Upper Truckee River Restoration Project

California Department of Parks and Recreation Reach

Riparian Ecosystem Restoration Feasibility Report

Upper Truckee River Restoration Project

California Departments of Parks and Recreation Reach

Riparian Ecosystem Restoration Feasibility Report

Prepared For:
Lake Tahoe Golf Course
2500 Emerald Bay Road
South Lake Tahoe, CA 96150
and
California Department of Parks and Recreation
Sierra District Resource Office
P. O. Box 16
Tahoe City, CA 96145

Prepared By:

RIVER RUN
c o n s u l t i n g
P. O. Box 8538
Truckee, California
96162
530 550 7629
mkiesse@exwire.com

In Association with
Eco Synthesis
Wildlife Resource Consultants
Hydro Science
Piedmont Engineering
Haen Engineering
Elizabeth Doherty Graphic Design

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Upper Truckee River has been negatively impacted by land use practices since Europeans settled the Lake Tahoe Basin. Comstock Era timber harvest increased erosion and flooding, and the transport of logs on the river caused direct impacts on the channel. Farming and ranching practices altered the channel and surrounding floodplain. In many locations, particularly in the lower portion of the river downstream of Meyers, the channel was straightened and enlarged to protect or improve farming operations. Much of the former marsh and delta at the mouth of the river was lost to accommodate residential development. The river was channelized and adjacent floodplain occupied in the construction of an airport. Adjacent floodplain was highly altered in the development of a golf course in the project reach. Downstream of Meyers, the river ecosystem of at least half of the length of the Upper Truckee River has been highly modified, resulting in the loss of habitat and water quality protection. These historic and ongoing modifications have negatively impacted the ecologic and geomorphic function of the Upper Truckee River.

The California Department of Parks and Recreation (CDPR) owns the reach upstream of Elks Club near Sawmill road to just downstream of the highway 50 crossing at Meyers. The CDPR property includes a Washoe Meadows State Park and Lake Valley State Recreation Area which includes the Lake Tahoe Golf Course. The golf course reach was identified as the greatest opportunity for rehabilitation in the "Upper Truckee River Upper Reach Environmental Assessment report" by Swanson Hydrology and Geomorphology (SH&G). SH&G recommended 4 possible options, ranging from (1) no action, (2) hard engineering (riprap), (3) creation of inset flood plain, to (4) restoration. This document reviews and summarizes a conceptual stream and ecosystem restoration project within CDPR property. Although several other restoration projects are currently being planned for the lower UTR, many significant constraints to full geomorphic or ecosystem restoration exist. The Washoe Meadows project represents a unique opportunity for restoration of the lower UTR because there are few constraints on project planning and implementation due to public ownership by CDPR (such as concerns about flooding on infrastructure or other potential restoration impacts).

Within the project area, the UTR has been channelized, resulting in a straighter and deeper channel. The stream responded to human disturbance by incising relative to the floodplain, which is now flooded less frequently. The stream has continued to adjust to past disturbance, resulting in high rates of instability. Construction of the golf course, much of which is in the former floodplain, has resulted in the loss of native riparian vegetation, including wet and mesic meadows and willow shrub-scrub. Because the golf course was constructed after major channel modifications in the project area, and significantly constrains the channel with bridges and fairways and greens on streambanks, it has also essentially locked the river into a modified alignment. Channel instability continues as the stream adjusts to past channel modifications, and maintenance of golf course infrastructure has become a continual problem, requiring extensive bank stabilization measures.

Human disturbance of the UTR within the project area, and resulting channel instability, have had a number of negative consequences for the stream ecosystem. Instream habitat is of poor quality, and former spawning habitat for salmonids has been lost. Riparian shrubs and meadows have been converted to golf course. The beneficial effect of disturbance caused by regular flooding on riparian habitats has been lost. Ongoing erosion threatens water quality in the stream and in Lake Tahoe, and the loss of overbank flooding no longer allows for the improvement of water quality by settling sediment on adjacent floodplain, or the uptake of nutrients by floodplain vegetation.

The primary objectives of the proposed project are to restore riparian ecosystem processes and function, and to restore stream geomorphic function. CDPR's goals for the project include:

- restore, to the extent possible, ecosystem function to the CDPR reach of the Upper Truckee River through restoration of natural geomorphic processes which sustain channel and floodplain morphology, and in turn promote the establishment of functional riparian vegetation communities, ecological processes and aquatic habitat;
- reduce erosion and improve water quality;
- reduce the impact of the golf course on the river, water quality, and riparian habitat;
- maintain recreation opportunities, including relocation and reconstruction of part of the golf course on higher capability lands in accordance with the highest environmental standards; and
- minimize risk in relation to expected benefits

Meeting these goals will require recognition that functional streams are dynamic over time. Available evidence indicates that, prior to human disturbance, the UTR channel was dynamic, both through slow migration of meander bends and through more rapid channel migration during larger floods. Riparian and aquatic ecosystems have evolved in response to the dynamism inherent in functional stream channels; many aspects of ecosystem function are dependent on the disturbance resulting from channel dynamics. Thus the restoration plan must allow for channel dynamics and channel change over time.

The proposed restoration plan has two basic components; passive restoration and active restoration. Passive restoration, or the removal of impacts to ecosystem and geomorphic function, is the essential first step in restoration planning. Thus, the first and most important restoration action is to remove golf course infrastructure from the historic floodplain area. This step requires removing greens, fairways, tees, bridges, irrigation system in former floodplain areas and potentially relocating them in nearby uplands, areas more suitable to this land use. Passive restoration is important to ecosystem restoration in the project area because it will allow for functional channel configuration and channel dynamics over time.

The second component of this plan is active restoration, the objective of which is to restore channel and floodplain processes and vegetation communities. The active restoration plan outlined in this document is designed to meet multiple objectives: restoration of geomorphic function; aquatic and riparian habitat restoration; water quality improvements; and reduction of maintenance of golf course facilities. Because regular disturbance by flooding, including some erosion, is critical to sustaining function in riparian plant communities, this plan seeks to restore natural rates of erosion and deposition rather than to completely stabilize all streambanks.

The active restoration plan calls for restoring length to the channel, and raising the channel bed. The new channel would incorporate segments of the existing channel with reactivation of abandoned meanders coupled with reconstruction of some obliterated meanders. Abandoned meanders that were active in the 1940's and 1950's, features that still exist, would be incorporated into the channel design. This would improve constructability of the restoration project as these meanders are currently well-vegetated. Over 50% of the existing channel would be retained, improving stability and construction feasibility. Grade control, and increases in channel elevation, would be accomplished through the use of coarse riffles at regular intervals within the channel. This restoration technique has been used in other Tahoe Basin projects with success. More highly engineered grade controls would be constructed at the upstream and downstream ends of the project area to assure stability and transition to downstream elevations. Finally, revegetation treatments would be applied to the former golf course to restore native vegetation communities.

This restoration plan would provide several important benefits. Merely removing the golf course from the floodplain would eliminate the need to manage the river to assure the stability of golf course infrastructure, including some under-sized bridges. Rip-rap and other measures that degrade stream function would no longer be required. Removal of the golf course would also allow for natural channel dynamics, an important requirement for the establishment of functional riparian vegetation communities. Important water quality benefits would be realized as well, by moving fertilization and irrigation out of the floodplain. And moving the golf course away from the river paves the way for active restoration measures, such as the reestablishment of riparian meadow and shrub vegetation communities.

Active river restoration, lengthening and raising the channel, would increase the amount and improve the quality of instream habitat. The river would flood the adjacent floodplain more frequently, providing the regular disturbance necessary to restore functional riparian vegetation communities. Streambank height and channel slope would be reduced, resulting in more stable banks and less erosion. More regular overbank flow would improve water quality, with fine sediment deposited on the floodplain during floods. Higher groundwater tables would enhance adjacent riparian vegetation communities and would provide water quality benefits by allowing for more effective nutrient uptake by plants. Over 45 acres of vegetation currently in golf course management would be converted to native vegetation types. Most of this converted vegetation would be riparian communities, such as wet and mesic meadows and riparian shrub.

The ecosystem consequences of moving the golf course to adjacent upland were also analyzed within this study. Potential ecological impacts and mitigation measures were summarized. No major ecological obstacles to golf course relocation were identified. Ecological benefits over the current configuration include:

- Better water quality protection through the construction of state-of-the-art water quality protection measures, such as computerized irrigation, effective sub-drains, and wetland treatments.
- Removal of golf course habitat impacts from relatively rare vegetation communities that have been significantly disturbed by human development (riparian meadows and shrub-scrublands) to a vegetation community type far more widely distributed and less disturbed in the basin (pine forests).

Finally, the feasibility of implementing the project was analyzed. The recommended construction techniques have been implemented in other Tahoe Basin projects and are feasible. Measures for protecting water quality in construction practices are outlined, including construction phasing, isolation of newly restored areas to allow for vegetation establishment, and use of clean substrates. Similar measures have been successfully implemented on other Tahoe Basin restoration projects. This analysis concludes that the project can be feasibly constructed while protecting water quality.

In summary, the restoration project for the UTR within Washoe Meadows State Park would provide important ecosystem restoration benefits, resulting in better riparian and aquatic habitat and improvements in water quality. This restoration project represents a unique opportunity to restore riparian ecosystems and geomorphic function to a reach of the UTR, the largest tributary to Lake Tahoe.

INTRODUCTION

Swanson Hydrology and Geomorphology (SH+G 2004) identified four alternatives for restoration of the Upper Truckee River (UTR) and its associated riparian ecosystem in the vicinity of Washoe Meadows State Park, located about five miles south of the city of South Lake Tahoe (Figure 1). Through a series of public meetings and meetings with agencies, Alternative 4, full geomorphic restoration of the river and relocation of some of the current golf course, was identified as a preliminary preferred alternative for additional consideration. This document, prepared for American Golf Corporation and California State Parks, further analyzes and develops the full restoration alternative to a conceptual level prior to full environmental analysis.

This study was completed in order to:

- Refine the full restoration alternative, considering geomorphic factors, ecosystem function, and construction feasibility
- Describe ecosystem benefits and potential impacts, both short and long-term
- Identify potential impacts that are not compatible with ecosystem restoration, the primary objective of the project
- Identify possible refinements to the preliminary project design that would minimize or avoid impacts
- Identify impacts that would be difficult or take undue periods of time to mitigate
- Examine construction feasibility, identifying construction issues that may be difficult to resolve, and providing conceptual guidance regarding phasing, construction techniques, or other construction issues.

PROJECT BACKGROUND AND OBJECTIVES

The Upper Truckee River is the largest tributary to Lake Tahoe. Impacts of various land use practices in the river corridor, including the Tahoe Keys, the Lake Tahoe airport, the Lake Tahoe golf course, and historic and current grazing, have led to concerns regarding erosion and the effects on Lake Tahoe. The river flows through two contiguous units of California Department of Parks and Recreation (CDPR) lands: Washoe Meadows State Park, and the Lake Valley State Recreation Area, which encompasses an 18-hole golf course. American Golf Corporation manages the golf course under a lease from CDPR.

The Upper Truckee River has been an important component of State Park management and planning for this park. As the largest tributary to Lake Tahoe, the Upper Truckee and its adjacent riparian meadows represent a unique and relatively rare ecological resource, and are important to Lake Tahoe water quality (Murphy and Knopp 2000; Simon et al. 2004). Preservation and restoration of the river corridor is an important factor in the management of CDPR lands.

The Upper Truckee River has also been the focus of planning efforts by other organizations. The Tahoe Resource Conservation District, with a grant from the Bureau of Reclamation, undertook a watershed assessment of the Upper Truckee River from the middle highway 50 bridge to the upper portion of the watershed. This assessment, by SH+G (2004), proposed a series of alternatives to improve ecologic and geomorphic function of the river and watershed. These alternatives included (1) no action, (2) hard engineering (riprap), (3) creation of inset flood plain, and (4) full restoration of geomorphic and ecosystem processes. CDPR held a series of meetings with the public and with Tahoe Basin agencies to discuss the results with respect to CDPR lands, and to gain feedback on preferred approaches for restoration. In these meetings, both agencies and the public generally supported Alternative 4, full restoration of geomorphic and ecosystem processes.

This restoration alternative meets CDPR management guidelines for the UTR. Specifically, the primary objectives of the proposed project are to restore riparian ecosystem processes and function, and to restore stream geomorphic function. CDPR's goals for the project include:

- restore, to the extent possible, ecosystem function to the CDPR reach of the Upper Truckee River through restoration of natural geomorphic processes which sustain channel and floodplain morphology, and in turn promote the establishment of functional riparian vegetation communities, ecological processes and aquatic habitat;
- reduce erosion and improve water quality;
- reduce the impact of the golf course on the river, water quality, and riparian habitat;
- maintain recreation opportunities, including relocation and reconstruction of part of the golf course on higher capability lands in accordance with the highest environmental standards; and
- minimize risk in relation to expected benefits

PROJECT OVERVIEW

In the following section, the characteristics of the Upper Truckee River watershed are described. It is important to note that all portions of river systems are interconnected; restoration of individual reaches must account for factors outside of the immediate project area. To provide a context for the restoration project within the entire watershed, aspects of geomorphic and ecosystem function of the much of the system are reviewed in the following section.

The lower portion of the Upper Truckee system, from the project area downstream to Lake Tahoe, has unique characteristics. Channel gradient is lower than upstream reaches, and large riparian meadows are found. Because landforms, vegetation communities and habitats in the lower part of the system have important ecosystem values, particular attention is paid in the following discussion to the entire lower Upper Truckee River system.

GEOLOGIC SETTING

SH+G (2004) provides a review of the UTR watershed, over 54 square miles in area, the largest in the Lake Tahoe Basin. The bedrock is predominantly granitic, but there are significant outcrops of Tertiary age volcanic rocks in the steep upper portion of the watershed (SH+G 2004).

SH+G (2004) notes that there are five distinct geological segments in the watershed based on landform and channel characteristics. The first segment is the upper watershed, which is a large cirque, with extensive glacial scour and till deposits. The lower portion of this segment is a steep glacial step with high stream gradient. The next segment downstream is Christmas Valley, from South Upper Truckee Road downstream to Meyers. The valley is relatively narrow, but with a flat bottom. The floodplain is bounded by moraines and outwash terraces. Wider portions of the valley contain some riparian meadow development, although gradients are higher and width of the floodplain is lower than in downstream reaches.

SH+G notes that the character of the valley and floodplain change significantly at Meyers. This is the upstream end of the third segment, which runs from the Highway 50 crossing at Meyers downstream to the Highway 50 crossing at Elks Club road, and includes the project area. The river and floodplain are far less confined by valley walls. The river flows over a broad valley flat composed of outwash and more recent alluvial deposits. SH+G's third segment can be further sub-divided into 2 sub reaches. A fairly distinct transition in channel and floodplain form occurs midway through the project area. In the upper sub reach, although the river is relatively unconfined by valley walls, the river flows within a relatively narrow recent floodplain, bounded by terraces of either outwash or abandoned modern floodplain. The lower sub reach has a different valley form. The valley flat becomes wider, with extensive areas of meadow adjoining the river through the middle and lower portions of the project area. Much of this meadow is an older alluvial fan on the south side of the river. It is also important to note that the lacustrine formations, deposited during higher lake stands, first occur in the project area (Figure 2). Thus the project area is a transition from a floodplain entrenched in glacial deposits to a broader meadow, much of which has been more influenced by modern alluvial processes than the outwash terraces.

Directly downstream of the project area is SH+G's 4th geological segment, encompassing the Sunset Ranch and the Lake Tahoe Airport, where landforms consist of broad meadows. A small portion of this segment, just downstream of the project area, is somewhat more confined, and is probably entrenched in outwash or till deposits. Channel form becomes progressively more meandering downstream through this reach.

The 5th and final segment identified by SH+G is the lowest portion of the river, from the lower Highway 50 crossing to the lake. This reach has been strongly influenced by lake base level; the lower portion is deltaic in form, with distributary morphology. Extensive meadows and marsh are found in this segment.

GLACIATION

The glacial history of the Upper Truckee River watershed was reviewed by SH+G (2004). Tioga glaciers (about 18-26k years before present (ybp)) do not appear to have progressed further downslope than Meyers. However, Tahoe moraines (60-90k ybp) are mapped on the west edge of the project area, and pre-Wisconsin (Donner Lake, 400-600k ybp) moraines are found to the east. Much of the valley floor through the project area is composed of outwash and reworked till from these glaciations and subsequent entrenchment and fluvial reworking during interglacials. Much of the sediment available locally to the modern river is found in outwash terraces, particularly in the reach upstream of the project area.

Changing lake levels throughout the Pleistocene and early Holocene have also strongly influenced sedimentology of the valley flat along the lower river. Based on the elevation of Donner Lake till in the Truckee River canyon downstream of Lake Tahoe, Birkeland (1963) suggest that the lake may have been impounded by ice during this time to an elevation of about 6,840 ft, a rise of 600 ft, about the current elevation of Page Meadow. Evidence for this high lakestand includes a prominent bench at about elevation 6,800 ft throughout the Lake Tahoe basin, though Birkeland (1963) notes that lakestands at this elevation may have been due to volcanic flows. He also notes that deltaic sands and gravels just north of Ward Creek at an elevation of 6,440, near the top of the Ward Creek alluvial fan, are pre-Wisconsin in age and may be Donner Lake.

Birkeland (1963) also suggests that Tahoe glaciation tills in the Truckee River canyon are evidence for lakestands up to 6,440 ft., or about 210 ft. above current lake level. However, there is no evidence for a lakestand at this elevation in the Lake Tahoe basin, though there are several terraces around the lake at 6,320 ft, or about 90 ft. above current lake level. Birkeland (1963) concludes that if the higher lakestands occurred during the Tahoe glaciation, they did not persist for long periods, and that the evidence supports maximum lake levels of around 90 ft. There is also a prominent 40 ft. (elevation 6,280 ft.) high terrace in several locations around Lake Tahoe, and Birkeland attributes this to Tahoe glaciation high lakestands as well. He notes that evidence of Tioga glacial advances in the Truckee River canyon suggests that ice may have caused local damming, but was unlikely to have substantially raised the surface of Lake Tahoe.

It is important to note that the high lakestands produced by glacial damming would have been relatively ephemeral; because ice is lighter than water, glacial dams tend to fail as the lake behind them fills. The resulting floods, termed jokulhlaups, often are of extremely high magnitude. Glacial Lake Missoula, whose failure resulted in the spectacular Bretz Floods across eastern Washington and through the Columbia Gorge, is thought to have filled at least 40 times during the last glaciation based on rythmites in flood deposits (Allen and Burns 1986).

Within the project area, the lower portion is mapped as lacustrine deposits, grading into Tahoe morainal deposits at the upstream end. The upstream end of the project area is near the upper end of Tahoe stage high lakestands. There was likely a delta in this area in Tahoe times, with coarser outwash deposits grading into fine-grained lacustrine deposits. Tioga and recent floodplain processes have reworked these deposits. Upstream of the Tahoe delta, the more recent fluvial processes have entrenched within the older Tahoe outwash, resulting in the modern floodplain entrenched within Tahoe and Tioga outwash terraces. A distinct transition occurs near the upstream end of the project area, downstream of which well-bedded, sorted and compact Tahoe age lacustrine deposits are the primary unit. Similar to reaches above the project area, Tioga and recent fluvial reworking of these deposits has occurred, but the underlying Tahoe deposits are of a different character.

The lacustrine deposits strongly influence channel form and function within the lower half of the project area. In many locations, resistant outcrops on the streambed influence channel gradient. Simon et al. (2004) noted that these resistant outcrops also influence patterns of streambank erosion. Mussetter Engineering, Inc. (2000) suggests that resistant lacustrine deposits have limited widening subsequent to incision.

Another transition through deltaic deposits associated with lower lake stands occurs at the downstream end of the project area, from the Highway 50 (Elks Club) crossing downstream to the upper end of the Lake Tahoe airport. From this area downstream, broad meadows are primarily mapped as lake deposits. Mussetter Engineering, Inc. (2000) notes that lacustrine deposits in the meadow just upstream of the lower Highway 50 (South Lake Tahoe) crossing are relatively young.

SOILS

The majority of the soils through the project area are Celio series (Figures 3a and 3b). These are poorly drained soils developed on the modern alluvial floodplain, 40-60 inches deep over a very gravelly hardpan strongly cemented with silica. Downstream of the project, valley bottom soils are loamy alluvial land. These soils are also fluvial deposits, poorly drained, and underlain by lake deposits (Mussetter Engineering, Inc. 2000). Near the downstream Highway 50 crossing, the lake deposits are likely recent, and are Pleistocene in age near the upstream end of the airport.

HYDROLOGY

SH+G (2004) extensively reviewed hydrology of the Upper Truckee River, and developed flow statistics based on a stream gauge at Meyers. The hydrograph is dominated by snowmelt (Figure

4). Base flows are typically low in late summer, and there is little augmentation by summer precipitation.

Peak flows are typically the result of snowmelt, and generate about 300-1,000 cubic feet per second (cfs) (Figure 4). The absolute magnitude of peaks generated solely by snowmelt is probably limited to around 1,000 cfs, as the rate of snowmelt is capped by available heat input. However, less frequent but larger floods occur as a result of rain-on-snow, usually from November through February, but sometimes occurring as late as June. These floods can be much larger, often several times the size of the typical snowmelt flood, due to lack of infiltration, snow melting, and other processes. Although relatively rare, the larger rain-on-snow floods occur often enough to have very significant geomorphic consequences. Large rain-on-snow floods occurred on the Upper Truckee in 1955, 1963, 1965 and 1997.

PRE-DISTURBANCE GEOMORPHIC FUNCTION

In the following section, the geomorphic function of the lower Upper Truckee River (Meyers to Lake Tahoe) prior to disturbance by European humans is described. Historic function is often inferred from characteristics of the floodplain as it appeared in 1940 and 1952 photographs or as it appears today. It must be stressed here that even the early photographs were taken approximately 80 years after the initiation of land-use activities capable of producing channel change. There is no direct evidence of channel form and function prior to disturbance. However, some estimate of historic function is necessary to understand changes in ecosystem processes resulting from human impacts, and to provide a basis for restoration measures. This discussion will form the basis for evaluating restoration efforts in the project area in the context of the lower Upper Truckee River ecosystem.

Channel Patterns

Historic channel patterns are often best seen on older aerial photographs. The earliest aerial photographs were taken in 1940, well after first human impacts, and channel patterns do not represent historic function. However, characteristics of meander cutoffs and other floodplain features on early historic photos often provide clues to historic patterns and channel dynamics. Figure 5 shows the location of historic-recent photo pairs for four areas within the lower Upper Truckee. The following paragraphs describe channel patterns and of the lower UTR prior to human disturbance, starting at the mouth of the river and moving upstream.

Historic photos show that the lower portion of the UTR, from the lower Highway 50 bridge downstream to Lake Tahoe, was a delta, with a complex, distributary channel system (Figure 6). Much of the lower delta was emergent marsh during high lakestands, with extensive wet meadow systems at the upper end.

For about one mile upstream of lower Highway 50 crossing, the river flows through a broad meadow (Highway 50 Meadow, Figure 5). Mussetter Engineering, Inc. (2000) suggests that the historic channel in this area may have been multi-thread and anastamosing, based on patterns of meander scars (Figure 7). They attributed this pattern to local base level control due to high lakestands and the valley constriction at the location of the current lower Highway 50 crossing.

A different historic channel pattern probably occurred from the southern end of the Highway 50 meadow upstream through the northern half of the Lake Tahoe airport (this area is seen at the upper portion of Figure 8). The valley bottom narrows throughout this area. Mussetter Engineering, Inc. (2000) suggests that channel patterns were probably historically single-thread. On the floodplain, there are sinuous abandoned channels, but few meander cutoffs or scroll bars, features common where meanders have translated across the floodplain.

The valley floor broadens again through the southern half of the Lake Tahoe airport (Figure 8). The historic channel pattern here was also likely single-thread, although there is ample evidence of scroll bars on the floodplain, suggesting meander translation across the floodplain was an important process (Mussetter Engineering, Inc. 2000).

From near the south end of the airport upstream to the Elk's Club Highway 50 crossing (just downstream of the project area), the floodplain is narrower and bounded by outwash terraces. In locations, the current channel pattern appears to be on the threshold of braiding channel (Mussetter Engineering, Inc. 2000), and older aerials show a similar pattern. The braided pattern suggests that sediment supply is high locally, probably from erosion of outwash deposits in the bounding terraces. The overall channel pattern in this reach tends to be straighter than in the broader meadow areas. SH+G (2004) hypothesizes that the historic channel was more sinuous, but was still likely straighter than in meadow areas. There are some meander cutoffs and scroll bars on the floodplain in historic photos, suggesting that meander translation and avulsion were important processes historically. However, these features are confined to a relatively narrow band of meadow within forested outwash terraces, unlike the meander scars found across the broad meadows downstream.

Above the Elk's Club Highway 50 crossing, the floodplain is a broad meadow again in the lower half of the project area. High amplitude, long wavelength meander scars are found on much of the floodplain (Figure 9), and radius of curvature is low. Scroll bars are also found, suggesting that meander translation was an important historic process. Some of the meanders exhibit abrupt cutoffs, which may be due to channel avulsion, perhaps resulting from woody debris jams. Alternatively, meander cutoffs may be the result of incision due to land use practices, especially those that appear recent in the 1940's photo.

In the upper half of the project area, the modern floodplain transitions again to an entrenched form within outwash terraces. This general valley configuration continues upstream to Meyers. Prior to human disturbance, channel pattern was likely similar to that described for the reach from the south end of the airport upstream to the Elks Club Highway 50 crossing. Some braiding in channel pattern occurs, suggesting relatively high local sediment supply. Historic photos and topographic analysis by SH+G (2004) suggests that historic channel pattern was more meandering. Some larger meanders that were active in the upstream portion of the project area on the north side of the current river in early aerial photography are now abandoned.

Sediment

The streambed becomes progressively finer moving downstream from Meyers. Above the project area, coarse riffles are common upstream to Meyers. Much of this material appears to be derived from adjacent outwash terraces (Simon et al. 2004). Gravel riffles are also found in the upper portion of the project area, though they are often deposited on top of lacustrine deposits. Gravel becomes less apparent in the bed through the middle reach of the project area, in an area of reduced slope. At the lower end of the project area, several gravel riffles are again found just upstream of the Highway 50 bridge. Gravel progressively grades to sand as the primary bed material from the project area downstream through the lower meadows (Mussetter Engineering, Inc. 2000). This downstream pattern of sediment size suggests that much of the coarse bedload in transport may be derived locally from outwash deposits, and may move only very slowly through the system, or may be flushed regularly from lower areas.

Stratigraphy of streambanks in meadow areas suggests that finer sediment deposition overbank has been an important process in the meadow area throughout the lower Upper Truckee River. Many of the streambanks within the project area have relatively high proportions of fine sediment (Simon et al. 2004). SH+G (2004) noted that volcanic rocks in the upper watershed tend to weather to fine particles; this sediment would provide material for the fine sediment found in upper portions of streambanks and adjacent meadows, and overbank deposition over time is probably largely responsible for this process.

Channel Dynamics

Natural channels are constantly changing in response to climatic variability, local sediment transport processes, input of woody debris, and many other factors. It is important to characterize dynamics in natural systems by recognizing the temporal and spatial scales over which change occurs, and magnitude and rate of corresponding changes. In the following discussion, potential magnitude and rates of channel change are considered over several temporal scales within the lower Upper Truckee system.

Channel forms change dramatically over glacial cycles. In the entire glacial cycle, the period of deglaciation probably results in the highest sediment yield (Benn and Evans 1998) due to exposed, unvegetated eroded slopes and glacial deposits. Following Tioga deglaciation, the Upper Truckee was likely a braided outwash system, with very high sediment supply and abundant water due to melting. Sediment supply has gradually decreased over the Holocene as vegetation has colonized the upper watershed and outwash deposits. As sediment supply decreased, the channel has incised within outwash, producing sediment locally. The meadow reaches dominated by lacustrine deposits have become single thread, meandering channels, while the reaches in outwash deposits retain some of the braided form, likely due to local sediment supply.

Substantial climatic variability has been documented in the Lake Tahoe Basin in the last 10,000 years (Lindstrom 2000). Significantly wetter periods are thought to have occurred, as well as much drier conditions. Drought has been implicated in lower Holocene lake levels, perhaps as much as 20 ft about 6,000 ybp (Lindstrom 2000). In the lower reaches of the river, changes in lake levels likely produced substantial geomorphic change. Persistent high lakestands would induce deposition in the delta, though overall channel patterns would likely remain consistent. Low lake levels probably resulted in substantial incision, which could have influenced channel patterns well upstream, though the amount of incision was likely limited by offshore deltaic deposits. Upper reaches that were not affected by base level lake changes were likely influenced to some extent by changes in sediment or water yield, with increased or decreased rates of erosion. In these areas, large-scale changes in channel pattern, such as the transition from braiding outwash to single-thread channels that occurred during deglaciation, are less likely.

Much of the non-anthropogenic channel change occurring in recent time is driven by climatic variability associated with El Nino and other weather patterns. Patterns of the occurrence of large rain-on-snow floods are clustered (Figure 4), with about a 30-year recurrence. These large floods can drive localized channel change, such as erosion of outside bend and point bar deposition. In meadow reaches, meander cut-offs are more likely to occur during large floods. Although these floods may cause significant local channel dynamics, larger-scale changes in channel pattern are not documented in areas that have not been modified by humans.

Patterns of meander scars and other evidence on meadow floodplains supports the hypothesis that channel dynamics over the last few centuries has probably been limited to small scale, progressive changes over time such as meander migration and local channel cutoffs. For example, meadows in the lower UTR do not exhibit terrace development, and meander scars tend to have high amplitude. The project area, likely due to its transitional position on the landscape, with outwash deposits upstream and lacustrine deposits downstream, appears to have been somewhat more dynamic, at least in the upper end. Meander scars in the upper portion of the project area have lower amplitude and tend not to exhibit scrolling, suggesting more episodic channel migration. These planform characteristics are also transitional through the project area. At the lower end, high amplitude meander scars suggestive of a highly sinuous channel are found to the east of the current channel.

This discussion suggests that general channel patterns derived from analysis of floodplain meander scars and other evidence are probably representative of a relative equilibrium prior to human disturbance. While climatic variability over the last several centuries has likely driven localized channel change, in the form of streambank erosion, floodplain deposition, localized meander cutoffs and instream bar formation, it has probably not resulted in large-scale changes in channel pattern due to extensive incision or avulsion. The historic channel at the upstream end of the project area may have been more dynamic historically, perhaps driven by sediment availability upstream and woody debris recruitment.

Woody Debris

In meadow reaches, woody debris has likely been a minor component of channel geomorphology. However, lodgepole pine forests border some reaches, particularly those entrenched within outwash. The upper end of the project area, which transitions from the entrenched outwash morphology upstream, has extensive riparian lodgepole forest. Woody debris is regularly recruited in this area, and strongly affects channel dynamics here and, to a lesser extent, downstream reaches.

Woody debris has many geomorphic functions in alluvial systems, driving both erosional and depositional processes. Wood stores coarse sediment and increases localized scour and pool depth (Bisson et al. 1987). In mid-order streams, wood functions to increase channel complexity and flow heterogeneity by 1) anchoring the position of pools along the thalweg, 2) creating backwaters along the stream margin, 3) causing lateral migration of the channel, and 4) increasing depth variability (Spence et al. 1996; Maser et al. 1988). Within reaches bordered by conifer forest (including the upstream end of the project area), the morphology of the historic channel was likely strongly influenced by woody debris, with high complexity and variability in depth and flow. Wood transported downstream to meadow reaches likely provided some of these same functions, although the density of wood was probably lower.

The relative influence of woody debris is a function of the size of wood relative to the size of the channel (Spence et al. 1996). In smaller streams, or where woody debris is large, debris accumulations tend to be stable and dominate hydraulic processes. Prior to Comstock and later logging of forests along the UTR, woody debris supplied to the channel may have been larger with more geomorphic influence.

LAND USE HISTORY

SH+G (2004) presents a review of the land use history in the UTR watershed. Specific characteristics of this history relevant to understanding the impacts of land use on ecosystem function are reviewed in the following section.

Logging

The period of Comstock logging, from about 1860 to 1890, resulted in widespread land disturbance that likely affected the UTR. Several direct modifications of channels occurred during this period, including the construction of small dams to run mills and splash damming to provide water to run logs down the river. While the effects of dams for local water supply may have been both local in effects and limited in time, the effects of splash damming were likely more widespread and persistent through time (Kondolf et al. 1996). Splash dams were generally timber crib or earthen structures, designed to create a small pond or lake, so generally 10 or 20 feet in height. They were designed to be destroyed at the height of runoff in the spring, typically with explosives. The resulting flood helped carry logs to the lake.

Splash damming had consequences all the way to the lake. The highly sinuous historic channel probably didn't float the logs very well; crews likely had to dredge and modify the channel to salvage logs that got caught up, and would have removed natural log jams to improve channel transport efficiency. Over time, it is likely that very tight meanders were cut off to improve transport efficiency. Historic accounts of splash damming in the Humboldt Bay watershed, for example, recount that crews worked much of the summer salvaging logs that did not reach the bay (Gates 1983). Adjacent farmers complained that jams of logs during the splash dam drive caused flooding on their property. For these reasons, splash damming was eventually outlawed in most areas.

Comstock logging also had pervasive watershed effects. Loss of trees and compaction of soils led to increased runoff. Soil disturbance resulted in increased erosion and sediment supply.

Ranching and Farming Operations

All meadow areas have been grazed since the latter part of the 1800s. The primary type of grazing has been cattle for dairy operations, though some grazing for horses and other ranch stock occurred. In some areas, the channel was probably modified to reduce the impacts of floods on adjacent pastures (small levees, meander cut-offs).

Channelization to improve agriculture operations has occurred through the lower reach of the UTR. Within the project area, the river was channelized just prior to the 1940 photos (Figure 9). Dredging and rip-rap have occurred in several locations since that time. The small tributary from the south was also channelized prior to 1940. In lower portions of the river, Comstock-era channelization also likely occurred in the lower meadow just upstream of the lower Highway 50 crossing (Mussetter Engineering, Inc. 2004)(Figure 7) and sometime prior to 1940 just upstream of the delta (Figure 6). Woody debris was probably also removed during channelization to improve flow capacity.

Adjacent meadows have been modified either for drainage or for irrigation. Within the project area, Angora Creek has been highly modified in the area of the confluence with the upper Truckee river. It originally entered the UTR just upstream of the Elks Club Highway 59 crossing (Figure 9). Sometime between before 1940, it was channelized into a bend of the UTR about 2,000 feet further upstream. This was likely done to dry out the lower meadow for grazing. A headgate and small pond were constructed within the Angora Creek meadow to allow for irrigation later in the year. Irrigation was also applied to the meadow on the south side of the river within the area currently occupied by the Lake Tahoe golf course. Ditches are extensive on the 1940 photos. The diversion point on the river for this ditch system was upstream of the project area (SH&G 2004).

Infrastructure

Modern development led to further modification of the lower UTR. The Tahoe Keys development in the early 1960s occupied a substantial portion of the delta and marsh at the lower end of the system (Figure 6). The river was channelized along the margin of the development.

Highway bridges at the lower Highway 50 crossing and the Elks Club drive crossing substantially altered the channel and floodplain. Floodplain area was significantly reduced, and the channel cross section was narrowed.

The Lake Tahoe airport was constructed in the lower meadow reach in the early 1960s (Figure 8). Almost entirely within the valley flat, the airport occupies most of the upper portion of this meadow. The river was channelized along the eastern portion of the meadow, including substantial grade control to control incision.

The Lake Tahoe golf course was constructed within the UTR floodplain in the project area between 1959 and 1964 (Figure 9). Several of the holes occupy former meadows and floodplain directly adjacent to the channel. In the lower portion of the project area, the golf course essentially borders the river, with only a narrow band of riparian vegetation remaining. Five bridges have been constructed across the river within the golf course. Because the bridges were generally undersized, most have required extensive maintenance to control local erosion.

Urban related development accelerated in the 1960's with a myriad of housing and roads throughout the watershed. As noted by SH+G (2004), these changes may have increased peak flood magnitude and the delivery of fine sediment to the UTR.

GEOMORPHIC EFFECTS

Because many of the impacts of European land use practices took place prior to photos or other records of the condition of the channel, the effects must be inferred rather than directly measured. While there can be no complete certainty using this approach, understanding of the response of channels to land use has improved substantially over the last few decades and reasonable inferences can be derived.

The land use history described above has resulted in a substantially altered channel (SH+G 2004). Channel length and sinuosity have been reduced throughout the lower Upper Truckee River. In the project area, SH+G (2004) calculated a 28% reduction in channel length between 1940 and 2004. Simon et al. (2004) reported similar results, with a reduction in sinuosity in the project reach between 1940 and 1994 of 1.54 to 1.14. While some of this decrease is likely attributable to channel response to human disturbance, direct meander cutoffs between 1940 and 1952 were also responsible. Similar impacts occurred in broad meadows downstream to the lake. Although much of the channel modification in the lower reaches took place prior to aerial photography, it is likely that human channel modifications have led to reductions in channel length similar to those described for the project area.

In many locations, the channel has also been enlarged. Channelization was designed to drain surrounding valley flats and provide flood protection, and the new channels constructed were therefore likely bigger and deeper to provide more hydraulic capacity. As will be described in the following section, subsequent channel response has further enlarged the river, and many channelized reaches today have high capacity with respect to surrounding valley flats (SH+G 2004), resulting in less frequent overbank flows.

Channel Response

In freely alluvial riverine systems (those whose bed and banks are composed of materials transported by the channel in current climatic conditions), the channel form and size are related to the amount of water and sediment supplied to the channel. That the amount of water carried by the stream is related to the size is intuitively obvious; larger rivers carry more water. However, examination of many different types of streams reveals that similar hydrologic regimes may result in far different channel forms and sizes. Streams with low rates of sediment supply (especially low rates of coarser bedload transport) tend to be highly sinuous and have narrow, deep channels, while those with high rates of coarse sediment supply tend to be straighter, and have shallower, broader channels. Thus sediment also influences channel morphology.

Substantial changes in the rates of supply water and/or sediment will result in changes in channel form. There are two general channel responses. An increase in sediment supply with respect to discharge tends to result in aggradation (an increase in the elevation of the channel bed, caused by deposition of sediment); decreases in sediment supply or an increase in discharge tend to result in incision (a decrease in the elevation of the bed, caused by erosion).

Natural factors, most commonly changes in climate, can trigger channel change. Channel response to climate change is complex, dependent on the time scale in question, and mediated by the response of vegetation throughout the watershed. Periods of increased rainfall, for example, may result in aggradation over short time-scales due to large increases in the rate of erosion and sediment supply to the channel. Over longer time-scales, vegetation cover may increase in response to additional rainfall, slowing erosion and sediment supply, which can result in channel incision. Some channel responses to climate change are less complex; lower lake levels during time of drought would likely cause incision in the lower portion of the UTR.

Human disturbance of the watershed can trigger similar channel responses. Some land uses tend to increase the supply of sediment and therefore result in aggradation. Timber harvest, for example, can substantially increase the amount of sediment supplied from the watershed to the channel, through erosion of roads, landings or other disturbed surfaces, or by causing an increase in the frequency of mass wasting. Extensive, watershed-wide grazing is also believed to have resulted in increased sediment supply to stream channels in some instances, again through land disturbance. Whatever the cause, an increase in sediment supply results in aggradation and reduction of channel capacity. Reduced channel capacity then tends to reinforce aggradation because sediment transport capacity is reduced. The channel generally becomes more dynamic, and may braid. Channel aggradation has been documented in many cases as a result of land use, but the causes tend to be large-scale inputs of sediment (hydraulic mining in the western Sierra and resulting aggradation on the Sacramento River, for example).

There is substantial evidence that human disturbance within the UTR watershed has increased the supply of sediment, especially following widespread Comstock-era forest harvest and during a decade or so of rapid development beginning in the early 1960's. Analysis of sediment cores in Lake Tahoe has shown increased sediment delivery to the Lake occurred at these times (Heyvaert 2002). These sediment cores also show that, following these disturbances, rates of sediment delivery to the lake returned fairly quickly to natural background levels. However, there is no evidence to suggest that the increase in sediment supply resulted in a large-scale aggradation response in the river. For example, soil stratigraphy exposed along the UTR through the Lake Tahoe Golf Course shows no evidence of former A-horizons buried under gravel deposits, or other features which would suggest a recent, system-wide aggradation event characterized by regional channel disequilibrium. Similarly, there are no channel remnants or scars on the floodplain suggestive of braided channel patterns typically found in actively aggrading systems. Other features that likely would have resulted from extensive aggradation, such as widespread recent terraces, are not found in the lower portion of the UTR. While human disturbance has increased sediment yield in the UTR, the additional sediment has not been sufficient to induce large-scale channel aggradation.

Incision is the other general channel response to land use. Incision is often triggered by an increase in erosive power or sediment transport capability without an increase in the amount of sediment available for transport. The additional power is expended on the channel bed and streambanks, resulting in incision. Increases in erosive power or sediment transport capacity can occur in one of four ways:

- Decrease in base level (the elevation at the downstream end of a reach of channel), resulting in increased slope, velocity, and erosive power.
- Reduction in channel length (cutoff of meanders), which also increases the channel gradient.
- Increase in water supplied to the channel, usually through impacts to the surrounding watershed. Bigger floods have more erosive power.
- Reduction in sediment supply without a corresponding change in water supply. Flowing water supplies the energy required to transport sediment; a reduction in sediment supply results in more available energy and more erosive force.

The most important of these factors with respect to the effects of land use on the UTR is reduction in channel length. As described above, channelization of the lower UTR has been extensive, and has resulted in a much shorter channel. While natural dynamism certainly also resulted in meander cut-offs and similar increases in gradient, the effects were likely localized. Human channelization has been far more widespread, and has affected most of the river from the golf course downstream to the lake. Several other land use practices had effects that can create incision. Removal of woody debris to “clear” the channel would have reduced sediment storage and increased erosive power. Channel clearing from splash damming and subsequent salvage operations would have increased channel size and erosive power. Much of the watershed disturbance resulting from logging and grazing would have reduced infiltration and increased runoff, resulting in larger floods, again increasing erosive power. It is also likely that earlier agricultural practices included draining adjacent meadows for pasture, which increased flow in the channel during floods and erosive power. Finally, extensive grazing of meadows reduced riparian vegetation cover, making the channel more susceptible to erosion.

Similar modifications of streams and watersheds have caused channel incision in many documented cases (Schumm 1999), and the UTR is no exception. Virtually all researchers investigating the channel and its response to human disturbance have concluded that the lower UTR has incised in response to channelization (Simon et al. 2004; SH+G 2004; Mussetter Engineering, Inc. 2000). It is important to note that once incision begins, positive feedback mechanisms promote additional incision. As the channel enlarges, larger floods are contained entirely within the channel, increasing shear stress on the streambed and causing more erosion and incision. Evidence supporting incision includes: the channel is much larger than would be expected in functional alluvial streams and floods adjacent valley flat less frequently than would be expected(SH+G 2004; Mussetter Engineering, Inc. 2000); bedforms common in functional streams are lacking (Mussetter Engineering, Inc. 2000); and rates of streambank instability are high (Simon et al. 2004; SH+G 2004; Mussetter Engineering, Inc. 2000).

In summary, the dominant geomorphic response of the lower UTR to human disturbance has been incision relative to the adjacent floodplain. The incision response has been pronounced within the project reach, where researchers have concluded that incision was caused by channelization within the project area and in downstream reaches (Simon et al. 2004; SH+G 2004).

Probable Future Trends

Simon et al. (2004) and Schumm (1999) present similar conceptual models for evolution of incised river systems (Figure 10). In early stages, incision is driven by land use changes, such as channel straightening, that increase the erosive capacity of the channel with respect to its bed. In subsequent stages, an increase in streambank height, increased shear stress at the toe, and reduced vegetative stability lead to widening (Stages 4 and 5). The widening both produces local sediment and probably results in reduced sediment transport capacity, leading to aggradation (Stage 5) and the eventual formation of a new floodplain, typically at a lower base level (Stage 6). This conceptual model has been extensively peer-reviewed and is widely accepted among researchers and managers of incised channels.

Schumm (1999) notes that once incision has commenced, it is unlikely that erosion will cease naturally until the channel has progressed through the several stages of the channel evolution model. Simon et al. (2004), in geomorphic assessments of the UTR, classified the stage of channel evolution for 12 locations in the lower UTR, from just upstream of the project area to near the lower Highway 50 bridge. Of the twelve sites, ten were classified as Stage 5. One in the lower meadow was classified as Stage 2, and one near the lower Highway 50 bridge was classified as Stage 6. These classifications suggest that throughout its lower reach, the UTR is still responding to the impacts of channelization through aggradation, widening, or both.

Schumm (1999) further notes that progression through the stage of channel evolution is highly variable. The type of sediment in the valley fill can significantly affect the process of channel incision and adjustment. Two factors in the UTR and the project area have likely influenced incision. First, dense lacustrine deposits have likely slowed erosion of both channel bed and banks. Mussetter Engineering, Inc. (2000) noted several locations in the meadow areas where resistant outcrops are controlling channel grade, including within the project area. Simon et al. (2004) noted that similar deposits are controlling rates of streambank erosion. Second, the outwash deltaic deposits at the upstream end of the project area appear to have influenced the upstream progression of incision. Longitudinal profiles through this area show a distinct break in slope in this reach, with substantially higher gradient. Repeated profiles and sections by CDPR in this reach show substantial vertical and lateral instability in this reach. The process of incision has likely been modified by coarser outwash deposits, and the river is still undergoing adjustment.

The control imposed by lacustrine sediments has important implications for the future progression of channel evolution. Schumm (1999) notes that channels incising into cohesive sediments deepen rapidly. However, throughout the meadow reaches, subsequent widening appears to have progressed relatively slowly. While larger rain-on-snow floods result in localized bank erosion, the low slope and cohesive sediments found in meadow reaches of the UTR do not allow for rapid adjustment. Thus the adjustment to a more functional channel is a very slow process.

Human modifications have also affected the progression of channel evolution with the project area. Rip-rap has been used extensively in the middle portion of the project area and around golf course infrastructure to stabilize streambanks. While this technique has provided temporary stabilization, unprotected streambanks are eroding throughout the project area (Simon et al. 2004). Moreover, continuing vertical channel adjustments has undermined rip-rap in many locations. Given that the geomorphic progression is toward widening, streambank stabilization in situ would require treatment of banks throughout the project area, and would also require that rip-rap treatments have deep toes, well below current streambed elevation, as headcuts continue to degrade the channel bed.

Some human modifications appear to have stabilizing effects on channel evolution. A grade control structure near the golf course clubhouse, constructed to provide a water intake, raised the streambed and has likely contributed to stability in a reach for a few hundred feet upstream. Weirs and grade control have been used to stabilize incised channels in many areas (Bravard et al. 1999).

It is also important to note that in some locations, particularly the upstream end of the project area, recruitment of woody debris during widening has important effects on the channel. In some locations, debris jams are serving to store sediment and creating some local aggradation. However, debris also tends to promote additional widening through lateral scour. In areas where woody debris jams are relatively abundant, widening still appears to be the dominant process based on CDPR repeat cross sections.

It is not possible to predict when the channel will complete adjustments to initial incision, or the specific channel morphology. The incision model predicts that a Stage 6 floodplain will be created at a lower base level. It is probably reasonable to assume that this floodplain will be broad enough to accommodate the approximate meander geometry of the historic channel, suggesting that current channel widening will substantially increase. SH+G (2004) notes that several thousand tons of additional erosion could occur. Given the relatively low rate of widening, this process will likely require decades or centuries.

Alternatively, the incised channel within the project area may eventually stabilize through aggradation to former floodplain elevation. Although this process is possible, available data do not suggest that aggradation is occurring. CDPR has repeated surveys of cross sections in the project area several times over the last twelve years. These sections were used by Simon et al. (2004) to validate a model of channel changes, CONCEPTS. This model, and the surveyed sections, showed that, generally, changes in channel elevation have been negligible over the past decade. Channel width, however, has increased significantly over that period, up to 6 m throughout the project area.

A fifty-year simulation was run with CONCEPTS based on the validation (Simon et al. 2004). The model predicted significant increased in width (up to 34m) at sections within the project area, especially near the upper end. It also predicted 1.1 m of deposition at one section near the upper end of the project area. These changes represent the principle form of channel change in the modeled area. Changes in both top width and bottom elevation were minor in downstream reaches.

These results are consistent with the following conclusions:

- In the project area, substantial additional channel adjustment can be expected as the result of historic channel modifications. This adjustment includes channel widening, and considerable vertical instability, including headcutting.
- Channel straightening and disconnection with the floodplain have led to increased stream power, erosion, and have likely led to decreased deposition within the channel in many areas.
- Aggradation is not likely to occur without substantial widening.
- Channel evolution is modified by the presence of lacustrine deposits; subsequent widening is likely to proceed at slow rates.
- The process of channel evolution has been modified by the presence of outwash deposits at the upper end of the project area, resulting in a highly unstable and dynamic reach.

RIPARIAN ECOSYSTEM IMPACTS

Geomorphic changes resulting from human disturbance of the lower UTR have had significant impacts on the riparian ecosystem, the largest lotic riparian ecosystem in the Lake Tahoe Basin. Impacts to this ecosystem are of special importance in Lake Tahoe for several reasons. First, riparian ecosystems are relatively rare in the basin, comprising only about 5.5% of total basin area (USDA 2000). Second, riparian ecosystems have important habitat values. Wetlands and riparian areas are essential for fish and wildlife foraging, reproduction, and escape cover, and are recognized as the most critical habitats needing preservation in California. Of the over 250 species of wildlife that inhabit the Tahoe basin during all or part of the year, 84% are associated with meadow and riparian habitats for breeding or feeding (USDA 1980). Third, riparian ecosystems provide significant water quality benefits. Wetlands and riparian zones are effective for nutrient and sediment removal from stormwater, for reduced flood peaks, and for increased retention time of surface flow (Currier et al. 1998).

Unfortunately, riparian areas are the most disturbed ecosystem in the basin. The largest riparian ecosystems are found near the lake, in areas of low relief, which are also the most suitable areas for human development. Over 75% of marshes, 50% of meadows and 35% of riparian areas historically found in the basin have been lost or degraded due to urban and residential development (SNFPA 2001). Since the mid 1900s, approximately 75% of marshes in the Lake Tahoe basin have been degraded and around 25% were developed between 1969 and 1970 (USDA 2000).

Geomorphic processes and ecosystem function are closely linked. Human disturbance of the lower UTR and the subsequent geomorphic effects, described above, have significantly degraded riparian ecosystems. This section reviews the relationship between channel geomorphic processes and riparian ecosystems, and changes in the riparian ecosystem in response to channel degradation.

Geomorphic Processes and Vegetation Communities

The distribution of plant communities in valley bottoms is generally reflective of substrate characteristics and water availability. In naturally dynamic fluvial systems, soils and groundwater are highly variable spatially and temporally. For example, valley flats away from the active channel generally tend to have deep, fine-textured soils resulting from deposition of fine sediment during floods over long periods of time, with high organic content as plant material is incorporated. Near the active channel, gravel bars deposits are coarse and well-drained, with little organic material. Coarser soils generally grade into finer soils with distance from the active channel.

Riparian environments have relatively high groundwater tables, but both spatial and temporal variability in groundwater availability is typical. Temporal variability occurs due to regular flooding on yearly time scales. Groundwater typically is close to (within a couple of feet) of the surface throughout the floodplain during high water in the spring and early summer, an active growth period for riparian plants. As streamflow drops through the summer, groundwater tables tend to fall as well. It is important to note that temporal variability also occurs over longer time-scales; groundwater tables will be different between wet and dry years.

High spatial variability in groundwater level with respect to the ground surface is typical in riparian environments as well. Generally groundwater elevation is higher near the channel and decreases with distance away from the channel. However, locations away from the active channel may have relatively high water tables due to a number of factors. For example, layers of fine sediment common in floodplain stratigraphy can perch groundwater, resulting in high groundwater levels far from the active channel. Perhaps more importantly, topographic complexity resulting from channel dynamics results in groundwater levels near the ground surface well away from the active channel. Old meander scars, for example, often have surface water in some locations late into the summer, or even throughout the entire year.

Adaptation of riparian vegetation to complex patterns of substrate and hydrology has resulted in specialization. Finely textured floodplain soils, often saturated during the wet season, are dominated by herbaceous species such as sedges (*Carex* spp.), rushes (*Juncus* spp.), or hydrophytic grasses (Kaufmann et al. 1997). Many riparian shrubs and trees, on the other hand, commonly become established on coarsely textured, well-aerated substrates such as those found on point bars in the 2- to 10-year floodplain (McBride and Strahan 1985; Bradley and Smith 1986). Seedlings of these plants require full light and water in well-drained sites. Seed dispersal and germination are timed to coincide with late spring flows when water tables are high and fresh alluvium has been deposited (Noble 1979). Recruitment of willows is poor in fine-grained soils already colonized by herbaceous vegetation, probably partly due to competition with herbaceous species, whose growth begins earlier in the spring. Once established, however, mature willows have deep rooting systems and can persist for several decades even though the active channel may migrate away. Similarly, some herbaceous species with deeper rooting systems are also capable of persisting through changes in hydrology (especially *Carex nebrascensis* or *Juncus balticus*), but will likely exhibit reduced growth period, vigor, and productivity.

Composition and structure of riparian vegetation communities is thus a reflection of complex spatial and temporal variability in substrate and hydrology, which in turn are driven by the dynamics inherent in natural fluvial systems. Geomorphic processes such as meander translation, meander abandonment, and overbank sediment deposition create complex edaphic and hydrologic environments. The resulting vegetation communities have complex structure characterized by the patchiness and abundance of edge important as wildlife habitat.

Prior to human disturbance of the UTR, many specific geomorphic processes were important to maintaining general characteristics of vegetation community structure within larger meadows (i.e., the downstream portion of the project area). Sites suitable for riparian shrub establishment within the herbaceous matrix were created by a host of processes. Streambank erosion during floods created small patches along streambanks where shrubs could establish. Bar deposits along the active channel provided excellent sites for shrub recruitment. Small overbank sediment deposits within herbaceous vegetation likely also created suitable sites. In the larger meadows, the vegetation community structure resulting from these processes was characterized by a relatively narrow band of shrubs along the active channel.

In portions of the UTR where the modern floodplain is entrenched in outwash deposits (i.e., the upstream portion of the project area), many similar processes were active and provided sites for riparian shrub establishment. However, coarse sediment was more abundant, and the channel was likely more dynamic and had more extensive bar deposits. As a result, the riparian shrub band was broader. Herbaceous patches formed within the shrub matrix where deposits of fine sediment developed in flow shadows on bars or around shrubs.

Larger-scale fluvial dynamics, such as channel avulsion or cutoff of meander bends, also strongly influenced the distribution of vegetation. Mature shrubs along abandoned channels persist for many decades, forming patches of shrubs well away from the active channel. The diverse topography of abandoned channels resulted in strong hydrologic gradients. Persistent open water in low areas of the channels was surrounded by emergent vegetation, which graded into herbaceous wetland species surrounded by belts of shrubs. This set of processes produced patchy vegetation communities away from the active channel in both meadows and the areas entrenched in glacial outwash.

Prior to incision, it is also important to note that groundwater levels in the floodplain were consistently higher. Saturation within the root zone persisted well into the growing season. In many areas, floodplain soils likely retained substantial moisture in the root zone throughout most average years.

In summary, following are key characteristics of the functional, historic riparian vegetation community along the lower UTR:

- A high degree of patchiness, both of willow shrubs and of the herbaceous community;

- active recruitment in the shrub communities along the river; and
- high productivity, with active growth well into the summer.

Riparian Vegetation Impacts

Direct disturbance has altered many of the riparian vegetation communities in the lower UTR. Grazing in larger riparian meadows altered historic riparian vegetation. The Tahoe Keys development filled, fragmented, and highly altered 750 acres of the Truckee Marsh (Rowland's Marsh). Construction of the Lake Tahoe airport and the Lake Tahoe Golf Course in the project area also directly altered riparian vegetation. The extent of direct human disturbance on the riparian vegetation community of the lower UTR is depicted in Figure 5, which shows vegetation classifications from Forest Service mapping for areas along the river. Note that vegetation communities classified as wet meadows, typical of floodplain riparian vegetation, have been extensively fragmented by areas classified as barren (natural vegetation communities have been removed) or urban (pavement or structures).

Changes in geomorphic processes resulting from channelization have impacted remaining riparian vegetation communities. Incision throughout the lower UTR has resulted in lowered groundwater tables in meadows. Although the magnitude of incision has been relatively small (probably from 2-5 feet in most areas), the ecological consequences of lowered groundwater levels have been more substantial. In wet or mesic meadow communities, the majority of the root zone is within about two to three feet below the ground. Changes of only one or two feet in groundwater level are sufficient to change wet communities to mesic types. Lower groundwater tables have also shortened the growing season and generally reduced riparian plant productivity. Reduced sediment deposition from overbank flooding may also have reduced productivity, as fewer nutrients are available for plant growth.

Although natural rates of streambank erosion promote shrub recruitment and vegetation community patchiness, incision has greatly increased the erosive stress and scour placed on streambanks during floods. Streambanks are also higher, with less available moisture. As a result, riparian shrubs are less capable of colonizing streambanks disturbed during floods, and streambank instability is common throughout the lower UTR. Riparian bands along the channel, particularly throughout broad meadows, have been eliminated or reduced in size.

Incised channels are more capable of transporting bedload, and tend to export bedload rather than storing it in bars within the channel. Processes of channel migration have also been slowed by incision and, in many locations along the UTR, meander migration has been eliminated through rip-rap or other channel constraints. All of these changes have reduced the development of instream bars, particularly point bars, which are focal points for riparian shrub recruitment. A loss of in-channel bars has reduced the area of riparian shrubs. This impact is prevalent throughout broader meadows, but far less pronounced in reaches entrenched in outwash, where fluvial adjustment to incision has led to the development of extensive in-channel bars, and distribution of shrubs is widespread.

Finally, natural rates of channel planform dynamics have been reduced. As mentioned previously, meander scars on the floodplain attest to fairly frequent meander cutoffs prior to human disturbance, particularly in broader meadows. Incision has reduced the potential for meander cutoffs or other channel planform changes by concentrating larger flows within the active channel. As a result, the formation of diverse, structurally complex abandoned channel environments has been slowed or eliminated. The long-term trend is toward simplification of floodplain topography and vegetation communities.

In summary, human modifications of the floodplain and stream channel, and subsequent channel responses, have had important consequences for riparian vegetation communities. Specific effects on riparian vegetation include the following:

- Reduced frequency and extent of establishment of new individuals of the dominant, community-defining species;
- lower vigor (or death) and productivity of surviving individuals, especially of species that are not as tenaciously drought-adapted as *C. nebrascensis* or *J. balticus*;
- overall conversion of wetter habitats to drier ones, and loss of small areas of standing water that are of great wildlife habitat value;
- reduced woody riparian habitat connectivity;
- lowered overall habitat complexity due to the ultimate loss of individuals from previous establishment episodes and lack of new colonization, resulting in lowered habitat values for wildlife; and
- consequent loss of diversity and lowered resistance to future catastrophe, disturbance, and/or gradual environmental change.

Most of the riparian vegetation along the lower Upper Truckee River, the largest stream in the basin, is impaired as defined in SNFPA (USDA 2001).

Terrestrial Habitat

The structural complexity and diversity in riparian vegetation communities, a product of the geomorphic dynamism inherent in fluvial systems, provides important habitat for terrestrial wildlife. Riparian areas are productive, diverse habitats with high biodiversity (Kattlemann and Embury 1996). The ecotones between vegetation types within riparian areas, and between riparian habitat and surrounding communities, are used by a variety of animals. Dense and diverse riparian vegetation provides a variety of nest and perching sites. Numerous types of food, including seeds, fruits, and insects, are present as well as shady, cool, moist microclimates. Structurally complex riparian environments also provide cover, migration stopover areas, migration corridors, and dispersal corridors.

The importance of riparian habitat to terrestrial animals is well-known. Sierra mountain meadows are recognized as critically important for breeding and post-breeding dispersal of neotropical migrants and resident landbirds, and provide stopover habitat for many migrating species (California Partners in Flight Riparian Bird Conservation Plan). The highest diversity and productivity of land birds in the western United States is found in riparian habitats (RHJV 2004). Some mammals, such as beavers (*Castor canadensis*) and mink (*Mustela vison*) are dependent on riparian habitat. Raccoons (*Pyrocon lotor*) are closely associated with riparian habitat, while others, such as black bears (*Ursus americanus*), use it during part of their wide-ranging movements. Because of high wildlife species diversity, many predators such as coyotes (*Canis latrans*) and weasels (*Mustela* spp.) are found in and near riparian environments. All the amphibian species found in the Lake Tahoe basin spend a significant portion of their life cycles in riparian areas (Jennings 1996). Riparian habitat characteristics such as damp soils, cool microclimate, and presence of water are important components of amphibian habitat.

Breeding habitat requirements of the willow flycatcher (*Empidonax traillii adastus*), listed by the State of California as endangered, provide a specific example of adaptations to diverse and structurally complex riparian habitat. Willow flycatchers have been found in riparian environments of various shapes and sizes ranging from small willow-surrounded lakes or ponds with a fringe of meadow or grassland to various willow-lined streams, grasslands, or boggy areas (Craig and Williams 1998). Nesting habitat typically includes moist meadows with perennial streams and smaller spring-fed or boggy areas with willow (*Salix* spp.) or alder (*Alnus* spp.) (Serena 1982; Harris et al. 1988). Willow flycatcher nest territories generally contain open water (i.e., running water or standing water), boggy seeps, or saturated soil (Bombay et al. 1999). In the Sierra Nevada, willow flycatchers have nested in meadows less than one acre to meadows several hundred acres (Serena 1982; Stafford and Valentine 1985; Flett and Sanders 1987; Bombay 1999). However, most willow flycatchers occur in meadows larger than 20 acres.

Riparian meadow sites used by willow flycatchers vary in size and shape and may contain relatively dense, linear stands of shrubs, or irregularly shaped mosaics of dense vegetation with open areas in between. Various researchers describe openings within thickets of riparian deciduous shrubs or tall clumps of shrubs separated by open areas as important components of willow flycatcher nesting habitat (Serena 1982, Harris et al. 1988, Sanders and Flett 1989). Large contiguous willow thickets are avoided (Sanders and Flett 1989, Harris et al. 1988).

The patchy, diverse historic UTR riparian ecosystem provided habitat required by the willow flycatcher. Historic records indicate that willow flycatchers were a fairly common summer resident in the Lake Tahoe basin (Orr and Moffitt 1971). Populations were associated with the Truckee Marsh and Upper Truckee River system (SNFPA 2001). It is important to note that the diverse habitat (open water, shrub patches) required by the willow flycatcher was a product of natural geomorphic dynamism over long time-scales described in previous sections. The alteration of geomorphic processes responsible for creating and maintaining habitat diversity, both direct modifications to the channel and floodplain and the resulting incision response, have reduced habitat value for riparian-dependent species such as willow flycatcher.

As a result, willow flycatchers have all but disappeared from the historic population centers associated with the Truckee Marsh and Upper Truckee River system at South Lake Tahoe (SNFPA 2001; Ray 1913; Erwin et al. 1995; Bombay 1999). Where they were once relatively abundant, recent surveys have found few willow flycatchers in UTR riparian areas from the lower Highway 50 bridge upstream to Meyers. In 1998, a single individual was detected in the project area in wet meadow/willow habitat south of the golf course and adjacent to the Upper Truckee River. None have been detected in subsequent surveys. More recently, willow flycatchers have been detected nesting along the Upper Truckee River approximately four miles upstream of the project area, but have not been detected in broader riparian meadows of the lower river. Throughout their range, the loss and degradation of riparian habitats is probably the primary cause of historic and recent declines in willow flycatchers (Craig and Williams 1998).

Degradation of riparian habitat in the lower UTR has affected all species that use this habitat, whether they are riparian dependent (amphibians) or occasional (bears, coyotes). Human alteration of floodplains and geomorphic processes has led to simplification of floodplain habitat, with the following specific consequences:

- Reduction in total shrub cover, and the number and size of shrub patches;
- reduction in structural complexity and ecotones;
- reduction in habitat diversity, especially the loss of rare or ephemeral habitats such as small open water or emergent vegetation patches; and
- loss of interconnectedness of shrub cover, which served as migratory and travel corridors.

Aquatic Habitat

Historically, the Upper Truckee River was the most important fishing resource for the Washoe tribe (USDA 2000). The Washoe fishery focused on spawning fish from Lake Tahoe, especially Lahontan cutthroat trout and whitefish. Based on accounts from Washoe elders, Lahontan cutthroat spawning was most extensive in the middle reaches of the lower UTR, from about the upstream end of the project area to Meyers (SH+G 2004). Maps of preferred Washoe fishing spots focus on this area, where the gravel deposits preferred by salmonids for spawning were likely extensive. Gravel recruited locally from outwash deposits, and sorted and stored by channel processes, including interaction with woody debris, likely provided complex and high quality aquatic habitat.

These accounts suggest that the historic habitat throughout the lower UTR was comprised of abundant pools and gravel riffles. Intact riparian vegetation likely provided extensive cover, and allowed for undercut streambanks. Temporary development of a lagoon at the mouth of the river, and a complex system of distributary channels immediately upstream, were important rearing habitat for juvenile fish migrating back to Lake Tahoe.

Channelization and resulting incision have dramatically altered aquatic habitat. The direct result of channelization is simplified habitat, with the loss of pools and riffles (Mussetter Engineering, Inc. 2000). Riparian cover was eliminated during channelization, and the high streambanks resulting from subsequent incision do not allow for the development of overhanging cover or undercut streambanks.

It is also likely that woody debris is less abundant throughout the system, especially in reaches entrenched in outwash where lodgepole forests border the channel. Reduction of woody debris has had important consequences for aquatic habitat. Perhaps the single best descriptor of functional aquatic habitat is high complexity; reduction of woody debris significantly reduces complexity (Bisson et al. 1987). This has led to less instream cover, fewer and shallower pools, less storage of gravel substrates important for salmonid spawning or macroinvertebrate habitat, fewer backwater and marginal habitats, and reduced refugia during floods.

Subsequent changes in geomorphic processes due to the incision response have further exacerbated habitat degradation. Much of the channel margin, particularly in low gradient meadows, consists of resistant lacustrine deposits. Gravel bedload is effectively transported over this material rather than being stored within the channel as bedforms (Mussetter Engineering, Inc. 2000). Gravel riffles, the required substrate for salmonid spawning, are now relatively rare, especially in meadow reaches, to the extent that the California Department of Fish and Game undertook a limited project to improve spawning habitat upstream of the project area, probably in the 1960's (SH+G 2004).

Changes in aquatic habitat have affected other portions of the aquatic ecosystem. A study of macroinvertebrates in the lower Upper Truckee River (Herbst 2001) found that impairment of aquatic biota increased in a downstream direction. Seasonal sampling results showed that the greatest impairment occurred during low flows in late summer. Habitat data collected with the biological information suggested that fine sediment was deposited throughout riffle sampling sites during lower flows, and may have been responsible for increased seasonal impairment. These findings are consistent with a significantly simplified channel in which the process of sorting finer sediments into depositional areas along channel margins has been lost.

LOWER UPPER TRUCKEE RIVER RESTORATION OPPORTUNITIES

Restoration planning is currently underway in several reaches of the Upper Truckee River, including the delta reach, near the airport, upstream of the airport at Sunset Stables, and this effort. All of these efforts present opportunities and constraints. Important opportunities include:

- The marsh at the mouth of the river represents the rarest ecosystem type in the Lake Tahoe Basin. It historically had the highest biodiversity in the basin.
- Large meadow riparian ecosystems along the lower Upper Truckee River (from the project area downstream to the lower Highway 50 crossing) are similarly unique and significant ecosystems, the largest such ecosystems in the basin.

However, many of these areas have substantial constraints:

- Restoration of the meadow and marsh near the mouth of the river is constrained by the Tahoe Keys development. Complete restoration of ecosystem function in this area is not feasible, though even partial restoration of this unique resource would be significant given its historic function.
- Much of the lower meadow system is in private ownership.
- Complete restoration of ecosystem function in the meadows adjacent to the airport is not feasible given the presence of the airport.

In this context, restoration of the Upper Truckee River and adjacent meadow in the project area has high potential value. The river and adjacent meadow represent a unique and important ecosystem type within the Lake Tahoe Basin. Restoration of ecosystem function is not constrained by adjacent uses. The opportunity to relocate the golf course away from the river would allow for reduction of direct impacts and enable restoration of channel and floodplain geomorphic and ecosystem processes.

Basis of Restoration Design

Rivers and their ecosystems are exceptionally complex systems. Attaining CDPR's overarching goal of restoring geomorphic and ecosystem function within the project area is a complicated task, and many different approaches to developing a restoration plan are possible. The following section reviews potential restoration alternatives and describes the development of our recommended restoration approach. This approach was developed by identifying essential characteristics of geomorphic and ecosystem function, examining project area geomorphic trends, and evaluating the opportunities and constraints of a number of specific restoration techniques.

Characteristics of Ecosystem Function

Many of the characteristics of the functional river and riparian ecosystem have been described in preceding sections. Prior to human disturbance, water tables were higher in the valley flat, supporting different vegetation communities. The channel was longer, and probably had more pool and riffle development. Regular flooding of adjacent valley flats resulted in fine sediment deposition, enriching floodplain soils and reducing sediment transport to Lake Tahoe.

Previous sections also note that a very important characteristic of function was regular disturbance caused by flooding and resulting channel dynamics. Slow migration of channel meanders across the floodplain led to the development of patches of riparian shrubs on point bars, in complex mosaics with meadows. Sporadic channel avulsions produced isolated channel remnants with standing water surrounded by shrub-meadow mosaics. Regular sediment transport, sorting and deposition provided suitable substrate for salmonid spawning. The importance of regular disturbance and dynamism in riparian ecosystem function is well-established (Kauffman et al. 1997; Bisson et al. 1997; Spence et al. 1996).

The properties of resistance and resilience are important in characterizing the dynamics of functional riparian ecosystems. Resistance is the capacity of an ecosystem to maintain natural function and structure after a natural disturbance or introduction of an anthropogenic perturbation (Kauffman et al. 1997). Human disturbance overwhelmed ecosystem resistance, resulting in substantial changes in both structure and function. The geomorphic response to direct channel manipulation and disturbance was channel incision, resulting in changes in groundwater levels and other factors which eventually led to wholesale changes in riparian vegetation community structure and function.

Resilience is the capacity of the ecosystem to recover after a natural disturbance or following the cessation of anthropogenic disturbance. Because riparian species evolved in environments with frequent fluvial disturbances, they are classic examples of a resilient biota (Kauffman et al. 1997). Prior to human disturbance, riparian communities near the UTR, in areas frequently modified by floods, maintained structure through rapid colonization of disturbed surfaces (gravel bars, streambanks). Human disturbance and the resulting channel response altered the morphology of the channel and floodplain, reducing the potential for colonization of disturbed areas by riparian vegetation. With channel incision, larger and larger floods are contained entirely within the channel. Larger floods place increased shear stress and erosive power on gravel bars and streambanks, locations where riparian vegetation typically colonizes. Increased and more regular scour of these surfaces prevents the colonization of riparian vegetation. The current vegetation community structure represents over 30 years of response to the cessation of channel modifications. Some smaller, isolated patches of riparian vegetation have become established within the larger channel, but they are significantly fragmented and the structure of the entire community has been completely altered. Clearly, channel changes in response to human disturbance have limited the natural ability of vegetation communities to maintain the historic community structure and function. In other words, the resilience of the riparian ecosystem to recover structure following natural disturbance has been lost.

More significantly, the historic floodplain is disconnected from the channel, and is not accessed by any but the largest floods. This is important because riparian ecosystems are not only resilient in the face of natural disturbance regimes, but require this regular disturbance to support function. Many riparian ecosystems rapidly degrade with the curtailment of natural disturbance; water impoundment and diversion projects have resulted in dramatic losses in riparian floodplain forests throughout North America (Kauffman et al. 1997). Riparian systems outside the current incised channel have obviously been affected by the construction of the golf course, but they have also been influenced by the loss of natural disturbance. The lack of regular flooding has eliminated important ecosystem processes, including the deposition of fine sediment, scour and deposition of gravel surfaces, and natural fluctuation of the groundwater table. Merely removing golf course infrastructure will not restore these processes, and will not, in and of itself, restore riparian community structure and function.

The available evidence suggests strongly that natural disturbance, and the resulting dynamism in riparian ecosystems, should be a fundamental goal of the restoration plan. That is, the expected outcome of restoration should be natural rates of channel dynamism. The restoration design should incorporate processes such as the construction of gravel bars through scour and deposition, and the recruitment of woody debris, which increases channel complexity and improves substrate through sorting and deposition. Quantification of natural rates of dynamics is not possible; there are no data on pre-disturbance rates of streambank erosion, for example. Instead, the restoration design should focus on reducing rates of streambank erosion, and establishing geomorphic processes that can be expected to restore natural rates of dynamism over time.

It should be noted that there may be some conflict between the goals of ecological restoration and objectives developed to address single purposes. For example, reducing sediment yield to Lake Tahoe would best be served by complete bank stabilization which, assuming that it is even feasible given the altered channel form and substantial problems with design, is incompatible with ecological restoration. This is not to say that ecological restoration will have no sediment reduction benefits; restoring historic channel function will result in lowered rates of erosion. However, some dynamism is a fundamental component of riparian system function. The goal of ecological restoration should not be to eliminate all eroding streambanks, but to substantially reduce rates of streambank erosion to levels similar to those which existed prior to human disturbance.

Given the enormous complexity of stream and riparian ecosystems, with the added complexity of dynamism and change through time, it is important to consider the objectives of restoration over larger spatial scales and longer temporal scales than is common in typical engineering approaches. For example, a standard engineering objective is to immediately stabilize a particular streambank in place. An ecological approach instead would have the objective of reducing rates of streambank erosion over the entire project area, often over longer time spans. Achieving these very different objectives requires far different restoration approaches and techniques.

PROJECT AREA GEOMORPHIC TRENDS

In the earliest aerial photographs, taken in 1940, large gravel bars suggest that channel instability was high in large meadows in the lower portion of the project area and in the area now occupied by the airport. In both areas, large gravel deposits dominate the channel, and meander radius of curvature is much higher in the 1940 channel than for meander scars on adjacent floodplain. Channel instability is much lower both downstream and upstream of these areas. For example, downstream of the airport area the channel appears relatively stable; a few low-radius, high-wavelength bends still exist in the 1940s photo, and gravel bar development is lower. Likewise, upstream of the project area, there is lower gravel bar development and more extensive riparian cover. These observations suggest that instability in 1940 was most prevalent centered on this project area and the airport area.

This pattern of instability is likely a response to recent channel alterations, in both the airport area (Mussetter Engineering, Inc. 2000) and the project area. Extensive recent channelization and cutoff of meanders are evident on both the 1940 and 1952 photographs (Figure 9). Large, rapidly migrating gravel bars are well-developed in the channel in both photographs, likely a response to human modifications. Nonetheless, some sense of pre-disturbance meander geometry is preserved in the early historic photos. Some meanders active in 1940 and 1952 are no longer active today, and the fresh appearance of others suggests that they had recently been active (probably cut-off during straightening).

Simon et al. (2004) estimated channel activity, defined as the mean rate of lateral migration along a river reach in dimensions of length, per unit time, by measuring the area between boundaries of the active channel between successive aerial photos sets. The area representing channel migration, or “worked area”, was calculated for three time periods: 1940-1952; 1952-1971; and 1971-1994. The lower end of the analysis was the downstream end of this project area, the upper end included another mile above the upstream end of this project area (Figure 11). Active area was high in the period 1940-1952 within the project area , and lower upstream. It then becomes high in the upstream reaches in the period 1952-1971. Both of these active periods resulted in lower sinuosity throughout his analysis area, with channel activity moderately high everywhere in the period 1971-1994. Overall, Simon et al. (2004) note that channel activity has been progressively reduced in the period 1940-1994, a result that correlates with gradual reduction in sediment yield over the period of record.

These results suggest the following interpretation. Channel instability was well underway in the 1940 and 1952 photographs. It is possible that the 1937 flood resulted in natural channel dynamism which inspired the channelization recorded in the 1940 and 1952 photos. Incision resulting from meander cutoffs during this period propagated upstream, driven especially by a series of rain-on-snow floods in 1955, 1963 and 1964, resulting in high channel activity in the upstream reach.

Although the analysis by Simon et al. (2004) shows that channel activity has gradually decreased between 1940 and 2004, it is important to note that the analysis ended in 1994, prior to the 1997 flood. CDPR has maintained a series of cross sections throughout the project areas since 1992, reproduced in SH+G (2004, Appendices). Many of these show substantial erosion following the 1997 flood, suggesting that instability continues and is driven by rain-on-snow events. These results are correlated with the results of CONCEPTS modeling by Simon et al. (2004) reviewed previously, which suggest increases in width in the future.

CDPR cross sections show that the most substantial channel adjustment following the 1997 flood occurred in the upper portion of the project area (SH+G 2004, Appendices). This is consistent with previous conclusions in this report that the upper portion of the project reach is in a significant period of adjustment. SH+G (2004) provides a longitudinal profile of the project area (plan view and stationing is on Figure 12; profile is on Figure 13). The upper project reach, from Station 4,000 upstream to Station 8,350, is significantly higher in slope than upstream or downstream reaches. Part of the reason for this higher slope may be related to the transition at this location through deltaic outwash deposits. However, the reduction of channel length between 1940 and 1952 is likely also responsible. Subsequent incision, migrating upstream, has encountered resistant outwash and interfingering lacustrine sediments in the bed, which hold higher slopes. Incision in lower reaches has at least partly been accommodated by higher slopes in the upper portion of the project area.

SH+G (2004) notes that repeat longitudinal profiles taken by CDPR suggest the movement of step-wise headcuts through the upper reach, increasing incision. During field reviews, we noted several outcrops of resistant deposits in this reach, often with headcuts. The resistant deposits occur as layers, with less resistant materials underneath and thin layers of fluvial sediments deposited on the surface. Erosion through the resistant deposits, and subsequent headcuts, appear to occur episodically. Initial erosion rates are slow, but once the resistant layer has been penetrated headcuts rapidly propagate upstream. This process would account for headcut formation and is an example of modifications of the incision response through this reach.

As noted previously, modeling by Simon et al. (2004) predicts long-term aggradation in this area. However, CDPR sections show that widening and local incision is the current response. Using these data for calibration of the CONCEPTS model, Simon et al. obtained similar results from a model run for 1991-2001. This run showed negligible change in bed elevation but substantial changes in width.

Eventual aggradation is predicted by both the conceptual model of channel evolution (Simon et al. 2004; Schumm 1999) and by the modeling results described above. Based on available data, however, the river does not appear to yet have entered the aggradation stage. This is an important conclusion for evaluating an appropriate geomorphic restoration approach. The available evidence suggests that the channel will widen until stream power and sediment transport capacity are lower, at which point aggradation will begin. Aggradation is driven by an increase in channel width, with the resulting reduction in slope and increase in width-to-depth ratio. It is also possible that sediment produced by erosion during widening contributes to aggradation.

Finally, it should be noted that golf course bridges are significant controls on future channel evolution. The upper two bridges are within the area predicted to widen, and both are undersized. Erosion problems around both of these bridges have required continual maintenance, and erosion will continue to be a problem at both into the foreseeable future. The current configuration of the bridges will not accommodate predicted geomorphic evolution of the channel, but instead cause and exacerbate local erosion.

RECOMMENDED RESTORATION APPROACH

SH+G (2004) reviewed three general stream restoration alternatives (in addition to a "no action" alternative): system-wide bank stabilization; creation of a new floodplain and channel at a lower elevation; and geomorphic channel restoration using the existing floodplain, through construction of a new channel at a higher elevation. Their analysis found that geomorphic restoration using the existing floodplain most closely met CDPR goals.

While bank stabilization, the second alternative, may restore some ecosystem values, it does not restore geomorphic and ecological processes. The current planform and channel geometry are the product of human disturbance. Stabilizing them in place may lower erosion and sediment yield, and could improve the condition of near-channel riparian vegetation. However, bank stabilization would not restore historic channel function, such as the processes of slow channel migration identified earlier in this document. Riparian benefits would be limited to narrow channel margins. Moreover, SH+G (2004) noted concerns about the technical feasibility of in-place stabilization of all streambanks within the project area over long time-frames. Many previous streambank stabilization projects within the project area have proved to be short-lived (there are several examples of eroding rip-rap), and often have negative consequences upstream or downstream. For these reasons, this approach does not meet CDPR goals.

The third alternative, creation of a new floodplain at a lower level, restores many ecosystem processes because it recognizes the likely trajectory of channel evolution in response to disturbance, i.e., formation of a new floodplain at a lower elevation. This alternative would require moving the existing golf course, but would result in expansion of riparian area, although not to the extent of the historic riparian ecosystem. Excavation of the floodplain would remove much of the sediment likely to be eroded and transported downstream as the channel continues to adjust to past disturbance, progressing through the channel evolution model. However, substantial constraints for this restoration approach include construction issues—large quantities of haul-off would be required, and all banks and the floodplain would require extensive stabilization. The channel profile also is still unstable and would require extensive grade control. This alternative would also require extensive construction within the existing channel and floodplain; water quality protection would be complex, expensive and uncertain. Finally, a project of this magnitude would be very expensive, with substantial risk and uncertainty.

The fourth and final approach entails restoring channel and floodplain morphology and geomorphic processes on the existing valley flat. An essential component of this plan is removal of the golf course from the active floodplain. Assuming that channel and floodplain restoration is feasible and successful, this approach has the most ecosystem benefit. It allows for the restoration of dynamic processes that are responsible for the creation and maintenance of aquatic and riparian habitat, throughout the area of historic riparian ecosystem occurrence. This approach also has lower risk. Because this alternative most closely meets CDPR goals, it has been selected for further analysis and conceptual design development, which is described in the following section. This restoration alternative can be considered to have two general components; removal of land uses incompatible with ecosystem function (passive restoration), and direct reconstruction of the channel and riparian vegetation communities (active restoration).

Passive Restoration

Removal of existing uses that are incompatible with geomorphic and ecosystem function can be considered passive restoration (Kauffman et al. 1997). Within the project area, passive restoration would include the removal of most golf course bridges, fairways and tees within the portion of the valley floor that has been occupied by the river in the recent past. The direct impacts of golf course construction and subsequent operation on the ecosystem include the conversion of native riparian and meadow habitats to golf course vegetation, water quality impacts from the application of fertilizer near streams and in areas of high groundwater, and increased erosion and channel dynamics caused by undersized bridges.

It is important to also note that restoration of channel and floodplain characteristics that existed prior to human disturbance of the lower UTR cannot occur without removing much of the golf course from the floodplain. Although the golf course was constructed after major channelization of the river, the golf course configuration has essentially locked the river into the post-channelization alignment. Restoration of the historic channel planform and floodplain function is incompatible with the current golf course layout.

While the term passive restoration implies less intense restoration effort, this should not be mistaken to mean that its restoration importance is lower than a more direct approach. Indeed, Kaufmann et al. (1997) note that it is the first and most critical step in restoration planning. Many riparian zones are capable of rapid recovery after human perturbations stop because the biota has evolved with frequent natural disturbance characteristic of riverine systems, and have adaptations to survive and even reproduce (Barnes 1983; Wilson 1970; Gecy and Wilson 1990). More importantly, restoration of dynamic ecosystem processes important to floodplain riparian communities, especially those processes relying on disturbance and dynamism, are not possible without removing incompatible land uses. Passive restoration also paves the way for subsequent direct restoration of native floodplain riparian vegetation. Fairways and greens were constructed along the river in areas undoubtedly formerly occupied by riparian shrubs and meadows.

Another important consequence of passive restoration is that it minimizes interactions between the river channel and golf course infrastructure. Continuing channel response to early channelization and other human disturbance have resulted in substantial conflicts between the river and golf course infrastructure. Channel widening and subsequent erosion have threatened bridges, fairways and greens, requiring active intervention in the form of rip-rap and other bank stabilization measures. While these measures have generally been successful in short-time frames, continuing adjustment of the channel upstream and downstream creates new problems, both at existing problem areas and in new ones. Moreover, protecting golf course infrastructure has highly modified the process of channel adjustment to previous human disturbance. Undersized bridges have contributed to streambank erosion and channel widening, especially in the upstream end of the project area.

In the current channel and golf course configuration, resolving conflicts between the river and infrastructure is an enormous task. For example, SH+G developed preliminary plans for a demonstration project of the inset flood plain alternative (alternative 2). The project was undertaken to address channel stability and protect infrastructure in the area of the Hole 6 bridge at the upstream end of the project area. Given the highly dynamic nature of the river in this location, the recommended approach required a high level of engineering, was very expensive, and still held a high level of risk. Similar problems exist at several areas in the golf course. Given that substantial changes in channel form are predicted from a geomorphic standpoint as the river continues to adjust to historic human disturbance, impacts on golf course infrastructure can be expected to continue over the long-term.

It should also be noted that while the general nature of channel adjustment can be predicted with some confidence (general widening, aggradation in upper reaches), the precise evolution of channel form at a particular locations depends on a complex series of processes such as adjustments in grade upstream and downstream, transport of sediment and woody debris, the distribution of erosion resistant sediment deposits in the bed and banks, and other stochastic variables. Site-specific channel evolution is therefore difficult or impossible to predict, suggesting that protecting infrastructure will be a long-term process of responding to unforeseen channel adjustments. To the extent that removing golf course infrastructure from the active area of channel migration is feasible, passive restoration resolves these problems with certainty.

In summary, passive restoration--merely removing the golf course from the active floodplain--has enormous restoration benefits. Removal of infrastructure will allow for the natural channel dynamics that tend to create and maintain aquatic and riparian habitat in functional fluvial systems. Expensive periodic maintenance and intervention will no longer be required to protect bridges, greens and fairways, practices that often negatively impacted riparian vegetation and instream habitat. And the use of fertilizer, which can degrade water quality, will be reduced or eliminated near the channel and riparian corridor.

Active Restoration

When losses in ecosystem structure, composition or function reach a sufficient magnitude, the simple cessation of perturbations may not be sufficient for ecosystem recovery (Kauffman et al.

1997). Factors that diminish resilience of the ecosystem, and hence prevent recovery, include severe changes in geomorphology such as channel incision (Kauffman et al. 1997). Such changes have been documented for the UTR in the project area. Active restoration will be required in the project reach to achieve ecological and geomorphic restoration.

Active restoration, however, may encompass a wide array of specific techniques, ranging from site-specific treatments designed to promote certain functions to complete reconstruction of the channel form hypothesized to exist prior to disturbance. For the purpose of developing an appropriate design approach for this project, active restoration approaches can be considered in two general categories:

1) Form-driven approaches, in which the primary objective is to directly reconstruct a channel form either considered geomorphically stable or that approximates the pre-disturbance form. This is the approach taken by SH+G (2004) in development of Alternative 4.
2) Process-driven approaches, in which the primary objective is to work with geomorphic process to recreate channel form over time.

The first type of approach focuses on direct reconstruction of the entire channel. An example of the second approach is managing near-stream forests for old-growth conditions to provide woody debris, or the establishment of grade controls to protect and reverse the effects of incision.

The objectives of the two approaches are the same. Complete channel reconstruction, if feasible and correctly done, restores geomorphic and ecosystem processes and has the benefit of restoring ecosystem function more rapidly. However, complete channel reconstruction is expensive and inherently more risky than less intensive approaches. In instances in which there is substantial uncertainty regarding complete channel reconstruction, either regarding design criteria or construction feasibility, less intensive approaches may be warranted.

To address these concerns, we recommend modification and refinement of the SH+G (2004) Alternative 4 to incorporate techniques based on a combination of the form and process-driven approaches. We believe that integration of the two techniques will result in far less cost, reduce the complexity of construction, protect water quality during construction, and help assure that the project will function as expected. It must be stressed here that both the SH+G Alternative 4 and this refinement are conceptual designs intended to provide a basis for environmental review. It is expected that designs will continue to be modified through the environmental review and design phases of this project.

<u>Refined Full Restoration Alternative</u>

Alternative 4 proposed by SH+G (2004) calls for form-based full geomorphic restoration. It consists of the construction of new channel throughout the project area, sized to an approximate bankfull discharge of about 350 cfs, or about a 1.5-year recurrence interval flood. The channel would have planform characteristics based on hypothesized pre-disturbance morphology, derived from analysis of historic photos and existing topography.

Based on the geomorphic analysis in preceding sections, we believe that it is appropriate to focus active restoration effort on the channel itself because direct modification of the channel (channelization) has been primarily responsible for degradation. Active channel restoration would not be warranted if changes in watershed condition (increased erosion or loss of hydrologic function) were primarily responsible for destabilization. If this were the case, the most appropriate restoration response would be to address factors responsible for channel degradation in the watershed, rather than within the channel. However, there is substantial evidence that changes in channel form were due to human disturbance of the channel itself. First, there is evidence of direct alterations to the channel described previously. Second, analysis of the timing of channel changes (Simon et al. 2004) shows that increased channel dynamics occurred in the project area prior to increased dynamics in the reach upstream. If watershed conditions were primarily responsible for increased channel dynamics and subsequent straightening, the upstream reach would likely have responded first. Because the degraded channel morphology is primarily due to direct channel disturbance, active restoration of the channel is an appropriate restoration approach.

Uncertainty regarding the planform characteristics of the channel prior to human disturbance complicates active channel restoration, however. The earliest aerial photos of the project area are from about 70 years after the initiation of Comstock logging and its impacts, and therefore do not represent the channel prior to human impacts. SH+G (2004) recommends restoration of a planform developed by connecting most meander scars on the surrounding floodplain, with a very high sinuosity. However, it is unknown if all of these meanders scars were active channel at the same time. The high sinuosity entails additional channel construction and represents substantial cost and risk.

There is also substantial uncertainty regarding the appropriate size of the channel. The development of SH+G's Alternative 4 was driven by developing a channel form of consistent capacity (a bankfull discharge, or about 350 cfs) with respect to surrounding valley flats throughout the project area. There are several potential issues regarding this approach:

- It assumes that the 1.5-year discharge is the effective discharge and therefore responsible for channel capacity. However, there is considerable controversy within geomorphic literature regarding the concept of bankfull discharge, particularly in fluvial environments where relatively rare, high magnitude floods perform a great deal of geomorphic work especially in rain-on-snow systems (subsequent sections contain more discussion of channel capacity and bankfull discharge).
- Valley slope is not consistent throughout the project area. There is a significant break in slope midway through the project area, with an area of high ground just downstream of the Hole 6 bridge. It will not be possible to construct a channel with a consistent capacity through this reach with respect to surrounding valley flats, and it is likely that the historic channel would have had a different relationship with the surfaces.

- As described above, the upper end of the project area is transitional, from entrenched, borderline braided reaches upstream to more meandering channel downstream. Different portions of the new channel will therefore have different forms. While it is theoretically feasible to completely reconstruct a new channel that transitions from on form to another, it is highly complex and carries more risk.
- The valley flat is highly dissected in many areas, likely due to human disturbance and the resulting channel erosion and incision. Identifying appropriate surfaces for floodplains, or bankfull channel capacity, will be difficult if not impossible. In many areas, maintaining channel capacity will require either excavating or filling adjacent surfaces.

Given the uncertainty surrounding active channel restoration, we recommend a less construction-intensive approach. Rather than reconstructing the highly sinuous historic geometry hypothesized by SH+G (2004), we recommend using approximately the 1940 geometry, including meanders that were cut off just before the photo was taken, as the basis for active restoration designs. Although this geometry may be somewhat less sinuous that the pre-disturbance geometry, length of the existing channel would be substantially increased and slope decreased. The accompanying decrease in erosive power would allow natural geomorphic processes to further refine channel morphology over time. Under this approach, active channel restoration would reverse the negative trends in geomorphic function caused by channelization, but the specific refinement of channel geometry would be accomplished by on-going natural geomorphic processes of erosion and deposition.

We also recommend incorporating as much of the existing channel and recently abandoned meanders as possible. This would substantially reduce construction cost and project risk. Several meanders that were active in 1940 have subsequently been abandoned but are still present on the floodplain. Small lengths of new channel, where the 1940 channel was completely obliterated, would be reconstructed.

Reach-scale lateral and vertical stability would be ensured through the construction of regular armored riffles designed to control grade. These riffles, constructed of cobble-sized material, would be placed in strategic locations to reduce and maintain slope and maintain general channel location. An important function of the grade controls would be to restore a smoother longitudinal profile that eliminates the headcuts and hydraulic discontinuities that have developed in response to human disturbance. These structures would also have the function of improving the connection of the stream to the floodplain; they would be constructed somewhat above the elevation of the existing channel, with smaller cross sections, and would define channel capacity at the placement location. Between grade controls, the size of existing channel segments would adjust over time through natural geomorphic processes such as bar deposition, riparian vegetation colonization, and woody debris recruitment.

This approach, which utilizes both active channel reconstruction and natural geomorphic processes to restore pre-disturbance channel morphology, would have substantial benefits over complete channel reconstruction with regard to construction feasibility. First, crossings of the existing channel by the new channel, which are problematic when water is finally introduced to the new channel, would be eliminated. Second, construction quantities, complexity and cost would be substantially reduced. Finally, and most importantly, many of the existing, stable streambanks would be incorporated into the restored channel. Under the SH+G conceptual design, streambanks would have to be reconstructed throughout the length of the new channel. While streambanks have been reconstructed successfully in other Tahoe Basin projects (sod revetment, root wad revetment), these techniques are very expensive and complex. Moreover, native meadow sod, an important material for successful streambank stabilization, is not available within the proposed channel alignment; reconstruction of all streambanks would require using sod from other areas, using less effective revegetation techniques, or using large rock or other materials that are not native to the site. Under the approach proposed here, extensive areas of well-vegetated streambanks along much of the existing channel and abandoned meanders would be incorporated into the restored channel.

It is important to note that while the process-based approach would have significant short-term benefits (increase in groundwater elevation, increase in flood frequency on adjacent valley flats), it would not have the primary objective of recreating the hypothesized pre-disturbance channel form in all locations immediately. Instead, it would provide basic channel form and grade, allowing natural geomorphic processes to establish site-specific final channel form, a process which could take several years in some locations. On the other hand, complete reconstruction of the channel, if successful, would establish an equilibrium channel immediately.

A realistic evaluation of both risk and cost must be set against this benefit, however. Complete channel reconstruction would be far more expensive than the approach proposed here. More importantly, it would carry substantially increased risk due to the inherent complexity of the site and uncertainty in design. Many feet of streambank, built at substantial cost, could be at risk of erosion. And complete channel reconstruction will have greater construction impacts. Given that the more process-based approach proposed here still provides substantial short-term benefits, is less complex, costly , and risky, has less construction impact, and has essentially the same projected outcome as complete channel reconstruction over longer time-frames, we believe it is the preferred restoration approach.

Summary of Recommended Design Approach

We strongly recommend an approach based on restoring ecological and geomorphic function. Restoration of natural patterns of disturbance thus must be a fundamental goal of the restoration approach. This will require reducing erosive power within the incised channel and restoring flooding to adjacent valley flats. Note that this does not mean eliminating erosion, but rather reducing rates of erosion to those typical of natural systems. These measures will enable restoration of the natural traits of resistance and resilience, while allowing for the dynamism important to the function of riparian ecosystems.

Passive restoration is a critical first step in ecological restoration. Removing uses from the valley flat that are incompatible with ecosystem function are essential to restoring dynamic geomorphic and ecological processes. Removing golf course infrastructure will also eliminate many of the current maintenance problems associated with the channel.

Active restoration measures are also required given the history of human disturbance and the resulting channel response. To manage risk, cost and feasibility, we recommend that channel restoration incorporate both techniques designed to recreate channel form, and techniques that use natural geomorphic processes to restore channel function over time.

PROJECT DESCRIPTION

Evidence reviewed above supports the following changes to geomorphic function, due to human disturbance of the historic channel:

- Reduction in channel length and sinuosity;
- decrease in base level with respect to surrounding valley surfaces and a
- corresponding increase in channel capacity with respect to these surfaces;
- decrease in meander amplitude,
- increase in meander radius of curvature; and
- development of significant breaks in slope, resulting in discontinuity in hydraulic characteristics.

Resulting changes in ecological function have been described in preceding sections. The primary goal of the project is to restore geomorphic and ecosystem function. The proposed design would increase sinuosity, raise the channel elevation, and restore riparian habitat and increase connectivity of the channel to the valley flat, and would require removing a portion of the existing golf course from the valley flat (a project overview is shown on Figure 14).

The following constraints were assumed in refinement of the restoration alternative.

- The golf course would likely remain an 18-hole operation. Any portions of the golf course removed from the floodplain would be relocated to upland areas in another portion of the State Park.
- The restored alternative cannot increase flooding for existing structures.
- One river crossing for golf course operations will be required.

DESIGN GOALS AND OBJECTIVES

Geomorphic Goal: Restore, to the extent feasible, natural geomorphic processes that sustain channel and floodplain morphology.

Specific objectives

- Increase channel length and sinuosity;
- raise the channel with respect to surrounding valley surfaces (reconnect channel with floodplain); and
- promote longitudinal continuity in hydraulic characteristics.

Engineering Goal: Assure that the conceptual design can be feasibly designed, permitted and constructed, and reduce or eliminate maintenance of both the restored channel and remaining golf course infrastructure.

Specific objectives

- Use proven or reliable construction techniques;

- comply with known permitting and regulatory constraints; and
- reduce the need for channel modifications to protect infrastructure near the channel.

Water Quality Goal: Maximize water quality benefits and minimize construction impacts.

Specific objectives

- Reduce erosion and improve water quality, including reduction of fine sediment and nutrient loading in Lake Tahoe;
- Minimize and mitigate short term water quality and other environmental impacts during construction; and
- Improve the golf course layout and management to reduce the environmental impact of the golf course on the river's water quality and riparian habitat.

Ecosystem Goal: Restore ecosystem process and function.

Specific objectives

- Restore, to the extent feasible, ecosystem function in terms of ecological processes and aquatic and riparian habitat quality;
- increase area of wet and mesic meadows;
- increase area of riparian vegetation, especially riparian shrubs; and
- improve in-channel habitat and habitat complexity.

DESIGN COMPONENTS

Components of the recommended conceptual design are shown in detail for the lower reach of the project area in Figure 15, the middle reach in Figure 16, and the upper reach in Figure 17.

Passive Restoration

Golf course infrastructure would be removed from the floodplain, to about the limits of meander scars on historic photographs. All golf course infrastructure on the north side of the river in the downstream end of the project area, between Angora Creek and the river, would be removed. The golf course holes nearest the river on the south side would be removed, along with bridges, although holes higher up on the southern alluvial fan would remain. All drainage and irrigation infrastructure associated with the holes eliminated would be removed.

The new golf course alignment would require one crossing, near the upstream end of the project area. Holes that remain near the river in this area should minimize impact to the river and floodplain and could be sited on the patch of higher ground just downstream of the Hole 6 bridge, or upstream of the bridge near a large mid-channel bar. The bridge, golf course fairways and greens, and golf cart paths should avoid flow obstructions in a portion of the active floodplain behind the current Hole 6 green (shown as an avoidance area on Figure 17), and should not block access to this overflow channel. The new golf course should also avoid flow obstructions near older meander scars on the floodplain upstream of the end of the restored channel (Figure 17). This area is likely flooded during larger floods under current conditions, and could become active floodplain if channel dynamics occur in the future. In the obstruction avoidance areas, paths or other infrastructure could be raised to allow flow underneath. It may be possible to place small amounts of flow obstruction within this area if flood flow paths are available around the obstruction.

Planform

An overview of the recommended channel alignment is shown on Figure 14. This alignment was developed to include elements of the planform of the 1940 channel, or features that had obviously been active not long before the 1940 photograph was taken. In some specific areas, planform development required evaluating how recently features on the 1940 photograph had been part of the active channel, or other design criteria. These areas include:

- Meanders visible on the 1940 photograph just upstream of the Highway 50 crossing on the south side of the river were eliminated. These meanders are visible in both the 1940 and 1952 photos, and indeed are still visible today, but they don't appear to be recent in historic photography (no gravel bar deposits). Also, location of the restored channel in this area would make construction of grade control at the downstream end of the project problematic. First, the grade control would have to be constructed off State Parks property, directly across from the private properties on the left bank at the downstream end. While the RB floodplain is CTC ownership, and most of the structure could probably be constructed on this parcel, connecting the grade control into higher ground would require disturbance on or very near private property. It would also require moving the channel away from private property, which is often not desirable. The second major problem with grade control in this location is that it is essentially downvalley of the private property. A hydraulic analysis by SH+G (2004) of the restoration alternative didn't show a significant increase in the 100-yr flood elevation, it did substantially increase the 5-yr elevation. One of the houses on the right bank is currently in the 10-yr floodplain, which would be increased to the 5-yr floodplain with the project.
- A meander active in the 1940s photograph near the downstream end of the project area, historically the confluence with Angora Creek, was also eliminated. The sewer crosses the river in this location in a siphon. Altering the channel configuration in this location would require substantially reconstructing the sewer, with placement of a new siphon. Given that grade control in this location would be problematic, and that benefits would be limited, this meander was eliminated and the grade control at the downstream end of the project area was placed upstream of the sewer crossing.
- Upstream of the clubhouse, recently active meanders in the 1940 photograph have subsequently been obliterated through golf course construction. We recommend the complete reconstruction of two meanders to restore sinuosity in this reach, while retaining a substantial portion of the existing channel.
- A large meander was active in 1940 extending into the Angora floodplain near the upstream end of the Angora meadow. Although this meander scar is still exists and is well-formed, a sewer line crosses the alignment. We recommend using the meander nonetheless, as it is important to increasing channel length and sinuosity. This design assumes that moving the sewer line would be preferable to constructing large amounts of new channel to gain comparable channel length.

- Two other meanders active in the 1940's but subsequently abandoned would be reactivated at the upper end of the

The recommend approach for planform restoration consists of four general channel treatments:

1) Grade Controls. Section of existing channel that will require the construction of grade control for transitions to upstream and downstream reaches of the existing channel.
2) Existing Channel. Portions of the existing channel that would be included in the final channel alignment with little or no modification. Some sections may require bio-engineered bank treatments.
3) Historic Channel. Meanders active in 1940, and still evident on the ground, which will be reoccupied with minor modifications.
4) Constructed Channel. Portions of the channel that will require complete construction. These are generally meanders evident in the 1940s photography that have subsequently been filled.

Table 1. Length of different treatment types within the restored channel.

Restored Channel Type	Length (ft)	Percent of Total
grade control	690	6
existing	5,830	50
historic	3,810	33
constructed	1,248	11
total	11,578	100

Total length of the restored channel, from the Highway 50 crossing at the downstream end to the upstream extent of potential modifications, is about 11,600 feet (Table 1). Of this total, about 50% would consist of existing channel. More detail on restoration treatments in each of the channel types is found in a following section.

Profile

The current longitudinal profile of the channel invert or thalweg elevation through the project area is shown in Figure 13. Note that current slope is higher in the upper portion of the project area, as described previously, and lower in the middle reach. A distinct change in slope occurs at Station 4,000, about midway through the project area. Prior to human disturbance, the slopes of these two reaches were probably different due to changes in the valley flat described previously. However, human disturbance and the resulting channel response have resulted in higher slope in the upper reach and lower slope in the downstream reach, increasing the difference in slope between the two reaches. The objectives of the development of the following profile were therefore to reduce slope in the upper reach, create a smoother transition between the upper and lower portions of the project area, and increase the elevation of the channel with respect to surrounding valley flats. Note that this is a conceptual design developed based on an evaluation of existing geomorphic conditions. It is assumed that conceptual designs will be modified through the environmental review and design process, with additional hydraulic and sediment transport analysis. This conceptual design is intended to provide basis for evaluating feasibility of the channel restoration approach and potential environmental effects.

The upstream end of channel modifications for restoration was assumed to be SH+G Station 8,350, just upstream of the Hole 6 bridge. At this location, the channel is adjusted to the surrounding floodplain, and habitat condition is good. Streambanks are relatively stable upstream. The current channel invert elevation of 6,276.4 was used at this location for the upstream end of the restored profile.

At the downstream end of the project area, the final grade of the profile must match the invert elevation of the Highway 50 bridge, or of the existing channel upstream of this point. The current channel is significantly incised under the bridge due to downstream channelization and confinement by the bridge. A restored channel closer to grade with the surrounding valley flat upstream will be substantially higher than the channel under the bridge. Grade control will be required to step the restored channel to the highway bridge grade.

A grade control for the golf course water intake is located about 500 feet upstream of the downstream end of the proposed for channel restoration. At the upstream end of the grade control, the channel thalweg elevation is relatively high with respect to surrounding valley flats. However, the channel is still somewhat incised in this area. The profile for the restored channel was developed by raising the thalweg invert elevation about one foot above the existing elevation at the upstream end of the existing grade control (6264.1) to reduce channel incision (see the following section on channel geometry for a discussion of channel size and relationship to the floodplain).

The final channel thalweg profile was derived by connecting the proposed elevation above the Hole 6 bridge to the proposed elevation at the upstream end of the golf course water intake through the length of the new planform. This profile was then adjusted to allow for somewhat higher slope in the upper portion of the project area, resulting in a concave profile (Figure 18). This profile reduces slope in the upper portion of the project area, increases slope in the lower portion, and reduces and smoothes the transition between the two areas (Table 2).

Table 2. Existing and restored channel slope in the project area.

Channel Segment	Slopes	
	Restored	Existing
Entire Reach	0.0015	0.0020
Between Grade Controls	0.0014	na
Upstream Reach	0.0015	0.0026
Downstream Reach	0.0011	0.0006

Grade Control

Two forms of grade control will be required within the proposed channel. First, highly armored grade controls, with a higher gradient than the restored channel, will be required to connect restored channel to existing channel at the upstream and downstream ends of the project. Second, grade controls with a gradient similar to overall restored channel gradient, essentially armored riffles, will be required within the project to establish the new grades of the restored channel. These grade controls would be placed where reactivated meanders tie into existing channel, entrances and exits of newly constructed meanders, and within long reaches of incorporated existing channel . These two types of grade control will require different designs and construction techniques, described in following paragraphs.

One of the higher gradient grade controls will be required at the upstream end of the restored channel. This purpose of this grade control is to stabilize the current bed elevation in the channel upstream of the project area. The current Hole 6 Bridge, which is undersized, appears to be maintaining a relatively high streambed elevation upstream, probably through backwater effects on sediment transport. Removal of this bridge would likely result in channel incision. It is therefore recommended that a grade control structure, consisting of larger rock placed in step-pool configuration, be constructed at this location to prevent incision and headcut migration. The slope through this structure, based on the restored profile, would be 0.0023. Construction of a stable grade control structure at this slope is feasible.

A similar grade control structure will be required at the downstream end of the project area due to incision through the Highway 50 bridge. This grade control structure will be steeper due to the restored channel design and the degree of incision under the Highway 50 bridge, with a slope of 0.0064. Based on a survey of the channel thalweg by SH+G, the current water supply intake grade control has a slope of 0.0065, similar to the proposed structure. This indicates that the proposed grade control will be stable in this area. Stability of the grade control is probably enhanced in this area by backwater effect from the Highway 50 bridge during large floods.

The low gradient grade controls are designed to raise the average bed elevation, maintain consistent slope, and define the channel cross section. We recommend that these structures be placed at the inlet and outlet of all larger meanders, or in long reaches of the existing channel. Bedforms or riffles in alluvial channels tend to occur about every 5-7 bankfull channel widths (Knighton 1998); given a width of 60 feet, armored riffles should be placed, on the average, about 300-500 feet apart. At the relatively low slopes of the restored channel profile, these structures could take the form of armored riffles, composed of materials of cobble size. Length, slope and placement of the riffles would be refined during detailed design based on analysis of hydraulics and substrate movement, and other design factors. The conceptual placement of all armored riffles is shown on Figures 15, 16 and 17, along with stations and elevations at the upstream end of the riffles. To prevent the channel from eroding around them, cobble material could be extended into the surrounding floodplain, in trenches capped with native sod.

Design Discharge and Channel Size

Previous researchers have estimated different values for the magnitude of the bankfull discharge of the functional, undisturbed UTR. Bankfull discharge is the flow which fills the channel to the elevation of the surrounding floodplain or valley flat. In alluvial channels, bankfull capacity is often considered to be equal to the effective discharge, which is the flow that transports the most sediment over time (Andrews 1980). Mussetter Engineering, Inc. (2000) suggests that bankfull discharge has a 2-year recurrence interval in self-formed equilibrium alluvial channels, citing Williams (1978), and therefore recommend 600 cfs for bankfull discharge downstream of the project area (probably equal to about 550 cfs in the project area). SH+G (2004), based primarily on identification of bankfull indicators such as vegetation lines and the elevation of bar surfaces, suggests a bankfull discharge within the project area of about 350 cfs, equivalent to the 1.5-year flood from the snowmelt flood, partial duration distribution.

Uncertainty concerning estimating bankfull discharge is not confined to the UTR, but is a common problem in geomorphology (Knighton 1998; Andrews 1980; Williams 1978). Williams (1978) is cited by Mussetter Engineering, Inc. as stating that the bankfull discharge is about a 2-year recurrence interval in alluvial channels, but he notes in his conclusions, based on analysis of several data sets from the western United States, that "bankfull discharge does not have a common frequency of occurrence among rivers." Among the data sets he reviewed, the most common recurrence interval for bankfull discharge was around 1.5 years, but only about one third of the cases were around 1.5 years, and recurrence intervals ranged from 1.01 to 32 years. Andrews (1980), in an extensive study of streams in the Yampa River basin, found that effective discharge correlated well with bankfull discharge. However, the recurrence interval of this flow varied between 1.18 to 3.26 years on the annual flood series, a range which incorporates both the recommended bankfull discharge of Mussetter Engineering, Inc. and SH+G for the UTR.

While the concept of bankfull discharge has important conceptual and practical utility, Knighton (1998) and other authors recognize the uncertainty and difficulties inherent in its application. These include:

- Valley flats are usually highly variable surfaces, consisting of a number of different sedimentary landforms. Determining which landform represents a bankfull elevation can be difficult, and many researchers have not clearly defined the geomorphic processes responsible for formation of the landform (Williams 1978). The bankfull channel is often difficult to define in the field, and there is not a consistent method for specifying it (Knighton 1998).
- Bankfull discharge may not be the most effective flow as regards sediment transport (Knighton 1998). Rarer flows may be more effective transport agents in streams with a high proportion of high discharges, while more frequent flows may be important in channels in which available stream power can move most of the available sediment at lower flows.
- Channel form is the product not of a single formative discharge but of a range of discharges, and has a memory for past events (Knighton 1998). This may be particularly important for the UTR, with the regular occurrence of rain-on-snow floods over decadal time scales, floods which may produce bedforms that strongly influence geomorphic processes in subsequent smaller floods.

It is beyond the scope of this document to resolve uncertainty regarding bankfull discharge and channel capacity. We assume that final channel dimensions will be developed through the design phase, using an iterative approach incorporating analysis of channel geometry in functional areas, sediment transport and hydraulic analysis, and other factors. We feel that rain-on-snow events have an important role in channel geomorphology, and field observations during runoff events support a flow of 450-550 cfs. Given that largest bankfull discharge suggested by previous researchers is about the 2-year recurrence interval, we assume, for the purposes of this study, that channel capacity in constructed portions of the restored channel will be about 550 cfs. Detailed design may result in lower bankfull discharge based on the analysis described above.

Given a criteria for bankfull discharge, channel restoration design will then require identification of the elevation of the stage at bankfull discharge. Usually, this stage is considered to be the same as the elevation of the surrounding floodplain. However, Williams (1978) notes that floodplain is a vague term, may represent a number of surfaces created by substantially different geomorphic processes, and may be interpreted differently by different disciplines or researchers. He recommends applying the following specific definitions of valley landforms to analysis of the bankfull channel:

1) Valley Flat. The main unit of flat or nearly flat surface in the valley bottom.
2) Inactive Floodplain. A surface inundated so rarely that it is no longer growing by present alluvial processes. Often called a terrace.
3) Active Floodplain. An overflow surface that is periodically constructed and possibly eroded by the river but is undergoing net growth during the 'present time' (past ten years or so).

Williams (1978) notes that all three surfaces are not commonly present in all locations. Often, the inactive floodplain is the valley flat, or active floodplain may be absent or inconspicuous. Most importantly, he notes that the valley flat may be either active or inactive floodplain, and that the practice of calling the valley flat the "floodplain" should therefore be abandoned. He notes that geomorphologists increasingly favor using the term floodplain to mean active floodplain, and terrace to mean an inactive floodplain, a practice adopted here.

The key question, from a restoration perspective, is what was the historic relationship between active floodplain and the valley flat? Obviously, incision has affected this relationship. It is often assumed that, in equilibrium alluvial channels, the valley flat was the active floodplain prior to human disturbance. This is often a reasonable assumption. For example, in larger meadow reaches of the lower UTR, extensive meander scars on the valley flat strongly suggest that the active floodplain was at or near the valley flat prior to human disturbance. Although much of the valley flat in these areas was formed by Pleistocene and early Holocene lacustrine processes, soil profiles show that the valley flat had been modified and was growing through modern fluvial processes such as overbank deposition of fine sediment, which conforms to the definition of active floodplain given above. However, many undisturbed channels are naturally entrenched within valley flat surfaces formed by geomorphic processes other than modern fluvial activity, such as outwash floodplains. In these cases, the active floodplain is relatively narrow surface within the valley flat, as described by Williams (1978). As reviewed previously in this document, the project area is a transitional reach between an active floodplain entrenched in outwash upstream, and less confined meadow reaches downstream, where the entire valley flat was likely near the active floodplain elevation prior to human disturbance.

The design for channel restoration must recognize the transitional nature of the project area and the implications that has for the relationship of the channel to the valley flat in the upstream versus the downstream portions of the project area. We do not believe that design should have the geomorphic objective of connecting the bankfull stage to the valley flat in all locations. Instead, the bankfull stage should be tied to the elevation of the active floodplain, which should transition from below the valley flat at the upstream end of the project area, where the stream likely was historically naturally incised within outwash deposits, to near the valley flat at the downstream end, where the valley flat was largely constructed by recent fluvial processes. This geomorphic function is consistent with interpretation of meander scars and belts on historic aerial photographs. Relatively recent meander scars at the lower end of the project area are found on the valley flat (which was formed by recent fluvial processes), while the recent meander belt in the upper portion of the project area is incised within the adjacent valley flat (which was formed primarily by glacial outwash channels).

The transitional nature of the project area adds complexity to restoration design. Further complicating the design, incision and resulting channel response have resulted in the formation of many transient depositional features developed as incision progressed. If maintaining consistent bankfull continuity with adjacent depositional surfaces throughout the project area were the primary restoration objective, large-scale grading would be required. Such a design would be complex and risky, requiring the reconstruction of streambanks and floodplain throughout the project area. We do not believe that the design of such a project can be practically accomplished, given the high degree of uncertainty and risk.

The proposed design has been developed to take into account the complexity of the project area and design and construction feasibility. It does not have the primary geomorphic objective of bankfull discharge continuity with all adjacent surfaces. Rather, the design recognizes that, in naturally functioning rivers, bank configuration and dimensions vary with distance along a reach, resulting in significant differences in bankfull discharge (Williams 1978). Due to the complexity of valley flat topography in the project area, this conceptual design is driven primarily by restoring channel length and profile characteristics rather than focusing on bankfull discharge at particular cross sections.

A fundamental assumption of the proposed design is that natural processes of erosion and deposition will establish appropriate channel dimensions over time in areas where the stream is not reconstructed (the majority of the restored channel). General channel dimensions would be established at armored riffles or constructed portions of the channel, but intervening reaches would adjust over time based on local sediment supply, transport and deposition. This is a reasonable assumption given that alluvial channels are, by definition, self-formed. Although several years may be required for the development of the equilibrium channel at some locations, we believe that this conceptual design is justified given the complexity and risk inherent in the design of complete channel reconstruction. It is also important to note that the proposed design will provide immediate benefits in terms of erosion by reducing slope and bank heights.

Although the conceptual design presented here does not inherently rely on establishing bankfull channel dimensions at all locations, construction of the armored riffles, grade controls and the portions of new channel construction will require establishment of criteria for channel sizing. For the purposes of this study, it is assumed that the channel geometry at armored riffles or other constructed areas will be similar to a riffle section measured in a functional reach upstream of the project area by CDPR (2004) (Figure 19). At this section, thalweg depth (maximum depth) at 550 cfs is about 3.5 ft, width is about 70 ft. Again, the sizing of the final sections will be based on further analysis in subsequent project phases, but these general channel characteristics are used in this study to evaluate restoration effects and feasibility.

The thalweg depth at bankfull of this typical cross section was applied to the thalweg profile described in the preceding section (Figure 18) to estimate water surface elevation for the restored channel at 550 cfs. Note that this is an estimate only of water surface elevation; local slope and roughness characteristics are not considered. For the purposes of this document, this estimate was considered adequate to evaluate changes in ecological function, but hydraulic modeling will be required during environmental analysis or final design. Existing thalweg elevation, restored thalweg elevation, and the estimated 550 cfs water surface elevation are plotted throughout the project area on Figure 18. The elevation of the low terrace, a surface identified by SH+G (2004) and probably roughly equivalent to the active floodplain, is also included on this figure. Water surface elevation at 550 cfs for the restored channel profile is near the low terrace.

Valley wide cross sections were constructed from LIDAR topographic data at seven locations throughout the project area (Figure 20). At these sections, channel thalweg elevations at riffles and estimated water surface elevations for the existing channel, the SH+G Alternative 4, and this proposal were calculated (Table 3). Hydraulic models for the SH+G existing conditions and Alternative 4 hydraulic analysis were based on the LIDAR topographic model, which overestimates bed elevation because LIDAR does not penetrate water. Also, it is important to note that the derived water surface elevations for this proposal are not based on hydraulic modeling but estimated from the CDPR model cross section characteristics. Hydraulic modeling should be performed in subsequent analysis. While there is some error in estimates of water surface elevation for all methods, the error is likely minor with respect to the changes resulting from restoration recommendations in SH+G Alternative 4 and this proposal. Both the SH+G Alternative 4 and this proposal significantly raise the bed elevation, baseflow and flood water surface elevations compared to existing conditions.

Table 3. Channel and water elevations at seven transects throughout the project area for existing conditions, SH+G Alternative 4, and this proposal.

		Channel Elevation			Estimated Baseflow Water Surface Elevation			Estimated 550 CFS Water Surface Elevation		
Transect No.	SH+G STA	Existing	SH+G Alt. 4	This Proposal	Existing	SH+G Alt. 4	This Proposal	Existing	SH+G Alt. 4	This Proposal
1	2230	6263.1	6265	6264.1	6264.0	6266.0	6265.1	6266.3	6267.7	6267.6
2	3035	6263.6	6266	6265	6264.5	6267.0	6266.0	6267.9	6269.6	6268.5
3	4076	6263.8	6268	6268	6265.0	6269.0	6269.0	6269.3	6270.8	6271.5
4	1575	6261.1	6264	6261.3	6262.0	6265.0	6262.3	6265.5	6267.4	6264.8
5	5475	6268.1	6271	6270.2	6269.0	6272.0	6271.2	6272.1	6273.8	6273.7
6	7060	6271	6274	6273	6273.0	6275.0	6274.0	6276.1	6277.5	6276.5
7	7850	6275.0	6276	6275.5	6276.0	6277.0	6276.5	6278.9	6279.5	6279.0

Water surface elevations for the 550 cfs discharge under existing conditions and for this proposal are shown on valley cross sections based on Lidar one-foot topographic data in Figure 21. Increases in water surface elevation are greatest in the middle section of the project area. At the upstream end, the channel invert has been raised the least to avoid backwater effects on upstream reaches. Because the channel is traversing high ground in this area, the restored design remains entrenched with respect to the valley flat, but this is likely the historic morphology in this area as the channel is flowing over, and entrenched within, older outwash deposits.

Valley Flat Topographic Modifications

In the lower portion of the project area, we recommend only minor modifications to the valley flat adjacent to the restored channel. Levees along the banks of the river should be removed. Where the topography has been altered for golf course infrastructure, such as greens or tees, the historic topography should be restored. Streambank rip-rap should be evaluated on a site-by-site basis in detailed design. In some cases, rip-rap banks will be on portions of the existing channel that are abandoned. In others, rip-rap may be retained to control bank erosion.

There are opportunities for minor valley flat grading throughout the lower project area to enhance habitat. Small depressions, designed to mimic abandoned meanders, could be constructed in areas where the golf course is removed. These features would provide variability with respect to groundwater, increasing habitat and vegetation diversity.

At the upstream end of the project area, the historic channel was likely naturally entrenched within the valley flat, a geomorphic unit that appears to consist of older deltaic outwash deposits. Valley flat adjacent to the channel is relatively high throughout this area, from the Hole 6 bridge downstream to STA 8,500 on the restored channel stationing. The current channel configuration, which has incised further due to human disturbance, contains little active floodplain on the east side of the river through this area, with high, eroding streambanks. Some active floodplain is found on the west side of the channel, with abandoned channels that may represent the channel configuration prior to human disturbance.

Raising the channel high enough to establish connectivity at 550 cfs with the valley flat unit within this area is not possible without creating significant discontinuity in the longitudinal profile. Downstream of this reach, the valley flat is lower and the profile cannot be raised significantly higher than recommended in this proposal. Raising the bed elevation higher than in the upper portion of the project area would therefore create locally high channel slope, and a distinct break in slope around STA 8,500. Such areas are typically exceptionally unstable due to discontinuity in sediment transport characteristics.

To address bank instability and resulting sediment contribution in the entrenched upper portion of the project area, selective active floodplain restoration on the east side of the river could be considered (Figure 16). This measure is only recommended on the east side of the river due to construction access problems and the potential for high construction disturbance on the west side of the river. Floodplain excavation would reduce bank height, provide additional flood flow area, and would remove streambank sediment likely to be recruited to the stream channel given high bank instability in this area.

The width of the excavated floodplain should be developed during design based on a number of criteria: extent of severe bank erosion; hydraulic characteristics of the final channel design; protection for existing vegetation, etc. For the purposes of this document, it is assumed that two feet of excavation would occur throughout the area shown in Figures 16 and 17. Erosion control measures will be required on all excavated active floodplain, as it may be subject to flow during floods the winter after construction. These measures could include placement of native sod blanket, other native erosion control materials such as willow transplants or wattles, placement of woody debris, or installation of erosion control fabrics over seeding.

Woody Debris

Throughout the entrenched portion of the restored channel, from the upstream end downstream to about STA 8,500, lodgepole forest commonly occurs on the valley flat. Woody debris is relatively common in the channel, and woody debris supply can be expected to remain relatively high in the portion of the channel. Woody debris jams could be constructed within this reach to help promote streambank stability, with the added benefit of improving instream habitat complexity. Small jams configured as flow deflectors along channel margins would likely be most effective. These jams should be carefully configured to avoid substantially increasing overall streambank erosion or affecting the function or armored riffles

Streambank Stabilization

A primary objective of this design would be to preserve and maintain as much of the existing vegetation as possible. By utilizing much of the existing channel, stable streambanks can be incorporated into the design. In historic meanders that are occupied by the restored channel, vegetation in the bottom of the channel will have to be removed (vegetation should be salvaged and used in other locations), but special care should be taken to preserve existing vegetation on the streambanks.

Another primary objective of this design is to create hydrologic conditions that make bank stabilization more feasible. One of the major obstacles to bank stabilization in the current configuration is that many streambanks are very high due to the incision history. In the montane, Mediterranean Lake Tahoe climate, with short, dry summers, revegetation of the high streambanks has limited feasibility. By increasing channel, flood and groundwater elevations, the height of streambanks will be reduced and the potential for revegetation improved.

Thus, in portions of the existing channel where streambanks are currently eroding, principally in the upstream entrenched reach, bioengineering approaches to stabilization would be more feasible than under existing conditions. These approaches are preferable to typical streambank stabilization incorporating rip-rap from an ecosystem restoration perspective because they allow channel dynamics to occur. Bioengineering approaches also tend to be less expensive, and therefore have less inherent risk. Water quality protection during construction is also less complex and risky. Bioengineering approaches that could be incorporated into the final design include willow facines, wattles or bundles, brush or tree revetments, and brush boxes or spurs, or native vegetation transplants, among many others (Hoag and Fripp 2002 contains descriptions of these and other bioengineering techniques). We recommend bioengineered bank stabilization throughout the entrenched reach, both of high eroding streambanks and any areas where floodplain excavation occurs (Figures 16 and 17).

In newly constructed channel segments, stacked native sod revetments could be used to stabilize outside bends. Streambanks in straight portions of the channel could be constructed using native sod blankets. Both of these techniques have been used with success in similar Lake Tahoe projects. Materials for this construction could be obtained from within the footprint of the new channels, salvaged from the bottom of historic meanders that are part of the restored channel, or from adjacent meadows.

Historic Meanders

The historic meanders which will be utilized under this proposed plan are currently highly vegetated, including vegetation throughout the bottom of the channel. In the lower portion of the project area, no more that one to two feet of grading will be required to reach design elevations. However, the upper meanders may require an average of three feet of excavation to reach design grade.

Care should be taken in construction to maintain the current bank vegetation. Although riparian shrubs can be pruned extensively, the soil and root structure of existing streambanks should not be disturbed, to the extent feasible. All vegetation removed from the bottom of these meanders should be salvaged and utilized in revegetation on other portions of the project.

Suitable substrates may or may not be encountered during grading of the historic meanders. At the upstream and downstream ends, the proposed design calls for placement of armored riffles. In other locations, appropriate gravel substrates may also be required.

Abandoned Existing Channel

Approximately 2,084 ft of the existing channel would be abandoned. These segments should be stabilized at the upstream and downstream ends with vinyl sheet piling across the channel, installed in sod and fill revetment plugs, with a top elevation equal to or slightly above surrounding valley flat elevation. These plugs typically should be at least 40-50 ft in length. Similar techniques have been used successfully on other Tahoe Basin projects.

The abandoned channel segments represent an important opportunity to create rare habitat types. By leaving portions of the channel unfilled, small pools of open water could be created, surrounding by riparian vegetation. The persistence of the standing water could be controlled through partial fill. These features would provide a relatively rare type of habitat important to riparian birds and amphibians. It must also be recognized, however, that standing water can provide the conditions necessary for mosquito reproduction, though habitat for mosquito predators such as dragonflies would also be created. Active mosquito management may be required, especially in areas near public access.

Vegetation Restoration

The proposed restoration alternative is designed to achieve a number of geomorphic and water quality goals, which will result in or facilitate increases in areas of vegetation communities that provide one or more of the following functions and values:

- potential removal of fine sediment or nutrients from surface or ground waters, to a greater degree than do the existing habitats at the same sites;
- greater geomorphic stability than the existing communities at the same sites;
- support for higher biodiversity than existing communities at the same sites; or
- increased suitability for special-status species or provide potentially suitable habitat for them.

These goals essentially represent restoring geomorphic and biological processes that have been impaired directly or indirectly by human alterations. Generally speaking, these goals are achieved by conversion of developed or upland vegetation communities to riparian communities, and to a lesser extent by conversion of riparian communities in which the soil surface is not as effectively stabilized by vegetation and/or other erosion-controlling cover (e.g., Lodgepole Pine – Mesic) to wetter ones in which the soil is more effectively stabilized (e.g., Willow or Wet Meadow). In some sites, such vegetation community conversion may achieved readily merely by alteration of soil moisture regime (e.g., by reversing channel incision); in others, grading and revegetation may be appropriate in order to achieve conversion to native vegetation types more rapidly.

Without any action other than removal of pavement and raised fills, the process of natural ecological succession would be expected to replace the existing golf areas with native vegetation types over some time scale, which would vary from short (one to five years) to long (decades) depending upon microsite. Some native wetland meadow species (specifically *Carex nebrascensis*) already invade portions of the fairway and, in small areas, even constitute a co-dominant species with the turf grass, despite being mowed regularly. The 1997 flood event showed that the existing maintained turf is extremely erosion resistant. Effecting restoration wherever possible without grading, leaving the turf intact, would have the advantage of eliminating the potential for generation of more sediment than is presently the case. However, it would have the disadvantage of delaying achievement of habitat goals. In order to balance these two important considerations, a combination of specific restoration actions and adaptive management responses is recommended.

In floodplain areas that require heavy equipment excavation or grading, these activities should occur in the same season as channel construction. All revegetated areas would then be irrigated for at least one year, leaving the channel in its current configuration to protect newly revegetated areas. Vigorous vegetation and well-stabilized soil surfaces should be achieved prior to activating the restored channel. This is important because the restored channel is intended to be better-connected to its floodplain; that is, the likelihood of surface water on the restored golf course surfaces is higher than at present.

In the Trout Creek meadows, a dense network of surviving rhizomes of wet meadow graminoids, specifically local species of sedge (*Carex nebrascensis)* and rush (*Juncus balticus)*, were known to be present prior to construction of the new channel. These rhizomes have given rise to extremely vigorous wet meadow vegetation in only a few years since the project was completed. Portions of the existing golf course turf may still be underlain by a sufficient rhizome network to form habitat without the need for drastic modification of the soil profile and extensive replanting. This buried meadow, as opposed to in-migrating seeds, is probably the source of the *Carex* and *Juncus* that is currently present in portions of the golf course.

In order to determine where buried plants can be relied upon to form the future habitat, soil cores that are sufficiently large that test plugs can be cultivated from them should be obtained during the design phase from sites throughout the portions of the golf course to be restored. This sampling will also provide near-surface soil profile logs and material for nutrient testing if desired, important data required for determining the need for soil amendments. The sampling could be carried out immediately prior to golf course opening in the spring, and the sampling sites could be refilled and the turf replaced, so this sampling and testing for viable buried plant material can be completed before the existing golf holes are closed.

The following habitat restoration actions encompass the range of options that will likely be applied to different areas within the golf course coverage area :

- Grading and rebuilding of the soil profile
- Deep-ripping, amendment, and revegetation
- Removal of turf and removal of unsuitable shallow fill
- Seeding and irrigation
- Turf abandonment

All treatments that entail the removal or substantial disruption of the existing erosion-controlling golf course turf should be followed by seeding and application of mulch (loose or hydraulically applied), or rolled turf pre-grown from native seed in coconut fiber turf-reinforcement mats. Where willows are desired and pre-existing relict graminoid turf is present, measures should be applied to create a competitive advantage for willow over the native meadow vegetation in which they will be planted.

Revegetation should employ species native to the project vicinity, with the possible exception of use of some grass species that are particularly valuable in soil stabilization and do not invade well-vegetated native habitat. To the extent feasible, native vegetation that must be removed in order to construct new channel, reconstruct channel capacity in segments of historic channel, or to construct floodplain should be salvaged and transplanted directly to habitat creation areas. If possible, all transplantation should occur during the periods of May 1 - June 30 and September 15 – October 15.

Grading and Rebuilding of Soil Profile

This restoration action would be applied to all hard coverage and, at a minimum, to all areas where the golf course topography is clearly significantly higher than the surrounding or pre-existing soil surface level: greens, tee boxes, and spoils "levees" along the river bank. Grading would achieve a final grade, after placement of salvaged soil, at an elevation that is expected to lie no more than one foot above the elevation of late spring or early summer groundwater. Along linear features (golf cart paths), flow breaks would be installed in the form of stacked turf or fiber-wrapped, seeded soil rising slightly above and extending many feet into the surface on either side. At suitable microsites, patches of willow plantings would be installed to create willow-meadow complexes such as presently occur elsewhere in the Upper Truckee River system.

The rebuilt soil profile would be revegetated with a combination of regionally collected seed, salvaged turf, and willow material (of various forms: cuttings, stubs, or entire rooted clumps).

Deep-ripping, Amendment, and Revegetation

This would occur where the topography is at the desired level, but no viable buried native rhizome bank is present, and/or the soil conditions are not likely to be conducive to the establishment of the dominant plant species of the desired vegetation type. No net change in elevation is intended, but a slight medium-term increase of the surface level is likely to result from reducing compaction and incorporation of amendments. Treated areas would be seeded, possibly planted with vegetative propagules (plugs) of desired species, and mulched.

This treatment will would be applied to portions of the areas that are anticipated to support Mesic Meadow, to Lodgepole Pine – Mesic or Dry Type, and to Dry Meadow. In these areas, ripping and revegetation could be applied in alternating bands, oriented along topographic contours, with the Seeding and/or Abandonment treatments described below.

Turf Removal and Removal of Unsuitable Shallow Fill

This would occur where investigation of the near-surface soil profile of the existing fairways shows that a buried A horizon and viable native meadow rhizome network is present underneath a layer of sand or unsuitable soil fill, which is believed to be too deep to permit direct re-establishment of wet meadow either for biological or topographic reasons (surface too high to have the necessary soil moisture regime). Existing golf turf would be salvaged for other restoration use, and the undesired layer of sand or soil will be scraped. The disturbed surface could be seeded with additional desirable species (e.g., *Deschampsia cespitosa*) and mulched.

Seeding and Irrigation

This would be applied where it is deemed desirable to retain the existing golf turf for its value in erosion protection, and no modification of the soil profile is judged to be necessary to support the desired future vegetation type. In some portions of the holes to be restored, this treatment and deep-ripping would be applied in alternating bands on topographic contours.

Turf Abandonment

Where study of the existing turfed areas shows that native wet meadow graminoids are still present and vigorous, no action would be taken. It is expected that native species such as *Carex nebrascensis* that grow up through the turf at present will readily outcompete the grass turf and re-establish wet or mesic meadow habitat. During the transition to native species, turf will provide valuable erosion control.

Adaptive Management

Adaptive management is the process of continually adjusting management in response to new information, knowledge or technologies. Adaptive management recognizes that unknowns and uncertainty exist in the course of achieving any natural resource management goal. Uncertainty will always be a part of the management of ecosystems, and adaptive management provides a mechanism by which uncertainty can become "…the currency of decision making instead of a barrier to it" (Walters 1986).

Given the complexity of the UTR restoration project, some uncertainty will exist with respect to the restoration approach. It will not likely be possible to eliminate all uncertainty regarding project outcomes or the performance of specific restoration techniques through extensive analysis. To address potential uncertainty, we recommend that adaptive management be incorporated into the project. In general, an adaptive management plan will include three components:

1) Clear statement of defined goals, objectives and anticipated outcomes;
2) A monitoring plan designed to measure progress toward goals and objectives, and to measure success of specific restoration approaches; and
3) A plan for modifications in restoration approach based on the results of monitoring.

For example, a stated goal might be a 25% reduction in the length of eroding streambanks. Post-project monitoring would include streambank erosion surveys. The success of particular treatments would be noted. Progress toward objectives would be evaluated in yearly post-project reports, with specific management recommendations based on the results of monitoring. Goals could be developed for geomorphology, fish and wildlife populations and habitat, and vegetation communities.

CONSTRUCTION CONSIDERATIONS

Sanitary Sewer

The new channel alignment would cross the existing sanitary sewer system, a gravity feed system owned by STPUD, in one location, about mid-way through the project, in the large meander that would be reoccupied (Figure 16). At this crossing, realigning the sewer around the channel is feasible, as a new alignment would have about the same length (and therefore slope) as the existing alignment. Restored channel would also come very close to the sewer in meanders near the upstream end of the project area (Figure 17). Restored channel designs should be developed to avoid conflicts with the sewer, which may require reconstructing portions of historic meanders. As mentioned earlier, we recommend that channel restoration end above the sewer crossing in the lower portion of the project area.

Bridge

A new bridge will be required near the upstream end of the project area. The bridge will have to accommodate two-way golf cart traffic, service vehicles, and possibly pedestrian access to the CDPR trail system. The bridge design will also have to incorporate river restoration designs that utilize additional active floodplain, and should be long enough to allow for potential future channel dynamics. The new active floodplain would provide opportunities for the placement of bridge piers and allow for additional bridge length. High ground in this area will ease design and construction of bridge approaches. A bridge could feasibly be incorporated into river restoration planning in the area of the existing upper two bridges near current holes 6 and 7.

The west approach of the bridge will have to be constructed through area which is likely a low terrace. Channel remnants still exist in this area. Although these remnants are not active during typical snowmelt floods, they likely carry local drainage during the spring and early summer, and may carry some flow during larger floods. This area also has stream environment zone characteristics. The east approach of the bridge should be constructed in a raised design or with regular culverts to pass flow. A second bridge may be required to cross an overflow channel in this area, and golf cart paths leading to the bridge on this side of the river will require specialized design to allow for flood flows to pass through or under the path.

Phasing

Vegetation is a critical component of riparian stability. Planning a restoration project to allow for vegetation establishment prior to exposure to disturbance by floods can provide substantial revegetation and water quality benefits. The proposed project has been developed with this benefit in mind, and provides several opportunities to allow for vegetation establishment through phasing construction. With the exception of the grade controls within the existing channel, all of the constructed features are outside of the current active channel, can be built in the first construction season, and can be effectively segregated from all but the largest floods during revegetation.

Re-location of the golf course holes and construction of the new bridge would occur prior to restoration work on the river and floodplain. Two restoration construction phases are recommended, each consisting of operations over a single season. In the first phase new channel segments, historic meanders and floodplain modifications would be constructed. As these features are located off the existing channel, they can be almost entirely constructed without disturbing the river. Entrances and exits of the meanders would be blocked from the existing channel by leaving small plugs of existing soil and vegetation, or with sandbag dams. Although larger floods over the following winter could access the newly constructed meanders, velocities would be low and drainage would be internal, with little chance of eroded sediment leaving the site.

Floodplain treatments (active floodplain construction in the upper portion of the project area and floodplain grading in areas occupied by the golf course) would also be primarily constructed during the first phase of construction. Techniques to protect these areas from erosion during floods the following winter could include small berms to segregate the areas from flood flows, or erosion control treatments such as native sod blankets or erosion control fabrics.

In the second phase of construction, which could occur either one or two years following the first phase, connections between the existing channel and constructed features would be built. Grade control segments within the existing channel would also be constructed during this phase.

Flow Diversion

No flow diversion would be required for the first phase of construction. In the second phase, diversion will be required for two specific activities; to construct portions of the grade control within the existing channel, and to divert flow into the new meanders. For the grade control structures, flow diversions will be required around the work site to construct the main grade control structures at the upstream and downstream ends of the project area. Flow in the main channel will have to be diverted around the work area, in pipes or temporary channels. This construction should therefore be undertaken during the lowest possible flow. Similar diversions have been successfully used in past Tahoe basin projects, and are feasible.

Final activation of the restored channel, following initial vegetation establishment on constructed meanders, will require diversion of water from the existing channel into constructed segments. Similar diversions have been undertaken in other Tahoe basin projects such as Trout Creek; they generally proceed as follows. Without disturbing the existing channel, plugs or sandbag dams at the entrance and exit of the meanders are removed. A sandbag or piling dam is constructed in the existing channel to divert flow into the new feature. Fill and sod revetment, or similar treatments, are then constructed downstream of the diversion dam in the existing channel.

Some water from Angora Creek seasonally flows into a diversion channel used during historic ranching operations, and then through one of the historic meanders proposed as new channel for this project. Angora flow will have to be directed down the main channel to dewater this construction area.

Water Quality Protection Measures

Based on our past experience with Tahoe Basin restoration projects, the following specific measures are likely to be a portion of project planning to protect water quality during construction:

- All substrate used in construction should be washed prior to placement
- The constructed channel should be cleaned by introducing flow several times, pumping turbid water produced into floodplain settling basins. This technique can also be used to irrigate revegetation between phases.

Access

All restoration construction activities on the south side of the river could be accessed through the golf course. In the lower portion of the project area, restoration sites on the north side of the river could be accessed through the existing golf course on that side of the river. Restoration activities further upstream on the north and west side of the river may require access through the sewer maintenance easement on the west side of the CDPR parcel.

Most of the construction area can therefore be accessed through sites already disturbed by golf course grading, sewer access, or existing trails and roads rather than across undisturbed meadows. Specialized road construction techniques to protect meadows will not generally be required. However, access roads may cross soft or wet areas, and require some stabilization. Access will have to remain in place for both phases of construction to access grade controls and flow diversions. Compaction under access roads is likely and restoration of these areas will require ripping and active revegetation.

Conceptual Level Quantities

Estimated quantities for the proposed restoration are shown in Table 4. These quantities should be viewed as a preliminary estimate, recognizing that this is a conceptual design; channel layout and grades may be altered during final design. Quantities were developed based on the following assumptions:

- The model cross section measured by CDPR upstream of the project area was used to develop average widths for restored segments (Figure 19). At a 550 cfs discharge, this cross section has a top width of about 70 ft and a bottom width of about 50 ft. To estimate excavation quantities, 60 ft was therefore used for average width. To estimate the width of armored riffles, the bottom width, or 50 ft, was used.
- Armored riffle length was estimated assuming that all of the elevation drop between the grade controls will be lost over the riffles. The total length was derived by assuming the target gradient for the riffle slopes will be about 0.0041 (12.2 ft elevation/2,980 ft in length), such that riffles comprise about one-third of the total restored channel length between grade controls. The final design for riffle length and gradient should be developed in detailed design phase based on sediment transport and hydraulic analysis, but this assumed gradient and length is a reasonable estimate at this stage of design.
- Depth of excavation required in the historic meanders will vary from about four ft in the upper meander to about 1.5 ft in the lower meander. The top foot excavated in these areas will likely be salvaged vegetation, for an average excavation depth of about two ft.
- Active floodplain excavation in the upper portion of the project area will require an average excavation depth of about two ft over the area shown in Figures 16 and 17.

About 11,000 cy of cobble and gravel fill will have to be imported to the site, to construct armored riffles, grade control structures, and to place buried wings of cobble fill under adjacent floodplain at the upstream end of the riffles and grade controls to prevent flanking. Excavated material is sufficient to fill the abandoned existing channel to about 75% of its total volume. With available on-site fill, topography of the abandoned channel would have low spots, providing habitat similar to natural abandoned meanders. If instead it is determined to totally fill the abandoned channel, import of about 10,000 cy of suitable material will be required. Fill of abandoned channel to less than 75% of existing volume will require material export. Larger rock will likely be required for grade control structures, depending on hydraulic analysis during detailed design. The quantity of large rock would replace cobble riffle as fill in Table 4.

Table 4. Estimated project quantities.

Area of Treatments

Treatment	Length (ft)	Width (ft)	Area (ft^2)
Historic Meanders	3,810	60	228,600
New Channel Construction	1,248	60	74,880
Grade Control	690	60	41,400
Armored Riffles	2,980	60	148,995
Active Floodplain	na	na	86,504
Bioengineering	na	na	37,457
Abandoned Existing Channel	2,084	na	na

Required Excavation

Treatment	Area (ft^2)	Average Depth (ft)	Volume (cy)
New Channel	74,880	4.0	11,093
Historic Meanders	228,600	1.5	12,700
Grade Control	6,825	5.0	1,264
Flanking Protection	16,000	1.5	889
Active Floodplain	86,504	2.0	6,408
		Total	32,354

Fill Requirements

Treatment	Volume (cy)
Cobble Riffle	11,083
Abandoned Channel	
Total Fill	40,789
50% Fill	20,395

Reducing Impacts of the New Golf Course

A major goal of the project is to improve the golf course layout and management to reduce the environmental impact of the golf course on the river's water quality and riparian habitat. By relocating the golf course away from the river, and constructing the majority of the new golf course on less environmentally sensitive land further away from the river, golf course impacts can be greatly reduced.

Objectives of the new golf course design should be to minimize ecological impact, including the following specific objectives:

- Maximize wildland or native vegetation between holes and minimize disturbance to native vegetation;
- minimize irrigation, and select for low water use plants;
- minimize turf (no net gain);
- reduce turf on 9 holes that remain in place and restore native vegetation to buffers between holes;
- minimize fertilizer use;
- minimize the area of the golf course in SEZ (Stream Environment Zone);
- golf course infrastructure which must be constructed within SEZ should be designed to minimize impacts to the SEZ; and
- physical barriers between golf course and native habitat should be included, where feasible.

Special designs will likely be required to protect groundwater quality near low-nutrient wetlands that currently exist in the vicinity of the former quarry. Lateral hydraulic conductivity of the soils should be studied to determine whether there is a reasonable anticipation of potential flow of subsurface water, under conditions that might occur at any time during the year, from beneath the nearby golf areas towards the low-nutrient wetlands. If such flow could be expected to occur, a compacted soil seepage curtain should be placed in the buffer zone between golf play areas and the low-nutrient wetlands.

Design of irrigation, fertilizer management, and drainage systems for the new golf course will be an important key to reducing potential impacts. Design and management of recent golf courses provides direction for techniques to minimize impacts to water quality (e.g., Geotrans, Inc. 2001) . These include:

- Grading to direct surface flows to treatment areas;
- drainage collection and treatment systems, including wetland treatments;
- irrigation systems designed to conserve and recycle water; and
- detailed fertilizer management plans.

ANTICIPATED AND POTENTIAL EFFECTS

Potential effects of the proposed project include the following:

BENEFICIAL

- Increase in woody riparian habitat (willow, alder-willow);
- increase in Wet Meadow, Mesic Meadow and Obligate Marsh vegetation types and associated habitat;
- increase in river channel length and quantity of aquatic habitat, and increase in the complexity and quality of riparian habitat;
- reduction of streambank erosion and fine sediment yield;
- increase in overbank flow magnitude and duration to increase the opportunity for fine sediment deposition and dynamic processes that create and maintain riparian habitat;
- reduction in land uses near the river that have the potential to degrade water quality, such as fertilizer application;

ADVERSE

- Conversion of existing conifer forest and other habitat types to golf fairways and rough
- Placement of infrastructure or fill within wetland and/or Stream Environment Zones (SEZs), including the intermittent tributary in the Jeffrey Pine forest in the new golf course area.
- Potential for direct impacts on special-status plant species where reconstruction of channel capacity in historic channel segments will affect existing wetlands
- Potential for adverse effect on groundwater, wetlands or SEZs near new golf holes due to sediment generation or transport, or surface or subsurface transport of nutrients or other materials applied for golf course maintenance.

This is not meant to be an exhaustive list of potential impacts, but a preliminary guide for assessing overall project feasibility. In the following sections, the proposed project is analyzed for effects related to the ecosystem restoration project goals only. This analysis is not intended to satisfy regulatory requirements; rather, it is intended to gauge the potential for the project to restore historic ecosystem processes.

WATER QUALITY

The current elevation difference between the river and the areas of the golf course which would be relocated varies from approximately 3-8 feet at low flows and from 1-5 feet during snowmelt runoff. These low areas in proximity to the river undoubtedly also have high seasonal water tables which mimic the river stage in the spring, and probably routinely exceed it during the spring, in some cases rising to within a foot or so of the surface. This high water table and proximity to the river creates a very high potential for the migration of fertilizers into the river, and then into Lake Tahoe. This is particularly true for both ammonium and nitrate, and especially for nitrate, which is highly mobile in groundwater. . Also, in many locations, the mowed turf is within a few feet of the streambank, and it would not be unexpected that fertilizer is occasionally over-spread directly into the river. While careful fertilizer management can minimize the transport of nutrients, the current golf course configuration nonetheless presents high risk setting for delivering nutrients to the river.

The existing and proposed golf courses were analyzed for proximity to the river and elevation. All areas that of land cover or disturbance to native vegetation communities (buildings, parking lots, tees, fairways and greens) were considered part of the golf course for this analysis. The footprint of the proposed course was based on a preliminary conceptual layout and will certainly be modified in future environmental analysis. The footprint used for this analysis is slightly larger than the existing course and that used for vegetation community analysis in the following section. Although the size of the proposed course will likely be reduced, the larger conceptual layout used for this analysis is conservative because reductions in size will take place in upland areas relatively distant from the river.

The proposed relocated golf course would be both farther from the river and higher in elevation (Figure 22). Much of the current course that is closest to the river would be relocated to areas greater than 500 feet from the river, especially those portions of the course that are currently within about 100 feet of the river (Table 5). The proposed golf course configuration would have about 12 fewer acres within 100 feet of the UTR. Moreover, the proposed course is far higher in elevation than the existing course (Figure 22). Several of the new golf course holes would be constructed on a hillslope above an elevation of 6,305, which is about 20 ft above the elevation of the river at low flows at the upstream end of the project area. Most of the holes that would be removed from the current course are less than 6,280 ft in elevation, and less than 10 ft above the elevation of the river at base flow. Because the proposed course would be both higher and farther from the river, the risk for fertilizers to be delivered to the river, both from migration through groundwater, and through actual direct delivery of fertilizer as it is applied, would be significantly reduced. This aspect of the project presents the greatest beneficial impact for water quality.

Table 5. Proximity of the existing and proposed golf courses to the UTR.

Distance From River	**Area of Existing Course**		**Area of Proposed Course**		**Net Area Removed and Restored**	
(ft)	(acres)	(% total area)	(acres)	(% total area)	(acres)	(% existing area)
0-50	7.0	5.6	1.7	1.3	5.2	75.4
50-100	8.7	7.0	1.7	1.3	7.0	80.8
100-200	15.9	12.8	3.8	2.9	12.1	76.3
200-300	16.0	12.9	8.6	6.6	7.5	46.7
300-400	16.3	13.1	10.1	7.9	6.2	37.8
400-500	14.7	11.8	12.4	9.6	2.3	15.8
over 500	45.9	36.9	90.6	70.4	-44.8	-97.5
Totals	**124**	**100**	**129**	**100**	**-4.40**	

Construction of the relocated holes provides an opportunity for the implementation of state-of-the-art irrigation and drainage systems which can eliminate the migration of fertilizers past the root zone. For example, water captured in subdrains could be captured and mixed with irrigation water. State-of-the-art irrigation systems could minimize the application of water beyond that which can be held by capillary forces and which would then be subject to percolation to the water table. Newly developed turf grasses also have lower growing rates, which, in turn, lower water and fertilizer use. The project should take advantage of every possible opportunity to utilize the best available technology to demonstrate that nutrients will not migrate past the root zone. Monitoring programs will need to be established to verify the success of these measures.

Although the principal water quality benefit of the project is the potential reduction in nutrient loading to the river and the water table, additional water quality benefits can accrue from restoring the area to SEZ. By raising the invert of the river by an average of about two feet, the water table throughout the area to be restored will also rise. This will increase the opportunities for anaerobic conditions necessary for denitrification, which has been found to occur in meadows in the Lake Tahoe Basin (Greenlee 1985). This process could be particularly effective in areas where the final restored ground surface is relatively low (portions of the existing channel that are not entirely filled, for example).

The restoration design should also reduce sediment generated from within the project area. Because the project is not intended to completely stabilize streambanks, there will be some continued sediment input to the river from this source. However, the net effect of the project will be a reduction in streambank erosion. Streambank erosion will be reduced in two ways. First, the area of streambanks available for erosion will be reduced by raising the bed elevation of the river. Streambank height and area will also be reduced in upstream portions of the project area through floodplain excavation. Second, streambanks are likely to become more vegetated due to an increase in the elevation of the water table. The more densely vegetated streambanks will be more stable and generate less sediment.

Restoration is likely to result in higher rates of sediment deposition on the floodplain. Raising the channel bed will increase flooding frequency; most of the adjacent floodplain in the lower portion of the project area, which is currently only flooded during rare floods (around a 10-year recurrence interval), would be flooded far more frequently (2 to 5-year recurrence interval). The restored floodplain will also be far more hydraulically rough than the current golf course turf and therefore much more likely to induce sediment deposition. These characteristics will result in greatly enhanced opportunities for fine sediment deposition.

VEGETATION

Mapping

Vegetation mapping for present conditions in the project area (Figure 23) generally follows that used in SHG (2004) but provides additional detail. For that study, vegetation was described according to types that provide somewhat more detailed information on ecological succession, soil moisture regime, restoration opportunities, and wildlife usage than is possible using the classification systems of the California Wildlife Habitat Relationships (WHR) system or CALVEG. In brief, the forest types used herein are essentially the same as in CALVEG, but the meadow types are more finely subdivided, and Lodgepole Pine forest is subdivided into dry and mesic types.

The subdivision of Lodgepole Pine forest allows for a preliminary assessment of impacts upon stream environment zones (SEZs) as defined by the Tahoe Regional Planning Agency (TRPA). Although the mesic lodgepole pine community is not a primary indicator of SEZ, areas or parts of areas mapped in this study as that vegetation type should be regarded as potentially being SEZ for the purposes of preliminary impact assessment. Also, it is likely that some mesic lodgepole pine forest would be converted into riparian habitat types by raising the river bed elevation and consequently raising the elevation and/or duration of soil saturation.

Vegetation mapping polygons were drawn and labeled according to the predominant characteristics of the vegetation in question. Thus, areas whose vegetation and wildlife values are primarily those of Dry Meadow would be mapped as such even though many scattered trees occur. Where mosaics of two types occur that substantially provide values attributed to both types, the vegetation was mapped as an association (e.g., Willow/Wet Meadow). Mapping was completed by a combination of field study and inspection of Ikonos and Lidar imagery.

Vegetation Classification for the Study Area

No single available reference accommodates the observed community types accurately and comprehensively. Sawyer and Keeler-Wolf (1995), which is recommended by some sources for vegetation mapping in California project sites, does not provide sufficient discrimination among the types of vegetation that are found within the study area to be useful for the present project. On the other extreme, CDFG (2002) subdivides some vegetation complexes too finely for practical application to the present project site. For example, CDFG recognizes separate willow scrub communities for the various willow species (Lemmon's Willow Scrub; Geyer's Willow Scrub). Many of the willow communities in the study site were not monospecific, but instead were mixtures of two or three species.

Accordingly, the woody vegetation types used here correspond to those of CALVEG and the California Wildlife-Habitat Relationship system. However, field observation at the Upper Truckee River site and many other areas in the Lake Tahoe region has shown that it is very informative to discriminate more finely among meadow types than either of those systems does.

The Tahoe Regional Planning Agency produced a vegetation reference in collaboration with the U. S. Forest Service that is used, in combination with other information, for stream environment zone (SEZ) determinations (TRPA/FS 1971). This reference provides species lists, without comments on dominance or trends, for 21 vegetation types, many of them with subtypes. Several of the TRPA vegetation types are regarded as primary indicators of SEZ, others as secondary indicators. Vegetation types that are primary SEZ indicators define an area as SEZ regardless of the presence or absence of other characteristics. Three of four secondary indicators must be present to define SEZ. Secondary indicators include: secondary riparian vegetation types; location within the 100-year flood plain; certain soil types associated with fluvial processes, such as Celio; and high ground water elevation characteristics. Secondary riparian vegetation includes the broad wet-mesic meadow type.

Although vegetation types within this classification system do not reflect the actual plant communities of the Lake Tahoe basin very well, it is necessary to try to assign associations of plant species that actually occur together to one or another of the TRPA subtypes in order to complete SEZ determinations. Because the actual combinations of dominant species and all species present in the vegetation found on the project site do not appear in any of the TRPA/FS community lists, the best reasonable effort was made to determine what ecological circumstances were intended by those lists and to determine which ones correspond best to the actual vegetation that was found on the project site. Appropriately, this judgment incorporated much consideration of the wetland indicator status of species present.

Commonly, shrub-dominated and herbaceous communities occurred in mosaics that appeared to be either dynamic or be comprised of sufficiently small patches that it was neither practical nor useful to map the constituent communities separately. For example, Willow Scrub often occurred mixed with mesic or wet meadow types, and the mixed nature of these communities has ecological values that are not reflected in either one or the other. Such areas were mapped as, for example Willow/Wet Meadow. Such mosaics have different wildlife habitat values than either community occurring alone.

Plant Species Wetland Indicator Status

Statements regarding dominance and occurrence are based on subjective observation; no quantitative vegetation sampling was carried out for the present phase of study. Terms such as abundant, common, rare, and so on are used according to common dictionary meaning. For example, a ubiquitous or common species would be within sight from nearly any point within a particular map unit; occasional or scarce plants would not be. Rare or scarce species might not be encountered at all by a casual reconnaissance of a community. Locally common species are abundant only within specialized microsites.

Ecological status of plant species is sometimes discussed in terms of the U. S. Fish and Wildlife Service wetland indicator statuses (USFWS 1996). Despite imperfections, this system and the statuses of many common riparian plant species are widely known (if not universally agreed to be accurate), thus it is an extremely useful communications tool. The status definitions are as follows, with comments on the soil moisture regime that is often found along with plants in each category:

OBL (Obligate). Species found in wetlands >99 percent of the time; occurrence of vegetation dominated by plants in this category is usually strongly correlated with soils subject to annual prolonged near-surface saturation.

FACW (Facultative-Wet). Species found in wetlands 67 to 99 percent of the time; usually correlated with near-surface saturation through at least a portion of the summer in most years.

FAC (Facultative). Species found in wetlands 34 to 66 percent of the time; species in this category are frequently found in a wide range of soil moisture conditions, from short-duration saturation during most years to almost never saturated during the growing season.

FACU (Facultative-Upland). Species found in wetlands 1 to 33 percent of the time; correlates with soil that is almost never saturated, or is only saturated very briefly during the early part of the growing season.

UPL (Upland). Species found in wetlands <1 percent of the time (also notated NI or "--" in the USFWS lists); correlates with soils that are never subject to prolonged saturation during the growing season.

The assignments of indicator status are subject to much question and discussion. For the present report, the most important issue is that many common wetland-associated species (FACW or OBL) become established only under a wetland hydrologic regime, but are able to persist for long periods of time even if the soil moisture regime becomes much drier. This can be misleading in making wetland or vegetation type determinations, but is extremely useful in interpreting ecological history and trend. Finally, some species that are closely associated with wetland soil saturation regimes may nevertheless require more dissolved oxygen than other wetland species and consequently tend to be found in wet areas where the water is flowing rather than stagnant.

Notwithstanding these considerations, the familiar USFWS wetland indicator status list does provide a useful *relative* categorization of the soil moisture regime with which the listed species are associated. Also, most areas that are dominated by species that are regarded as hydrophytic by the federal wetland identification manual (FAC, FACW, and/or OBL species) are likely to delineate as wetlands, so the community mapping provides a useful initial guide to permitting requirements. However, some areas that are defined as stream environment zones by the Tahoe Regional Planning Agency lie outside the federal wetland definition.

Vegetation Community Types

The assemblages of plant species that were observed in the project site are described below. Some vegetation types occurred characteristically (not merely occasionally) as mosaics with one another. The poor resolution of the Ikonos imagery made it impossible to circumscribe the separate types of vegetation in these areas; such detailed mapping would be of questionable ecological and planning value anyway. Accordingly, some areas appear on the map as mixed communities, for example, Willow mixed with Wet Meadow (W/WM). Such designation is both more accurately reflective of actual field conditions and is ecologically useful in understanding wildlife use, because many wildlife species use or even require mixed communities. On the other hand, where scattered elements of one community (e.g., individual lodgepole pines) occurred within another community type (e.g., Dry Meadow), the entire area was mapped according to the predominant ecological character for wildlife habitat and planning purposes. Only where the mixture of community elements was more even was a mixed community mapped. Vegetation community types that occur in the project area are found in Table 6, Appendix A, with map acronyms used in Figure 23 and a crosswalk to three other vegetation classification systems.

Jeffrey Pine Forest (JP)

Structure

Jeffrey pine forest canopy is composed primarily of very variable aged pine trees, some exceeding 30 inches diameter at breast height (dbh). The subcanopy and understory are patchy but generally sparse, without any areas of the typically solid shrub layer that is seen in some mixed coniferous forest communities in the basin. Herbaceous vegetation is also not dense. Recruitment of new pines is ongoing at a relatively slow rate, compared with the Lodgepole Pine Forest where hundreds of small sized trees may be present per acre.

Species Composition

The majority of the canopy, and all of the largest trees, are Jeffrey pines (*Pinus jeffreyi*); a small portion of the canopy is lodgepole pine (*Pinus contorta* ssp. *murrayana*) and white fir (*Abies concolor*). In some areas, a more significant lodgepole pine component is present, but the larger trees are almost all Jeffrey pines, showing that this is the real community type and that the lodgepole pines represent a flush of new establishment during the recent decades of more vigorous fire suppression. Species composition of the shrubby and herbaceous understory strata is similar to that of the Lodgepole Pine Forest and Dry Meadow communities.

Lodgepole Pine Forest (LPD and LPM)

Occurrence and Structure

This community type includes extensive areas of forest with variable canopy structure, ranging from open woodland to densely forested areas with 100 percent canopy cover. Where the canopy is more open, scattered shrubs are present, but do not form a nearly continuous shrubby understory. The herbaceous stratum is highly variable in terms of cover and species composition. The descriptions of lodgepole pine communities that appear here pertain to the project study area and other areas of similar geomorphic position and elevation. They do not describe the forest or woodland communities that include lodgepole pine but occur on mountain slopes at much higher elevations.

Trees larger than 24 inches diameter at breast height (dbh) are present but uncommon in this community type. In areas where the pre-existing forest community was disturbed by logging and/or mass grading, the forest is composed of an extremely high density (individuals per unit area) of small trees (almost all less than 12 inches dbh).

The distinction between Lodgepole Pine – Dry Type and Lodgpole Pine – Mesic Type is in the shrub and herbaceous strata, as specified below.

Species Composition

The woody canopy is comprised almost entirely of lodgepole pine. In some areas, occasional trees of white fir and/or Jeffrey pine are present, but almost never form an ecologically significant portion of the canopy.

The shrub stratum of Lodgepole Pine – Dry Type is usually relatively sparse and consists of strictly upland species such as wax currant (*Ribes cereum*), snowbush (*Ceanothus cordulatus*), and mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*). In Lodgepole Pine – Mesic Type, the shrub stratum, where it exists at all, is usually limited to remnants or stringers of riparian species (willow and other riparian shrubs) that persist along abandoned small channels.

The herbaceous stratum similarly varies. In Lodgepole Pine - Dry Type, this layer of the vegetation is generally dominated by FACU to upland grasses (*Elymus glaucus, Poa pratensis, Bromus carinatus, Elymus elymoides*, *Achnatherum* spp.) with a forb component that is usually relatively sparse or ephemeral (consisting of plants which complete their annual growth and reproduction cycle in the spring or early summer). By itself, *Elymus glaucus* is a poor indicator, as it occurs both in quite dry and quite moist settings.

Most of the Lodgepole Pine - Mesic Type forest has a herbaceous stratum with a significant forb component, of which most species are FAC (*Epilobium angustifolium, Heracleum lanatum, Maianthemum stellata, Thalictrum fendleri, Veratrum californicum,* and others), sometimes mixed with *Elymus glaucus* or "wetter" graminoids.

Lodgepole pine is capable of invading the Mesic Meadow and Dry Meadow vegetation types described below. Thus, either of these types may be type-converted to dense lodgepole pine forest if the saplings are not controlled mechanically or by fire. Lodgepole pine does not vigorously invade Wet Meadow as defined herein.

Willow Scrub (W)

Willow Scrub community types occur throughout the study area, generally in combination with mesic and wet meadow vegetation, but also on depositional bars. Where the vegetation of a gravel bar is very sparse or composed of a mixture of species that could not easily be categorized, a type labeled "Bar" was mapped.

Structure

Willow scrub varies from dense stands (80-100 percent cover) on bars and in old channel segments to more open vegetation either in early succession (some bars) or in meadows where dense turf inhibits the establishment of a willow monoculture.

Species Composition

In the present study area, most of the willow is either Lemmon's or Geyer's (*Salix lemmonii* or *S. geyeriana*), with some Pacific willow (*S. lucida* ssp. *lasiandra*) present on recent alluvial bars. One small patch of mixed mountain alder (*Alnus incana* ssp. *tenuifolia*) and willow was included in the Willow Scrub type.

Dry Meadow (DM)

Structure

Dry Meadow is a herbaceous plant community dominated by upland (including FACU and some FAC) plant species. Scattered trees, primarily lodgepole pine, are present in most areas mapped as Dry Meadow, however, for the purposes of understanding of habitat values and restoration planning, the character of these areas is primarily meadow rather than woodland.

Dry Meadow habitat is structurally very different from other meadow types discussed below in having much lower aerial and basal vegetative cover, consequently, this community type is highly susceptible to erosion, both the small-scale surface erosion resulting from intense precipitation and the large-scale erosion that results when channels become reoriented through previously unflooded areas.

Species Composition

The species composition of this community is somewhat variable depending upon its ecological history. Typical dominant species include *Elymus elymoides, Bromus carinatus, Carex rossii, Carex subfusca, Lupinus lepidus, Gayophytum* sp., and *Achnatherum* spp.

Revegetation Dry Meadow (RDM)

This community is ecologically similar to native Dry Meadow, but occurs in areas of surface disturbance that were revegetated using species not native to the area.

Structure

The structure of this community is similar to that of Dry Meadow.

Species Composition

Due to the long time period that has elapsed since these areas were revegetated, they have been colonized by many of the native Dry Meadow species. However, Revegetation Dry Meadow is characterized by the frequent to dominant presence of soil stabilization species such as *Dactylis glomerata, Bromus inermis, Festuca trachyphylla,* and *Elytrigia intermedia* ('Luna').

Sagebrush Dry Meadow (SDM)

Structure

This community is a mixed scrub and meadow vegetation type, with somewhat lower shrub cover than is usually the case for Sagebrush Dry Meadow. As for Dry Meadow, some scattered trees are present, but the predominant characteristics and habitat values of the community type are of scrub and meadow rather than woodland.

Species Composition

The dominant species composition of Sagebrush Dry Meadow is essentially the same as that of Dry Meadow, described above, except for the addition of mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*). Also, FACU species such as *Poa pratensis* and *Elymus glaucus* are rare to absent in Mountain Sagebrush Scrub.

Mesic Forb (MF)

Structure

Mesic Forb is a dense herbaceous wetland community, typically with 90 to 100 percent canopy cover. Due to the different subterranean growth forms of forbs and graminoids (the latter having much more rhizome and root biomass at and near the soil surface), Mesic Forb community type is much more susceptible to erosion than are graminoid-dominated meadows.

Species Composition

Typical examples of Mesic Forb Community type include a relatively diverse assemblage of plants that are codominant or at least common in one or another microsite within the habitat patch. These species include *Veratrum californicum, Lupinus polyphyllus, Thalictrum fendleri, Heracleum lanatum, Polemonium occidentale,* and *Senecio triangularis.* Numerous other species are common in one or another example of this community, such as *Dodecatheon jeffreyi, Geum macrophyllum, Smilacina stellata,* and *Platanthera leucostachys*. Graminoids may also be present, usually as a small component of the vegetative cover. Depending upon soil moisture regime, the associated graminoids may vary from dry-site species such as *Poa pratensis* and *Elymus glaucus* to OBL species such as *Carex* and *Juncus* species.

Mesic Meadow (MM)

Mesic Meadow vegetation is a graminoid-dominated community with relatively high vegetative cover. Many occurrences of Mesic Meadow actually represent dewatered Wet Meadows (see below), where the previous FACW dominants persist in abundance but are not vigorous and usually flower little or not at all. Thus, common practice would be to denote these as Wet Meadow on the basis of presence of numerous stems of such species as *Juncus balticus* and/or *Carex nebrascensis*. However, this may be misleading in terms of ecological trend and wildlife values.

Another very significant difference between the two meadow types is that Mesic Meadow is susceptible to invasion by lodgepole pine, whereas Wet Meadow is not. Conversely, whereas Wet Meadow is susceptible to establishment of new willow clumps under high stage events that either scour portions of the surface or deposit mineral soil material, Mesic Meadow is too dry for establishment of vigorous willow clumps.

Ecologically, both meadow types have very similar topographic, edaphic, and hydrologic requirements to Willow Scrub, consequently the meadow and wetland scrub communities generally occur as mixed mosaics, as shown by the vegetation base map.

Interestingly, the text of the WHR habitat description for Wet Meadow (WHR definition) states that an ecologically distinct subtype of Wet Meadow exists, implying that a separate type should be defined. Thus, although a type heading is not provided, the WHR system implicitly recognizes Mesic Meadow as defined herein.

Structure

Mesic Meadow usually has moderately high basal and aerial vegetative cover, typically in the range of 70-80 percent. Due to the rhizomatous and fibrous-rooted nature of the dominant graminoid vegetation, areas of Mesic Meadow with higher cover have relatively high resistance to erosion, and also tend to exclude colonization by other species except lodgepole pine.

Species Composition

Species composition includes plants with a range of wetland indicator statuses. Dominants usually include both FACU species such as *Poa pratensis* and *Achillea millefolium,* intermediates such as *Carex subfusca*, FACW plants such as *Potentilla gracilis, Sidalcea oregana, Penstemon rydbergii* var. *oreocharis,* and *Juncus balticus* (this last usually not as a codominant), and species with upland affinities such as *Elymus trachycaulus* and *Lupinus lepidus*. Depending on hydrology, areas of Mesic Meadow might delineate either as upland or as jurisdictional wetland.

<u>Wet Meadow (WM)</u>

Structure

Wet Meadow is structurally distinguished from Mesic Meadow by its higher basal and aerial cover, commonly 95-100 percent. Consequently, this community has the highest erosion resistance of any herbaceous dominated vegetation type within the study area.

Species Composition

Species composition of Wet Meadow is dominated by FACW and OBL plants such as *Carex nebrascensis, Juncus balticus, Sidalcea oregana, Potentilla gracilis,* and *Penstemon rydbergii* var. *oreocharis.* Wet Meadow sites near the river channel are also (or alternatively) dominated by a slightly different suite of FACW species such as *Poa palustris* and *Juncus nevadensis*. Most Wet Meadows also include some proportion of one or more FACU species such as *Phleum pratense, Poa pratensis, Achillea millefolium, Taraxacum officinale,* or *Perideridia lemmonii.*

<u>Obligate Sedge Wetland (OM)</u>

Obligate Sedge Wetland occurs primarily in depressions on floodplains, or in areas where springs supply perennial surface saturation.

Structure

Obligate Sedge Meadow is structurally almost identical to Wet Meadow, forming a dense rhizome and root turf.

Species Composition

Floristically, Obligate Sedge Meadow is markedly distinct from Wet Meadow in having much lower diversity. Typically, only two or three species are present, dominated or composed entirely of OBL sedges: *Carex utriculata, Carex nebrascensis, Carex aquatilis,* and *Scirpus microcarpus.*

Gravel/Cobble Bar (B)

Structure

This community type occurs on recently deposited sediment bars, the surface of which is usually covered mostly by cobble-sized particles, but which contain much material in the sand to gravel size ranges in the interior. The community has a highly variable structure, in keeping with its extremely patchy species composition. There are usually patches of 100 percent shrub cover, patchy forb vegetation, and areas of low to 100 percent graminoid cover.

Species Composition

Species composition includes a very wide variety of plant species groups: Lemmon's and Geyer's willows, OBL sedges (see Obligate Sedge Wetland), Wet Meadow species (*Poa palustris* and *Juncus nevadensis* are particularly common), FAC herbs such as *Solidago canadensis*, and fully upland, colonist species such as *Lupinus lepidus* and *Lepidium densiflorum.*

Developed Areas

Developed areas are where soils or vegetation have been significantly altered by human development. This includes areas considered hard or soft cover within SEZ by TRPA, such as golf cart paths, buildings, or gravel and dirt roads. Developed areas also include areas considered disturbed as defined by TRPA, such as golf course turf or other planted vegetation. These areas are designated "D" in Figures 23 and 24 and in Tables 6 and 8. Proposed new golf course turf or other developed coverage in upland habitat is designated "D" in Figure 24 and Table 8.

Vegetation Mosaics

In all cases, mapped vegetation types include scattered individuals that are discordant with the type as a whole (e.g., occasional pine trees in Dry Meadow). Where these individuals were numerous, or where more than one vegetation type as defined above occur together either in small patches, vegetation mosaics were mapped and labeled with the predominant type in the association listed first (W/WM = considerable Willow Scrub in a Wet Meadow matrix). These are not merely a mapping convenience, but are also of wildlife habitat value that is often higher or at least different than that of either type occurring alone.

Some mixed types represent areas where the vegetation is merely intermediate, for example, Mesic Meadow/Wet Meadow. Others represent stable long-term types that are the result of the normal geomorphic process, such as Willow Scrub/Wet Meadow. One type merits special comment: Obligate Sedge Wetland/Mesic Forb/Pine. This labeling was applied to three spring supported complexes where elements of all three of the constituent types occur well mixed together. Spring complexes are often of special biodiversity values, as well as sometimes being very important as a source of surface water that may be remote from other sources, or have a longer season of flow than other nearby tributaries. Flow rates vary over time. In the most southwesterly of the springs, which had once been improved by the placement of a wooden barrel to provide a human or livestock water source, a large swath of dead lodgepole pine trees occurs downslope. These trees clearly seem to have been killed by a relatively recent increase in the spring flow rate, resulting in an elevation or duration of soil saturation that is too high for the survival of lodgepole pine.

In the present study area, one large groundwater-supported wetland mosaic is present in the old quarry location (this is the largest of the three spring complexes shown in Figure 23). This wetland supports some species that are not common in the Lake Tahoe region (e.g., *Drosera rotundifolia* [sundew], *Spiranthes porrifolia* [ladies tresses orchid]), possibly as a result of relatively low levels of plant-available nutrients. Similar habitat occurs just off site near this area, in a very extensive wetland that is hydrologically a fen (supported by groundwater) but ecologically a bog (acidic).

Inspection of the topographic mapping shows that the spring complex that lies within the site occurs on the old quarry high wall, and may or may not have existed prior to mining. Thus, whether a similar wetland existed before, or whether the present one was created by the quarry excavation extending into the groundwater, this wetland and the shallow depressions below into which it drains are unquestionably human-modified.

Predicted Vegetation Community Changes

The conceptual habitat restoration design and the description of expected habitat results that appears below are based upon assumptions pertaining to the channel restoration concept and inferences about surrounding ground water elevations, as follows:

- Existing and restored channel invert elevations will be as presented in transects 1-7 within the restoration project area (Figure 21).
- Existing baseflow is assumed to be equal to elevations in Lidar topography, as the Lidar was developed during low flows and generally records the water surface elevation (Lidar does not "see" under the water). The channel bed is estimated to be approximately one ft lower.
- Restored baseflow elevation at each transect will be one ft higher than the restored channel invert from grade controls (i.e., restored baseflow depth at riffle thalwegs will be about one ft).
- Existing stage at 550 cfs (approximate two-year recurrence interval flood) was derived from HEC RAS modeling (SH+G 2004) at most transect locations, and from actual measurements at others. The difference between existing baseflow water surface elevations derived from LIDAR topography and existing 550 cfs stage averages about 2.7 ft (range 2.2 to 3.6 ft) in the project area.
- Restored stage at 550 cfs is assumed to be 3.5 ft higher than the elevation of the restored channel bottom at the riffle thalweg.
- Average highest yearly ground water elevation after restoration is assumed to be the same as the 550 cfs peak stage; that is, a water table was assumed to extend horizontally from the creek along the transect orientation shown in Figure 21. This discharge has generally

occurred, on the average, every other year over the period of record (see SH+G (2004), Figure 3.2). Elevations were interpolated subjectively between the ends of transects.

The water table in alluvial riparian sites is often concave early in the season, when snowmelt percolating into the soil mounds on less permeable materials before flowing laterally to contribute to stream flow. It then changes to convex late in the season, when stream flow based largely on the upper watershed is lost into the adjacent coarse alluvial materials. The actual seasonal soil moisture regime at a variety of microsites will vary according to the diversity of the soil materials and varying depths at which similar materials might occur, and to a lesser extent upon the vegetation. Indeed, a range of variation in physical conditions is more desirable for habitat restoration than is a situation that conforms to a modeled ideal, because a range of ecological conditions results, increasing the system's biological diversity and resistance to disturbance or varying climate.

Ground water monitoring at other sites, including the lower Angora Creek meadows and Trout Creek, tends to support the hypothesis that vigorous wet meadow habitat and willow growth are supported where the ground water level rises to one foot below the surface, or higher. This is in accordance with the U. S. Army Corps of Engineers wetland hydrology field indicator (prolonged saturation to within 12 inches of the surface). Mesic meadows are supported where the ground water level is not necessarily quite as high. The ground water threshold for SEZ determination according to TRPA criteria (potentially applicable, for example, to Lodgepole Pine - Mesic Type) is about three feet below the surface.

The project design and analysis of habitat effects thus explicitly recognize that a range of variation is expected to result, but that the predicted vegetation communities can reasonably be anticipated to develop approximately as shown in Table 7.

Table 7. Predicted post-restoration vegetation communities based on relationship to estimated flood water surface elevations.

Future Vegetation Type	Relative Elevation of Soil Surface to Restored 550 cfs Water Surface Elevation
Obligate Sedge Wetland	Below
Willow, Wet Meadow	0-1 ft above
Mesic Meadow	1-3 ft above
Lodgepole Pine – Mesic	2-4 ft above
Dry Meadow (or LPD/DM)	At least 3-4 ft above

Based upon the assumptions identified above, we developed a map of vegetation of the project area under the predicted post-restoration hydrologic regime and after application of the restoration methods described in previous sections (Figure 24). Area of post-project vegetation communities was calculated based on this mapping (Table 8). Revision of the assumptions stated above on the basis of actual ground water monitoring data would result in modification of the plan areas where different revegetation specifications

Table 8. Existing and predicted post-project vegetation of the UTR project area. Acreages determined from GIS maps and software and rounded to the nearest 0.1 acre. Net change is shown as an increase (+) or loss (-) of each type (net change may not equal existing-future due to rounding). Vegetation types that do not occur at present but will be created by the restoration project are denoted "n. a." in the Existing column.

Mapping Unit	Existing Acreage	Future Acreage	Net Change
River	8.9	11.0	+2.1
Pond	1.0	1.0	0
Bar	3.2	0.7	-2.6
JP	93.6	74.6	-19.0
JP/DM	2.1	2.1	0
LPD	17	13.7	-3.3
LPD/DM	46.2	40.8	-5.5
LPM	49.2	43.6	-5.6
LPM/MM	n. a.	0.1	+0.1
W	5.7	14.4	+8.8
W/OM	n. a.	1.6	+1.6
W/WM	7.7	23.6	+15.8
W/MF	0.1	0	-0.1
W/MM	3.3	2.7	-0.5
OM	0.8	0.3	-0.5
OM/MF/JP	0.8	0.8	0
OM/MF/LP	3.5	3.5	0
WM	2.7	5.3	+2.6
MM/WM	5	4.3	-0.7
MM	26.2	40.2	+13.9
MF	0.4	0.4	0
DM	9.8	3.6	-6.3
RDM	4.5	4.5	0
SDM	7.3	7.1	-0.2
D	53.8	48.1	-5.7

would be applied and the extent of different habitat types to be expected, but would not alter the fundamental habitat restoration approach. In light of the usually concave water table shape during the early growing season, it is more likely that the assumptions used to determine the predicted vegetation communities will prove to be overly conservative than overly optimistic. That is, the actual future communities may well turn out to be wetter than predicted here.

Note that the developed area under current conditions is somewhat greater than developed area under predicted conditions. The vegetation mapping for this report was based on very preliminary renditions of future golf course layout. It is likely that the area disturbed by the new golf course is somewhat underrepresented in this analysis, and should be updated in future efforts, which should also include analysis of changes in regulatory cover and disturbance. Developed area for the new golf course beyond that shown in this vegetation mapping would mostly occur in drier forested vegetation communities (Jeffrey Pine or Lodgepole Pine Dry Type).

Special-Status Species

Occurrences of one or another special-status plant species are known from nearly every habitat type that occurs within the Lake Tahoe basin. In general, the potential for occurrence of such species is almost non-existent in montane conifer forest that lacks rocky outcrops or other features such as small seeps, and higher in boggy or wet meadow areas. Thus, the Jeffrey Pine and Lodgepole Pine forest areas where new golf holes are proposed to be constructed do not provide habitat suitable for special-status plant species, but small wetland areas in historic channels that are to be reoccupied might provide such habitat.

WILDLIFE

Habitat Types in the Project Area

Five major terrestrial habitat types can be differentiated in the project area, based on ecological significance to biota that may be affected by the proposed project. Two of these are forest habitats; Jeffrey Pine and Lodgepole Pine. The others are riparian habitats: willow-dominated; meadow; and freshwater emergent wetland. Existing and proposed conditions are described for each of these types.

<u>Forest Habitats</u>

Forest habitat comprises the major habitat type within the Lake Tahoe basin. The area of lower and upper montane forests, including all seral phases is almost 95,000 acres (USDA 2000). Only 4% of this is old growth conifer forest. No old growth occurs in or near the project area. The closest areas are situated west of the project area and east of Fallen Leaf Lake. A small patch is mapped near Tahoe Mountain, north of the project area. Logging has occurred in all forest habitats in the project area.

Within the project area, tree size and canopy cover data for forest habitats were obtained from the Region 5 Remote Sensing Lab.

Jeffrey Pine Habitat Type

The Jeffrey pine habitat type includes two vegetation community classifications used for this study: Jeffrey Pine and Jeffrey Pine-Dry Meadow. The 95.7 of acres of Jeffrey pine habitat is situated primarily in the westernmost portion of the project area Forest Service remote sensing data suggests that trees generally range in size from 11 to 24 inches diameter at breast height (dbh), but some trees up to 30"dbh are also found. Canopy closure is variable. Fifteen percent of the canopy is from 10 to 24 percent closed; forty-six percent of the canopy has from 25 to 39 percent cover; and thirty-eight percent of the canopy ranges from 40 to 59 percent. A single canopy layer is present.

Conditions within this habitat are variable. In some locations, the canopy cover is contiguous while in others it is characterized by an absence of trees. Trees are less dense where there is a dry meadow layer. Understory shrubs, mainly bitterbrush and sagebrush, are relatively sparse. Evidence of previous human disturbance, such as old logging roads, drainage channels, and slash, is extensive in some areas. Stacked logs are located along the westernmost project boundary from a previous timber harvest.

Following project completion, 76.7 acres of Jeffrey pine habitat will be present, reflecting a loss of 19 acres.

Lodgepole Pine Habitat Type

The lodgepole pine habitat type includes four vegetation community classifications used for this study: Lodgepole Pine-Dry, Lodgepole Pine–Mesic, Lodgepole Pine Dry/Dry Meadow mosaic, and Lodgepole Pine Mesic/Mesic Meadow mosaic. The 112.4 acres of lodgepole pine habitat are situated primarily in the vicinity of the Upper Truckee River. Trees range in size from 11 to 24 inches dbh. Canopy closure is variable. Twenty-five percent of the trees range from 10 to 24 percent; forty-two percent of the trees range from 25 to 39 percent; and thirty-three percent of the trees range from 40 to 59 percent. Areas with higher canopy cover are located closer to the river. A single canopy layer is present. An understory of mid and late seral stage riparian shrubs (e.g., willows, alders) is patchily distributed in some portions of the Lodgepole Pine-Mesic habitat, mainly those areas close to the river. Typically, an herbaceous layer of forbs and grasses occurs where sufficient light is present. In contrast, the Lodgepole Pine-Dry habitat lacks a mid-height shrub understory.

Lodgepole pines in this habitat type tend to occur either as large solitary trees, patches of even-aged trees, and thickets of small trees. Snags and down logs in all stages of decomposition are common. Human disturbance in this habitat is mainly situated adjacent to the river and includes the golf course, the recreational trail that parallels the river's west bank, and the sewer line. Roads and evidence of previous timber harvest are also present.

Following project completion, 98.1 acres of lodgepole pine habitat will be present, reflecting a loss of 14.4 acres.

<u>Willow-Dominated Habitat Type</u>

The willow-dominated habitat type includes four vegetation community classifications used for this study: Willow, Willow-Wet Meadow, Willow-Mesic Forb, and Willow-Mesic Meadow. The project area currently contains approximately 16.8 acres of willow habitat. Downstream of Transect 7 (Figure 24), willow-dominated habitat is located in discontinuous, relatively narrow bands along the Upper Truckee River. The linear nature of the willow habitat is more typical of streams with steeper gradients and steeper side slopes than streams of shallow gradient in broad valleys. Due to various human disturbances, the hydrologic conditions conducive to the development of a patchy willow distribution of various ages no longer occur. Upstream of Transect 7, the willow habitat is relatively more extensive, but is still primarily linear in nature. Some river bends have willow patches that are 100 feet wide. The willow shrubs are mostly mature plants, except for some point bars that new willows are colonizing. Willow habitat is considered a biologically diverse ecosystem with unusually high species richness (USDA 2000).

Following project completion, 40.8 acres of willow-dominated habitat will be present, reflecting a gain of 24 acres. It is likely that these changes will occur over several decades.

Meadow Habitat Type

The meadow habitat type includes six vegetation community classifications used for this study: Wet Meadow, Mesic Meadow-Wet Meadow, Mesic Meadow, Mesic Forb, Dry Meadow, and Revegetation Dry Meadow. The project area currently contains approximately 48.6 acres of meadow habitat. Various combinations of grass, sedge, rush, and forbs are present. Species dominance and diversity depend on soil moisture, substrate, and hydrology. Sedge and rushes occur in the wettest areas, while grasses and forbs dominate drier sites. A thatch of dead vegetation occurs intermittently with patches of bare ground. These patches of variable herbaceous cover increase biological diversity. Willow shrub layers are absent or sparse. Lodgepole occur along the meadow edge. No pools of standing water were noted during field surveys. The golf course is the primary source of human disturbance.

Following project completion, 70.7 acres of meadow habitat will be present, reflecting a gain of 22.1 acres. It is likely that these changes will occur over several years.

Freshwater Emergent Wetland Habitat Type

The freshwater emergent wetland habitat type includes three vegetation community classifications used for this study: Obligate Sedge Wetland, Spring Complex, and Abandoned Channel. The project area currently contains approximately 5.1 acres of freshwater emergent wetland habitat in five disjunct patches. Two of these sites are associated with previous human disturbance: a historic spring and a quarry. This habitat type is characterized by low plant species diversity and a continuous vegetation canopy. Standing water is present during all or part of the year, flooding is frequent, and surface water is typically present into hot summer months. Freshwater emergent wetland is considered a biologically diverse ecosystem with unusually high species richness (USDA 2000).

Following project completion, 6.2 acres of freshwater emergent wetland habitat will be present, reflecting a gain of 1.1 acres. It is likely that these changes will occur over several decades.

Anticipated Effects on Focal Species

The project is designed to restore ecosystem function and processes. This approach provides greater success in ecological restoration than targeting specific wildlife species or guilds of species, such as willow flycatchers or riparian-dependent birds (Silveira et al. 2004), and it is the prevailing model of restoration (Picket et al. 1992). Restored hydrologic, geologic, and edaphic landscape processes will create the conditions that convert the project area into more natural, self-sustaining, native vegetation and its associated patterns and forms. Restoration of ecological processes that shaped the evolution of the associated wildlife species will ultimately provide suitable habitat (SNFPA 2000). Although not designed to restore certain species such as willow flycatchers, the project will have positive effects on habitat availability for such species.

Changes in project area habitat type and quality will affect wildlife species' richness and density in and near the project area. This section describes the anticipated project effects on focal species and special status wildlife species (i.e., federal and state threatened, endangered, and sensitive species, USFS sensitive species, TRPA special interest species) that might occur in or near the project area. Habitat is assumed to have been historically present for focal species prior to channel alterations. Focal species are likely to have been adversely affected by construction of the golf course, and by habitat loss and fragmentation in the Upper Truckee River watershed. A focal species might currently occur in low numbers and in limited distribution in the project area. Many species are likely to increase in numbers and/or distribution post-project, while others might decrease.

Two sources were used to identify focal species, the Lake Tahoe Watershed Assessment (LTWA) and the Sierra Nevada Forest Plan Amendment (SNFPA 2001). The LTWA identified focal species of concern and interest using a variety of ecological and cultural criteria (USDA 2000). Eighty-three bird species, 53 mammal species, six amphibian species, and three reptile species were identified as focal taxa of the greatest interest and concern in the basin. The authors suggest these species receive special consideration in monitoring, management, conservation, and research.

Using three variables, population size, population trend, and change in distribution, the SNFPA (2001) assessed the vulnerability of 427 terrestrial vertebrates (SNFPA, Appendix R-3). Species in the High Vulnerability Group have both declining population trends and have experienced large reductions in their distribution in the Sierra Nevada Bioregion. Species in the Moderately Vulnerable Group have declining trends, but have experienced smaller or no changes in distribution. Species in the Low Vulnerability Group are characterized by stable or increasing populations and relatively stable distributions. The completed assessment resulted in a final distribution of 42 species in the High Vulnerability Group, 168 in the Moderate Vulnerability Group, and 217 species in the Low Vulnerability Group. Twenty-one (53%) of the High Vulnerability Group are dependent on riparian/meadow and aquatic environments, and one (2%) is dependent on late seral/old-growth forest.

This section analyses potential project effects on eight terrestrial focal species (northern goshawk, willow flycatcher, pine marten, mule deer, muskrat, long-toed salamander, pacific chorus frog, and western aquatic garter snake) and one group of terrestrial focal species (small rodents, rabbits, and shrews) that might be positively or adversely affected by the project. The effects of the restored ecosystem processes will occur over variable time scales. The anticipated project effects on focal wildlife species and their habitat are analyzed at three time scales: post-project, five years, and 50 years.

Northern Goshawk

Status

The northern goshawk (*Accipiter gentilis*) is listed as a species of special concern by the State of California, as a sensitive species by Region 5 USDA Forest Service, and as a special interest species by the TRPA. The LTWA (USDA 2000) identified the goshawk as a focal terrestrial species dependent on old forest. The SNFPA (2001) classified the goshawk in the moderate vulnerability group.

Habitat

Preferred habitat consists of older-age coniferous, mixed, and deciduous forest habitat. The habitat also consists of large trees for nesting, a closed canopy for protection and thermal cover, and open spaces allowing maneuverability below the canopy (USDA 1988). Snags, down logs, and high canopy cover are critical habitat features. The former two are also an important component used by numerous prey species. Many of the species that provide the prey base for goshawks are associated with open stands of trees or natural openings containing an understory of native shrubs and grass (Fowler 1988).

Northern goshawk nesting habitat is characterized by dense canopy closure (50-90%) with mature timber. Nest trees for this species are commonly located on benches or basins surrounded by much steeper slopes (Call 1979). Mature trees serve as nest and perch sites, while plucking posts are frequently located in denser portions of the secondary canopy. The same nest might be used for several seasons, but alternate nests are common within a single territory. The chronology of nesting activity varies annually and with elevation. In general, nesting activities are initiated in February. Nest construction, egg-laying, and incubation occur through May and June. Young birds hatch and begin fledging in late June and early July. They are independent by mid-September (USDA 1992).

Historic and Existing Project Area Conditions

Historic forest conditions in the project area were likely to have provided suitable nesting habitat for northern goshawks.

Nesting northern goshawks have not been documented in Washoe Meadows State Park (LTBMU records; California State Parks records). However, no protocol surveys for nesting goshawks have been conducted. An active goshawk territory is documented on U.S. Forest Service land in the Angora Creek area. Six nest sites have been recorded in this territory between 1981 and 2003. The LTBMU delineated a protected activity center (PAC) for this territory that trends north south. The PAC and nests are situated less than 1.5 miles west of the westernmost portion of the project area. This pair of goshawks has been regularly observed foraging in the northern portion of Washoe Meadows State Park in the vicinity of Angora Creek (CDPR 2003).

Using the CALVEG mapping (2004) provided by the LTBMU, the Jeffrey pine habitat meets the minimum criteria for potential goshawk nesting habitat (SNFPA 2001). Suitable nesting habitat is defined as stands with an average tree size of at least 11 inches diameter at breast height (dbh) and > 40% canopy cover. An additive model of goshawk nest habitat suitability developed by the TRPA (2001) rated basin habitat as high, intermediate, and low. According to the model, the Jeffrey pine habitat, and all of Washoe Meadows State Park, is low suitability nesting habitat. The additive model uses the following six criteria: (1) vegetation (type, size, and canopy cover); (2) distance to streams; (3) land use (using the TRPA Land Use map depicting Tourist, Residential, Conservation, Recreation, and Commercial Zones); (4) slope; (5) aspect; and (6) elevation. Figure 25 depicts the existing suitable nesting habitat using the TRPA model.

Project Area Conditions with Project

Time Frame: post-project

The project would convert approximately 19 acres of Jeffrey pine habitat situated in the southwest portion of Washoe Meadows State Park into golf course. If goshawks forage in this portion of the project area, they are unlikely to do so once the golf course is in-situ, both due to changes in forest structure and to the presence of recreationists. However, the project would not affect the structural suitability of foraging habitat in other portions of the park.

State Park lands are managed for recreation, and the southwest portion of the park does receive some recreational use (egg, skiers, hikers, mountain bikers, horseback riders). However, most use is concentrated on the path that parallels the Upper Truckee River. Conflict between recreationists and nesting goshawks can occur due to the bird's breeding chronology. Goshawks initiate breeding when the ground is still covered with snow. Some pairs construct nests directly along roads and trails that provide flight access (SNFPA 2001). Goshawks are aggressive nest defenders and attack people who enter their nest stand. After the snow melts, these sites can become candidates for conflict as people begin to use the trails and roads. Conflict between golfers and goshawks are not anticipated because suitable nesting habitat will not exist where any portion of the golf course is sited.

Time Frame: five years

An increase in the goshawk prey base of small mammals and birds could occur due to increased prey productivity as a result of increased riparian and meadow habitat.

Time Frame: 50 years

The forest habitat would develop late seral/old growth characteristics such as increased tree size and increased canopy cover. The forest habitat north of the golf course would provide foraging habitat for goshawks. Goshawks could potentially nest in this habitat depending on the proximity of other territorial nesting pairs.

Future Conditions Without Project

Under California State Park's land management, the Jeffrey pine habitat in Washoe Meadows State Park would develop into forest with late successional characteristics. This would increase its suitability as nesting habitat for goshawks. However, current LTBMU policies also manage forest habitat for old-growth characteristics (SNFPA 2004). These concurrent policies would expand the availability of suitable nest habitat throughout the Lake Tahoe basin. Because State Parks has less land to manage compared to LTBMU, they might pursue more active management that could create this forest type sooner than would occur with LTBMU lands.

Additional factors, such as other nearby occupied nesting territories, affect the likelihood of another pair of goshawks nesting in suitable habitat. Nesting suitability of the Jeffrey pine habitat in the southwest portion of the project area is reduced because of the proximity of the active Angora Creek territory situated less than 1.5 miles west. The average distance between goshawk territories is 2.2 miles (October 17, 2002; phone consultation; Brain Woodbridge, author Survey Methodology for Northern Goshawks in the Pacific Southwest Region, U.S. Forest Service (9 August 2000)). The goshawk survey protocol delineates a one-mile no-survey radius around active goshawk nests. The likelihood of locating another goshawk territory is marginal one mile from a known territory but increases the farther away one moves, hence the rationale for excluding the one mile radius around a nest from further survey efforts. According to Woodbridge, goshawk nest densities one mile apart were documented only once in a unique location (adjacent to a burned area).

Topographic features, such as two watersheds separated by a steep mountain, could create a sufficient barrier to allow pairs to nest closer than the average of 2.2 miles. No topographic features separate the Angora Creek territory from the southwestern portion of the project area. The habitat between the two locations consists of a 3% eastward slope over a distance of approximately 1.5 miles. Approximately 0.5 miles of this linear distance is a residential neighborhood. The LTBMU has no record of goshawks nesting in residential neighborhoods.

A brief GIS analysis of goshawk nest sites in the basin was performed. Two assumptions were made if goshawks nested in the Jeffrey pine habitat in the southern portion of the project area. First, nesting goshawks are known to be sensitive to human disturbance (Keane 1999; SNFPA 2001). Therefore, it was assumed the goshawks would select a site as far as possible from the residential neighborhoods and as far as possible from winter recreational use along the river. This resulted in a nest centrally located 250 meters from either disturbance.

Known goshawk nest sites (LTBMU data) from 1978 to 2003 were buffered with a 250 meter radius and the number that intersected with residential neighborhoods was computed. Only 7.8% of the buffered nest sites intersected a portion of residential neighborhoods. In all cases, the nest sites were near development on one side, but were otherwise surrounded by undeveloped land. Of these nest territories, approximately three were subsequently abandoned due to disturbance from people.

Even with more suitable forest structure and an assumed loss of the Angora nest territory, for the reasons discussed above, the project area's habitat suitability for nesting goshawks is unlikely to change from marginal to high suitability.

Willow Flycatcher

Status

Willow flycatchers (*Empidonax traillii adastus*) are listed by the State of California as an endangered species. The Pacific Southwest Region of the U.S. Forest Service and Region 1 of the U.S. Fish and Wildlife Service have designated the willow flycatcher as a sensitive species. The LTWA

(USDA 2000) identified the willow flycatcher as a focal terrestrial vertebrate species potentially imperiled due to an estimated range contraction of 90-100 percent. The SNFPA (2001) classified the willow flycatcher in the high vulnerability group.

Habitat

Nesting habitat typically includes moist meadows with perennial streams and smaller spring-fed or boggy areas with willow (*Salix* spp.) or alder (*Alnus* spp.) (Serena 1982; Harris et al. 1988). Willow flycatchers have been found in riparian environments of various shapes and sizes ranging from small willow-surrounded lakes or ponds with a fringe of meadow or grassland to various willow-lined streams, grasslands, or boggy areas (Craig and Williams 1998). Willow flycatcher nest territories generally contain open water (i.e., running water or standing water), boggy seeps, or saturated soil (Bombay et al. 1999).

Nests constructed of grass and sedges are usually located in willows between 3.3 to 10 feet in height (Serena 1982). In mountain meadows, duff from the previous growth season must be available when the flycatchers construct their nest (Craig and Williams 1998).

In the Sierra Nevada, willow flycatchers have nested in meadows less than one acre to meadows several hundred acres (Serena 1982; Stafford and Valentine 1985; Flett and Sanders 1987; Bombay 1999). However, most willow flycatchers occur in meadows larger than 20 acres. Riparian meadow sites used by willow flycatchers vary in size and shape and may contain relatively dense, linear stands of shrubs, or irregularly shaped mosaics of dense vegetation with open areas in between. Various researchers describe openings within thickets of riparian deciduous shrubs or tall clumps of shrubs separated by open areas as important components of willow flycatcher nesting habitat (Serena 1982, Harris et al. 1988, Sanders and Flett 1989). Large contiguous willow thickets are avoided (Sanders and Flett 1989, Harris et al. 1988). According to Sanders and Flett (1989), openings within willow patches appear to increase habitat suitability. However, Harris et al. (1988) found it was not possible to predict presence or absence of willow flycatchers by willow clump sizes. Nonetheless, some openness in the shrub stratum seems important. The loss and degradation of riparian habitats is probably the primary cause of historic and recent declines in willow flycatchers (Craig and Williams 1998).

Historic and Existing Project Area Conditions

Historic records indicate that willow flycatchers were a fairly common summer resident in the Lake Tahoe basin (Orr and Moffitt 1971). Populations were associated with the Truckee Marsh and Upper Truckee River system (SNFPA 2001). In 1998, a single individual was detected in the project area in wet meadow/willow habitat south of the golf course and adjacent to the Upper Truckee River. None have been detected in subsequent surveys. More recently, willow flycatchers have been detected nesting along the Upper Truckee River approximately four miles upstream of the project area.

Considering the extensive alteration that has occurred in the project area and region, it can be assumed that much more extensive habitat of higher quality was available pre-disturbance. It is also reasonable to assume that willow flycatchers could have occurred in the pre-disturbance project area.

Using aerial photographs, the LTBMU mapped willow flycatcher emphasis and potential habitat in the project area. Emphasis habitat is wet meadows larger than 15 acres with at least some deciduous riparian shrubs. Potential habitat is emphasis habitat and small wet meadows (< 15 acres) with shrubby vegetation. The mapped emphasis habitat generally corresponds to the willow vegetation community types mapped for this project. However, much of the potential habitat is located in Lodgepole Pine-Mesic vegetation communities and is not suitable willow flycatcher nesting habitat.

Vegetation community mapping for this project was utilized to estimate available habitat for willow flycatcher. For this analysis, Category 1 habitat is defined as potentially suitable nesting habitat, and is comprised of willow-dominated vegetation community types that provide willows (structure) necessary for nest sites. The following vegetation community types mapped for this project are assumed to provide Category 1 habitat: W/MF--Willow scrub/mesic forb; W/WM--Willow/wet meadow; W--Willow scrub; and W/MM--Willow/mesic meadow. Category 2 habitat is defined as potentially suitable foraging habitat, but is less likely to provide nesting habitat because of the lack of willow structure (willows may be absent or present in low numbers). Where willows are present, the habitat type could be used for nesting (ie, the willow provides structures for nest sites). The following vegetation communities comprise Category 2 habitat: MF--Mesic forb; OM--Obligate sedge wetland; OM/LPM--Fen or bog wetland; WM--Wet meadow; MM--Mesic meadow; and MM/WM--Mesic meadow/wet meadow. Figure 26 depicts the currently available Category 1 and 2 willow flycatcher habitat in the project area (a total of 16.8 acres).

Project Area Conditions with Project

Time Frame: post-project

Depending on construction techniques, there could be a temporary decrease in the amount of riparian vegetation in the proximity of Transect 3 (Figure 24). No other changes in riparian vegetation are anticipated post-project. The increase in ground water level would contribute to favorable conditions for existing riparian plants. Overall, habitat for riparian dependent bird species would be the same.

Time Frame: five years

Higher ground water will contribute to more vigorous herbaceous growth. An increase in bar development, including point bars and the formation of more surfaces near the channel, will provide colonization sites for early seral stage riparian vegetation. Recruitment areas also include old meander cut-offs. The foliage cover of the willows would grow in height and lateral cover and could eventually provide habitat for bird species that forage under shrubs as well as low-canopy species such as song sparrows (*Melodia melospiza*).

Time Frame: 50 years

Suitable willow flycatcher habitat will be present. Based on vegetation community changes described earlier in this report, a total of 40.8 acres of predicted project area willow flycatcher habitat would develop in the future (Figure 27), and increase of 24 acres.

The riparian habitat will provide natural ecosystem structure and function. Connectivity between the river, floodplain, and surrounding habitats will be high. An intact native plant community, including a shrub layer, herbaceous understory, down wood, and litter will be present along the length of the existing channel. Under restored flow regimes, disturbance by various levels and durations of flooding will result in riparian vegetation with a patchy distribution, such as along old meander cut-offs and off-channel beaver impoundments. A diversity of riparian shrub age classes will be present, regeneration will occur, and the shrub cover will meet the habitat needs of riparian-dependent species. Shading will occur at historic levels. Habitat diversity, integrity, and function will be resilient and remain after disturbance events such as flooding.

Riparian habitat upstream of Transect 7 (Figure 24) is expected to be similar in nature to the existing habitat. Gravel bar development is expected to be high in this reach, creating relatively wide communities dominated by shrubs. Downstream of Transect 7 the riparian habitat will be characterized by a linear patch of shrubs along both sides of the stream, which is likely to be less dynamic that in upstream reaches. The largest patches with the tallest plants will be located on bar or meander cutoffs where water is or was present. Smaller patches will be present in recently disturbed areas, such as enlarging point bars. Some lodgepole trees will be scattered throughout the area, but the overstory will be primarily present along the meadow edge. Wet portions of the meadow will be dominated by sedge, while drier areas will be dominated by grasses and forbs. Early in spring, standing water from snowmelt or overbank flows is likely to be present in old depressions and meander cutoffs. To the extent that topography with variable elevations is created on the restored golf course, water will remain in these sites for varying periods of time.

The restored project area will comply with several objectives of the Riparian Habitat Joint Venture of Partners in Flight (RHJV 2004). It will provide high quality riparian habitat that contributes to the long-term persistence of birds dependent on riparian ecosystems; it will provide habitat for declining species; and could function as source populations for other sites. With increased willow habitat of all ages, bird species associated with vertically stratified shrub habitats would be expected to increase, as would species' richness of foliage gleaners.

The restored project area would provide suitable riparian habitat for other focal bird species identified in the LTWA (USDA 2000) including Lincoln's sparrow (*Melospiza lincolnii*), MacGillivray's warbler (*Oporonis tolmiei*), and black-billed magpie (*Pica pica*). These species were classified as potentially vulnerable vertebrates that use terrestrial and riparian habitats, are habitat specialists, and use fewer than 30 percent of CWHR habitat type/seral stage combinations. Suitable habitat would also be present for warbling vireo (*Vireo gilvus*), Wilson's warbler (*Wilsonia pusilla*), yellow warbler (*Dendroica petechia*), and song sparrow. These species were listed as focal species by the Riparian Habitat Joint Venture Bird Conservation Plan (Version 2.0) (2004).

Future Conditions Without Project

Restoration of the geomorphic processes that create new nursery sites for riparian vegetation through sediment deposition and change in flood inundation, timing, duration, and magnitude would not occur. Compared to systems with natural flow regimes, the riparian vegetation would be impaired. The habitat would be characterized by less regeneration and more even-aged stands. Riparian habitat would continue to be limited to the main river channel. The opportunity to re-establish riparian corridor connectivity in the project area would not occur. The most important factors causing declines in riparian bird populations are habitat loss and degradation (RHJV 2004). These processes would not be reversed in the project area.

<u>Pine Marten</u>

Status

The pine marten is a Forest Service sensitive species. The LTWA (USDA 2000) identified the marten (*Martes americana*) as a focal terrestrial vertebrate species dependent on old forest. The SNFPA (2001) classified the marten in the moderate vulnerability group.

Habitat

Preferred habitat is dense (60-100% canopy closure), multi-story, multi-species mature coniferous forests with a complex physical structure near the ground (Buskirk and Powell 1994). High numbers of large snags and down logs are an important component of marten habitat, especially in winter when snow covers much of the ground. Snags and down logs provide denning and resting sites for marten, access to subnivian areas, and habitat for marten prey (White 1993). Subnivian habitat is also important for resting and thermoregulation during winter (Buskirk and Ruggiero 1994). In winter, martens usually require forest with a canopy closure at least 50% (Bissonette 1991).

High quality habitat includes close proximity to forested riparian corridors that are used as travelways and an interspersion of small (<1 acre) openings with good ground cover used for foraging (Spencer et al. 1983; Freel 1991; Jones and Raphael 1991). Travelways between 300 to 600 feet in width are recognized by one expert as the minimum for marten dispersal (Chapel et al. 1992). Riparian corridors or other means for dispersal are necessary to martens to provide safe and frequent movements through poor habitat areas and between habitats. These travelways should be multistoried stands and should have a minimum canopy closure of 50-60% (Freel and Stewart 1991). Martens forage at the edge of openings, especially natural meadows, but they avoid traveling across large openings.

The presence of roads and clearings has been documented to act as behavioral barriers to movement by martens (Freel 1991). Martens generally avoid habitats that lack overhead cover, and various authors have reported complete or partial avoidance of non-forested habitats (Ruggiero 1994). The association of marten with mature, closed-canopy forests has been postulated to result from decreased risk of predation, increased abundance of subnivian resting sites, and increased availability of prey when compared to early-successional forests (Chapin et al. 1997).

Marten do use a variety of other habitat types, but depend on a well-connected expanse of late-successional forest. Variable sizes for home ranges within the Sierra Nevada are reported in the literature; male home ranges vary between 673 to 3,000 acres and females range from 427 to 1,075 acres (USDA 1999).

Martens are active throughout the year and hunt by traveling on the ground or snow surface. Their diet includes a variety of small mammals, birds, reptiles, insects, and amphibians (Zeveloff 1988). In fall, berries and other fruits are important foods, while in winter, voles, mice, hares, and squirrels dominate their diet (USDA 1994). Subnivian mammals such as voles, mice and shrews are caught when martens enter access points to the subnivian space created by coarse woody debris and other structures (Corn and Raphael 1992). Raine (1987) found that martens made less use of subnivian space when the snow surface was crusted, probably because of difficult access. At such times, martens may climb trees in search of prey, such as squirrels. Martens are active at various times of the day and night and appear to be flexible in their activity patterns (USDA 1994).

Historic and Existing Project Area Conditions

Martens are likely to have inhabited suitable habitat where it historically occurred in the project area. A habitat suitability model developed by TRPA (2001) rated basin habitat for pine marten as high, intermediate, and low. According to the model, the central portion of the project area on the river's west side has intermediate habitat suitability (Figure 28). Portions of the delineated habitat encompass the proposed golf course.

Project Area Conditions with Project

Time Frame: post-project

Approximately 33.4 acres of forest habitat, both Jeffrey pine and lodgepole pine, would be converted to golf course. It is unknown whether martens currently use this portion of the State Park as no surveys have been performed. While contributing to forest fragmentation, the habitat conversion more accurately represents a loss of potential habitat. The value of this habitat is lessened by its proximity to residential neighborhoods; the TRPA model excluded habitat within 800 feet of development. The areas south and west of the proposed golf course location are residential neighborhoods; martens are unlikely to disperse through these areas to upland habitat.

The size of openings that martens have been observed to cross varies from 10 meters (m) (Spencer et al. 1983), 30 m (Hargis and McCullough 1984), 40 m (Simon 1980), to 100 m (Koehler and Hornocker 1977). Some portions of the golf course greens would exceed the maximum size opening martens are known to cross. Even if martens traversed the golf course, small mammal prey numbers are expected to be reduced since golf courses do not provide high quality habitat compared to a natural environment with its increased cover and structure.

During the summer months, the golf course would increase the number of people present in the project area, which might result in displacement of any martens that use the area after conversion to golf course. Martens are known to cohabit in close proximity to human structures and to even approach people (USDA 1994; Kudrna, USFS pers com.; Boatner, pers com.). While marten co-existence with winter recreation use is documented (e.g., alpine ski resorts, including Heavenly Valley, Sugar Bowl, and Alpine Meadows), no known studies have examined co-existence with summer recreation uses. The fact that martens persist in ski areas suggests some level of habituation to year round human presence has occurred.

Time Frame: five years

No significant changes from post project conditions would be expected.

Time Frame: 50 years

Although trees with late seral/old growth characteristics would be likely to occur in areas in and near the golf course, no changes in project area habitat suitability for marten would be expected. The forest habitat north of the golf course would develop late seral/old growth characteristics and would continue to provide suitable marten habitat.

Future Conditions Without Project

No large timber removal would occur. In the long-term, habitat suitability for martens would increase because California State Park's is managing forest habitat for late successional characteristics. Current LTBMU policies also manage forest habitat for old-growth characteristics (SNFPA 2004). These concurrent policies would expand the availability of suitable marten habitat throughout the Lake Tahoe basin. Because State Parks has less land to manage compared to LTBMU, they might pursue more active management that could create this forest type sooner than would occur with LTBMU lands.

The proximity of the residential areas west and south of the State Park to forest habitat likely reduces the value of the habitat bounded by these developments. For example, dogs and cats could affect habitat suitability through reduction in prey numbers and dogs could chase martens.

<u>Mule deer</u>

Status

The LTWA (USDA 2000) identified the mule deer (*Odocoileus hemionus*) as a focal terrestrial vertebrate species because it is occasionally hunted in the basin and because it is commonly viewed by the public for pleasure. The SNFPA (2001) classified the mule deer in the moderate vulnerability group.

Habitat

Mule deer prefer earlier successional communities, open woodlands, meadows, and riparian areas. Mule deer preferentially browse on shrubs rather than graze on forbs and grasses. Preferred shrubs are mostly in the rose family and include bitterbrush, cliff-rose, and rose. Willows and many other riparian species are also favored. Tree thickets, brushy areas, and tall shrub understory are used for escape cover.

Mule deer make seasonal migrations. To avoid heavy snows and reduced forage, mule deer migrate to lower elevations. The regional migrations of the Carson River deer herd entail movements from summer range into lower elevation winter range located outside the Tahoe Basin, east of the project area. Stands of brush located in their winter range provide winter forage while stands of mixed conifer provide thermal and protective cover for mule deer. Critical winter range occurs at lower elevations where brush stands remain snow free and readily accessible for browsing and cover. Transitional ranges provide mule deer with necessary cover and forage to allow movement between winter and summer habitats. Important forage and cover species for mule deer in both winter and transitional ranges include bitterbrush, sagebrush, mountain mahogany, and aspen.

Preferred habitat for fawning includes high elevation, undisturbed, shrub land, meadows, riparian areas, and dense herbaceous stands that provide hiding cover and succulent forage. Females use areas where brush, tree-thickets, and vegetation protect offspring from predation.

Historic and Existing Project Area Conditions

Mule deer are likely to have inhabited suitable habitat where it historically occurred in the project area. Although no signs such as tracks or scat of mule deer were noted during the site visits, suitable habitat is present. Mule deer have been detected foraging and resting in the riparian habitat upstream of the Myers Highway 50 river crossing. No high ranked suitable fawning habitat occurs in or near the project area (TRPA 2001).

Project Area Conditions with Project

Time Frame: post-project

Foraging habitat would be reduced due to conversion of the forest to golf course. Depending on how the golf course is landscaped, potential browsing opportunities could increase if palatable shrubs are introduced.

Time Frame: five years

An increase in wet meadows could increase browse species such as Wood's rose for deer. An increase in the height of herbaceous and shrub vegetation would increase cover for deer.

Time Frame: 50 years

The structural composition of riparian habitat would provide increased cover, foraging, and loafing sites for deer. Foraging habitat consisting of wet meadow habitat would increase. A more extensive riparian corridor would also improve the habitat's function as a travel corridor. However, old forest cover would be lost.

Future Conditions Without Project

There could be a marginal benefit in cover although there may be a loss in foraging habitat due to succession of early seral stage forest into late seral stage forest.

Muskrat

Status

The LTWA (USDA 2000) identified the muskrat (*Ondatra zibethicus*) as a potentially vulnerable vertebrate based on its dependence on aquatic habitat, low mobility, and small home range. The SNFPA (2001) classified the muskrat in the high vulnerability group.

Habitat

The aquatic muskrat occupies marshes, creeks, lakes, and quiet rivers. Active throughout the year, muskrats are mostly active at night, dusk, and dawn. Muskrats construct either conical houses or dig burrows into banks. Lodges and feeding platforms are constructed of aquatic plants on top of piles of roots and mud. Muskrats primarily eat aquatic vegetation such as cattails and sedges. Occasionally individuals eat freshwater clams, crayfish, frogs, and fish. Muskrat predation can affect the size and age distributions of clams (Convey et al. 1989). Numerous vertebrates and invertebrates use muskrat houses as nesting places (Willner et al. 1980). Amphibians and garter snakes can take refuge in muskrat bank burrows. Raccoons and mink prey on muskrats. In one study, an increase in muskrat population was followed by an increase in mink population a year later; and the increase in mink was followed by a decrease in muskrats a year later (Bulmer 1974). Other predators include bald eagles and great horned owls. Muskrat home range sizes are relatively small. Most foraging activity occurs within a five to 10 meter radius of a den.

Historic and Existing Project Area Conditions

According to Grinnell (1933), the "Nevada" muskrat (*Ondatra zibethica mergens*) is native to Lake Tahoe. Grinnell cites sources from the museum of vertebrate zoology. Orr (1949) reported muskrats in the lower part of the Upper Truckee River and occasionally near the mouth of Burton Creek and Glenbrook Creek.

Muskrats occur downstream in the Upper Truckee River marsh and they have been detected upstream of the Highway 50 Myers bridge crossing in meander cut-offs and impounded water behind inactive beaver dams. Suitable habitat is not present in the project area. However, habitat is present along the restored portion of Angora Creek upstream of the confluence with the Upper Truckee River (and outside of the project area), and signs of this species were noted (e.g., cut vegetation, trails, bank burrows). It is likely that suitable habitat was historically present in the project area in meander cut-offs and at the confluence of the Upper Truckee River and Angora Creek.

Project Area Conditions with Project

Time Frame: post-project

No changes in habitat suitability are expected.

Time Frame: five years

The higher ground water is likely to result in pooled water in old meander cut-offs and the subsequent development of aquatic vegetation. Such habitat would provide dispersal sites for young muskrats.

Time Frame: 50 years

An increase in the area of suitable habitat, including old meander cut-offs and the freshwater emergent wetland that would develop in the vicinity of the confluence between Angora Creek and the Upper Truckee River, is expected. In addition to such sites providing suitable herbaceous food, an increase in animal foods might also occur. The native freshwater clam (*Margaritifera margaritifera*) occurs in the Upper Truckee River north of the airport reach. It is unknown what effect the project would have on this species. However, it is assumed that restoration of the natural geomorphic processes to which this species evolved would improve habitat conditions for it, which could increase foraging opportunities for muskrats as well as species such as raccoons.

An improvement in habitat for muskrats would likely also improve conditions for potential muskrat predators such as mink (*Mustela vison*) and raccoons. The LTWA (USDA 2000) identified the mink as a focal terrestrial species that is moderately imperiled due to small population size, known population declines, and suspected range contraction.

Future Conditions Without Project

Suitable habitat would remain restricted to the existing conditions along Angora Creek, outside the project area.

Long-toed Salamander

Status

The LTWA (USDA 2000) identified the long-toed salamander (*Ambystoma macrodactylum*) as a potentially vulnerable vertebrate based on its dependence on aquatic habitat, low mobility, and large home range. In the basin, this species has been documented at several temporary ponds, wet meadows, and small lakes, primarily those without trout on the west side of the basin.

Habitat

Temporary ponds are the primary breeding habitat, but permanent lakes and wet meadows may also be used. In low elevation ponds, larvae can transform in a single season, but at higher elevation sites, they may take two years. Adults are found in piles of rotten wood, under bark, rotting logs, rocks, and other objects near quiet water of ponds, lakes, or streams (Stebbins 2003). Females deposit between two to 12 eggs. Recent metamorphs and others use downed logs (and underground in rodent burrows) rock crevices, and human structures. Introduced fish prey on larvae. Salamanders in the basin appear to breed only in fishless waters (USDA 2000). Because salamanders are probably unable to breed in temporary ponds at high elevations, and cannot use permanent lakes because of the presence of fish, they are essentially restricted to ponds that retain water all year but that cannot support fish (USDA 2000).

Historic and Existing Project Area Conditions

It is likely that habitat was historically present in meander cut-offs. Currently, long-toed salamander larvae were found occupying a temporary pond along with pacific chorus frog (*Pseudacris regilla*) larvae near the old quarry site north and west of the project area. This location is the only potentially suitable habitat in or near the project area. Individuals probably originate from the bog system perched above the wetland. None of the larvae survived to metamorphosis as the water evaporated. The golf course ponds could provide potential breeding habitat, as long-toed salamander larvae were found in the Edgewood Golf ponds (USDA 2000). However, these sites were not surveyed for larvae.

Adults and larvae have been observed downstream in the Upper Truckee Marsh. The larvae were found in abandoned channels with speckled dace (*Rhinichthys osculus*) and Lahontan redsides (*Richardsonius egregius*).

Project Area Conditions with Project

Time Frame: post-project

Depending on the design of the new course, the habitat in man-made ponds in the quarry may be lost, although mitigation alternatives may result in maintaining the available habitat in this area. Similarly, some habitat may be lost in meander scars near new golf course holes on the north side of the UTR at the upper end of the project area.

Habitat within the existing golf course will increase substantially with higher groundwater elevation. Small depressions in the floodplain which are currently dry would likely provide seasonal habitat. Placing only partial fill in portions of the existing channel that are abandoned would also substantially increase available habitat.

Time Frame: five years

The conversion of dry meadow into wet meadow would increase herbaceous cover and create a microclimate more suitable to survival of adult salamanders. A concurrent increase in rodents within the wet meadow and willow habitat would provide burrows for refugia.

Time Frame: 50 years

The amount of suitable habitat is predicted to increase as meander cut-offs lacking fish are more likely to exist. Sites that hold water until the end of summer or throughout the year would provide suitable breeding sites for long-toed salamanders. Snags (most likely lodgepole) that were created due to the raised water table are likely to have fallen and the down wood would provide additional foraging sites and cover for this species.

Future Conditions Without Project

Restoration of suitable habitat would not occur. Conversion of wet meadow into a drier microclimate would occur as the river continues to downcut. This could decrease the likelihood of additional breeding sites from developing and could reduce habitat suitability for adults that require a moist microclimate.

Pacific Chorus frog

Status

The LTWA (USDA 2000) identified the pacific chorus frog (*Pseudacris regilla*) as potentially imperiled due to known population declines, and as a potentially vulnerable vertebrate based on its dependence on aquatic habitat, low mobility, and small home range. The SNFPA classifies the pacific chorus frog in the moderately vulnerable group.

Habitat

Pacific chorus frogs breed in both permanent and temporary water. In the basin, they are typically found in temporary pools with submerged and emergent vegetation. Breeding choruses form shortly after snow melt. As with other anuran larvae, tadpoles transform most rapidly in warm water and take longer in cooler bodies of water, which are typically located at higher elevations. The length of time to metamorphosis ranges from one month to more than three months. Adults are found in moist niches under decomposing logs or in the burrows of small mammals.

Historic and Existing Project Area Conditions

In suitable habitat, the pacific chorus frog would have been a common inhabitant of the project area. Suitable habitat would have been much more extensive due to a higher water table, meander cut-offs, and snowmelt pooled in depressions.

Pacific chorus frog larvae were found occupying a temporary pond along with salamander larvae near the old quarry site north and west of the project area. The water evaporated before any larvae could transform. This site appears to have undergone some change in surface area as older USGS topographic maps show a much larger pond than was observed in the field, even following a very wet winter.

Project Area Conditions with Project

Similar effects would be anticipated as those described for the long-toed salamander. In addition, because pacific chorus frogs breed in temporary pools, it is expected that potentially suitable breeding sites would be more extensive (e.g., depressions in wet meadows hold water for one or more months).

Future Conditions Without Project

Additional breeding habitat is unlikely to develop and changes in plant communities that result in less herbaceous cover could produce less favorable conditions for adult frogs.

Western Aquatic Garter Snake

Status

The LTWA (USDA 2000) identified the western aquatic garter snake (*Thamnophis couchii*) as potentially imperiled due to known population declines, and as a potentially vulnerable vertebrate based on based on its dependence on aquatic habitat, low mobility, and small home range.

Habitat

This diurnal species is highly aquatic and is usually found in the vicinity of permanent or semi-permanent water. It basks in streamside vegetation and swims into the water when disturbed. The western aquatic garter snake forages in and along water (USDA 2000). In temporary water it preys on anuran and salamander larvae and on newly transformed adults. In permanent streams, its prey includes fish such as size-appropriate trout. At night, it is found in mammal burrows, crevices, and beneath rocks and logs.

Historic and Existing Project Area Conditions

It is likely suitable habitat was historically present in meander cut-offs, areas along the river where emergent vegetation occurred, and in pooled water associated with the wet meadow habitat.

An unidentified garter snake was briefly observed (before it fled down a muskrat hole) in freshwater emergent wetland habitat found along Angora Creek, upstream of its confluence with the Upper Truckee River. Although the western aquatic garter snake was not positively detected, it is likely to occur in the downstream portion of the Angora Creek watershed to the creek's confluence with the Upper Truckee River.

Project Area Conditions with Project

Similar effects would be anticipated as those described for the long-toed salamander.

Future Conditions Without Project

Similar effects would be anticipated as those described for the long-toed salamander. In addition, the downcutting along the river's banks would provide less cover for western aquatic garter snakes, which could increase their vulnerability to predators and reduce foraging opportunities on terrestrial invertebrates due to less vegetation. A continued lack of suitable amphibian breeding habitat would further reduce habitat suitability due to reduced foraging opportunities. Any individuals that disperse into the project area from the suitable habitat in Angora Creek meadow would be unlikely to find preferred habitat.

<u>Small Rodents, Rabbits, and Shrews</u>

Status

The LTWA (USDA 2000) identified the following focal terrestrial and riparian small mammal species as vertebrates that are potentially vulnerable to habitat or population decline. These species are high habitat specialists, using fewer than 30 percent of CWHR habitat type/seral stage combinations: dusky shrew (*Sorex monticola*), Trowbridge's shrew (Sorex *trowbridgii*), Nuttal's cottontail (*Sylvilagus nuttallii*), least chipmunk (*Tamias minimus*), long-eared chipmunk (*T. quadrimaculatus*) and lodgepole chipmunk (*T. speciosus*).

The following focal small mammal species are also potentially vulnerable to habitat and population declines. They are moderate habitat specialists, using 30 to 60 percent of CWHR habitat type/seral stage combinations, and have low mobility and moderate home range: longtailed vole (*Microtus longicaudus*), broad-footed mole (*Scapanus latimanus*), vagrant shrew (*Sorex vagrans*), and mountain pocket gopher (*Thomomys monticola*).

Habitat

Small mammals use a variety of meadow and riparian habitats and the niches therein. Some species, such as deer mice, prefer habitat with riparian plants, while others such as shrews are found in locations with moist soils and high herbaceous canopy cover. Most species dig their own burrows or use those dug by others (e.g., shrews). Except for gophers and moles, most species primarily forage above ground. Some species are nocturnal (e.g., deer mice) while others are intermittently active day and night (e.g., shrews). Small mammals are important prey items for a variety of predators including owls, hawks, coyotes, bears, weasels, and snakes.

Historic and Existing Project Area Conditions

It is assumed that the historic, pre-development project area provided suitable habitat for small mammals adapted to a variety of meadow and riparian conditions. The undeveloped portions of the project area currently provide suitable habitat for a variety of small mammals and shrews whose distribution would depend on site-specific conditions. In contrast, the golf course is managed to exclude small mammals because their burrows and foraging can interfere with golf course operations. Moreover, the short grass found on the golf course provides no cover from predators. During population increases and when young animals disperse, certain species such as voles and gophers might occasionally occupy the golf course. However, it is expected that such occupancy would be brief due to unsuitable habitat and/or management actions.

Project Area Conditions with Project

In general, golf course impacts will be reduced within the existing course, but increased within areas of the new course in upland habitats. Golf course impacts will therefore be transferred from an area more riparian in character to a forested area. This is generally likely to be a positive impact for these species, as riparian habitat is far less common in the Tahoe Basin.

Future Conditions Without Project

Suitable habitat would remain restricted to the existing conditions and would not be expected to increase in quantity or quality. The meadow habitat could become drier and could be invaded by lodgepole and sagebrush. Continued invasion of the meadows could lead to habitat conversion from meadow to upland habitat. Species that are associated with wetter environments, such as shrews, would likely diminish in number and distribution. A long-term shift in species composition could occur (and might already be occurring) where meadow and riparian species (e.g., voles) are replaced with upland species (e.g., chipmunks). The golf course would continue to provide unsuitable habitat.

Wildlife Opportunities and Constraints

This project provides several opportunities for habitat restoration and improvement within the design. There are also important constraints to ecological restoration that must be considered.

Opportunities include:

- Development of topographic diversity within areas of current golf course that will be restored;
- Partial fill of abandoned existing channel designed to create topographic diversity and low spots;
- Increase in native vegetation between fairways in the existing golf course, and maximization of native vegetation in the design of the new course;
- Habitat enhancement of the small tributary within the existing course, including riparian vegetation;
- Development of small ponds and wetlands in or near the disturbed quarry;
- Preservation of old meander scars on terraces north of the river at the upper end of the project area;
- Preservation of larger trees in areas where the new golf course is constructed

Constraints

Bullfrogs

Bullfrogs (*Rana catesbeiana*) currently occupy the project area. Bullfrogs have adversely affected native ranid frogs through predation (Moyle 1973, Hayes and Jennings 1986, Kiesecker and Blaustein 1998, Fisher and Shaffer 1996). It is unknown whether they affect the distribution of long-toed salamanders and pacific tree frogs through competition, predation, and displacement. It is also unknown to what extent bullfrogs also affect other terrestrial vertebrates through competition for food (e.g., insectivorous shrews) or through predation.

Because bullfrog larvae can take two years to metamorphose, they need quiet permanent water for reproduction. The project could provide additional suitable habitat in locations where it currently does not exist (e.g., meander cut-offs). Sites that are suitable for breeding long-toed salamanders are also likely to be suitable for bullfrogs. Competition for food between salamander and bullfrog larvae would not occur. Salamander larvae feed on aquatic invertebrates of appropriate sizes while bullfrog larvae are herbivorous filter feeders. However, bullfrogs are highly aquatic and usually remain in or near permanent water. They could prey on transformed salamanders when they leave the water. The potential for competition with other anurans is low where temporary pools form, sites that are typically used by pacific tree frogs for reproduction. However, bullfrogs prey on other smaller frogs, which would include all sizes of treefrogs, including recent metamorphs.

Brown-headed Cowbirds

The brown-headed cowbird (*Molothrus ater*) lays its eggs in the nests of other bird species and the host species hatches and rears the cowbird's offspring. Cowbird nest parasitism may adversely affect the reproductive success of other bird species (Ehrlich et al. 1988). Cowbird impact in the basin is currently being assessed as part of the Multi-Species Inventory and Monitoring project of the Forest Service.

Landscape scale land use patterns significantly affect the population levels of brown-headed cowbirds in an area (RHJV 2004). Human activities, such as cattle grazing (Moser Meadow) and golf courses can provide foraging areas for cowbirds who feed in short stature vegetation within commuting distance of their laying areas. With increases in cowbird populations, host species often suffer poor reproductive success and possibly population declines. The creation of artificial edge habitats can facilitate parasitism by cowbirds and therefore increase songbird mortality (Brittingham and Temple 1983). Maintaining large areas of contiguous habitat to maximize the habitat-to-edge ratio can reduce adverse effects of edge (Robinson et al. 1993).

The project would increase the potential for cowbird parasitism on forest bird species. Approximately 33.4 acres of forest habitat, both Jeffrey pine and lodgepole pine, would be converted to golf course. This would continue the trend of upland fragmentation that occurred prior to State Park's acquisition of the land (i.e., timber harvest, roads). However, moving the golf course features out of the riparian zone could reduce the effects of cowbird nest parasitism on vulnerable riparian cup-nesting species, although cowbirds can fly up to six miles in search of suitable nests.

In general, the project will probably have a positive effect with respect to cowbirds. As previously discussed, riparian-dependent bird species are most at risk of population declines. The effects of nest parasitism would be at least partially transferred to forest habitat birds, but species in these habitats are typically at less risk of population decline. Moreover, the proposed location of the golf course, which is near residential homes, has reduced value for many species.

Constraints on Construction

Prior to any disturbance activities, protocol willow flycatcher surveys will need to be conducted. Detection of any willow flycatchers could impose a limited operating period of a variable radius around the detection point.

Any management activities that require removal of riparian vegetation or trees should be conducted outside the avian nesting season unless a qualified biologist determines that no nesting is occurring. The chronology of each year's nesting could vary due to snow loads. The project proponent should consult with the agency wildlife biologists to determine the most appropriate time of year for performing any willow removal.

FISHERIES AND AQUATIC RESOURCES

The proposed project will substantially increase the length of channel within the project area, resulting in more available habitat. Increased sinuosity will improve pool development, and more rigorous riparian vegetation will lead to increased complexity and riparian cover. Reduced channel gradient will allow for more storage of gravel bedload in the channel, with the development of riffles important for macroinvertebrate production and fish spawning.

Some of these improvements will be realized immediately. The construction of restored meanders can include measures to increase pool volume and provide cover. Armored riffle substrates used in grade control can also be designed to provide spawning substrate, and will provide habitat for aquatic macroinvertebrates. Restoration treatments in the upper portion of the project area may also included woody debris, which will increase habitat complexity and cover.

Many of the benefits of the restoration project will be realized over time as functional geomorphic processes shape channel morphology. For example, reduced streambank height and increased riparian vigor will allow for the development of undercut streambanks, important cover for fish. The cover provided by riparian vegetation will also increase as riparian vegetation matures. Colonization of streambanks and instream bars by riparian vegetation will result in variability in resistance to erosion and will promote deposition in localized areas, increasing channel complexity. These processes, which rely on regular disturbance resulting from floods, will result in improvements in aquatic habitat improvement over a period of several decades, and will assure that aquatic habitat is maintained over time.

REFERENCES

Allen, J. E., and M. Burns. 1996. Cataclysms on the Columbia. Timber Press Inc., Portland, OR. 213 p.

Barnes, W. J. 1983. Population dynamics of woody plants on a river island. Can. J. Bot. 63:647-655.

Birkeland, P. W., 1963, Pleistocene Glaciation of the Northern Sierra Nevada, North of Lake Tahoe. Journal of Geology, 72:810-825.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. Pages 143-190 *in* E. O. Salo and T. W. Cundy, editors. Streamside management: forestry and fishery interactions. Contribution No. 57. Institute of Forest Resources, University of Washington, Seattle.

Bisson, P. A., G. H. Reeves, R. E. Bilby, and R. J. Naiman. 1997. Watershed management and Pacific salmon: desired future conditions. In: Pacific salmon and their ecosystems: status and future options. Chapman and Hall Publishing, New York.

Bissonette, J.A. 1991. Regression in forest successional stages and its implications for core sensitive species: A global look at marten habitat futures. Symposium on the Biology and Management of Martens and Fishers. Laramie WY., 29 May-1 June 1991.

Boatner, Kris. Personal communication. Unit wildlife biologist, Forest Service, Amador Ranger District, Pioneer, Ca. December 1999, March, June 2000.

Bombay, H.L., M.L. Morrison, and L.S. Hall. 1999. 1998 Annual report for the challenge cost-share agreement between California State University, Sacramento and USD Forest Service, Tahoe National Forest regarding willow flycatcher monitoring. February 22, 1999.

Borgmann, K.L., and M. Morrison. 2004. Pre-restoration wildlife inventory and monitoring in the Lake Tahoe basin, California. Lake Tahoe Basin Management Unit, South Lake Tahoe, CA..

Bradley, C. E., and D. G. Smith. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montain. Can. J. Bot. 64:1, 1,433-1,442.

Bravard, J. P., G. M. Kondolf, and H. Piegay. 1999. Environmental and societal effects of channel incision and remedial strategies. In: Darby, Stephen E. and A. Simon, eds. Incised river channels: processes, forms, engineering and management. John Wiley and Sons, New York. 442 p.

Brittingham, M.D., and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline. Bioscience 33:31-35.

Bulmer, M.G. 1974. A statistical analysis of the 10-year cycle in Canada. J. Anim. Ecol., 43:701-718.

Buskirk, S.W., and L.F Ruggiero. 1994. American marten. in The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the United States. Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, L.J. Lyon and W.J. Zielinksi, tech eds. 1994. Gen. Tech. Rep. RM-254. Ft. Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184pp.

CWHR California Wildlife Habitat Relationship. 2005. Pacific chorus frog *Pseudacris regilla*. California Department of Fish and Game. Sacramento, CA.

Call, M.W. 1979. Habitat management guides for birds of prey. U.S.Dep. Interior, Bureau of Land Management. Tech. Note TN-338. 70pp.

CDPR California Department of Parks and Recreation. 2003. Biological review for Lake Valley State Recreation Area stream restoration project. September 2003.

Chapin, T.G., D.J. Harrison, and D.D. Katnik. 1997. Influence of landscape pattern on habitat use by American marten in an industrial forest. Conservation Biology. Vol. 12 No.6: 1327-1337.

Convey, L.E., J.M. Hanson, W.C. MacKay. 1989. Size-selective predation on unionid clams by muskrats. J. Wildl. Manage. 53(3): 1989.

Corn, J.G., and M.G. Raphael. 1992. Habitat characteristics at marten subnivean access sites. Journal of Wildlife Management. 56:442-448.

Currier, B. K., N. M. Clemenza, M. C. Wademan, O. Wilchfort, J. R. Lund, C. R. Goldman, and J. E. Reuter. 1998. Highway stormwater quality management practice for Lake Tahoe—Draft Report. Prepared for Caltrans, Department of Civil and Environmental Engineering, U. C. Davis.

Darby, S. E., and A. Simon, eds. 1999. Incised river channels: processes, forms, engineering and management. John Wiley and Sons, Ltd, West Sussex, England.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon and Schuster, New York, NY.

Erwin, K., K. Melody, and L. Allesio. 1995. Willow flycatcher habitat assessment project-final report. USDA Forest Service and California Tahoe Conservancy. CTA-1039. 28 p.

Fowler, C. 1988. Habitat capability model for the northern goshawk. USFS Tahoe National Forest, Nevada City, Ca. 21pp.

Freel, M. 1991. A Literature Review for Management of Fisher and Marten in California. Unpublished Document, United States Department of Agriculture Forest Service, Pacific Southwest Region.

Fisher, R.N., and H.B. Shaffer. 1996. The decline of amphibians in California's great central valley. Conservation Biology 10(5):1387-1397.

Freel, M., and R. Stewart. 1991. A literature review for management of the marten and fisher on national forests in California. USDA Forest Service PSW Region, San Francisco. July 1991. 22 pp.

Gates, J. H. 1983. The life and death of a redwood lumber town. Moonstone Publishing, Trinidad, CA.

Gecy, J. L., and M. V. Wilson. 1983. Initial establishment of riparian vegetation after disturbance by debris flows in Oregon. Am. Midl. Nat. 123:282-291.

Geist, V. 1978. Behavior. <u>In Big Game Animals of North America: Ecology and Management</u>, eds., J.L. Schmidt and D.L. Gilbert, 238-296. Harrisburg, Pennsylvania: Stackpole Books. 494 pp.

Geotrans, Inc. 2001. Chemical application and management plan for the Eaglewood Golf Course, Placer County, California. 20 p.

Greenlee, D.L., 1985. Denitrification Rates of a Mountain Meadow Near Lake Tahoe, University of Nevada, Reno, Master's thesis.

Harris, J.H., S.D. Sanders, and M.A. Flett. 1988. The status and distribution of the willow flycatcher in the Sierra Nevada: results of the 1986 survey. California Department of Fish and Game. Wildlife Management Division Administrative Report. 88-1. 32 pp.

Hargis, C.D., and D.R. McCullough 1984. Winter diet and habitat selection of marten in Yosemite National Park. Journal of Wildlife Management. 48:140-146.

Hayes, M.P., and M.R. Jennings. 1986. Decline of ranid frog species in western North America: are bullfrogs (*Rana catesbeiana*) responsible? Journal of Herpetology 20(4):490-509.

Herbst, D. 2001. Biomonitoring on the Upper Truckee River Using Aquatic Macroinvertebrates: Watershed Restoration Baseline Data for 1998-2000. Sierra Nevada Aquatic Research Laboratory, University of California, Mammoth Lakes, CA. Submitted to Lahontan Regional Water Quality Control Board. December 2001.

Heyvaert, A.C., 2002, An Environmental History of the Tahoe Basin as Reconstructed From Lake Sediment Core, Geological Society of America, GSA Abstracts with Programs, Vol 35.

Jennings, M.R. 1996. Status of amphibians. In Sierra Nevada Ecosystem Project: Final report to Congress, vol. II., chap 31. Davis: University of California, Centers for Water and Wildland Resources.

Kauffman, J. B., R. B. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries Vol. 22, No. 5, p 12-24.

Kattleman, R., and M. Embury. 1996. Riparian areas and wetlands. In Sierra Nevada Ecosystem Project: Final report to Congress, vol. III. Davis: University of California, Centers for Water and Wildland Resources.

Kiesecker, J.M., and A.R. Blaustein. 1998. Effects of introduced bullfrogs and smallmouth bass on microhabitat use, growth, and survival of native red-legged frogs (*Rana aurora*). Conservation Biology 12(4):776-787.

Knighton, D. 1998. Fluvial forms and processes: a new perspective. Oxford University Press, New York, NY.

Koehler, G.H., and M.G. Hornocker. 1977. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. Journal of Wildlife Management. 41:500-505.

Kondolf, G. M., R. Kattelmann, M. Embury, and D. C. Erman. 1996. Status of riparian habitat. IN: Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources.

Kudrna, Dan. Personal communication. Unit wildlife biologist, Forest Service, Tahoe National Forest, Sierraville Ranger District. March 2000.

Manley, P., J. Roth, M. McKenzie, and M. Schlesinger. 2002. Multiple-Species Inventory and Monitoring 2002 Monitoring Report. Lake Tahoe Basin Management Unit (rev. Nov, 13, 2002).

Maser, C., R. F. Tarrant, J. M. Trappe, and J. F. Franklin. 1988. From the forest to the sea: a story of fallen trees. General Technical Report PNW-GTR-229. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. Published in cooperation with the U.S. Department of the Interior, Bureau of Land Management and the U.S. Department of Labor.

Mayer, K.E., and W.F. Laudenslayer (eds). 1988. A guide to habitats of California. California Department of Forestry. Sacramento.

McBride, J. R., and J. Strahan. 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream. Am. Midl. Nat. 112:235-245.

Moyle, P.B. 1973. Effects of introduced bullfrogs, *Rana catesbeiana*, on the native frogs of the San Joaquin Valley, California. Copeia 1973(1):18-22.

Murphy, Dennis D., and C. Knopp, eds. 2000. Lake Tahoe watershed assessment: Volume 1. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: Pacific Southwest Research Station, Forest Service, U. S. Department of Agriculture. 736 p.

Mussetter Engineering, Inc. 2000. Geomorphic assessment of Upper Truckee River watershed and Section 206 aquatic ecosystem restoration project reach. Report submitted to: U. S. Army Corps of Engineers, Sacramento District. Sacramento, CA. 43 p.

Noble, M. G. 1979. The origin of Populus deltoids and Salix interior zones on point bars along the Minnesota River. Am. Midl. Nat. 102(1):59-67.

Hoag, C., and J. Fripp. 2002. Streambank soil bioengineering field guide for low precipitation areas. Interagency Riparian/Wetland Project, USDA-NRCS Plant Material Center, Abedeen, ID. 65 p.

Orr, R.T., and J. Moffitt. 1971. Birds of the Lake Tahoe region. Cal. Acad. Sci., San Francisco, CA.

Parker, I., and W.J. Matyas. 1981. CALVEG: a classification of Californian vegetation. U.S. Dep. Agric., For. Serv., Reg. Ecol. Group, San Francisco.

Pickett, S.T.A., V.T. Parker, and P.L. Feidler. 1992. The new paradigm in ecology: implications for conservation biology above the species level. Pages 65-88 in: P.Fielder and S.Jain (eds). Conservation Biology: The theory and practice of nature conservation, preservation and management. Chapman and Hall., New York. 507 pp.

Raine, R.M. 1987. Winter food habits and foraging behavior of fishers (Martes pennanti) and martens (Martes americana) in southeastern Manitoba. Canadian Journal of Zoology. 65:745-747.

Rey, S. M. 1913. Some further notes on Sierran field work. Condor 15:198-203.

RHJV(Riparian Habitat Joint Venture). 2004. Version 2.0. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight.

Robinson, S.K., F.R. Thompson III., T.M. Donovan, D.R. Whitehead, and J. Faaborg. Regional forest fragmentation and nesting success of migratory birds. Science 267: 1987-1990.

Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinksi, tech eds. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the United States. Gen. Tech. Rep. RM-254. Ft. Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184pp.

Sanders, S., and M.A. Flett. 1989. Ecology of a Sierra Nevada Population of Willow Flycatchers (Empidonax traillii), 1986-87. State of California, The Resources Agency, Department of Fish and Game, Wildlife Management Division Non-game Bird and Mammal Section.

Serena, M. 1982. The status and distribution of the willow flycatcher (Empidonax traillii) in selected portions of the Sierra Nevada, 1982. California Department of Fish and Game, Wildlife Management Division Administrative Report NO. 82-5, 28pp.

Schumm, S. A. 1999. Causes and controls of channel incision. In: Darby, Stephen E. and A. Simon, eds. Incised river channels: processes, forms, engineering and management. John Wiley and Sons, New York. 442 p.

SH&G. 2004. Upper Truckee River, upper reach environmental assessment. Report prepared for the Lake Tahoe Resource Conservation District, South Lake Tahoe, CA.

Silveira, J.G., F.T. Griggs, D.W. Burkett, K.Y. Buer, D.S. Efseaff, G.H. Golet, S.L. Small, R. Vega, and J.E. Isola. (2003) An ecological approach to restoring riparian habitats at the Llano Seco Unit, Sacramento River National Wildlife Refuge. United States Fish and Wildlife Service, Sacramento, CA. August 5, 2003.

Simon, T.L. 1980. An ecological study of the pine marten in the Tahoe National Forest. Sacramento, CA: California State University. M.S. Thesis.

SMMC 2004. Creation of a regionally significant riparian habitat comlex on the alluvial floodplains of the 588-acre Soka University property. Santa Monica Mountains Conservancy, Dec. 2004.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. R-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR .

Spencer, W.D., Barrett, R.H., and Zielinski, W.J. 1983. Marten habitat preferences in the northern Sierra Nevada. Journal of Wildlife Management. 47:1181-1186.

Stafford, M.D., and B.E. Valentine. 1985. A preliminary report on the biology of the willow flycatcher in the central Sierra Nevada. California-Nevada Wildlife Transactions, 66-67.

Stebbins, R.C. 2003. A field guide to western reptiles and amphibians. Houghton Mifflin Company, Boston, Mass.

Tahoe Regional Planning Agency (TRPA/FS). 1971. Vegetation of the Lake Tahoe region: a guide for planning. TRPA, Stateline, NV.

USDA. United States Department of Agriculture. 1988. Land Resource and Management Plan. Lake Tahoe Basin Management Unit. South Lake Tahoe, CA.

-----1992. Biological Evaluation for Drought-related Timber Salvage on National Forests of the Sierra Nevada Province, Pacific Southwest Region for Threatened, Endangered, Sensitive, and Proposed Animals. August 17.

-----1999. Biological evaluation birds, mammals, amphibians, reptiles, fish, invertebrates, Donner Summit snow-park expansion project. Truckee District, Tahoe National Forest. June 30, 1999.

-----2000. Lake Tahoe Watershed Assessment. Forest Service, Pacific Southwest Region, May 2000.

-----2001. Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement, Record of Decision. Forest Service, Pacific Southwest Region, January 2001.

-----2004. Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement, Record of Decision. Forest Service, Pacific Southwest Region, January 2004.

Williams, G. P. 1978. Bank-full discharge of rivers. Water Resources Research, 14(6): 1141-1154.

Willner, G.R., G.A. Feldhamer, E.E. Zucker, and J.A. Chapman. 1980. *Ondatra zibethicus*. Mammalian Species. No. 141, pp 1-8.

Wilson, R. E. 1970. Succession in stands of *Populus deltoides* along the Missouri River in southeastern South Dakota. Am. Midl. Nat. 83:330-342.

Zeveloff, S.I. 1988. Mammals of the Intermountain West. University of Utah Press, Salt Lake City. 365 pp.

APPENDIX A: VEGETATION COMMUNITY CLASSIFICATION

Table 6. Vegetation community classification for this project, with equivalents in other classification systems.

This Report	Map Symbol	CALVEG	WHR	TRPA/FS, 1971 (best estimate)	TRPA Code
River	River	Water	Water	Open Water	Primary riparian
Pond	Pond				
Bar	B	Water	Water	Open Water	Primary riparian
Intermittent tributary	not yet mapped	Water	Water	Open Water	Primary riparian
Ephemeral tributary	not yet mapped	Water	Water	Open Water	Primary riparian
Jeffrey Pine	JP	Jeffrey Pine	Jeffrey Pine	Pine	Non-riparian
Lodgepole Pine – Dry	LPD	Lodgepole Pine	Lodgepole Pine	Pine	Non-riparian
Lodgepole Pine – Mesic	LPM	Lodgepole Pine	Lodgepole Pine	Lodgepole - Wet Type	Secondary riparian
Willow Scrub	W	Willow	Montane Riparian	Willow Thicket	Primary riparian
Obligate Sedge Wetland	OM	Wet Meadows	Freshwater Emergent Wetland	Swamps and Pools	Primary riparian
Wet Meadow	WM	Wet Meadows	Wet Meadow (maybe FEW)	Elements of Wet Marsh or Meadow, Sphagnum Bog, and Wet Mesic Meadow	Primary and secondary riparian
Mesic Meadow	MM	Perennial Grass/Forbs	Perennial Grass	Wet Mesic Meadow	Secondary riparian
Mesic Forb	MF	Wet Meadows	Wet Meadow	Wet Mesic Meadow	Secondary riparian
Dry Meadow	DM	Perennial Grass/Forbs	Perennial Grass	Mesic Herb	Non-riparian
Revegetation Dry Meadow	RDM	Perennial Grass/Forbs	Perennial Grass	Mesic Herb	Non-riparian

This Report	Map Symbol	CALVEG	WHR	TRPA/FS, 1971 (best estimate)	TRPA Code
Sagebrush Dry Meadow	SDM	Mountain Sagebrush	Sagebrush	Sagebrush	Non-riparian
Turf and other maintained vegetation, including some pavement and structures	D	Urban/Developed	Urban	No equivalent	Non-riparian, primary riparian, and secondary riparian (former and present)
Jeffrey Pine/Dry Meadow	JP/DM	Jeffrey Pine and Perennial Grass/Forbs	Jeffrey Pine and Perennial Grass	Pine and Mesic Herb	Non-riparian
Lodgepole Pine – Dry Type/Dry Meadow	LPD/DM	Lodgepole Pine and Perennial Grass/Forbs	Lodgepole Pine and Perennial Grass	Pine and Mesic Herb	Non-riparian
Lodgepole Pine – Mesic/Mesic Meadow	LPM/MM	Lodgepole Pine and Perennial Grass/Forbs	Lodgepole Pine and Wet Meadow	Lodgepole Pine - Wet Type and Wet Mesic Meadow	Secondary riparian
Willow/Obligate Sedge Wetland	W/OM	Willow and Wet Meadows	Montane Riparian and Freshwater Emergent Wetland	Willow Thicket and Swamps and Pools	Primary riparian
Willow/Wet Meadow	W/WM	Willow and Wet Meadows	Montane Riparian and Wet Meadow	Willow Thicket and Elements of Wet Marsh or Meadow, Sphagnum Bog, and Wet Mesic Meadow	Primary riparian, possibly small areas of secondary riparian
Willow/Mesic Meadow	W/MM	Willow and Perennial Grass/Forbs	Montane Riparian and Perennial Grass	Willow Thicket and Wet Mesic Meadow	Primary and secondary riparian
Willow/Mesic Forb	W/MF	Willow and Wet Meadows	Montane Riparian and Wet Meadow (possibly also some FEW)	Willow Thicket and Wet Mesic Meadow	Primary riparian
Spring complex	OM/MF/JP	Wet Meadows and Jeffrey Pine	Freshwater Emergent Wetland, Wet Meadow, and Jeffrey Pine	Swamps and Pools with elements of Sphagnum Bog and Wet Marsh or Meadow, and Pine	Primary riparian

This Report	Map Symbol	CALVEG	WHR	TRPA/FS, 1971 (best estimate)	TRPA Code
Spring complex	OM/MF/LP	Wet Meadows and Lodgepole Pine	Freshwater Emergent Wetland, Wet Meadow, and Lodgepole Pine	Swamps and Pools with elements of Sphagnum Bog and Wet Marsh or Meadow, and Lodgepole Pine – Wet Type	Primary riparian
Mesic Meadow/Wet Meadow	MM/WM	Perennial Grass/Forbs and Wet Meadows	Perennial Grass and Wet Meadow	Elements of Wet Marsh or Meadow, Sphagnum Bog, and Wet Mesic Meadow, Vernal Pool (Type 0), and Vernal Pool (Type 1a)	Primary and secondary riparian

APPENDIX B: FIGURES