25	4,000
250 – 150	20	2,500
150 – 70	15	1,300
70 – 26	5	600

Recommendation for Ecosystem Flow Regime

Developing recommendations for Truckee River ecosystem flows involved a three step process: (1) determination of the magnitude, frequency, duration, timing, and rate of change for the natural flow regimen; (2) changing management of available water to mimic the natural flow regime as closely as possible; (3) finding new sources of water if existing quantities that are available for environmental purposes are determined to be inadequate to sustain the riverine ecosystem.

An Ecosystem Flow Working Group composed of USFWS, Otis Bay Ecological Consultants, Stetson Engineers, and Pyramid Lake Paiute Tribe developed ecosystem flow recommendations based on the steps one and two above. These recommendations are deemed as experimental until the determination is made that the new ecosystem flow regimes will sustain the Truckee's riverine ecosystem. After the recommendations are tested, USFWS should determine if additional flows are needed (step three) or if changes in flow management are necessary.

Developers of the ecosystem flow regimes used several sources of information and analyses to formulate flow recommendations: (1) determination from many scientific literature sources that variable flows across seasons and across years are needed to maintain a riverine ecosystem; (2) analysis of nondimentional flow duration of unregulated streams in the northern Nevada region; (3) analysis of geomorphically effective Truckee River discharge; (4) investigation for Truckee River forest recruitment flows; (5) previous analyses of the spawning needs for cui-ui and LCT; (6) modeled flow-temperature considerations for maintaining temperatures suitable for a cold-water invertebrates and fishes; and (7) water availability for ecosystem flows determined by a Truckee River Basin operational model.

Based on the seven criteria above and the recognition that water availability varies across years, the Ecosystem Flow Working Group formulated eight ecosystem management flow regimes that range in water availability from an *extreme dry* condition to a *very wet* condition (Table 5).

Members of the Ecosystem Flow Working Group recognized that currently during the *very wet* and *wet* years (regimes WET 1 and WET 2) instream flows usually equaled or exceed the values listed in Table 5. Therefore, further analysis for these high-flow regimes at this time was deemed unnecessary; although, if increased water demand changes this situation then active management of these two regimes should be reevaluated. Table 7 presents the remaining six flow regimes proposed as experimental.

Table 7. Proposed experimental flow regimes for Lower Truckee River [a/] (in cfs).

Month	Flow Regime No. 1[b]	Flow Regime No. 2[c]	Flow Regime No. 3	Flow Regime No. 4	Flow Regime No. 5	Flow Regime No. 6
January	160	150	120	110	100	90
February	160	150	120	110	100	90
March	290	220	200	160	160	140
April	590	490	420	350	300	200
May	1000	800	600	530	400	300
June	800	600	500	400	270	170
July	300	300	300	200	150	120
August	200	200	200	200	150	110
September	170	170	120	110	100	100
October	160	150	120	110	100	100
November	160	150	120	110	100	90
December	160	150	120	110	100	90
Total (Acre-Feet)	**249,000**	**211,800**	**176,400**	**150,000**	**121,800**	**96,000**

[a] *Managed instream flows for the purpose of utilizing stampede Reservoir storage for the lower Truckee River.*
[b] *Based on 20 percentile (appendix A)*
[c] *Based on 10 percentile (Appendix A)*

Note:
(1) In years when natural flows in the Truckee River below Derby Dam are high during the spring runoff period (in excess of 1000 cfs for May and june), the recession flows during summer and fall months are managed to maintain 300 cfs in August-September and 200-250 cfs in October – December.
(2) Cottonwood recruitment flows are managed to have a decline not to exceed one inch per day.

Table 8 presents an interactive decision making process to choose a flow regime dependent on current water year condition (i.e., the forecast water supply from snow pack as measured at the end of winter) and storage in Stampede Reservoir. The criteria for the hydrologic condition and storage in Stampede Reservoir are given in Table 9 and 10 respectively.

Table 8. Decision Factors for selecting flow regimes based on yearly water availability and ecosystem needs.

Primary Decision Factors **Water Availability**
Amount of water in snow pack in March
Stampede Reservoir storage level
Other reservoir storage levels
Expected river flow before ecosystem flows
Expected reservoir flood surcharge

Secondary Decision Factors **Ecosystem Factors**
CUI-UI FACTORS
Time since most recent successful cui-ui spawn
Cui-ui population size
Cui-ui age class representation
RIPARIAN WOODLAND FACTORS
Last successful cottonwood tree recruitment
Availability of geomorphic surfaces for willow/tree recruitment
Presence of new cottonwood\willow (<5 years old)saplings on the banks
PELICAN FACTORS
Condition of the pelican population
Time since most recent significant recruitment to the pelican population
LCT FACTORS
LCT population size
Time since most recent significant recruitment of LCT
INVERTEBRATE AND RIVERINE ENVIRONMENT FACTORS
Target water temperatures for the year
Condition of the stream invertebrate community
Water supply to oxbow wetlands
Level of riparian drought stress conditions in most recent years
Time since flows equaled or exceeded effective discharge

Table 9. Criteria for hydrologic year types

Hydrologic Year Type	Stampede March – July Inflow [a] (acre-feet)
Wet	Greater than 150,000
Above Average	Greater than 107,000 and less than 150,000
Average	Greater than 76,000 and less than 10700
Below	Greater than 52,000 and less than 76,000
Dry	Greater than 30,000 and less than 52,000
Critical	Less than 30,000

[a] *Little Truckee River flow at Stampede dam site based on forecasted runoff for March through July*

Table 10. Stampede Reservoir storage levels

Storage Level	Stampede March storage a (Acre-feet)
Full	Greater than 200,000
High	Greater than 150,000 and less than 200,000
Low	Greater than 100,000 and less than 150,000
Critical	Less than 100,000

[a] *Project water in Stampede Reservoir on March 1*

The hydrologic year type and storage in Stampede Reservoir are cross-selected to form a flow regime selection matrix (Table 11). Flow regimes should be selected in March and then in subsequent months re-evaluate the water supply. River managers should change flow regimes if water supply significantly changes.

Table 11. Flow regime selection matrix

Storage Condition	Hydrologic Year Type					
	Wet	Above	Average	Below	Dry	Critical[a]
Full	1	1	1	1	3	4
High	1	1	2	2	4	5
Low	1	2	3	4	6	6
Critical[a]	2	3	5	6	6	6

Note: Designated numbers in the above matrix represent Flow Regime Nos. 2 through 6.

[a] Critical represents an extreme low water supply condition.

To test the proposed ecosystem flow methodology, Stetson Engineers used the selection matrix and Truckee Basin model simulations to determine the frequency of occurrence of flow regimes for the hydrologic period 1901-1997 (97 years) (Table 12). These model results show that the proposed methodology provides the variability expected in natural western river system, although the projected discharges are lower than the natural conditions. As these experimental flows are tested over a multiple year period, river managers should monitor indicators of ecosystem health to verify that the proposed flows will sustain the Truckee River ecosystem.

Table 12. Frequency of occurrence of flow regimes for hydrologic period 1901-1997 (97 years).

Year	Flow Regime	Year	Flow Regime	Year	Flow Regime
1901	1	1934	6	1967	1
1902	1	1935	5	1968	3
1903	1	1936	5	1969	1
1904	1	1937	5	1970	1
1905	1	1938	1	1971	1
1906	1	1939	3	1972	1
1907	1	1940	3	1973	3
1908	1	1941	1	1974	1
1909	1	1942	1	1975	1
1910	1	1943	1	1976	5
1911	1	1944	3	1977	6
1912	3	1945	2	1978	5
1913	4	1946	2	1979	6
1914	1	1947	4	1980	2
1915	1	1948	6	1981	4
1916	1	1949	6	1982	1
1917	1	1950	5	1983	1
1918	1	1951	2	1984	1
1919	2	1952	1	1985	1
1920	4	1953	1	1986	1
1921	3	1954	3	1987	4
1922	1	1955	6	1988	6
1923	1	1956	2	1989	5
1924	4	1957	1	1990	6
1925	6	1958	1	1991	6
1926	6	1959	3	1992	6
1927	9	1960	6	1993	3
1928	2	1961	6	1994	6
1929	6	1962	6	1995	2
1930	6	1963	5	1996	1
1931	6	1964	2	1997	1
1932	5	1965	2		
1933	6	1966	3		

Figure 7. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) Source: Laurie Moore

VI. LCT LIFE HISTORY CHARACTERISTICS

Historically, LCT occurred throughout the Truckee River drainage from the headwaters in California downstream to Pyramid Lake (Gerstung, 1988). The LCT in Pyramid Lake and Lake Tahoe were known regionally as a valuable food source consumed by the Pyramid Lake Paiute Tribe, the Washoe Tribe, early explorers and by commercial fishermen (Fowler and Bath 1981; Knack and Stewart 1984; Houghton 1994; Lindström et al. 2000).

LCT populations historically persisted in large interconnected aquatic ecosystems throughout their range (USFWS 1995). These systems were either lake habitats with tributary streams or large stream networks consisting of a river and tributaries. LCT can express both resident and migratory life histories such that resident forms use tributary habitats and migratory use both river and/or lake habitats in addition to tributaries. (Sigler et al. 1983; Northcote 1992, Rieman and Dunham 2000, Neville-Arsenault 2003) The Truckee River and tributaries connect several notable lakes (Lake Tahoe, Donner, Fallen Leaf, Independence and Pyramid Lakes) which produced large fish. Truckee River and its tributaries provided spawning and rearing habitat for fluvial and lacustrine life history forms. These forms are functionally different as they use different habitats and express different growth rates, fecundity and longevity (Harvey and Stewart 1991; Bozek and Hubert 1992). Pyramid Lake supported a population of the largest inland trout in North America (Sigler et al. 1983; Coleman and Johnson 1988; Gerstung 1988; Behnke 1992).

LCT evolved in a range of habitat types, including cold water high elevation streams to warmer, more alkaline lake environments. It is likely that localized, natural events historically caused the local extirpation of small populations of LCT. Those events included landslides and rock falls, fires, drought, and debris flows that restricted movement. LCT population persistence is associated with the ability to maintain connectivity among populations, i.e. networked populations. A networked system is defined as an interconnected stream and/or stream-lake system in which individuals can migrate or disperse into areas from which fish have been extirpated (Ray et al. 2000). This ability to disperse and repopulate habitats allows populations to persist (Dunham et al. 1997; Rieman and Dunham 2000; Ray et al. 2000; Neville-Arsenault 2003). Periodic repopulation by upstream or downstream sources enabled LCT to survive extreme circumstances and provided for genetic exchange (Neville-Arsenault 2003).

As subpopulations become isolated due to physical and biological fragmentation, migration rates decrease, local extirpation may become permanent, and the entire population may move incrementally toward extinction. Maintaining a networked population may provide the ability to recover LCT without having to establish fish in every tributary in the Truckee River basin.

LCT is adapted to a variety of lake habitats, from small alpine lakes to large desert terminal lakes (La Rivers 1962; Behnke 1992; Moyle 2002). LCT can tolerate higher alkalinity and TDS than other non-anadromous salmonids (Koch et al. 1979; Galat et al. 1983; Wright et al. 1993; Wilkie et al. 1993 and 1994; Young 1995). This characteristic allowed LCT to be successfully introduced to saline-alkaline lakes in Nevada, Oregon, and Washington for recreational purposes (Trotter 1987; USFWS1995).

Fluvial populations of cutthroat trout including LCT appear to be intolerant of competition or predation by non-native salmonids, and rarely coexist with them (DeStaso and Rahel 1994; Schroeter 1998; Dunham et al. 2000). However, while there is limited understanding of non-native salmonid interactions with lacustrine LCT, there are examples of co-existence in lake environments, e.g., the Independence Lake LCT population currently coexists with brook trout, brown trout, and kokanee (Lea 1968; USGS BRD in preparation).

Specific habitat requirements of LCT vary seasonally and with life stage. Like most cutthroat trout species, LCT are obligatory stream spawners which predominantly use tributary streams as spawning sites. Spawning typically occurs from April through July throughout the range of LCT, depending on stream elevation, stream discharge, and water temperature (USFWS 1995). Fish may exhibit three different strategies depending upon conditions, outmigration as fry, as juveniles, or remain in the river as residents (Ray et al. 2000; Neville-Arsenault 2003).

Fluvial LCT fed primarily on aquatic insects, zooplankton and terrestrial forms of food. The lacustrine form of LCT utilized habitat and food sources of lake environments, which include zooplankton and other fish species such as tui-chub (*Gila bicolor*), Lahontan redside shiners (*Richardsonius egregius*), speckled dace (*Rhinichthys osculus*), and Tahoe suckers (*Catostomus tahoensis*) (Sigler et al. 1983).

Dependent on river flow, trout were rather common throughout the entire course of the Truckee River before the river was altered by irrigation dams, factories and sewers (Snyder 1917). Seasonal increases in river flow stimulated mass movement of large trout from lakes and as river flows decreased large trout were less abundant in various reaches of the river. It is likely that a certain proportion of the hatched lacustrine form of LCT stayed in the tributaries and became acclimated to the local habitats and exhibited life history characteristics more typical of fluvial species.

Because the Truckee River basin has been altered removing important habitat elements that once supported LCT in the basin, more information is needed to characterize suitable habitat (river and lake) for all life stages to determine ecological requirements of a self-sustaining, interconnected network population of LCT. In the Truckee River/Pyramid Lake system, information on the thermal requirements of LCT is limited because the population was extirpated before basic ecological information was obtained. However, laboratory and field research show LCT can tolerate elevated water temperatures (Vigg and Koch 1980; Dickerson and Vinyard 1999; Dunham et al. 2002). Upper thermal limits from laboratory studies and research conducted on stream populations ranges from 22°C to 24°C (Dickerson and Vinyard 1999; Dunham et al. 1999; Meeuwig 2000; Dunham et al. 2002). Other investigations previously conducted, on-going, or in development within the basin that may provide ecological insights to restore an interconnected, self-sustaining network of LCT populations include: Development of specific ecosystem monitoring and inventory protocols to summarize and evaluate existing information and develop recommendations to improve data collection; effect of water quality on survival of LCT eggs in the Truckee River (Hoffman and Scoppettone 1984); an assessment of nonpont source pollution in the lower Truckee River (Lebo et al. 1994); introductions of LCT in selected reaches of the river to track their growth performance, movement and/or residency; perform a watershed assessment to identify water quality and migration barriers and connect access to desirable spawning and rearing habitat within the basin; and develop/implement hydrologic studies to evaluate site specific habitat improvement projects.

Non-Native Fish Species

Introductions of non-native fish into the Truckee River system began in the 1870s, both from private and public entities (Leitritz 1970). The addition of non-native salmonid species has contributed to the decline of most if not all cutthroat trout subspecies including LCT. In aquatic ecosystems modified by human disturbance, non-native fish species often become dominant and out-compete native fish species (Deacon and Minckley 1974; Shepard et al. 1997; Brandenburg and Gido 1999; Schindler 2000; Knapp et al. 2001; Zanden et al. 2003). At present, there are over 40 non-native fish species within LCT's historic range (Behnke 1992). Non-native salmonids have adverse effects on the distribution and abundance of native species in Sierra Nevada streams (Moyle and Vondracek 1985; Moyle and Williams 1990). The most prevalent non-native salmonids in the Truckee River are rainbow and brown trout. Kokanee salmon (*Oncorhynchus nerka*) and lake trout (*Salvelinus namaycush*) are prevalent in Lake Tahoe, Donner, and Fallen Leaf Lake. Brook trout and brown trout compete with cutthroat trout for space and resources (Gerstung 1988; Gresswell 1988; Griffith 1988; Fausch 1989; Hildebrand 1998; Schroeter 1998; Dunham et al. 1999). Rainbow trout, a closely related species, spawns at the same time and uses the same spawning habitat as LCT with which it interbreeds creating hybrids individuals. Lake trout, a voracious fish eater in Lake Tahoe, now occupy the trophic niche similar to that of historical LCT, as the top predator (Zanden et al. 2003). Carp and mosquito fish are the most common introduced species in the lower Truckee River. Non-native salmonid populations are maintained by release of hatchery-reared fish to provide additional recreational fishing opportunities.

Although the presence of non-native species have dramatically altered aquatic ecosystems, hybridization and competitive interactions between lacustrine LCT and non-native species is not well understood. The Independence Lake LCT have coexisted with non-native salmonids for the past 100 years (Gary Scoppettone, Section Chief, Western Fisheries Research Center, USGS, personal communication). Their coexistence provides opportunities to investigate minimizing the threat of hybridization and competition.

LCT Genetics

Recovery of LCT will involve habitat restoration as well as re-establishing populations of strains native to each of the three distinct population segments defined for this subspecies. Early genetic analyses (Loudenslager and Gall 1980; Gall and Loudenslager 1981; Xu 1988) revealed significant differentiation among LCT in the Walker, Carson, Truckee, Reese and Humboldt River drainages. Genetic differences may be the result of adaptations to different habitat types e.g., lake versus river dominated ecosystems.

The use of genetic data to make informed decisions about which LCT strains to use in recovery of western DPS waters will depend upon a working knowledge of both the extent of population differentiation among basins and the hierarchical relationships among populations within basins. Recent genetic analyses of Macklin, Edwards and Pilot Peak LCT, out-of-basin populations of putative Truckee basin native fish, represent a contemporary effort to identify all sources of fish native to the Truckee basin (Dunham et al. 1998; Nielsen 2000; Nielsen and Sage 2002). Similar analyses to evaluate fish believed to be native to the Walker and Carson basins are ongoing.

For recovery planning, genetics data will be used to:
(1) determine genetic relationships of populations within and among basins,
(2) assess levels of genetic variation per population, and
(3) compare levels of genetic variation among populations to help assess contemporary and past population dynamics and extinction risk.

Background

Phylogenetic analysis (phylo = historical, genetic = genes) is an analytical tool to determine evolutionary (or historical) relationships among populations, subspecies or species. This approach is based upon the general premise that the greater the number of genes individuals have in common the more closely related they are. An analogous human example would be individuals in a nuclear family are more genetically similar to one another than they are to their first cousins, first cousins in turn are more genetically similar to each other then they are to their second cousins and so on. This can be expanded to more distant relationships such as a comparison of individuals of English descent, who should be more closely related than they are to say individuals of Italian descent.

The historical relationships among populations within species or subspecies can be reconstructed using the genes found in contemporary individuals, i.e., the longer the time since populations or species had a common ancestor, the fewer genes they are likely to have in common. Thus it is both the genetic similarities and differences among individuals within populations and among populations that provide the information to elucidate historical relationships

Genetic data are typically more useful for phylogenetic analysis than morphological characters because they tend to be more variable, i.e., there are more traits to compare among individuals. As a result, genetic data have been routinely used to distinguish among populations, subspecies and species for the past 40 years (Lewontin and Hubby 1966; Avise 1994; Weir 1996).

Over the past thirty years, researchers at the University of California Davis, Brigham Young University, Clear Creek Genetics Laboratory (Boise, ID) University of Montana, Stanford University and the University of Nevada Reno have conducted genetic analyses on Lahontan cutthroat trout populations throughout its range (Loudenslager and Gall 1980; Gall and Loudenslager 1981; Leary et al. 1987; Xu 1988; Mirman et al. 1992; Williams et al. 1992; Williams et al. 1998; Dunham et al. 1998; Nielsen 2000; Nielsen and Sage 2002).

The University of Nevada Reno (Dunham et al. 1998; Peacock et al. 2001; Nielsen and Sage 2002) has spearheaded the compilations and evaluation of all existing genetic studies on LCT (see appendix H). Studies conducted to date, have used one type of or a combination of three classes of genetic markers: (1) proteins (allozymes) (2) mitochondrial DNA (mtDNA), and (3) nuclear DNA (microsatellites) which provide information on LCT evolution at different spatial and temporal scales (Table 13). The relatively recent discovery of a class of highly variable genetic markers, microsatellites, has greatly increased statistical power to detect genetic differences among individuals within and among populations (Chapuisat et al. 1997; Estoup et al. 1998; Baker et al. 1999). Microsatellites markers are currently being used to elucidate genetic relationships among LCT populations un-resolvable with other classes of genetic markers.

Historical and Contemporary Patterns

Genetics data support the designation of three evolutionarily distinct groups of populations or evolutionarily significant units (ESUs) within the historical range of LCT. These ESUs or distinct population segments (DPS) are defined as follows: (1) the Humboldt River basin populations including the Reese River populations, (2) populations in the Quinn River basin and (3) populations in the Truckee, Carson and Walker river drainages.

Historical populations within the Truckee, Carson and Walker river drainages are also distinct from each other and have been referred to as separate microgeographic races of LCT (Loudenslager and Gall 1980). Because divergence has occurred on a river drainage scale, recovery activities, e.g., transplantation of fish into recovered habitats should if possible involve fish native to the respective DPS and in some cases, fish native to individual drainages.

Table 13. Classes of Genetic Markers

Classes of Genetic Markers

- ***Allozymes*** *– protein products of nuclear DNA sequences. Allozymes are widely used for phylogenetic analyses. Their use is limited to identification of significant differences between genetically different populations. Closely related populations exhibit low levels of allozyme variation.*
- ***Mitochondrial DNA*** *– is a maternally inherited single molecule, which is widely used for phylogenetic analyses at the population, subpopulation and species level. The level of resolution of the mitochondrial DNA differences between and among populations and species is dependent upon the level of genetic variation. Mitochondrial DNA exhibits a faster rate of evolution than allozyme markers.*
- ***Microsatellites*** *– nuclear non-coding DNA that is highly variable. Microsatellites exhibit the highest and fastest rate of evolution and therefore has the highest accumulation of variation within and among populations. Microsatellites are use for phylogenetic analyses at population, subspecies and closely related species levels. Microsatellites are useful markers for examining relationships among populations at small spatial scales such as may be found in geographically close basins.*

There are few indigenous populations of LCT remaining in the Truckee River basin drainage. However genetic evidence suggests that original Truckee River basin fish reside in out-of-basin habitats such as Macklin, Morrison

(Pilot Peak) and Edwards creeks. Macklin Creek fish were used to reestablish populations in Pole Creek and the Upper Truckee River. These fish are currently being evaluated for use in recovery activities in the Truckee basin. Because this strain of the subspecies historically lived in the large interconnected Truckee River and Pyramid Lake system, it is likely that these fish are best suited for recovery of a naturally reproducing population in the Truckee basin.

Large interconnected stream and/or stream and lake habitats are thought to be crucial to long-term population persistence of cutthroat trout populations in desert environments. Genetic and demographic data from LCT populations in the Humboldt DPS, other cutthroat trout subspecies, and other inland trout species such as bull trout (Rieman and Dunham 2000; Ray et al. 2000) support this hypothesis. Most lacustrine LCT habitats are found in the western basin drainages, e.g., Independence, Pyramid and Walker lakes. LCT historically occupied all of these lake habitats. Lake habitat is not sufficient, however, for recovery of naturally reproducing populations, as river habitat is necessary for spawning and also provides habitat for younger aged fish, prior to migration back to lake habitat, and for fish that are resident in the river year round.

The large river systems in the eastern basin are comparable to the western lake and river systems in that the large mainstem rivers provide habitat analogous to the lake habitat for large LCT that adopt a migratory life history. Data from contemporary studies, as well as historical geological data, show that river and lake-habitats have periodically gone dry. The mainstem Mary's River in the Humboldt system went dry during the drought period in the early 1990s and was later re-colonized by fish from tributaries (Dunham and Vinyard 1996). Walker Lake has gone dry on at least three separate occasions during its history and has stayed dry ranging from 300-1000 years, only to be re-colonized by fish from river habitat in each instance. Walker Lake dried up (1) 11,000 years before present and was rewetted at ~10,750 years; (2) 5,000 years before present and rewetted at 4,000 years and again at (3) 2,500 years before present and rewetted at 2,000 (Benson 1988; Benson et al. 1991; Bradbury et al. 1989).

During these periods, fish found refugia in extant river habitats and re-invaded mainstem river and lake habitats when conditions were appropriate. The LCT subspecies is thought to be at least 30,000 years old and may have evolved in the late Pliocene Era, which predates the drying episodes in the Walker basin. These data also show that fish have the ability to successfully re-invade lake habitats despite living in river environments for considerable periods of time and strongly suggest that fish presently confined to river habitat do have the ability to utilize lacustrine habitat. Pyramid Lake has remained wetted throughout the history of pluvial Lake Lahontan and until early in the 20th century retained an intact fish fauna dating back to the Pliocene Era and perhaps earlier. Genetic evidence suggests that populations of the original Truckee basin strain of LCT are found in river habitat in out-of–basin locations. There is no evidence suggesting that present day Truckee basin fish, confined to river habitat for less than 50 years (a very short time period on an evolutionary timescale), have lost the ability to express both migratory (lake fish) and resident (river fish) life histories.

Determination of the appropriate strain or strains necessary to achieve recovery will be initially guided by the strategy outlined in the Recovery Plan (USFWS 1995) to maximize genetic variation of the remaining stocks of LCT. The strategy states that any isolated population of fishes is a potentially unique gene pool with characteristics that may differ from all other populations, and whenever possible, genetic stocks should be maintained within their historic basin source. The Recovery Plan (USFWS 1995) further states that recognition of the uniqueness of locally adapted LCT populations is recommended by many taxonomists and conservation biologists for restoration and future utilization of the resource.

The question of whether transplanted populations retain the genetic and ecological characteristics of the extirpated Pyramid Lake and Lake Tahoe populations can only be made based on a combination of scientifically peer reviewed genetic research, population viability analysis, and strain evaluation programs. Preliminary genetic research indicates that Pilot Peak LCT, collected from Morrison Creek and LCT from Edwards Creek in the Desatoya Mountains, are closely related to the Macklin Creek population, a known Lake Tahoe strain. This relation provides strong evidence for Truckee River basin origins of Pilot Peak and Edwards Creek LCT.   Strain evaluation and performance studies will be conducted within the scientific framework to determine which strains exhibit known Truckee River basin lacustrine life history characteristics such as large size (Behnke1992 and 1993), longevity (Benke 1992), and age at sexual maturity (Calhoun 1942, Lea 1968, King 1982). (For full description of the genetics issues, refer to Appendix G).

VII. SHORT-TERM ACTION PLAN

Short-Term Goals and Objectives

The purpose of the Short-Term Action Plan is to identify and prioritize actions for implementation during the next five years (the first five years of the Short-Term Action Plan) to facilitate the restoration/recovery of naturally reproducing lacustrine LCT. The goal is to present a specific five-year action plan for restoration of the Truckee River and Pyramid Lake ecosystem for recovery of LCT in conformance with the Recovery Plan (USFWS 1995).

Prioritization of recovery actions was central to the development of the Short-Term Action Plan. For example, the presence of fish passage barriers is a significant recovery issue fragmenting the ecosystem and acting as a constraint to recovery. While fish passage will be addressed over time, certain recovery actions can be implemented immediately that will address habitat conditions and promote re-colonization of historic habitats. Proactive measures, including the use of hatcheries and streamside egg incubation facilities, will “jumpstart” the recolonization process.

Stocking of fluvial LCT in selected headwater reaches, as identified in the Recovery Plan, will be continued to promote a transition in the fish community in support of native fish species. As outlined in the Recovery Plan (USFWS 1995) and in the short-term action, it is proposed that certain tributaries will be managed exclusively for LCT. The sequencing and prioritization of actions promotes recovery progress while future activities that require additional data or commitments of resources are assessed. The process of recovery will be implemented and evaluated through an adaptive management program.

Development of the Short-Term Action Plan associated with the recovery of the LCT in the Truckee River basin were assessed by addressing each action with the following screening criteria:

Each Short-Term Action should:

- Address a specific factor identified as impacting the ability of the LCT to sustain itself in the Truckee River basin.
- Relate directly to the Recovery Goal and Recovery Criteria.
- Tie directly to a specific agency and/or Tribal entity management action.

The development of short-term actions required information and knowledge regarding the Truckee River basin, understanding of the level and quality of the existing ecosystem information, and identification of technical and scientific areas of concern and opportunity. Once a baseline of information is determined, then development of specific short-term actions and a prioritization of those actions can occur.

Table 14. Geographic Areas of Concern

The Truckee River basin was divided into five geographic sections based on specific geomorphic, hydrologic and management issues.

	Basin / Watershed Area	Rationale
I	Above Lake Tahoe	Access to historically used spawning tributaries
II	Lake Tahoe	Historical lacustrine habitat
III	Truckee River from Lake Tahoe to East McCarran Bridge	Mainstem Truckee River through the canyon environments
IV	Truckee River from East McCarran Bridge to Pyramid Lake	Mainstem lower Truckee River
V	Pyramid Lake	Historic lacustrine habitat

The TRIT focused initial efforts on developing a better understanding of primary sources of information and data that the various agencies, Tribes, and groups have on the Truckee River basin.

After a review of the existing information, the TRIT team identified five primary areas of technical and administrative concerns with which short-term tasks could be categorized.

Table 15. Areas of Specific Technical Concern

Topic	Reference	Listing Factor
General Issues	Applicable to all areas of technical concern	General concerns that support specific species responses
Genetics and Population dynamics	Strain issues Networked populations	Fish populations
Physical habitat and environment	Location, distribution, and access	Habitat loss
Biological and limnological (chemical) environment	Water quality, biological processes	Biological sustainability
Recreation	Fishing and water use	Habitat and people impacts

The TRIT focused on identifying specific actions that could address the following questions:

1. Does the short-term action address a specific threat or issue in the Truckee River basin that led to the listing of LCT?
2. Does the short-term action address the goal of LCT recovery?
3. Can the short-term action be assessed against the criteria for recovery established by the TRIT?
4. Can the short-term action be accomplished in a timely and cost effective manner?
5. Are prerequisite studies required prior to implementation of the short-term action?

Truckee River Basin Short-Term Actions

The actual short-term tasks identified by the TRIT are a result of approximately three years of discussion, debate, evaluation and recommendation. The short-term tasks identified in the next five tables comprise the Short-Term Action Plan as part of the recovery effort for LCT in the Truckee River basin. Six groups of short-term tasks are identified for the Truckee River basin.

- Group A – General integrating issues
- Group B – Genetics and population dynamics
- Group C – Physical habitat and environment
- Group D – Biological and limnological (chemical)
- Group E – Recreational fisheries
- Group F – Specific Locations

Once the short-term tasks were identified, the TRIT determined the timeframe for each proposed short-term action. Each action was assigned a timeframe in terms of when in the process the individual action should be implemented. The assigned priorities are as follows: Year 1-3 high priority and need; Year 3-5 medium priority or need for prerequisite study to be completed; and year 5+ lower priority or action that could begin and/or continue beyond year 5 if conditions and information needs dictate.

Responsibility for implementing the specific actions has not been designated. This task will occur after the MOG reviews the recommendations and direction for implementation occurs. Six task groups reflecting the approach outlined above are presented in Tables 16 through 21. Items marked with a "+" are noted as extending beyond the initial five-year period.

Table 16. Short-term Tasks for Recovery Task Group A General Integrating Issues

TASK	TITLE	TIMELINE	RESPONSIBILITY
A1	**Document existing data and the level of analysis required to make useable by the TRIT**	**HIGH Yrs 1-5**	**USFWS data acquisition with handoff to other TRIT members**
A1a	Develop an integrated GIS-based data system and identify specific analytical tools for analysis	Yrs 1–5+	
A1b	Compile all fish management plans, regulations and data	Yrs 1-2	
A1c	Compile existing water management plans, policies, regulations and data	Yrs 1-2	
A1d	Compile existing habitat, data, and other land management plans	Yrs 1-2	
A1e	Compile existing multiple use and Tribal resource management plans as appropriate	Yrs 1-2	
A1f	Identify landowners who may be partners in LCT recovery efforts	Yrs 1-5+	
A1g	Identify and evaluate existing water quality, sediment and flow data	Yrs 1-5+	
A2	**Develop an education and outreach program for TRIT activities (would be coupled with MOG outreach program)**	**HIGH Yr 1**	**USFWS initiate with handoff to CA, NV, FS, and PLPT**
A3	**Continue to develop longer-term tasks for implementation of the**	**MEDIUM Yrs 3-5**	**TRIT**

	TRIT plan and tie to adaptive management plan		
A4	**Develop monitoring plans for LCT recovery efforts with specific protocols. Link to adaptive management program (tie to specific B, C, D, and E tasks)**	**MEDIUM Yrs 3-5**	**Action agency**
A5	**Determine necessity and level of peer review necessary for tasks on a case-by-case basis**	**LOW Yrs 4-5**	**TRIT**

Table 17. Short-Term Tasks for Recovery Task Group B Genetics and Population Dynamics

TASK	TITLE	TIMELINE	RESPONSIBILITY
B1	**Identify native and non-native salmonid populations that are maintained by natural reproduction**	**HIGH Yrs 1-5**	**States with funding**
B2	**Identify the role of hatcheries in Truckee River basin LCT recovery. Develop HET to coordinate remaining B2 tasks**	**HIGH Yrs 1-5**	**USFWS initially to Hatchery Evaluation Team (HET)**
B2a	Organize a hatchery evaluation team to coordinate remainder of B2 tasks	Yr 2	USFWS initially to HET
B2b	Develop/Implement hatchery management techniques and protocols for LCT propagation and broodstock development and maintenance	Yrs 2-5	
B2c	Develop/Implement production objectives for Federal/State/Tribal LCT hatcheries to assist in recovery program	Yrs 2-5	
B2d	Compile and evaluate stocking records for existing populations (LCT and other salmonids) or those planned for recovery actions	Yrs 2-5	
B2e	Determine what additional research will be required for growth and performance assessments	Yrs 2-5	
B2f	Identify locations and opportunities to improve LCT broodstock and propagation programs	Yrs 3-5	

B3	**Develop report on hybridization potential and technical studies needed to identify/characterize hybrids**	**LOW** **Yrs 4-5**	**USFWS and UNR**
B4	**Complete genetic research and reports**	**HIGH** **Yrs 1-2**	**UNR with funding from others**
B4a	Develop recommendations for implementing and evaluating genetic management programs	Yr 2-5	
B4b	Determine which strains of LCT should be used in the Truckee basin recovery efforts	Yrs1-2	Basinwide TRIT

Table 18. Short-Term Tasks for Recovery Task Group C Physical Habitat and Environment

TASK	TITLE	TIMELINE	RESPONSIBILITY
C1	**Develop and/or support a quarterly water quality sampling and analysis program for Truckee River Basin including Pyramid Lake**	**MEDIUM** **Yrs 1-3**	**USFWS with handoff to entities upon initiation**
C1a	Evaluate existing plans and protocols	Yr 1	
C1b	Identify cumulative, cause and effect relationships of point and non-point source pollutants	Yrs 1-2	
C1c	Recommendations for future water quality monitoring	Yrs 2-3	
C2	**Identify and evaluate fish passage and existing barriers within the Truckee River Basin**	**MEDIUM** **Yrs 3-5**	**USFWS initially**
C2a	Recommend passage and barrier activities	Yrs 3-5	
C3	**Develop watershed analysis of the physical components of the Truckee River Basin**	**HIGH** **Yrs 1-5+**	**USFWS initially and then transfer to agencies**
C3a	Summarize and evaluate existing information	Yrs 1-3	
C3b	Prioritize river sections for assessment	Yrs 1-3	
C3c	Develop recommendations	Yr 3	
C3d	Develop watershed and regional partnerships	Yrs 3-5	

C3e	Evaluate cumulative, cause and effect relationships	Yrs 3-5	
C3f	Link to GIS data system	Yrs 1-5+	
C4	**Develop specific ecosystem monitoring and inventory protocols for future data collection and assessments**	**MEDIUM Yrs 3-5**	**TRIT with agency Implementation**
C4a	Summarize existing information · Biological · Physical	Yrs 3-5	
C4b	Evaluate existing information	Yrs 3-5	
C4c	Develop recommendations for priority	Yrs 3-5	
C4d	Link to GIS data system	Yrs 1-5+	
C5	**Develop and implement hydrologic studies for the Truckee River**	**HIGH Yrs 1-3**	**USFWS, agencies and PLPT**
C5a	Evaluate historical studies and determine what additional information and analysis necessary	Yrs 1-3	

Table 19. Short-Term Tasks for Recovery Task Group D Biological and Limnological

TASK	TITLE	TIMELINE	RESPONSIBILITY
D1	**Identify where LCT existed in the past and what species assemblages exist there now**	**HIGH Yrs 1-2**	**USFWS**
D1a	Review historic information and document LCT specific information	Yrs 1-2	
D1b	Conduct oral history reviews with Tribal members, historians, ranchers and fishermen	Yrs 1-2	
D2	**Develop, implement, and monitor a Wild LCT Management Plan that will not impact donor or newly established populations**	**HIGH Yrs 1-5**	**States and PLPT**
D2a	Monitor population abundance and variability	Yrs 1-5+	
D2b	Determine minimum number of fish and/or eggs from donor populations to establish populations required to support recovery	Yrs 2-3	
D3	**Develop specific fish distribution GIS overlays for both native and non-native fish**	**HIGH Yrs 1-3**	**USFWS initially with handoff to states and PLPT**

D3a	Identify fish assemblages by reaches	Yr 1	
D3b	Identify fish densities/population structure	Yrs 1-2	
D3c	Document life history requirements for each species and determine biological overlap	Yrs 2-3	
D3d	Identify fish distribution patterns (by season)	Yrs 1-2	
D4	**Evaluate the extent of non-native fish survival in the Truckee River basin and develop approaches to minimize the effects of non-native salmonid populations on LCT recovery**	**MEDIUM Yrs 3-5**	**USFWS with handoff to research entities**
D4a	Identify and evaluate the potential impacts to LCT of self-sustaining non-native salmonid populations and recommend appropriate actions	Yrs 1-5+	
D4b	Develop and implement measures to reduce or eliminate impacts of non-native salmonid populations to extant or introduced LCT populations where appropriate	Yrs 1-5+	
D5	**Initiate habitat surveys to evaluate potential LCT introduction streams and validate against existing LCT inhabited streams**	**MEDIUM Yrs 3-5**	**TRIT develop process with handoff to agencies**
D5a	Complete C3 and C4 tasks	Yrs 1-3	
D5b	Implement physical and biological protocols. Concentrate on interconnected, networked population approach outlined in genetics section	Yrs 3-5+	

Table 20. Short-Term Tasks for Recovery Task Group E Recreational Fisheries as Related to LCT Recovery

TASK	TITLE	TIMELINE	RESPONSIBILITY
E1	**Evaluate the potential of LCT recovery as a recreational fishing opportunity**	**HIGH Yrs 1-5+**	**USFWS with handoff to states with funding**
E1a	Summarize and evaluate existing information	Yrs 1-2	
E1b	Develop recommendations for study and/or assessment	Yr 2	
E1c	Implement specific studies and/or actions as appropriate	Yrs 1-5+	

E1d	Develop marketing program for recreational LCT fishing opportunities	Yrs 1-5+	
E2	**Determine the interaction of LCT recovery on the Pyramid Lake recreational fisheries**	**LOW Yrs 4-5**	**USFWS, States and PLPT with funding**
E2a	Summarize and evaluate existing information	Yrs 4-5	
E2b	Develop recommendations for monitoring, study and/or assessment	Yrs 4-5+	
E2c	Implement monitoring, specific studies and/or actions as appropriate	Yrs 4-5+	

Table 21. Short-Term Tasks for Recovery Task Group F Site Specific Actions Related to LCT Recovery

TASK	TITLE	TIMELINE	RESPONSIBILITY
F1	Hunter Creek	HIGH	TRIT with NDOW
F2	Mainstem Truckee River - East McCarran Bridge to Pyramid Lake	HIGH	NDOW/PLPT/USFWS
F3	Sagehen Creek	MEDIUM	TRIT with CDFG
F4	Fallen Leaf Lake	MEDIUM	USFWS with TRIT
F5	Mainstem Truckee River - Lake Tahoe Dam to Donner Creek	HIGH	CDFG and USFWS
F6	Coldstream Creek	MEDIUM	TRIT
F7	Independence Lake	HIGH	USGS and TRIT
F8	Perazzo Creek	HIGH	USFWS, FS, and CDFG
F9	Martis Creek*	MEDIUM	TRIT

*- Martis Creek has the long-term potential to benefit recovery of LCT when it is reconnected to the mainstem Truckee River. When the system is reconnected, Martis Creek will provide important spawning and rearing habitat. The TRIT, working with partners and the local community, including anglers and guides, will initiate a planning effort to develop solutions to restore connectivity of the Martis Creek system to the mainstem Truckee River.

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