



Tuolumne Wild and Scenic River Comprehensive Management Plan Draft Environmental Impact Statement

Tuolumne River Values and Baseline Conditions

After five years of study and stakeholder involvement, the Tuolumne Wild and Scenic River Comprehensive Management Plan and Draft Environmental Impact Statement (Tuolumne River Plan/DEIS) will be released in summer of 2011.

In advance of the plan's release, the NPS is providing the Tuolumne River Values and Baseline Conditions chapter as a preview into one of the plan's most foundational elements. Sharing the baseline information in advance of the plan will give members of the public an understanding of river conditions today and specific issues that will be explored in the Tuolumne River Plan. Public comments on all elements of the Tuolumne River Plan, including the baseline conditions chapter, will be accepted when it is released for review this summer.

What follows is a description of the unique values that make the Tuolumne stand apart from all other rivers in the nation. This chapter also provides a snapshot in time, documenting overall conditions and implications for future management. In particular the baseline chapter examines,

- What are the outstandingly remarkable values that make the Tuolumne River worthy of special protection under the Wild and Scenic Rivers Act (WSRA)?
- What do we know about the condition of these values (in addition to water quality and free-flow), both at time of designation in 1984 and today?
- Based on those conditions, what are the management concerns that signal the need for action(s) to protect and enhance those values?

When it is released this summer, the Tuolumne River Plan/DEIS will contain

- The management elements required by the WSRA, including boundaries, classifications, river values, free-flowing condition (Section 7) determination process
- THIS CHAPTER: A description of the river values, their baseline condition, and implications for future management action
- Management objectives for river values and a monitoring program
- An ecological restoration program and a suite of comprehensive management actions needed to protect and enhance the river
- A user capacity program that establishes numeric capacities that are protective of river values
- Alternatives that explore a range of use levels, types and levels of facilities, and types of visitor experiences that are protective of the river

Yosemite's interdisciplinary team for the Tuolumne River Plan has devoted the last two years to not only finalizing data collection on baseline conditions, but tracking and reaffirming that all of the proposed actions in the plan tie back to the protection of the river—and address the implications discussed in this baseline chapter. In total, the Tuolumne River Plan represents a comprehensive strategy that will inform park managers and establish work priorities in the river corridor for the next 20 years.

Tuolumne River Values and Baseline Conditions



Tuolumne Meadows and the Tuolumne River with Cathedral Peak and Fairview Dome. NPS photo by Randy Fong

Discussion

The Tuolumne River was added to the national wild and scenic rivers system based on three categories of values: (1) its free-flowing condition, (2) its water quality, and (3) its outstandingly remarkable values. Collectively, these are referred to as the river's values (or *river values*), with a subset being its *outstandingly remarkable values*. Accurately and adequately expressing a river's values and documenting their conditions provides a foundation for planning and management activities within a wild and scenic river corridor.

Section 10(a) of the Wild and Scenic Rivers Act directs that

Each component of the national wild and scenic rivers system shall be administered in such manner as to protect and enhance the values which caused it to be included in said system without, insofar as is consistent therewith, limiting other uses that do not substantially interfere with public use and enjoyment of these values. In such administration primary emphasis shall be given to protecting its aesthetic, scenic, historic, archaeologic, and scientific features. Management plans for any such component may establish varying degrees of intensity for its protection and development, based on the special attributes of the area.

In the Tuolumne River Plan, protection and enhancement of river values will be achieved by (1) establishing the baseline conditions of river values, (2) defining management objectives for each value that will result in its protection and enhancement, (3) establishing measurable indicators and standards to ensure that the objectives are met and maintained over time, and (4) identifying and implementing the management actions needed to achieve the objectives.

In determining the management actions needed to protect and enhance river values, knowledge of baseline conditions is a critical first step. This section of the Tuolumne River Plan describes the values of the river corridor, discusses the current conditions of those values, and identifies the management concerns associated with the current conditions. Actions to address these management concerns are presented in chapters 7 through 9. Actions that would be common to all alternatives are described in detail in chapters 7 and 8 (chapter 7 focuses on management of resources, while chapter 8 focuses on management of visitor use). If a range of solutions is being considered, these actions are presented for comparison in chapter 9, “Alternatives.”

Outstandingly remarkable values were first considered for the Tuolumne River as part of the development of the 1979 Tuolumne Final Study, which established the eligibility of the Tuolumne River for inclusion in the national wild and scenic rivers system. Since the completion of that study, the Interagency Wild and Scenic Rivers Coordinating Council has issued specific guidance and criteria for identifying outstandingly remarkable values in the Interagency Reference Guide (IWSRCC 1999). The ORV criteria developed by the Interagency Council can be summarized as follows:

- The value must be river related or river dependent. To be considered river related or river dependent, a value must
 - ✓ Be located in the river or on its immediate shorelands (generally within ¼ mile on either side of the river) *and*
 - ✓ Contribute substantially to the functioning of the river ecosystem *or*
 - ✓ Owe its location or existence to the presence of the river
- The value must be rare, unique, or exemplary in a regional or national context. To be considered rare, unique, or exemplary, a value should be a conspicuous example from among a number of similar values that are themselves uncommon or extraordinary.

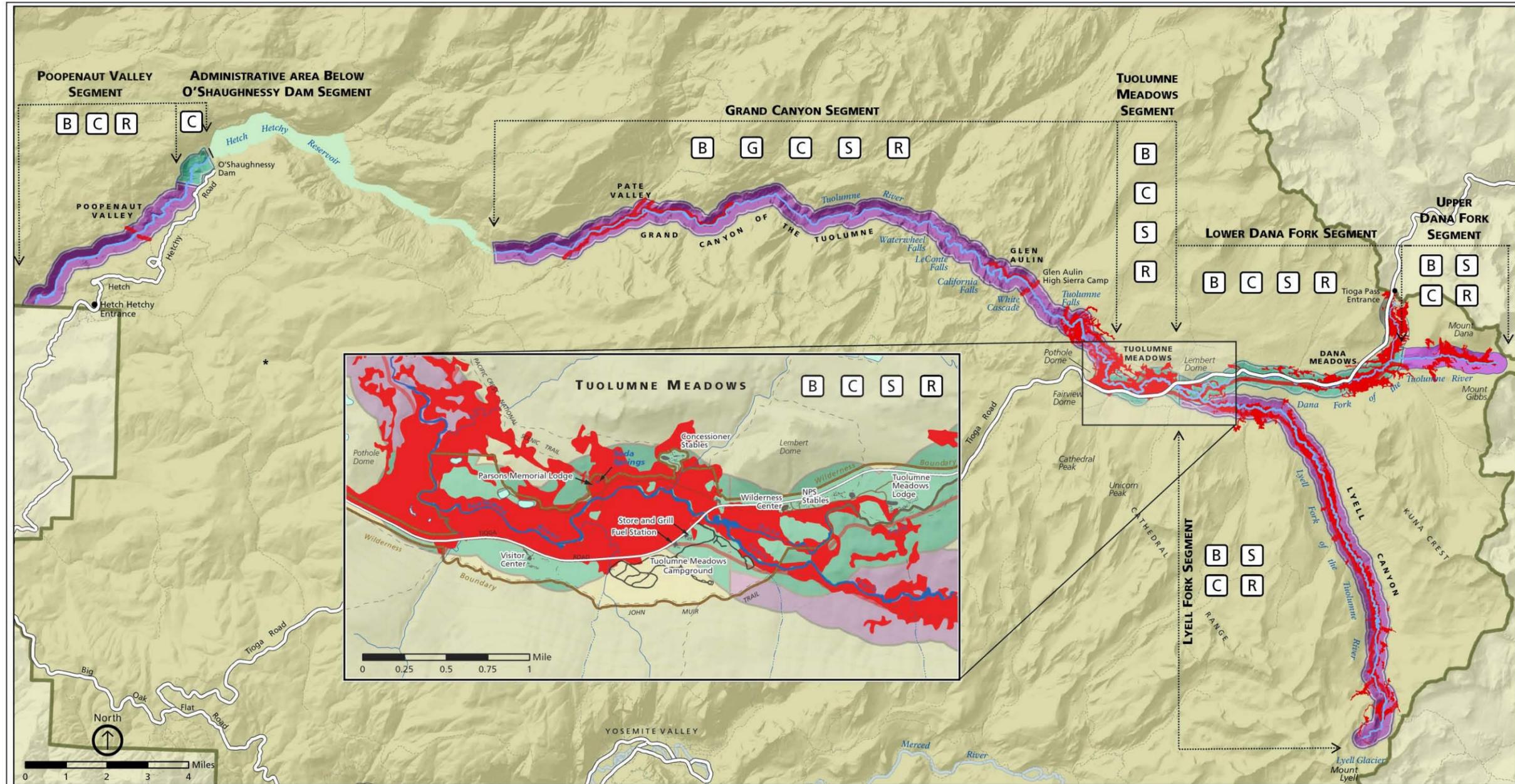
The Interagency Council provides additional criteria for assessment for each ORV category listed in the Wild and Scenic Rivers Act, noting that these criteria may be modified to make them more meaningful to a particular river. The Interagency Council also notes that while no specific national evaluation guidelines have been developed for the “other similar values” mentioned in the Wild and Scenic Rivers Act, agencies may assess additional river-related values, including but not limited to hydrology, paleontology, and botany resources, consistent with the guidance provided (IWSRCC 1999).

With input from other agencies, tribes, and members of the public, park staff used the best available science along with professional judgment to articulate river-related values, with the Sierra Nevada forming the primary region of comparison. Using these criteria, ten outstandingly remarkable values have been identified for the Tuolumne Wild and Scenic River. (A discussion of how the descriptions of these values have evolved over the course of the planning process is documented in appendix F.)

Outstandingly Remarkable Values of the Tuolumne River

Outstandingly Remarkable Values of the Tuolumne River

- BIOLOGICAL** Tuolumne Meadows, Dana Meadows, and the meadows along the Lyell Fork comprise one of the most extensive subalpine riparian and meadow complexes in the Sierra Nevada.
- Rare low-elevation riparian and wetland habitat at Poopenaut Valley supports an exceptionally diverse assemblage of bird species.
- Rare mineral spring habitat supports special status plant species at Tuolumne Meadows (Soda Springs), Lyell Canyon, and Pate Valley.
- GEOLOGIC** A series of basins interspersed with steep drop-offs, where the river plunges into spectacular cascades and waterfalls between Tuolumne Meadows and Pate Valley, provides a textbook example of stairstep river morphology.
- CULTURAL** The Tuolumne River and its associated ancient trail system provide a geographic connection between the archeological landscape of the prehistoric past and places important to the ancestral heritage and ongoing cultural traditions of contemporary American Indian tribes and groups.
- Parsons Memorial Lodge, a national historic landmark with expansive views of the Tuolumne River, Tuolumne Meadows, and soaring peaks and domes, attests to and commemorates the significance of the river in inspiring conservation activism and protection of the natural world on a national scale.
- SCENIC** The dramatic scenery through Lyell Canyon offers remarkable and varied views of lush meadows, a meandering river, a U-shaped glacially carved canyon, and distant glimpses of the Lyell Glacier.
- The scenery through Dana and Tuolumne Meadows offers exemplary views encompassing the meandering river, adjacent meadows backed by glacially carved domes, rugged mountain peaks of the Sierra Crest, and expansive skies.
- The scenery through the Grand Canyon of the Tuolumne offers views of a rugged and rocky canyon encompassing vast escarpments of granite, hanging valleys, and dramatic cascades of falling water.
- RECREATIONAL** The Tuolumne River provides for a variety of wilderness-oriented recreational activities in an iconic High Sierra landscape where dramatic scenery, the sounds of nature, and opportunities for relative solitude shape the experience.



Wild and Scenic River Classifications

- Wild river area:** Per the Wild and Scenic River's Act, the sections of the river that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.
- Scenic river area:** Per the Wild and Scenic River's Act, the sections of the river that are free of impoundments, with shorelines or watersheds still largely primitive.

Outstandingly Remarkable Values of the Tuolumne River

Outstandingly Remarkable Values

- Location of a river-related biological, geologic, cultural, scenic, or recreational value that makes the Tuolumne River rare, unique, or exemplary in a regional or national context.
- B Biological Value C Cultural Value* S Scenic Value
- G Geologic Value R Recreational Value

* Locations of archeological sites are not shown.

Biological Values

Tuolumne Meadows, Dana Meadows, and the meadows along the Lyell Fork comprise one of the most extensive subalpine riparian and meadow complexes in the Sierra Nevada.

The unusual extent and influence of glaciations in the Tuolumne River corridor has resulted in extensive low-relief areas—forming meadows—separated by steep sections of river flowing over bedrock. The unusually long low-gradient reaches along much of the Lyell Fork, the lower Dana Fork, and below the confluence through Tuolumne Meadows are conducive to the accumulation of sand, silts, and organic debris. They are also conducive to seasonal flooding and active channel migration, which sustain high groundwater conditions in these areas. The organic carbon-rich soils that developed under these conditions are highly productive, and result in meadow and riparian habitats for a great diversity of species. Because of the scale of the river topography, this meadow/riparian complex is one of the most extensive in the Sierra Nevada and is the largest in Yosemite National Park.



The Tuolumne River winds through Tuolumne Meadows. NPS photo by Greg Lawler

Rare low-elevation riparian and wetland habitat at Poopenaut Valley supports an exceptionally diverse assemblage of bird species.

Poopenaut Valley is one of the few undeveloped and largely undisturbed low-elevation riparian/meadow/wetland complexes in the region. A mix of wetland, upland, riparian, and forested plant communities provides habitat for a great variety of river-dependent species, including an exceptionally diverse assemblage of bird species and several special status bat species. Results from bird surveys indicate that Poopenaut Valley provides important breeding areas for a diverse group of birds representing a variety of breeding niches and differing seasonal strategies (resident species and short-distance and long-distance migrants), as well as species that are indicators of riparian health (NPS, Stock et al. 2007).

Aquatic/riparian systems are the most altered and impaired habitats of the Sierra Nevada (UC Davis 1996), and loss of these habitats may be the most important cause of population decline among land bird species in western North America (DeSante and George 1994). This gives special significance to the extensive riparian and wet meadow habitats at Poopenaut Valley, which are some of the most productive in the park.



Wetlands in Poopenaut Valley. NPS photo by Kristina Rylands



Soda Springs at Tuolumne Meadows. NPS photo by Kristina Rylands

Rare mineral spring habitat supports special status plant species at Tuolumne Meadows (Soda Springs), Lyell Canyon, and Pate Valley.

Alkaline springs are unusual in the high Sierra Nevada. Soda Springs, a natural alkaline spring, supports localized populations of special status plant species, such as Buxbaum's sedge and marsh arrowgrass (NPS, Buhler et al. 2010; NPS, Acree et al. 2007a). An iron spring in Pate Valley supports a population of

scratchgrass (Snyder 2005; NPS, Acree et al. 2007a). A number of soda springs are found along the Lyell Fork; some of these are dry, with some mineralization, while others are quite damp and gurgling (Davis-King and Snyder 2010). Populations of scratchgrass, marsh arrowgrass, seaside arrowgrass, and Sucksdorf's dodder have been found near these springs in Lyell Canyon.

Geologic Value

A series of basins interspersed with steep drop-offs, where the river plunges into spectacular cascades and waterfalls between Tuolumne Meadows and Pate Valley, provides a textbook example of stairstep river morphology.



Stairstep river morphology along the trail to Glen Aulin. NPS photo by Randy Fong

The Tuolumne River corridor represents one of the finest examples of stairstep river morphology in the Sierra Nevada. This glacially carved morphology extends over an unusually long gradient. A series of broad basins interspersed with steep drop-offs help define the river's overall character. Between Tuolumne Meadows and Pate Valley the river plunges into spectacular cascades and waterfalls, including Tuolumne Fall, White Cascade, California, LeConte, and Waterwheel Falls.

Cultural Values

The Tuolumne River and its associated ancient trail system provide a geographic connection between the archeological landscape of the prehistoric past and places important to the ancestral heritage and ongoing cultural traditions of contemporary American Indian tribes and groups. This landscape, linked through time and space, holds outstandingly remarkable scientific, interpretive, and cultural value for traditionally associated peoples and the public.

The nearly continuous archeological landscape along the Tuolumne River contains dense concentrations of resources reflecting thousands of years of travel, settlement, and trade. Some of these sites individually hold exceptional data potential, and the landscape itself provides exemplary documentation of the cultural land use pattern stretching from the lowest levels along the river to the uppermost reaches of the watershed at trans-Sierra passes. Dana and Tuolumne Meadows have the potential to provide information about how and why prehistoric people occupied these riparian/meadow areas and the relationships between ecological and cultural change over millennia. The record of cultural continuity at specific locations is longest along the Dana Fork, where it extends back at least 6,000 years (NPS 2007a and 2007g).



Obsidian flake. NPS photo by Kristina Rylands

In addition to this regionally significant scientific and interpretive value, the sites have value to American Indian tribes and groups as a connection to their ancestors. Places important to the cultural traditions of American Indian tribes and groups—including sources of water, food, and medicinal plants, healing waters, and geologic or geographic formations having spiritual and cultural significance—exist along the length of the Tuolumne River. For American Indian tribes and groups on both sides of the Sierra, the river in its entirety has exceptional value as a “silver thread” connecting places of spiritual, historical, medicinal, and cultural importance. An ancient trail system connects important locations along the river and features prominently in continued traditional cultural practices of American Indian people (Davis-King and Snyder 2010).



Parsons Memorial Lodge. NPS photo

Parsons Memorial Lodge, a national historic landmark with expansive views of the Tuolumne River, Tuolumne Meadows, and surrounding peaks and domes, attests to and commemorates the significance of the river in inspiring conservation activism and protection of the natural world on a national scale.

Beginning at the end of the 19th century, the Sierra Club played a major role in garnering appreciation and support for the

preservation of wild rivers and natural areas for the benefit of all Americans. The Soda Springs area was a historic center of activity for these efforts. Following John Muir's early meetings in the Soda Springs area with people influential in the conservation movement, the Sierra Club purchased the Soda Springs property in 1912 and subsequently built Parsons Memorial Lodge in 1915, just above the banks of the Tuolumne River. The lodge served as a mountain headquarters, reading room, and gathering place where ideas were exchanged and acted upon, including the establishment of national parks and the protection of rivers. Parsons Memorial Lodge continues to fulfill its historic role as a forum, a meeting place where people learn, share ideas, and champion a greater understanding and appreciation of rivers and other wild places (NPS 1975, NPS 1985g, NPS 1987, NPS 2007i).

Scenic Values

The dramatic scenery through Lyell Canyon offers remarkable and varied views of lush meadows, a meandering river, a U-shaped glacially carved canyon, and distant glimpses of the Lyell Glacier.

The scenery throughout Lyell Canyon unfolds and becomes more spectacular around every bend in the trail. Views of the meandering, glass-like river as it winds through thick meadows create a vivid foreground to the rocky outcrops of the Kuna Crest (including the Kuna Creek falls) to the east and Amelia Earhart Peak to the west. Spectacular views of a U-shaped river valley include mountain peaks, ridgelines, and the largest glacier on the western flank of the Sierra Nevada. Specific views from the bed and banks of the Lyell Fork include Mount Lyell, Lyell Glacier, Lyell Canyon, Kuna Crest, the cascades at Kuna Creek, and the meandering Lyell Fork through extensive alpine and subalpine meadows. Ephemeral wildflower displays enhance these impressive views.



Sweeping views of Lyell Canyon and a distant Mount Lyell. NPS photo by Kristina Rylands

The scenery through Dana and Tuolumne Meadows offers exemplary views encompassing the meandering river, adjacent meadows backed by glacially carved domes, rugged mountain peaks of the Sierra Crest, and expansive skies.

Tuolumne Meadows offers breathtaking views of the large, low-lying river valley, adjacent meadows, glacially carved domes, rugged mountain peaks, and expansive skies. Specific views from the bed and banks of the river include Lember, Pothole, and Fairview Domes, the Kuna Crest, Mount Dana, Mount Gibbs, Cathedral and Unicorn Peaks, Juniper Ridge, and the river meandering through subalpine meadows. Exceptional views can be seen from the linear view corridors along Tioga Road and trails following the Great Sierra Wagon Road, from vista points at Pothole and Lember Domes, and from Parsons Memorial Lodge.

Dramatic views from the Dana Fork encompass glacially carved mountains and ridgelines, alpine and subalpine meadows, and expansive skies. Specific views from the bed and banks of the Dana Fork include the Kuna Crest, Mount Dana, Mount Gibbs, and the meandering Dana Fork through Dana Meadows.

In both Tuolumne and Dana Meadows, the low-relief topography of the meadows allows for impressive views of the sky, often contrasted by dramatic weather, along with ephemeral wildflower displays throughout the summer.



The scenic interface of meadow, river, forest, and granite peaks in Tuolumne Meadows. NPS photo by Randy Fong



Waterwheel Falls. NPS photo by Randy Fong

The scenery through the Grand Canyon of the Tuolumne offers views of a rugged and rocky canyon encompassing vast escarpments of granite, hanging valleys, and dramatic cascades of falling water.

Spectacular views from the trail leading from Tuolumne Meadows to Glen Aulin and through the Grand Canyon of the Tuolumne allow rare opportunities to view some of the wildest segments of the river along its dramatic canyon descent. Views include steep canyon walls, the untrailed Muir Gorge, hanging valleys, and cascades of falling water. Visitors

who travel the canyon are rewarded with dramatic views of rare water features, including Tuolumne, LeConte, California, and Waterwheel Falls and White Cascades.

Recreational Value

The Tuolumne River provides for a variety of wilderness-oriented recreational activities in an iconic High Sierra landscape where dramatic scenery, the sounds of nature, and opportunities for relative solitude shape the experience.

The Tuolumne River provides outstanding opportunities for visitors to engage in a variety of river-related recreational activities in a wilderness setting characterized by dramatic natural scenery. Remote areas of the river, from its headwaters through Dana Meadows and Lyell Canyon, down through the Grand Canyon of the Tuolumne, provide visitors with wilderness experiences where solitude and an intimacy with the river and its natural sights and sounds shape the experience. Primary activities in these segments include hiking and backpacking.



Family camping in Tuolumne Meadows, circa 1925. From the collection of Kristina Rylands

At the doorstep to wilderness in Tuolumne Meadows, the meandering river surrounded by granite domes and distant snow-capped peaks provides an inspiring backdrop for visitors to easily access and connect with the Tuolumne, engaging in recreational activities such as viewing scenery, hiking, swimming, fishing, picnicking, camping, and educational or interpretive programs. Newcomers as well as people with strong traditional ties are drawn to the Tuolumne for its exceptional high-elevation, wilderness-oriented recreational and educational opportunities.



White Cascade at Glen Aulin. NPS photo by Kristina Rylands

Baseline Conditions

What follows is an examination of conditions that will serve as a foundation for determining recommended management actions to protect and enhance Tuolumne River values. The assessment considers (1) conditions known to exist when the Tuolumne River corridor was designated wild and scenic in 1984, (2) conditions known today, and (3) concerns for future management, which will direct the actions outlined in this Tuolumne River Plan to protect and enhance river values.

The overarching goal articulated in section 10(a) of the Wild and Scenic Rivers Act is to protect existing high-quality conditions and to improve (or enhance) those conditions that are not meeting management objectives. The 1982 Interagency Guidelines for Wild and Scenic Rivers interpret section 10(a) of the Wild and Scenic Rivers Act as “a nondegradation and enhancement policy for all designated river areas, regardless of classification. . . . Specific management strategies will vary according to classification but will always be designed to protect and enhance the values of the river.”

The Tuolumne River Plan complies with section 10(a) by

- documenting the baseline condition of river values (which is the topic of this chapter of the Tuolumne River Plan)
- developing management objectives for high-quality conditions and a monitoring program, including measurable standards, to ensure that those objectives are met (which is the topic of chapter 6)
- identifying management actions needed to keep river values within high-quality standards (which is the topic of chapters 7 through 9)

As described below, river values throughout the corridor are generally in the same or better condition than what existed at the time of designation in 1984. A number of management actions have been taken since then to improve the condition of water quality and habitat quality in areas impacted by visitor use, particularly at Tuolumne Meadows. However, some conditions still do not meet the management objectives developed as part of this Tuolumne River Plan, and some localized impacts and potential risks to high-quality conditions are still present in the corridor.

Localized impacts and potential risks are not synonymous with degradation within the context of the Wild and Scenic Rivers Act and do not necessarily require remediation *if* high-quality conditions can be maintained. An example is the presence of fuel tanks, which poses a potential risk to water quality, but which does not affect the current excellent condition of water quality in the corridor. These localized impacts and potential risks may be addressed differently among the alternatives in chapter 9.

Degradation in the context of a wild and scenic river is a documented downward trend in condition, and such a downward trend always requires remediation under the Wild and Scenic Rivers Act. The only known example of such a downward trend within the river corridor is the declining condition of the subalpine meadow and riparian system in the Tuolumne Meadows area, which is described below. Major management actions to address this trend are common to all the Tuolumne River Plan alternatives and are presented in detail in chapter 7 and summarized in chapter 9.

The “Management Concerns” presented below in this chapter provide the basis for the management actions presented in chapters 7 through 9. Actions that would be common to all the planning alternatives are described in chapters 7 and 8; site-specific actions that would vary by alternative are presented by alternative in chapter 9.

Free-Flowing Condition

Condition at the Time of Designation

Above the Hetch Hetchy Reservoir, the designated river segments were largely free of structures that would impede flow or otherwise alter the free-flowing condition of the river. Seasonal flow variations included high-velocity, high-volume flows from snowmelt and runoff during spring and early summer. However, the natural flow regime below O'Shaughnessy Dam was altered by the dam.

Between late May and late October, water was taken from the Dana Fork by way of a low cement diversion to support seasonal visitor and operational uses in Tuolumne Meadows. The quantity of water withdrawn at that time is not known. Water was also taken from the river at the Glen Aulin High Sierra Camp through an intake hose placed in the river. Water withdrawals are described in greater detail under "Current Condition."

One vehicle bridge crossed the river at Tuolumne Meadows, and approximately seven footbridges crossed at various locations. The vehicle bridge and the footbridge near Parsons Memorial Lodge both contained abutments that might cause the river channel to back up during periods of high flows and to cause accelerated flows downstream.

Current Condition

Measured discharges typically vary between 110 million and 25.3 million gallons per day on the Lyell Fork and between 57 million and 9.7 million gallons per day on the Dana Fork, with greater volumes occurring in early summer when snow melt is high. Early in the snow-melt season, the Lyell and Dana Forks contribute about 60 percent and 40 percent of the flow beneath the Tioga Road bridge in Tuolumne Meadows, respectively, proportions comparable to their relative drainage areas. As the melt season continues in mid-summer and snow cover decreases, the Lyell Fork contributes a greater fraction (66-75%) of the total flow into Tuolumne Meadows (Lundquist et al. 2005).

Data recording Tuolumne River discharges into Hetch Hetchy Reservoir from the fall of 1982 to 2002 show that there is considerable variability from one year to the next. During the 1982-2002 period, the greatest water year annual discharge into Hetch Hetchy was about 539 billion gallons in 1983, while the least was about 108 billion gallons in 1987. The periods from 1983-86 and 1995-98 were relatively wet (averaging 354 billion and 379 billion gallons), while the periods of 1987-94 and 2000-02 were relatively dry (averaging 160 and 187 billion gallons), indicating that wet and dry conditions can occur over multi-year spells (Lundquist et al. 2005).

Several attempts in the mid-1990s to develop a groundwater source as a viable water supply for the Tuolumne Meadows area were not successful (HRS Consultants 1994). Water continues to be taken from the Tuolumne River to support seasonal visitor and operational uses in Tuolumne Meadows. The Dana Fork water intake extends across a portion of the river. During high flows, water moves around and over the cement structure. However, during periods of



Dana Fork water intake. NPS photo by Kristina Rylands

lower flows in the fall, the structure impounds a portion of the river. Because the structure is on a steep and rocky section of the river, it does not affect riparian integrity.

Water withdrawals from the Dana Fork from late May to late October are estimated to average about 60,000 gallons per day. As is typical in most surface water diversions in the Sierra Nevada, maximum withdrawal coincides with annual minimum flows. In this case, 60,000 gallons per day approaches 10% of flow at 1 cubic foot per second (Waddle and Holmquist 2011). Waddle and Holmquist found that flows of less than 1 cubic foot per second occur on 9 or more days in at least 25% of years and that flows of less than 3 cubic feet per second occur on 47 or more days in at least 25% of years. When flows are less than 3 cubic feet per second, wetted habitat losses are substantial, decreasing invertebrate production during these periods. However, because the amount of water withdrawn for use at Tuolumne Meadows amounts to less than 10% of lowest flow rates, the decreases in wetted habitat that naturally occur during low-flow periods are considered to be only minimally affected by these withdrawals.

Leaking underground pipes that are part of the aging water delivery system in Tuolumne Meadows are suspected of losing a currently unknown amount of the water withdrawn from the river before it can be consumed. This will be assessed as part of future utilities improvement work and water-conservation planning.

At Glen Aulin, water consumption from the main stem of the river has been limited to 600 gallons per day to address concerns about leachfield capacity (see “Water Quality,” below). Since designation, the water intake hose at Glen Aulin has been moved to a deeper collection pool, which is outside the boundary of the potential wilderness addition and inside designated wilderness.

The bridges that existed in 1984 remain. They include the Tioga Road bridge at Tuolumne Meadows, a single-vehicle bridge below O’Shaughnessy Dam, and seven footbridges: one crossing the upper Lyell Fork near the middle base camp, Twin Bridges near Tuolumne Meadows, a Dana Fork bridge, a footbridge at Parsons Memorial Lodge, another “twin bridges” above Glen Aulin, a footbridge at Glen Aulin, and a bridge in Pate Valley. Three tributary bridges are proximate to the river corridor on Rafferty Creek just outside of Tuolumne Meadows, and along Conness and Return Creeks in the Grand Canyon reach. The vehicle bridge along the Tioga Road in Tuolumne Meadows and the historic footbridge at Parsons Memorial Lodge both contain abutments that may cause the river channel to back up during periods of high flows (NPS, Noon and Martin 2010h), as described in greater detail below.

Large floodplains along portions of the Lyell Fork, the Tuolumne Meadows area, and in the Poopenaut Valley area have helped create extensive wetland/meadow complexes in these areas. In other portions of the Tuolumne River corridor, in particular in the Grand Canyon of the Tuolumne and below Poopenaut Valley to the western park boundary, river gradients are steep. In these and similar areas, floodplains are quite narrow (and in some places virtually nonexistent due to steep canyon walls) and typically confined to narrow strips on each side of the river that support pockets or small areas of riparian habitat.

In 2006 the National Park Service conducted a study to determine the 100-year floodplain and the ordinary high water mark in developed areas at Tuolumne Meadows and at the Glen Aulin High Sierra Camp. A 100-year flood is defined as one which has a 1 percent probability of occurrence in any given year. Facilities within the 100-year floodplain include parts of the Tuolumne Meadows campground,

the Tuolumne Meadows store/grill and associated employee cabins, employee cabins at the Tuolumne Meadows Lodge, portions of Tioga Road including the Tioga Road bridge, and the entirety of the Glen Aulin High Sierra Camp. A small portion of the road between Lemberg Dome and Parsons Memorial Lodge is also in the floodplain (see figure 5-1).

Existing development below the ordinary high water line in the river corridor includes the Tioga Road bridge and several trail bridges. Other development within 50-100 feet of the ordinary high water line include the Tuolumne Meadows Lodge and employee cabins, most of the Glen Aulin High Sierra Camp, several A-loop campsites and the access road into the Tuolumne Meadows campground, and a short segment of the Tioga Road near the existing wastewater treatment plant (NPS, Roche et al. 2006a).

After the 1997 flood, a short section of boulder riprap was placed along the Lyell Fork to harden the riverbank and protect the campground A-loop access road (NPS, Buhler et al. 2010a).

Recent research has documented that erosion in excess of natural rates, with the potential for channel widening, is occurring on the outside meanders of the river at Tuolumne Meadows. This condition is believed to be associated with historic grazing and a lack of willows and other woody vegetation on the riverbank and point bars (Cooper et al. 2006). This and other management concerns are described in greater detail below.



Seasonal high water in the Tuolumne River, Tuolumne Meadows. NPS photo by Kristina Rylands

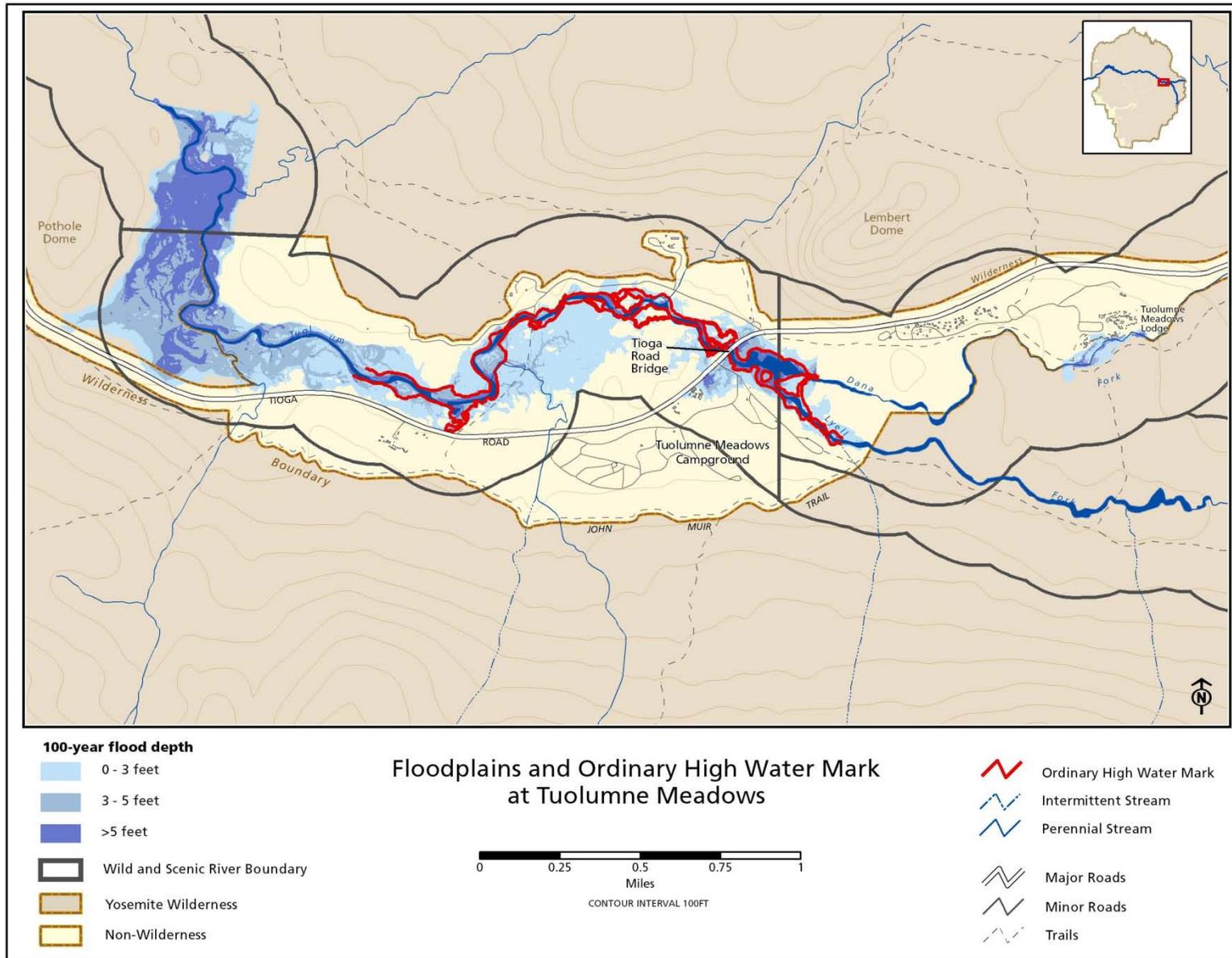


Figure 5-1. Floodplain and Ordinary High Water Mark at Tuolumne Meadows

Management Concerns

Based on a preliminary condition assessment (Pritchard et al. 1998) of the Tuolumne River in Tuolumne Meadows, a team of hydrologists and river managers determined that several reaches of the Tuolumne River appear to be 'functioning at risk' with an undetermined trend. Cooper and others (2006) found that the banks of the Tuolumne River are eroding on outside meanders without concomitant riparian vegetation (primarily willow) recruitment on the complementary point bar, likely resulting in channel widening. As part of the assessment of historical and contemporary influences on vegetation, Cooper and others found that the decrease in willows may be associated with extensive sheep grazing during the late 1800s, exacerbated by heavy browsing of the few remaining willows by deer. Probably the result of multiple factors, the riverbanks on the Tuolumne River (particularly on the west end of Tuolumne Meadow) have little to no vegetation, particularly willows, and are characterized by extensive erosion and riverbank loss (NPS, Buhler et al. 2010a.) Vegetation loss and the subsequent riverbank erosion may be exacerbated by visitor trampling (NPS, Buhler et al. 2010a). Certain reaches of the Tuolumne River that experience high levels of visitor use are devoid of riverbank vegetation.



An example of channel widening on an outer river bend in Tuolumne Meadows. NPS Photo

Channel widening produces a shallower channel with a lower river stage for any given flow volume and a concurrent drop of the water table associated with the river (Cooper et al. 2006, Loheide and Booth 2010). Because wet meadows form where a shallow water table during the summer fulfills the water requirements of this groundwater-dependent ecosystem (Loheide et al. 2009), a drop in the water table could adversely affect wet meadow vegetation. A wider, shallower channel also influences the magnitude and frequency of overbank flow and associated sheet flow processes (NPS, Buhler et al. 2010a). These concerns are addressed in greater detail as they relate to the meadow/riparian complex, below.

Ongoing periods of drought and the effect on water availability is one of several determining factors limiting overall use and development in Tuolumne Meadows. A recently completed study (Waddle and Holmquist 2011) examined microinvertebrate response to changes in stream flows along the Dana Fork. Microinvertebrates were selected for study because they are a sensitive indicator of riparian health. The study concludes that withdrawals at or less than current levels and of similar duration are likely to have a minimal impact on downstream habitat. However, the study notes that in light of climate change, which may lead to longer low-flow duration occurring earlier in the summer, continuous river flow monitoring is warranted to determine whether reevaluation of withdrawal levels might become necessary in the future.

The vehicle bridge along the Tioga Road in Tuolumne Meadows and the historic footbridge at Parsons Memorial Lodge both contain abutments that may cause the river channel to back up during periods of high flows. The Tioga Road bridge has a 400-foot length of approach that is essentially a levee of fill bisecting the wetland floodplain into two separate areas. The transfer of waters downstream across the right bank floodplain is essentially eliminated, forcing overbank flows back through the constricted

bridge opening and increasing the hydraulic pressure on the bridge (NPS, Noon and Martin 2010h). This condition could eventually erode the riverbanks and compromise the structural integrity of the bridge.

The short section of riprap placed to protect the A-loop campground road interferes with the free flow of the river within this section. Riprap can be effective in protecting infrastructure from further flood exposure, but it decreases the free flow of the river, compromises channel morphology, and alters scour and deposition dynamics associated with natural riparian processes (NPS, Buhler et al. 2010a).



Riprap near Tuolumne Meadows campground. Photo by Adam Hamburg

The natural flow regime below O’Shaughnessy Dam is altered by the dam. The National Park Service, in collaboration with the San Francisco Public Utilities Commission, the Stanislaus National Forest, and the U.S. Fish and Wildlife Service, is conducting research below the dam to inform the timing, duration, and magnitude of flows that will reduce the effects of dam operations on downstream habitats. This is discussed in greater detail under “Low-Elevation Riparian and Wetland Habitat at Poopenaut Valley,” below.

Water Quality

Conditions at the Time of Designation

At the time of designation water quality in the river corridor was characterized as generally high-quality water, low in dissolved nutrients, with low conductance, adequate dissolved oxygen, and pH in the range expected for granitic watersheds. A portion of the river at Tuolumne Meadows had high coliform and biological oxygen demand (BOD) levels associated with large numbers of recreation users and the proximity of a wastewater treatment plant to the river (USFS and NPS 1979).

Previous impacts to water quality at Glen Aulin had been addressed in 1983 by replacing the septic tank and leachfield at the High Sierra camp and by installing a composting toilet facility at the backpacker camp. Manure at the stock corral, which was relatively close to the river, likely affected water quality.

Current Conditions

Water quality is exceptionally high. Levels of coliform and BOD, which had been high in 1984 at Tuolumne Meadows, are now within established NPS standards throughout the corridor and well below state water quality standards (NPS 2007b; NPS 2009b; SFPUC 2009). During the late spring and summer months, water quality is monitored for nutrients (total dissolved nitrogen, nitrate + nitrite, total phosphorous and total dissolved phosphorous), *E. coli*, and total petroleum hydrocarbons. Associated field data collected with each water quality sample includes water temperature, specific conductivity, dissolved oxygen, and pH. Results from 2006, 2007, 2008, and 2009 indicate that no samples exceeded water quality standards established by the National Park Service (NPS 2006e and 2008a). Data from several of these years was used to establish park-specific standards, and all these standards require water quality far superior to existing state and EPA standards.

In 2009 water sampling occurred during the summer at five locations on the Tuolumne River. In addition two storm events were sampled, and bimonthly winter samples were obtained from two sites in Tuolumne Meadows (Lyell Fork above Twin Bridges and Tuolumne River above Budd Creek). At all other wilderness locations, winter samples were not obtained due to access constraints. Nutrients (total dissolved nitrogen, nitrate, total phosphorous and total dissolved phosphorous) were sampled at all sites. *E. coli* was sampled only at frontcountry sites due to the maximum six-hour hold time for these samples. The river was also sampled for total petroleum hydrocarbons at four locations downstream of developed areas. In addition to collecting samples, field staff measured water temperature, specific conductivity, pH, and dissolved oxygen, as well as river stage where possible (NPS 2009c).

Based on 2009 monitoring results, water quality in the Tuolumne River corridor remains excellent and well within state water quality standards. That is, nutrient and *E. coli* concentrations are not significantly (at the 95% confidence level) different from conditions in 2005-2008, when the baseline data were collected (NPS 2009c). Water quality remains low in dissolved nutrients, with low conductance, adequate dissolved oxygen, and pH in the range expected for granitic watersheds.

Because water quality in the Hetch Hetchy Reservoir is critical to the water supply for the City of San Francisco, the 1913 Raker Act grants the city provisions to protect the Hetch Hetchy watershed, including requirements for the treatment or disposal of sewage and garbage, restrictions on bathing, the washing of clothes or cooking utensils, and watering stock or any other activity that in any way could pollute the watershed (SFPUC 2008). Water quality data collected by the National Park Service and the San Francisco Public Utilities Commission in 2006-09 show that the water quality of the Hetch Hetchy water supply remains exceptional.

Numerous actions have been taken over the past two decades to reduce risks to water quality. In the Tuolumne Meadows area these actions have included relining the wastewater treatment ponds, removing underground tanks at the public fuel station, repairing and installing new sewer lines, and removing manure from stables and trails. At Glen Aulin actions have included enforcing water use restrictions, moving the corral farther from the river, and removing manure. In 1993 a backpacker campground (35 people) was created to relocate campers and the potential effects to water quality (such as soil erosion and human waste) away from Conness Creek. Regulations protective of water quality and other river values are enforced by rangers hired specifically for that purpose.

The “little blue slide” is a road cut along the Tioga Road just east of Tuolumne Meadows that is immediately adjacent to the Dana Fork of the Tuolumne Wild and Scenic River. Continuous sloughing of silt and boulder-sized material from the cut affects water turbidity, as described in greater detail under “Management Concerns,” below.



Fine soils along a portion of Tioga Road, which can contribute to river turbidity during storm events. NPS Photo by Kristina Rylands

Management Concerns

Although water quality remains exceptional, some potential localized risks to water quality remain in the corridor. According to the 2009 survey of conditions related to the Hetch Hetchy water supply, conducted by the San Francisco Public Utilities Commission (SFPUC 2009), the potential for water quality concerns exists, given certain circumstances, at the Tuolumne Meadows wastewater treatment plant facilities and sprayfield, the sewage system at Glen Aulin, the NPS and concessioner stables, and the road cut near the Dana Fork. Each of these concerns is discussed below.

While the National Park Service operates in compliance with Central Valley Regional Water Quality Control Board permits, the water and wastewater treatment facilities at Tuolumne Meadows must be updated to meet current standards. A potential for displacement of wastewater from the treatment ponds in Tuolumne Meadows poses a risk to water quality, as does the potential for saturation of the sprayfield (SFPUC 2009). Past impacts associated with leakage from the wastewater line that runs beneath the river and meadow from the wastewater treatment plant to the wastewater ponds have been corrected and mitigated by the installation of a new line. However, the potential for future impacts cannot be totally eliminated as long as the line remains beneath the river and meadow.

At Glen Aulin the leachfield was found to be over capacity to adequately treat previous levels of wastewater, prompting water use restrictions that capped use at a maximum 700 gallons per day to protect water quality. In 2011 water use was further restricted to 600 gallons per day. These measures have successfully avoided any subsequent leachfield failure; however, a potential risk to water quality remains with the minimally sized leachfield.

The water treatment system for the domestic water supply at Tuolumne Meadows is also operating within permitted regulations; however, this system does not meet new state regulations. In 2006 the State of California decreased its direct filtration turbidity standard from 0.5 NTU (nephelometric turbidity units) to 0.1 NTU, assuming that all particulate matter in the water is a pathogen or an organic that could be harmful to human health. The current system does not consistently meet the new standard. Silt washed from the unstable road cut near the Dana Fork (see below) affects the quality of the Tuolumne Meadows public water supply, as the intake is a short distance downstream from the cut.

A microbial water quality study in the Tuolumne River watershed was completed to consider the potential risk of surface water contamination by stock (Atwill 2008). This study focused on giardia and cryptosporidium shedding by stock. While the study suggests that stock-associated waterborne contamination was of low concern, recommendations were made to protect water quality. For example, since most manure occurs within the first quarter-mile of trails from stable operations, it was recommended that trails be patrolled and manure removed from watercourses in these areas. This management practice is now ongoing.

Impacts from the fuel facilities at Tuolumne Meadows have been corrected and mitigated (SFPUC 2009); however, the potential for future impacts cannot be totally eliminated as long as fuel facilities remain. Two vapor-extraction cleanup projects associated with older buried tanks are ongoing. In addition, the fuel station is required to operate according to all applicable state laws and best management practices, including having a spill-prevention plan.

Impacts resulting from the road cut near the Dana Fork include reduced water quality and impacts to river habitat, higher maintenance costs, and reduced scenic quality. Road cuts can have a substantial

effect on water quality, especially in high-elevation glacial till found in the upper reaches of the Tuolumne River watershed, where extreme weather, coupled with sparse vegetation, accelerates the erosion process. At the "little blue slide" site, under-snow winter runoff, spring runoff, summer storms, and emerging groundwater are continually depositing silt into the Dana Fork of the Tuolumne River and undermining larger boulders that fall onto Tioga Road. Silt washed from the fill slope below the road blankets the bottom of the river. This scar on the landscape is visible from most vista points along the Cathedral Range. According to the park's hydrologist and specialists from the NPS Water Resources Division, the cut has destabilized the slope both above and below the road and will not stabilize naturally without intervention (NPS, Noon and Martin 2010h).

Biological Values

Subalpine Meadow and Riparian Complex Extending from the Lyell Fork and Dana Meadows through Tuolumne Meadows

Condition at the Time of Designation

At the time of designation, the subalpine meadow and riparian complex was largely undeveloped, with high biodiversity and productivity. The vast meadows—the annual floodplains for the Tuolumne River—were largely free of structures. Most facilities, with the exception of roads and trails, were concentrated in upland areas around Tuolumne Meadows. Tioga Road skirted the southern edge of the meadow. Culverts along the Tioga Road allowed for flows from upland areas to connect to Tuolumne Meadows (although these flows did not replicate natural sheet flows).

Facilities at the time of designation supported basic visitor services for seasonal use from May to October, and included a small store, campground, rustic tent lodging, employee tents and hard-sided cabins, administrative and concessioner stables, and a visitor contact station. Water and wastewater treatment systems were present. Localized impacts associated with visitor use, principally trampled vegetation and compacted soils along informal trails, were evident near popular visitor attractions, such as the Cathedral Lakes trailhead, Pothole Dome, Soda Springs, Lembert Dome, and the trail to Glen Aulin. From November to April the meadows were covered with deep or melting snow, the roads were closed, and visitor use was limited to hearty travelers with the ability to hike or ski into the region.

While the meadows were largely undeveloped, historic activities along the river and other anthropogenic (human-induced) influences over the past 100 years had probably affected the stability of the subalpine meadows in the Tuolumne River corridor. Recent studies have found significantly higher levels of bare ground in Tuolumne Meadows in areas where soils and hydrology would normally support dense and productive meadow vegetation (Cooper et al. 2006; NPS, Buhler et al. 2010a). Several lines of evidence suggest that intense livestock grazing in the late 1800s had lasting meadow impacts that are apparent to this day (Cooper et al. 2006; NPS, Ballenger et al. 2010c). Recent studies also show significantly higher levels of bare ground in subalpine meadows with currently high levels of pack stock use,



Meadow and riparian vegetation in Tuolumne Meadows. NPS Photo by Randy Fong

such as meadows along the Lyell Fork, when compared with meadows with currently lower levels of pack stock use (NPS, Ballenger et al. 2010b). Impacts from historic grazing and more recent pack stock use were likely present at the time of designation.

Impacts associated with foot traffic in areas of concentrated visitor use, such as Soda Springs, were also occurring at the time of designation, as evidenced by restoration projects conducted in the 1980s.

Other historic actions that may have contributed to conditions at the time of designation in Tuolumne Meadows include adding oil to ponded areas for mosquito abatement, extensive aerial spraying of malathion/diesel mix in an effort to kill needleminer, the free-form camping that allowed people to drive across the meadow to their desired campsites, and the installation and repair of sewer lines between the old Sierra Club campground and the current Tioga Road.

Lodgepole pine encroachment into subalpine meadows had been managed by prehistoric inhabitants by pulling seedlings (Davis-King and Snyder 2010), and mechanical removal of conifers had been practiced by the National Park Service since at least 1933 (Cooper et al. 2006) and was ongoing.

Current Condition

Natural processes continue to shape the landscape and the meadow and riparian complex that extends through Tuolumne Meadows, Dana Meadows, and Lyell Canyon. At the scale of the river segments, this subalpine meadow and riparian complex remains mostly undeveloped and retains a high degree of biodiversity and productivity.

Little change in development has occurred since designation. Facilities remain concentrated in upland areas, where a wilderness center has been added, parking has been expanded at Dog Lake and the visitor center, and the number of campsites in the campground has been reduced by about half since 1984. Resource management projects have been conducted routinely to address impacts to meadow and riparian areas. Since the river's designation, these have included restoration efforts to repair impacts to meadow/riparian areas across Tioga Road from the store/grill, near the Cathedral Lakes trailhead, at Pothole Dome, at Soda Springs, at Lember Dome, along the trail to Glen Aulin, and along the lower Lyell Fork (NPS 2009a).

Overall, the finely textured wet soils in these subalpine riparian and meadow areas remain highly productive. Soils closest to the Tuolumne River and flat central portions of the meadows have the highest organic content (Cooper et al. 2006). Meadow invertebrate assemblages at Tuolumne Meadows have been found to be remarkably diverse, with relatively low dominance of any one form (Holmquist and Schmidt-Gengenbach 2003).

The meadow and riparian complex provides habitat for a diversity of plant and animal species, including several special-status species (e.g., slender lupine [*Lupinus*



Meadow and riparian vegetation along an ephemeral stream in Dana Meadows. NPS photo by Kristina Rylands

gracilentis], Yosemite bulrush [*Trichophorum clementis* (*Scirpus clementis*)], Yosemite toad [*Anaxyrus canorus*], and several species of bats), and migratory bird populations (NPS, Buhler et al. 2010a).

Although productivity of these riparian and meadow areas remains high, several recent studies document changes in the ecological integrity of the meadows, exemplified by expanding areas of barren ground, atypical plant species, conifer encroachment, and diminished willow vegetation along riverbanks (NPS, Buhler et al. 2010a, Cooper et al. 2006). Researchers suspect that a disruption of ecological processes resulting from historic sheep grazing, coupled with the emerging stress of more frequent periods of low precipitation, is being exacerbated by foot traffic and pack stock use in sensitive meadow habitats, heavy browsing by deer of the few remaining willows, and a high level of ground disturbance by gophers and voles (Cooper et al 2006; NPS, Ballenger et al. 2010b). While studies continue, currently there are no simple explanations for these findings of instability in particular meadows and riparian areas in the region. However, the cumulative effects of these past, present, and emerging stresses have the potential to change the long-term productivity of the meadows. These management concerns are described in detail below, and are addressed by proposals included in the ecological restoration program sections of this Tuolumne River Plan (see chapter 7).



Meadow along the John Muir Trail in Lyell Canyon. NPS Photo by Kristina Rylands

Monitoring is being conducted to document the extent and condition of informal trails in meadows of the Tuolumne River corridor. The results will be used to inform management decisions regarding protection of meadow health. Four areas were monitored in 2009: the main meadow at Tuolumne Meadows, the small meadow near the ranger station, the upper meadow of Lyell Canyon, and Dana Meadows. For Dana Meadows, Tuolumne Meadows, and the meadow in upper Lyell Canyon, this represented the second consecutive season of monitoring. The following maps (figures 5-2 through 5-9) document locations and conditions of informal trails in Tuolumne, Dana, and the upper Lyell meadows (NPS 2009c).

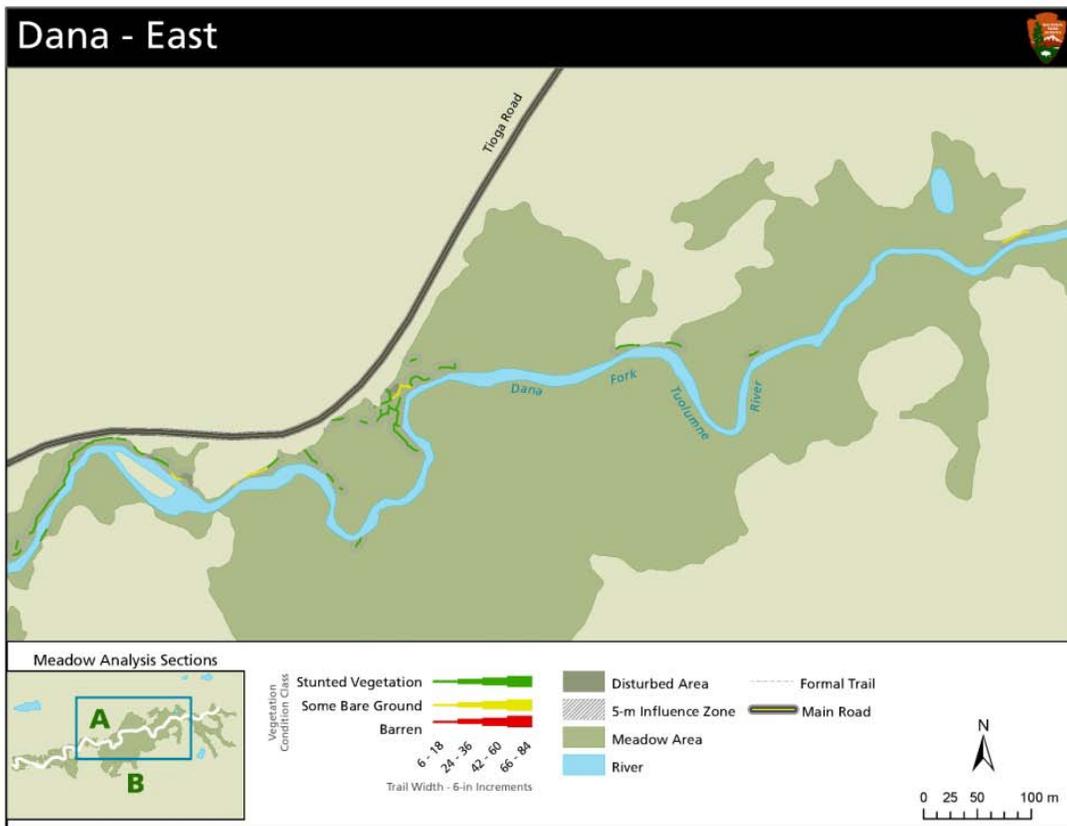


Figure 5-2. Location and Condition of Informal Trails, East Dana Fork

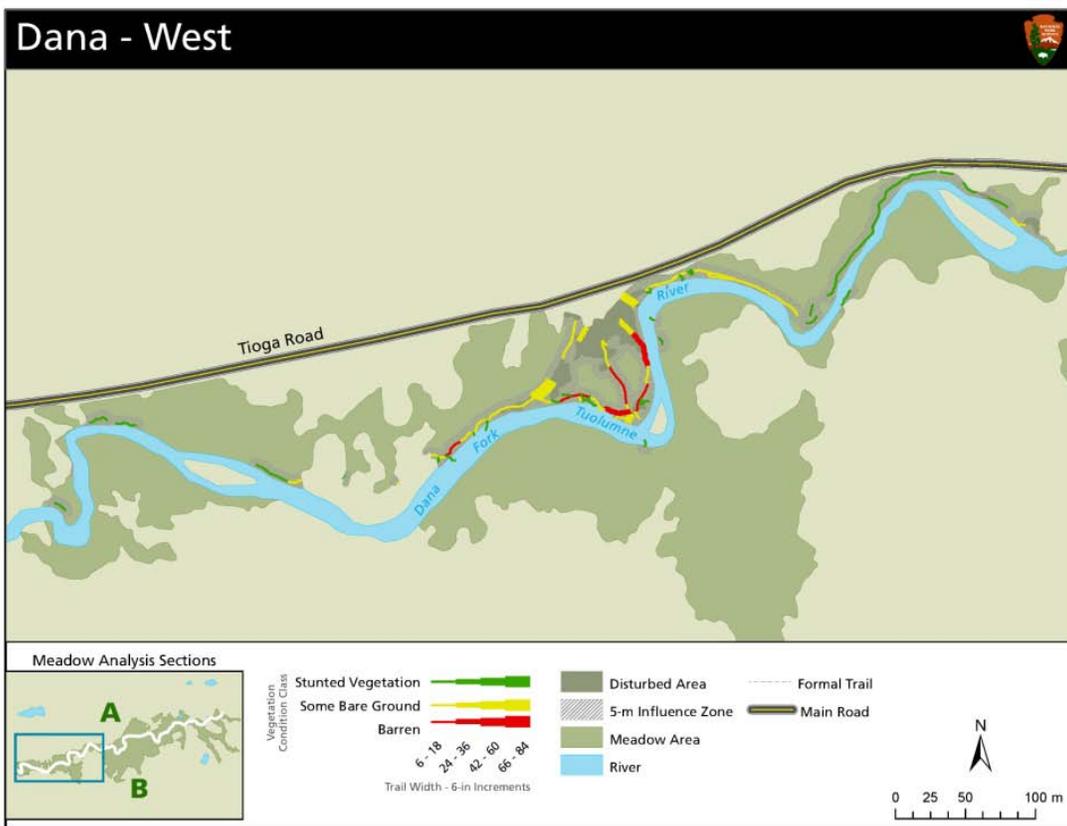


Figure 5-3. Location and Condition of Informal Trails, West Dana Fork

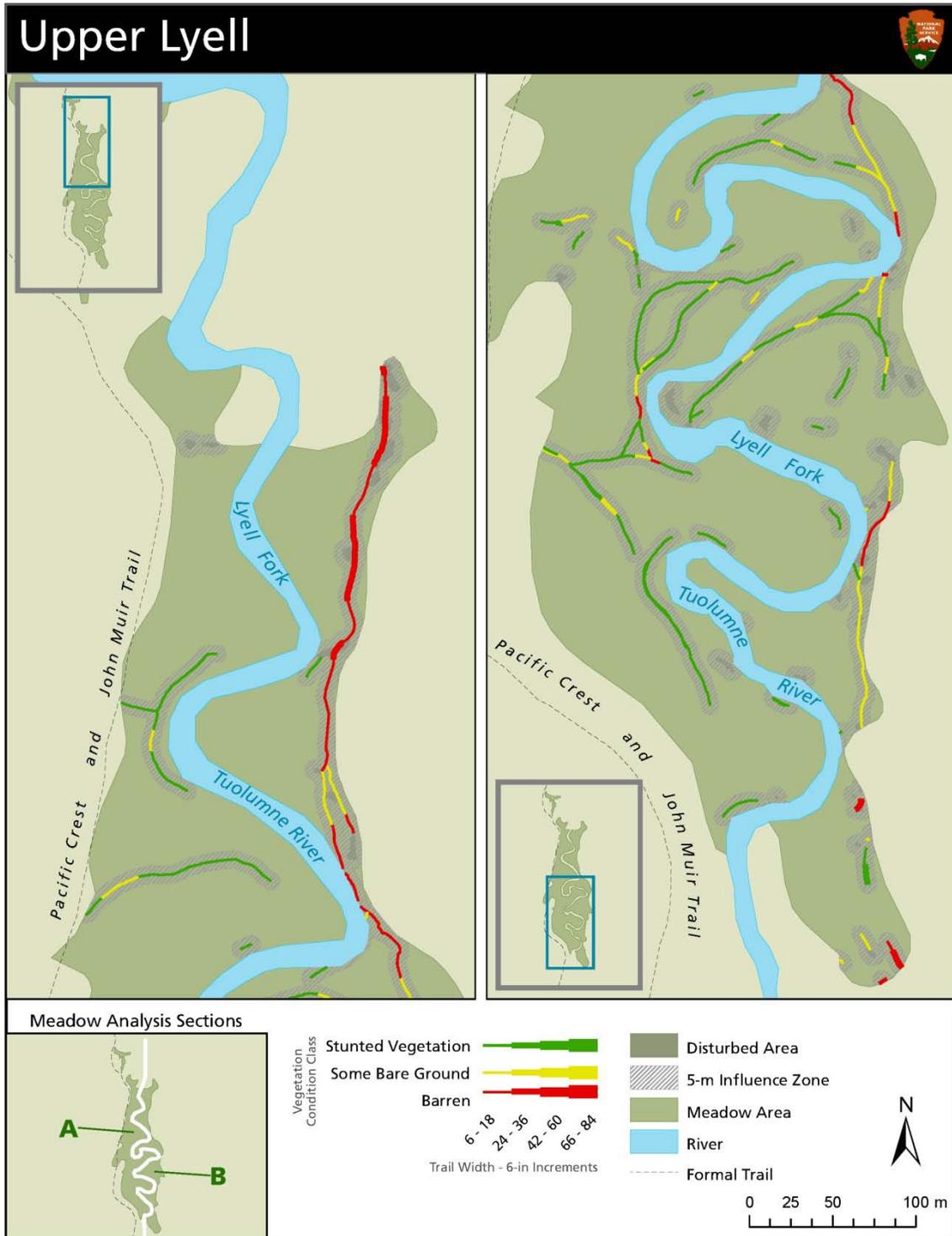


Figure 5-4. Location and Condition of Informal Trails, Upper Lyell

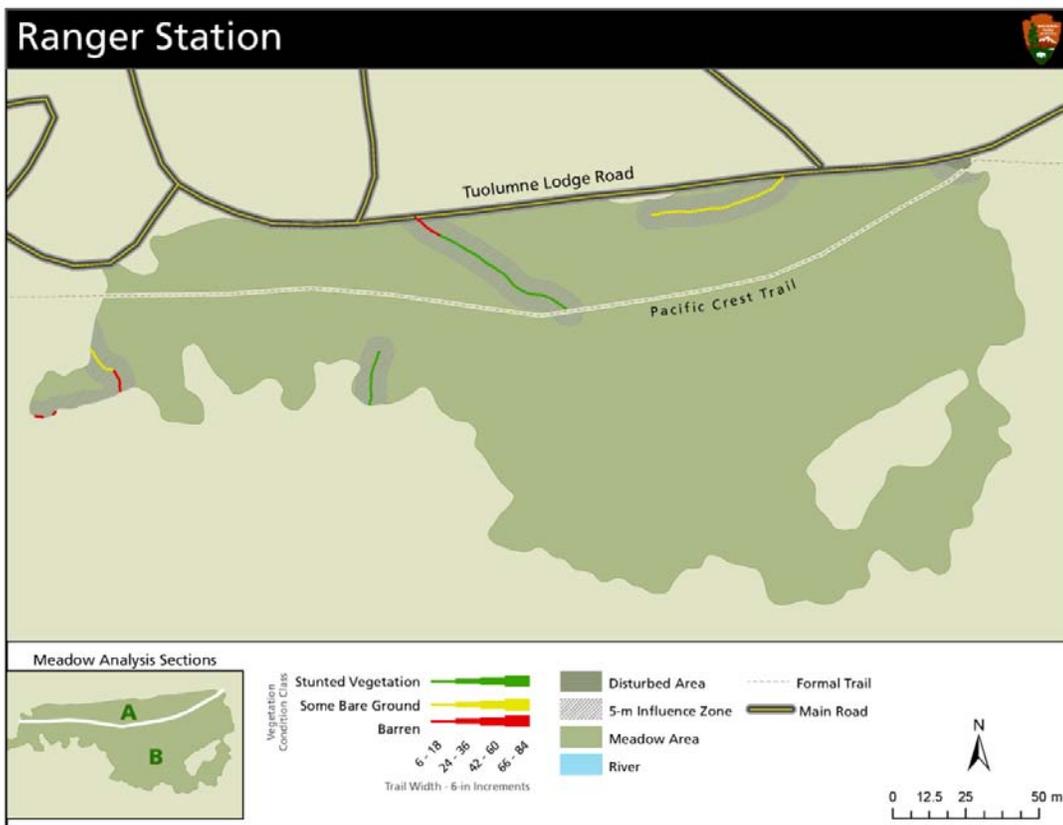


Figure 5-5. Location and Condition of Informal Trails, Ranger Station

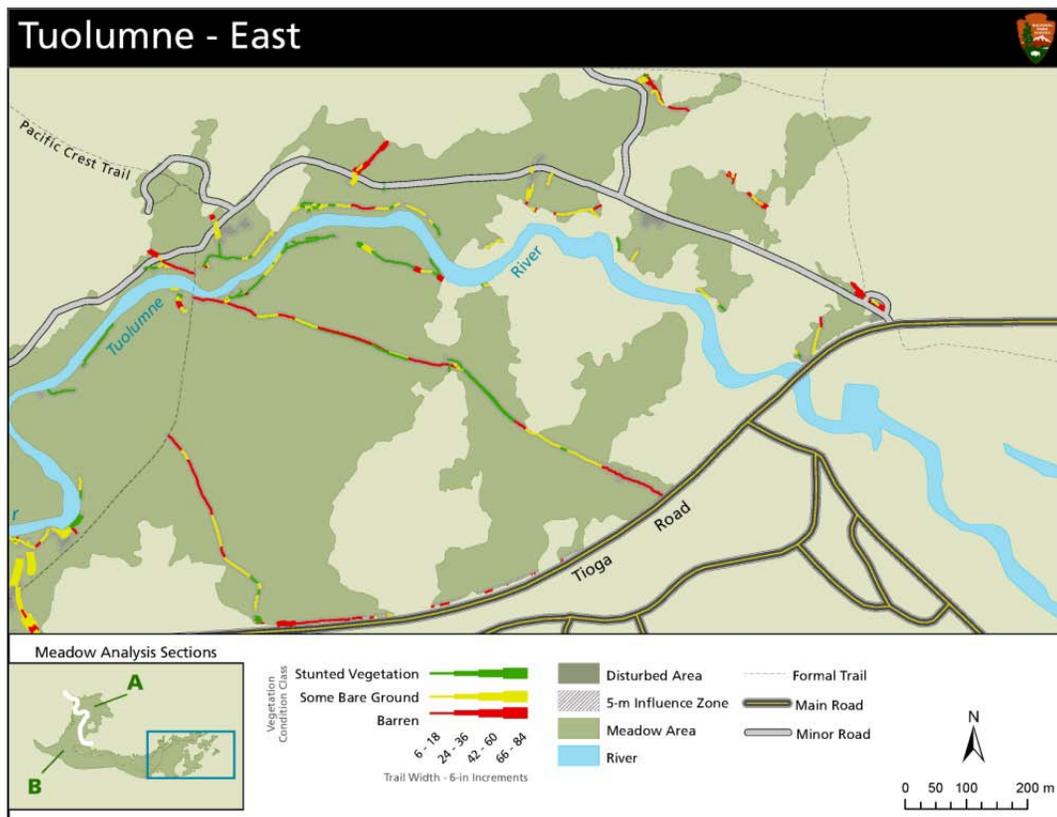


Figure 5-6. Location and Condition of Informal Trails, East Tuolumne Meadows

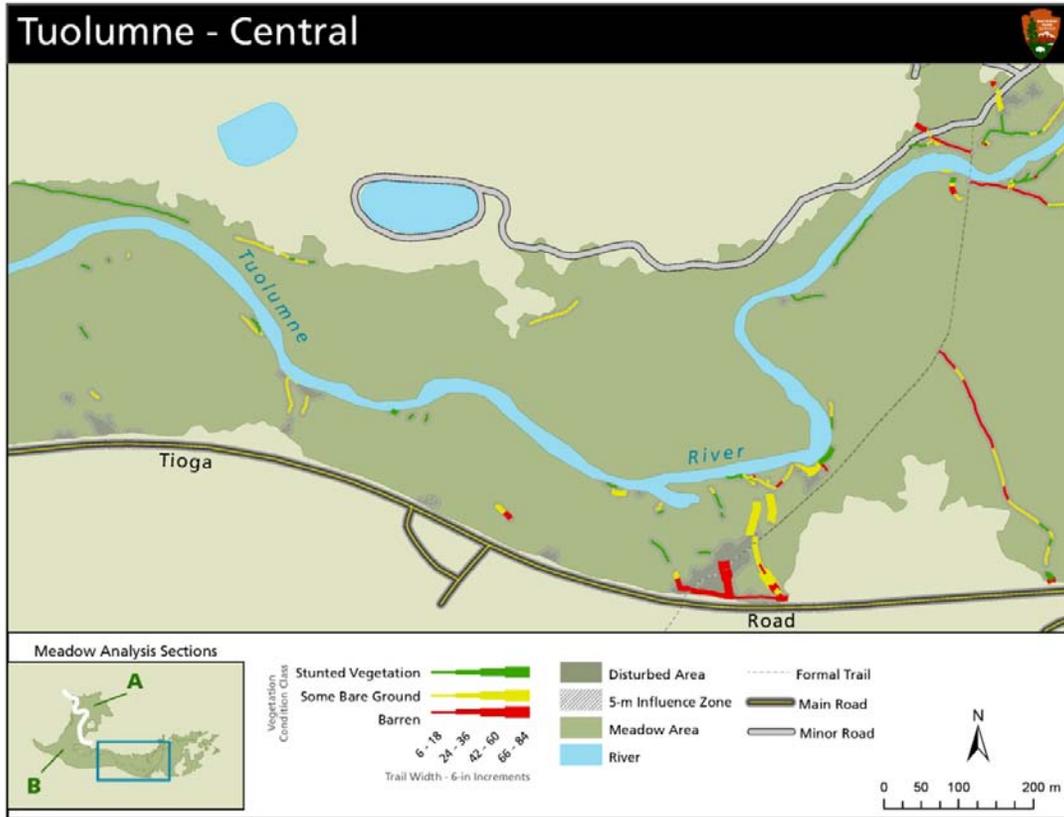


Figure 5-7. Location and Condition of Informal Trails, Central Tuolumne Meadows

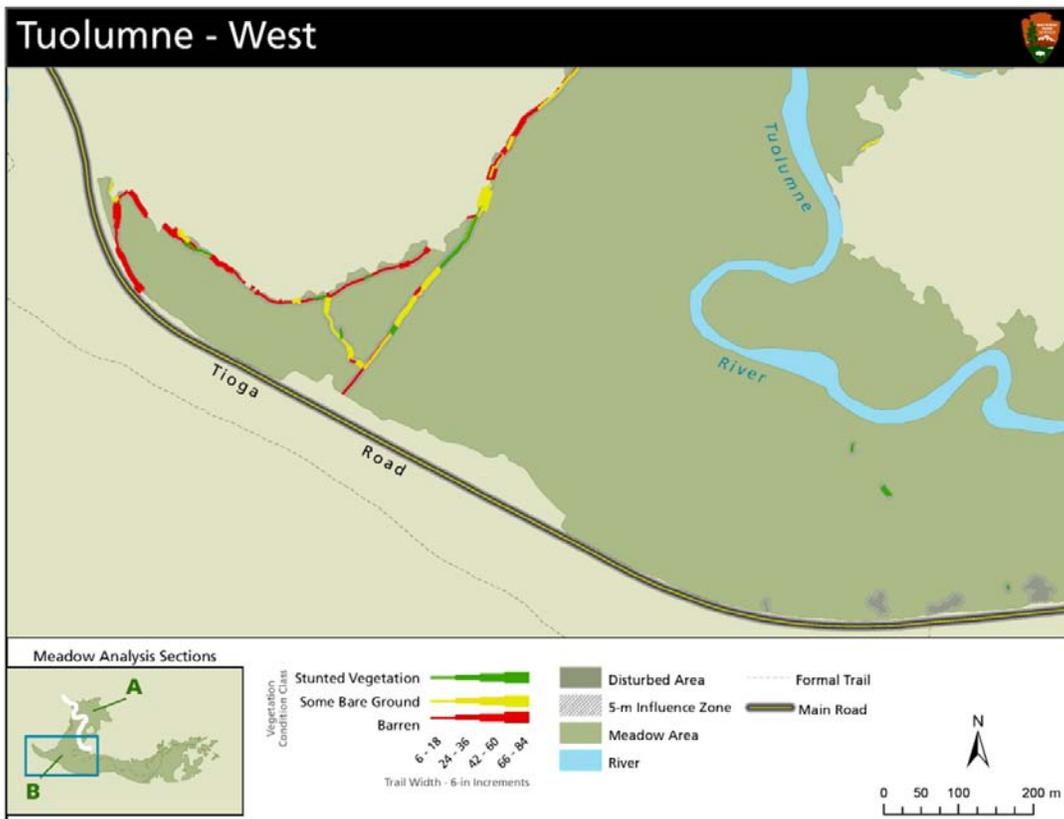


Figure 5-8. Location and Condition of Informal Trails, West Tuolumne Meadows

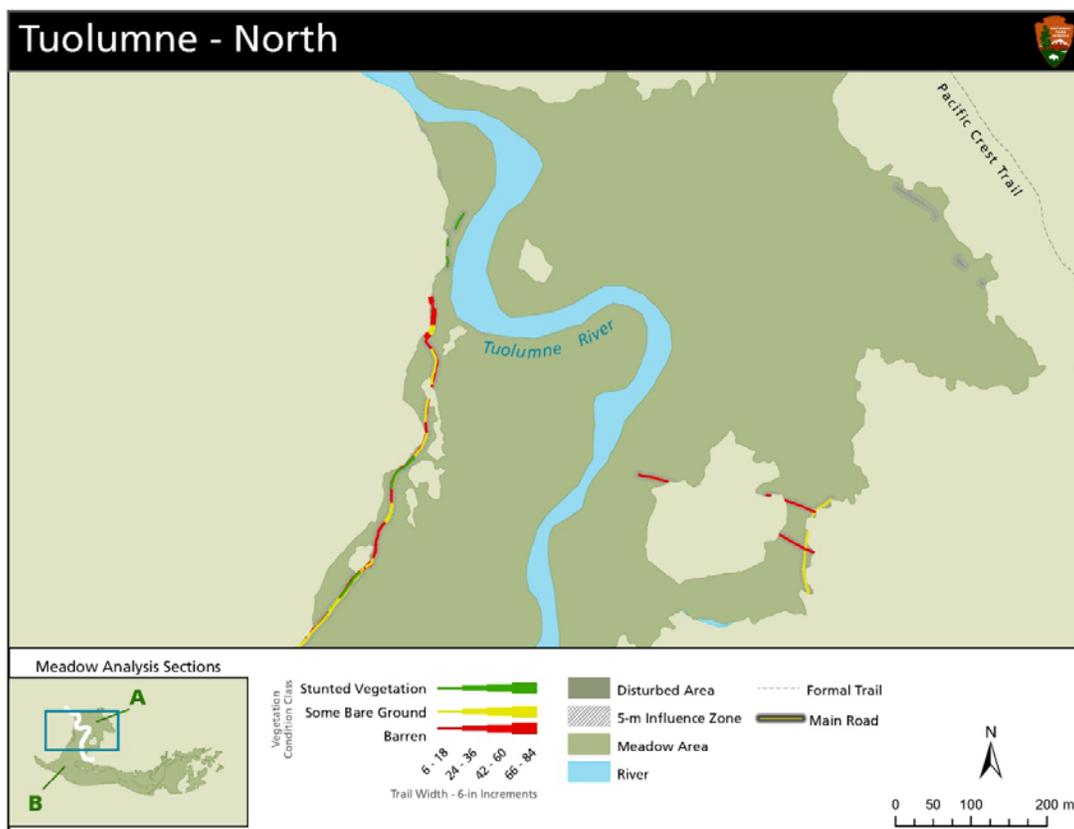


Figure 5-9. Location and Condition of Informal Trails, North Tuolumne Meadows

Subalpine meadow and stream monitoring continues to examine the impacts of commercial and administrative stock use practices. Recent studies show significantly higher levels of bare ground in subalpine Yosemite meadows with currently high levels of pack stock use when compared with meadows with currently lower levels of pack stock use (NPS, Ballenger et al. 2010b). Resource managers are using meadow condition assessments and past research (Cole et al. 2004) to develop grazing capacities for meadows in the Lyell Fork (NPS, Ballenger 2010b). One important step in this process is to estimate the grazing levels that can be sustained without undesirable effects on meadow areas. The ultimate goal of these studies is to provide information to develop management strategies that allow for wilderness stock use without compromising the integrity of meadow resources.

Management Concerns

Tuolumne Meadows and Dana Meadows

The suite of recent subalpine meadow studies mentioned in previous sections are of particular interest as they speak to a loss in the *ecological resistance* of the meadow ecosystem (or the amount of disturbance that a system can take before key ecosystem elements change), and the *adaptive capacity* of the meadow ecosystem (the ability to deal with unpredictable change). As resource managers develop an understanding of what leads to apparent loss of ecological resistance, they are focusing on impacts to hydrology, vegetation, geomorphology, and soils.

Soil moisture and hydroperiod (length of time soil remains saturated) is the single most important driver in determining the presence and integrity of meadows (Heady and Zinke 1979, Allen-Diaz 1991). Loheide and Gorelick (2007) and others have documented stream channelization and straightening, drainage efforts, and culvert construction in northern Sierra Nevada meadows as cumulative changes that have altered the hydrology of meadows in a way that has lowered the water

table, triggered a succession to xeric plant species, and degraded ecosystem function throughout the meadow systems of the region.

Geomorphic changes such as channel widening could affect groundwater levels critical to meadow habitats. Willows along the riverbank serve an important role in preventing river widening. Riverside willows, once abundant along the river in Tuolumne Meadows in 1867 (Cooper et al. 2006), appear to have diminished greatly. The lack of willow establishment on sandbars and riverbanks allows water to flow unimpeded, increasing velocity and altering scour and deposition relationships (NPS, Buhler et al. 2010a). Cooper and others (2006) suggest that heavy browsing of willow seedlings by deer may be limiting willow recruitment on river bars, which are normally an ideal establishment environment for willow, and recommend a detailed study of willows to understand what factors limit willow establishment and persistence in the study area.

Tioga Road runs east to west along the southern edge of Tuolumne Meadows, and surface water flowing from the southern slopes is channeled through 35 culverts. Cooper and others observed that in 2006 culverts were clogged with vegetation and sediment in 12 locations, and signs of ponding water south of the road were observed in 23 locations. Ponding is much more frequent near the eastern end of the meadow, where culverts are spaced farther apart. This is also where the campground, gas station, store, and other infrastructure, coupled with lower gradient surface slopes, further interrupt water flow.



Tuolumne River vehicle bridge on Tioga Road in Tuolumne Meadows. NPS photo by Kristina Rylands



Headcut associated with Budd Creek.
NPS photo



Partially blocked culvert.
NPS photo



Culvert set too low in meadow.
NPS photo

Culverts force previously dispersed runoff into localized channels, and downcutting of these channels has occurred downstream of many of the culverts, particularly in the west end of the meadow. This downcutting in localized channels lowers the groundwater table and deprives the higher elevations of sheet flow inundation (Cooper et al. 2006). Headcuts are another feature that occurs when sheet flow is concentrated and channeled at high velocity, increasing scour and altering sedimentation dynamics. Like downcut channels, headcuts lower the adjacent water table and limit sheet flow across the meadow. Many of the Tioga Road culverts were installed lower or higher than the surface level of the meadow, which exacerbates downcutting, headcutting, and ponding. The resulting changes in meadow hydrology influence species composition changes within the meadow communities (NPS, Buhler et al 2010a).

The section of the Great Sierra Wagon Road from the visitor center to Parsons Memorial Lodge, now a trail, and the section from Parsons Memorial Lodge to Lembert Dome, used by maintenance vehicles, include segments of raised roadbed edged with ditches that empty into culverts. The damming action of the roadbed, headcuts, vegetation loss, and incised channels associated with the ditches and culverts interrupt the natural surface flow of water throughout the meadow (NPS, Buhler et al. 2010a).

The section of the Great Sierra Wagon Road between Tuolumne Meadows Lodge and Lembert Dome, now a trail, is deeply rutted and affecting the hydrology of the meadow. Its proximity to the Tioga Road and the Tuolumne River, combined with the sandy substrate, has led to deep channeling, heavy erosion, headcuts, and sediment transport into the river. Sheet flow coming off Lembert Dome is channeled through culverts and along the deeply rutted trail toward the river. This diverts water from the meadow areas and exacerbates erosion in the deep ruts (NPS, Buhler et al. 2010a). Numerous lateral headcuts and several informal trails leading to the main trail exacerbate and expand the channeling effects through the local terrain. Because the historic roadway is so deep and sandy in certain sections, it is difficult to walk on, so visitors and pack stock walk on the edge of the trail, promoting more vegetation loss and further widening of the incised trail. If this condition was allowed to persist, continued erosion and alteration of the natural and cultural terrain would likely occur (NPS, Noon and Martin 2010h).

As reported by Cooper and others (2006) several lines of evidence indicate that livestock grazing in the late 1800s has had lasting impacts on the vegetation of Tuolumne Meadows. First, and most broadly, the main vegetation types in Tuolumne Meadows all have a much higher percentage of bare soil than would be expected for an area with an intact wet meadow hydrologic regime. Intense grazing and hoof punching can destroy the underground network of rhizomes that supports sod-forming plants, and their reestablishment is an extremely slow process. Once a rhizomatous sod layer is broken apart, the loose, bare ground is susceptible to erosion and invasion by nonmeadow plants. Shallow rooted

annuals dominate these disturbance patches, and lodgepole pine seedlings are common. The high organic content of these soils and low below-ground plant production suggests that the existing vegetation could not have formed these soils. Thus, the modern vegetation is likely the product of intensive historic disturbances from which it has not recovered. The only recent large-scale disturbance was grazing by cattle and sheep from the 1860s to 1891.

The low density of below-ground roots and rhizomes allows pocket gophers and voles to maintain these communities in a perpetual state of disturbance. It also impacts the water retention capacity of meadow soils, exacerbating the drying effects of the previously described impacts on hydrologic processes (Lowry and Loheide 2010). Together, these disturbances may have created an alternative stable state (Suding et al. 2004) that would require more than mitigating disruptions to hydrologic processes to reverse. In other words, enhancing the hydrology of the river, while critical, would not be sufficient to reverse the disturbance to the meadow. The current studies are inconclusive, however, and the fundamental causes of the existing conditions require more research (Cooper et al. 2006).

Conifer encroachment into the subalpine meadows could decrease the extensiveness of the subalpine meadows along the Tuolumne River. Lodgepole pine invasion at Tuolumne Meadows is linked to periods of low precipitation and low year-to-year variability in moisture conditions (Cooper et al. 2006). Although Tioga Road was previously suspected to be a cause of invasion of lodgepole pines along the southern margin of Tuolumne Meadows, subsequent research indicates the cause is more likely the more general meadow degradation described above, which provides bare ground that is essential for past and ongoing tree establishment (Cooper et al. 2006). The National Park Service has continued to mechanically remove conifer saplings encroaching into meadows.

Tuolumne Meadows remains highly susceptible to impacts on vegetation, soils, and soil organisms associated with foot traffic (Holmquist and Schmidt-Gengenbach 2008). Areas of concentrated visitor use, including trailheads and visitor facility sites, are experiencing localized meadow habitat disturbance associated with increasingly heavy foot traffic (NPS, Buhler et al. 2010a). Areas recommended for management action to protect and enhance meadow and riparian vegetation and soils are listed below:

- Informal trails near popular attractions, such as Soda Springs, Pothole Dome, Lumbert Dome, and locations along the banks of the Tuolumne River
- Shoulder parking along Tioga Road, particularly near the Cathedral Lakes and Parsons Memorial Lodge trailheads, which results in informal trails across meadows
- The concessioner employee tent cabins behind the store and grill, which are situated in a wet meadow area
- The concessioner employee tent cabins in riparian communities near the river at Tuolumne Lodge
- The south bank of the Lyell Fork near the Tuolumne Meadows campground
- Bare meadow areas with soils and high water tables that could support more dense meadow vegetation.

Lyell Canyon

Lyell Canyon is a very popular backpacking destination, as well as an extremely popular destination for commercial stock use; therefore, it represents a unique intersection between stock use impacts and those created by hikers and backpackers. According to monitoring studies conducted by the National Park Service in 2009, the eastern portion of the upper Lyell Canyon meadow is the second highest

ranked meadow of concern for the park (NPS 2009c). Despite the fact that hikers and pack stock must cross the Lyell Fork of the Tuolumne River to access the eastern meadow, it is receiving a larger extent of trailing impacts than the western meadow (1,597 square meters of measured impact compared to 506 square meters). The larger extent of impact is most likely due to the fact that horses are pastured on the east side of the meadow, and most of the backcountry campsites are concentrated there, as well (NPS 2009c).

Analysis of 2008 meadow condition assessments revealed significantly higher levels of bare ground in Lyell Fork meadows, compared with meadows with low stock use and no stock use. Hoof punching was highest in meadows with more area dominated by wetland species, suggesting that meadows are receiving stock use while soils are still wet and more susceptible to impacts. The analysis recommends consideration of three key factors to mitigate meadow impacts: the amount of pack stock use, timing of use, and consideration for resources of special concern. One important step is to estimate grazing levels that can be sustained without undesirable effects on meadow areas. Resource managers have used meadow condition assessments and past research (Cole et al. 2004) to develop target grazing capacities for meadows in the Lyell Fork (NPS, Ballenger 2010b). The study also recommends annual monitoring of meadow areas receiving high use (NPS, Ballenger et al. 2010c).

Recent studies document conifer encroachment, potentially related to extended periods of drought, into subalpine meadows along the Lyell Fork (Cooper et al. 2006).

Low-Elevation Riparian and Wetland Habitat at Poopenaut Valley

Condition at the Time of Designation

Research conducted since the time of designation (NPS, Stock et al. 2007c), elaborated on below, indicates that the low-elevation riparian and meadow habitats at Poopenaut Valley, a half mile below O'Shaughnessy Dam, represent a productive and diverse mix of wetland, upland, riparian, and forested communities that provide essential habitat for wildlife, despite alterations to the hydrologic regime caused by dam operations. It is assumed that this was also the condition at the time of designation.

Current Condition

In the river corridor below Hetch Hetchy Reservoir, the O'Shaughnessy Dam has influenced the magnitude, timing, duration, frequency, and rate of change of the hydrologic regime. However, Poopenaut Valley and its ecosystems have been largely spared the severe impacts seen downstream of other dams because of several factors unique to this setting, such as a low overall gradient and a downstream bedrock constriction that promotes floodplain inundation (NPS, Stock et al. 2007c). Despite a reduction in available water during the growing season, a diverse mix of riparian, wetland, and upland plant communities remain in Poopenaut Valley. These are some of the most diverse communities in the park.

Wetland and upland meadows comprise most of the valley floor, with relatively extensive (compared to other shoreline areas below the dam) riparian vegetation adjacent to the river and tributary streams. Several wetland areas in Poopenaut Valley exhibit an unusual assemblage of plants, and certain upland areas exhibit hydric soils and some hydrophytic vegetation, suggesting that wetlands were more extensive in the past (NPS, Stock et al. 2007c). A 2007 wetland delineation at Poopenaut Valley indicates that there may be riparian encroachment associated with low, regulated flows (NPS, Buhler and Santana 2007d). There has been some encroachment of conifers into meadows. The National Park Service is in the process of developing and implementing a long-term monitoring program to better

understand and quantify the effects of O’Shaughnessy Dam on the hydrologic processes that support riparian, wetland, and upland plant communities in the Poopenaut Valley area.

Birds observed in Poopenaut Valley’s riparian-associated habitats occupy understory, mid-story, and canopy breeding niches, suggesting that the available habitat provides structural integrity beneficial to a wide diversity of birds (NPS, Stock et al. 2007c).

Management Concerns

The research conducted by Stock and others suggests that some wetland areas may be transitioning to drier upland habitat due to lowering groundwater levels in the meadows, while riparian areas below the dam appear to have expanded, creating more habitat for riparian birds and other wildlife. The degree to which these changes have been influenced by dam operations is currently being studied, as are the fluctuations of bird populations in Poopenaut Valley, to determine whether they are due to natural inter-annual variation or population declines (NPS, Stock et al. 2007c). The overarching goal of these studies is to provide information that dam operators can use to make decisions about dam releases that will be most beneficial to maintaining, and even enhancing, ecosystems downstream of the dam. Improvements to the downstream environments may be made in the short term by science-based management of water releases (NPS, Stock et al. 2007c).



Poopenaut Valley, meadow, river, and seasonal pond. NPS photo by Kristina Rylands

Mineral Spring Habitat at Tuolumne Meadows, Lyell Canyon, and Pate Valley

Condition at the Time of Designation

The mineral spring habitat in Lyell Canyon and Pate Valley was undisturbed and sustained by natural processes. However, the habitat at Soda Springs in Tuolumne Meadows was receiving concentrated visitor use resulting in localized trampling of soils and vegetation.



Water bubbling up from Soda Springs in Tuolumne Meadows. NPS photo by Kristina Rylands

Current Condition

The mineral spring habitat in Lyell Canyon and Pate Valley remains undisturbed and sustained by natural processes. Since the time of designation Soda Springs has been a focus of natural resource restoration and visitor use management. An effort to minimize impacts to the greater Soda Springs area was completed in the past decade; however, many informal trails still lead into this very popular area (NPS, Buhler et al. 2010a). Soda Springs supports localized populations of special status plant species (e.g., Buxbaum's sedge [*Carex buxbaumii*] and marsh arrowgrass [*Triglochin spp.*]). Habitat for these species is largely undisturbed (NPS, Acree et al. 2007f). Soda Springs appears to function as it did historically, indicating that the hydrologic connectivity of the springs remains intact (Davis-King and Snyder 2010).

Management Concerns

The Soda Springs habitat remains highly vulnerable to impacts associated with visitor use due to its relatively sparse vegetative cover, very wet conditions, and popularity as a visitor destination. The Glen Aulin trail, heavily used by stock for commercial day rides and High Sierra camp supply trips, passes near the springs and may cause radiating effects into this area (NPS, Buhler et al. 2010a). There are currently no management concerns regarding the springs at Pate Valley and Lyell Canyon.

Geologic Value

Stairstep River Morphology through the Grand Canyon of the Tuolumne

Condition at the Time of Designation

At the time the Tuolumne River was included in the wild and scenic river system, the extensive stairstep river morphology was shaped by natural processes and unaltered by human intervention.

Current Condition

No natural event or human intervention has perceptibly changed the morphology of the river corridor since the time of designation.

Management Concerns

Natural processes will continue to shape the landscape and the geologic value. There are no foreseeable management concerns associated with the condition of stairstep river morphology in the Tuolumne River corridor.



Tuolumne Fall between Tuolumne Meadows and Glen Aulin. NPS photo by Randy Fong

Cultural Values

An ancient river-related trail system connecting the archeological landscape of the prehistoric past and places important to the ancestral heritage and ongoing traditions of contemporary American Indian tribes and groups

Condition at the Time of Designation

When nominated for inclusion on the National Register of Historic Places in 1978, the Tuolumne Meadows Archeological District was considered to be in fair condition overall (NPS, Anderson and Hammack 1977). The Hetch Hetchy Archeological District (NPS 1979), like the Tuolumne Meadows Archeological District, had been determined eligible for the National Register of Historic Places based on the surveys of the 1950s and 1970s (Bennyhoff 1956; Napton and Greathouse 1976). Two sites comprised the Hetch Hetchy district at that time, one of which was located within the wild and scenic river corridor, in the segment below O'Shaughnessy Dam (NPS, Montague 2006d). This site was in fair condition.

Only nine sites along the Tioga Road corridor where it follows the Dana Fork had been formally evaluated for their eligibility to the National Register of Historic Places. Seven of these sites were found eligible and two were found ineligible. One of the eligible sites had undergone data recovery excavation, conducted to mitigate the impacts of highway construction.

The ancient trail system connecting sites important to the cultural traditions of American Indian tribes and groups had been altered at the time of designation by historic period non-American Indian actions, such as additions of formal alignments, wooden bridges, and rock abutments (Davis-King and Snyder 2010). A formal evaluation of the ancient trail system and the culturally important sites it connects had not occurred prior to the time of designation. However, recent documentation (see "Current Condition," below) shows that they retain a relatively high degree of integrity in terms of the critical elements of location, setting, views, and feeling, vital to retaining a connection to the ancestors and cultural life ways of traditionally associated American Indian tribes and groups. It is assumed that this was also the condition at the time of designation.

Current Condition

Documentation, condition assessments, and the few evaluation projects since designation (NPS, various authors 1985a-f; NPS, Montague 1996; NPS, Montague 2000 a-f; NPS, Gavette 2004 and 2005b; NPS, Shive 2007a; among others) have expanded the body of knowledge about the archeological importance of the river corridor. Many sites have been documented, and previously unknown sites continue to be discovered. Sites that have not yet been evaluated are considered potentially contributing resources to the outstandingly remarkable archeological values of the Tuolumne River until determined otherwise through formal evaluation (NPS, Montague 2006d)

Lyell and Dana Forks

One hundred and thirty-four archeological sites have been identified along the Lyell and Dana Forks. Although few of these sites have been formally evaluated for their NRHP eligibility, many of the sites along both forks appear to have important research potential that might make them significant (NPS, DePascale and Curtis 2006b, among others).

Most of the sites that were evaluated for disturbance levels over the past decade have low or moderate disturbance, but one site near the lower Dana Fork is undergoing severe disturbance, primarily due to visitor use. Almost all the sites along these forks are impacted indirectly by informal trails that bring visitors to the site area (NPS, Shive 2007a). Most of the remaining, unevaluated sites appear to be in fair

to good condition, with five sites documented as being in poor condition, based on surface indicators. However, since archeological sites are largely subsurface, their data values and integrity cannot be fully evaluated without some form of excavation or scientific analysis; therefore, the condition of the majority of sites in these segments remains unknown (NPS, Montague 2006b). Seven sites were visited in Lyell Canyon in 2009. The majority (57%) of these sites were in good condition, but some exhibited severe or moderate disturbance levels. Commonly observed impacts were erosion, camping, informal trails, and park operations (NPS 2009c).

Tuolumne Meadows

The Tuolumne Meadows Archeological District contains a significant concentration of sites, diversity of materials contained in the sites, and research potential to provide data on thousands of years of human prehistory.

Currently, approximately three-quarters of the sites in the Tuolumne Meadows Archeological District are judged to be in good or fair condition. Four sites are in poor condition, and the condition of seven sites is not known (NPS, Montague 2006b). Most of the severely disturbed sites are in the developed areas, including the campground, wastewater treatment ponds, and along road or trail corridors. Twenty-five sites in the greater Tuolumne Meadows area were visited in 2009. The majority of these sites (56%) were in good condition; however, the others showed evidence of severe disturbance. According to the 2009 data, the most common impact to the integrity of archeological sites is from the displacement of artifacts or archeological features, caused either by natural forces (evident at 78% of the sites visited in 2009) and/or visitor use (evident at 42% of the sites visited in 2009) (NPS 2009c).

Glen Aulin

The large site right at the Glen Aulin High Sierra Camp has been heavily impacted by development, use, and ongoing utilities work at the camp. Approximately three-quarters of the other sites in the broader area of the camp are judged to be in good or fair condition. Four sites are in poor condition, and the condition of seven sites is not known (NPS, Montague 2006b).

Grand Canyon

Within the Grand Canyon of the Tuolumne segment, 39 prehistoric sites have been identified, 8 of which also fall within the Tuolumne Meadows Archeological District (discussed above). Sites located in the Grand Canyon of the Tuolumne provide distinct evidence of trade and travel routes, tool caching, food and medicine procurement and processing, and related settlement. They may also contribute to the understanding of human demography and cultural occupation in recent prehistory. Three sites that are located in the Grand Canyon and also within the Tuolumne Meadows Archeological District have been evaluated for their eligibility to the National Register of Historic Places. Thirty-five prehistoric sites have not been formally evaluated (NPS, Montague 2006b), while 1 site has been recommended as eligible in 2005 (NPS, Gavette 2005b). This site was determined to be in fair condition after being affected by flooding, erosion, illegal collection of artifacts, and scientific study.

The condition of other prehistoric sites in this river segment is, in general, fair to good, with approximately one-third of all documented sites in good condition, and approximately half in fair condition. Three sites are documented as being in poor condition. The condition of several sites in this segment is not known (NPS, Montague 2006b). The most common causes of site disturbance in the river corridor below Tuolumne Meadows are erosion and use by hikers and/or pack stock. Less common sources of disturbance include camping, trail construction, unauthorized collecting or looting, rodent activity, fire, and grazing or trampling. Just under half of the medium- and high-

probability areas within the river corridor below Tuolumne Meadows have been surveyed. It is assumed similar types and levels of disturbance may be found at as-yet undocumented sites. However, since most road and trail corridors have been surveyed, and unsurveyed areas tend to be more isolated, human-related disturbance in unsurveyed areas may be somewhat less.

Below Hetch Hetchy

Sites in the lower elevations of the Sierra Nevada (2,000-4,000 feet) have the potential to be places occupied year-round, which could provide depth of settlement and subsistence data to the archeological record. They are more likely to have architectural features, such as house pits and dance houses, to be associated with burial areas, and to have food storage and cooking features, in contrast to the higher elevation sites. Further, obsidian obtained from Bodie Hills may signify certain cultural affiliation and trade networks, particularly in the most recent prehistoric past.

The one site in the Hetch Hetchy Archeological District that is inside the river corridor was in fair condition in 1997, having been impacted by road construction, fire, and flooding since its original documentation (NPS, Keefe et al. 1999). No new sites have been recorded in the Hetch Hetchy district to date.

Outside of the Hetch Hetchy Archeological District, nine prehistoric sites have been recorded in the lower elevation portions of the river corridor. Four of the sites were considered to be in fair condition, three in good condition, one in poor condition, and one of unknown condition (NPS, Montague 2006b). None of the sites have been formally evaluated for National Register of Historic Places eligibility (NPS, Montague 2006b).

Sites with Traditional Cultural Importance

Ongoing consultations with the associated American Indian tribes and groups is expanding the knowledge of the importance of the river and particular sites to the traditional cultural practices of the tribes. The ancient trail system connecting these sites still retains a relatively high degree of integrity in terms of location, setting, and feeling. The trail system remains important to American Indian tribes and groups as a connection to their ancestors and cultural life ways (Davis-King and Snyder 2010). The unaltered river corridor landscape contributes to the feeling of authenticity of this ancient trail system (Davis-King and Snyder 2010). It is likely that this trail system is eligible for listing on the National Register of Historic Places; however, a formal evaluation for eligibility, including an assessment of its integrity, has not occurred. While the general alignment of this trail system is known, additional information is needed to establish a better understanding of the extent of the system, the relative importance that may be attributed to particular trails, and the structure of the traditional trails, including their physical characteristics, such as length, width, and any drainage structures placed by the tribes.

Management Concerns

Archeological sites in developed areas continue to be at high risk for ongoing visitor- and construction-related impacts (including impacts of facility maintenance and repair). Almost all the sites in the meadows and along the river are impacted by informal trails, many of which emanate from roadside parking and bring visitors close to sensitive sites. Several sites have evidence of camping and campfires. Many sites in Dana and Tuolumne Meadows are at risk of losing some of their integrity from ongoing visitor use impacts associated with informal trails near the sites (NPS, Montague 2006b and 2007p; NPS, Shive 2007a). Many locations of archeological sites in the greater Tuolumne Meadows area, especially adjacent to the Tuolumne River, receive high levels of use in the summer months.

The potential for future development, repair, and maintenance of facilities and underground utilities to support visitor use is also a management concern.

Changes to the ancient trail system are ongoing due to a variety of factors, including administrative use and maintenance work, visitor foot traffic and informal trails, and stock use. While it is acknowledged that trails are not a static resource (by their very nature they change in location and structural characteristics over time), there is not enough information available to determine what impacts historic and current uses are having on the integrity of the ancient trail system as a whole. A baseline understanding of whether the system is eligible for the national register and the status of its integrity is needed.

Parsons Memorial Lodge

Conditions at the Time of Designation

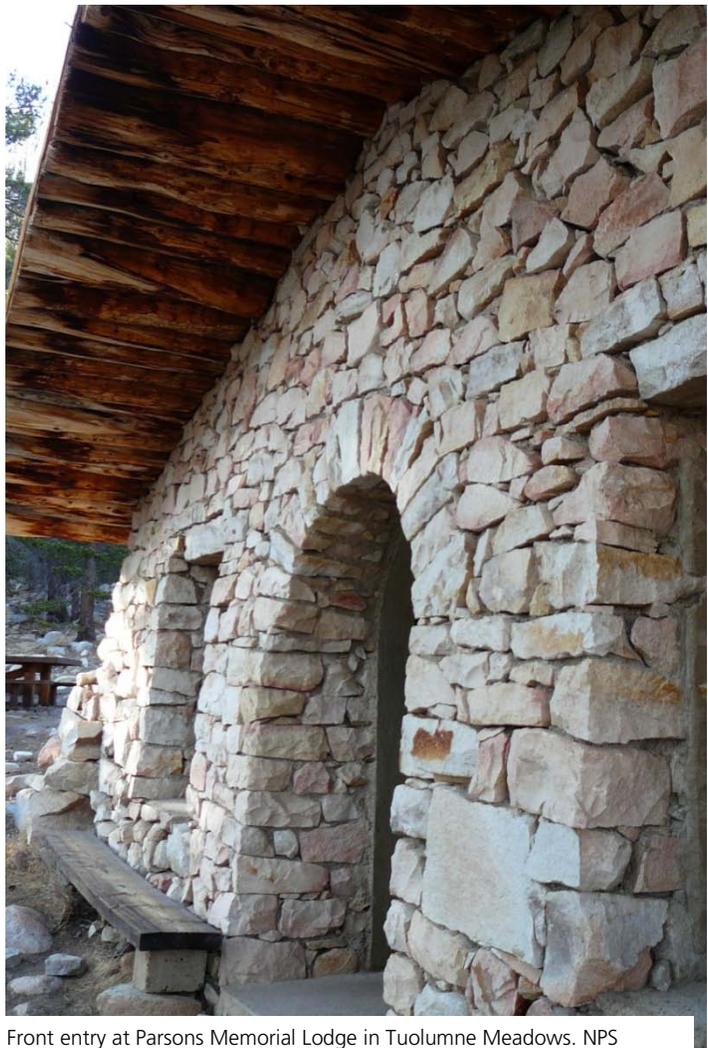
Parsons Memorial Lodge was designed in the office of the renowned Berkeley architect Bernard Maybeck with a thorough understanding of the harsh environmental conditions encountered at its location at 8,640 feet. The national historic landmark nomination for Parsons Memorial Lodge, prepared in 1985, states that the building had undergone a few minor changes over the years, but none that marred its historic integrity. Its condition at that time was rated as good (NPS, Harrison 1985g). It is assumed that the building was in the same condition at the time of designation in 1984.

Current Conditions

The lodge receives scheduled preservation and maintenance treatment and is in good condition (NPS 2007i). It is part of the greater Soda Springs Historic District, which was determined eligible for listing on the National Register of Historic Places in 2007. The structure continues to be used as gathering place, as it was historically.

Management Concerns

There are no immediate management concerns associated with the condition of Parsons Memorial Lodge.



Front entry at Parsons Memorial Lodge in Tuolumne Meadows. NPS photo by Kristina Rylands

Scenic Values

Scenic Corridor through Lyell Canyon

Condition at the Time of Designation

The Tuolumne Wild and Scenic River Study (USFS and NPS 1979) found that the area's unspoiled condition, its variety of landscape types, its vegetation, and its backcountry values ranked that portion of the river at least as high as the national forest portion (which had been studied and given a high aesthetic rating compared with other rivers).

Current Condition

Views from the river and trails in Lyell Canyon continue to have high aesthetic value.

Management Concerns

There are no immediate management concerns associated with the condition of the scenic corridor through Lyell Canyon. As in all wild segments of the river (also located in designated wilderness), scenic values will continue to be shaped by natural processes.



Views of upper Lyell Canyon. NPS photo by Kristina Rylands

Scenic Corridors and Vista Points through Dana and Tuolumne Meadows

Condition at the Time of Designation

Expansive views were afforded by the natural vegetation patterns at Tuolumne Meadows. The natural features created numerous scenic viewing opportunities, ranging from high panoramic views to views into and away from Tuolumne Meadows. Views into and away from the meadows were maintained and occasionally expanded by the mechanical removal of encroaching lodgepole pines. Additionally, the siting of all post-1920s development was guided by the principle of not obstructing or competing with the naturally occurring views and vistas. Reducing human visual impacts was a key reason for realigning the Tioga Road and eliminating all camping inside the meadow. Building locations and circulation patterns were designed to take advantage of the scenic opportunities of this landscape, while remaining as unobtrusive as possible (NPS 2007h).

Current Condition

At the scale of the river segments, views from trails and vista points through Dana and Tuolumne Meadows continue to have high aesthetic value. The predominantly open meadows provide for a remarkable series of visual experiences, including unobstructed views of the craggy Sierran horizon line, watching dramatic weather formations roll in from the west, and stargazing. Even from the periphery of the meadows, where denser vegetation obstructs the panoramic views, a sense of openness is provided by glimpses of the meadows and distant peaks between the trees.

The built environment at Tuolumne Meadows remains relatively unchanged since the river was designated and the Tuolumne Meadows segment was classified as scenic. Most development remains sited just within the surrounding forest, to take advantage of views and to prevent any development that might obstruct views into and across the meadows themselves (NPS 2007h). A scenic analysis conducted in 2007 for the Tuolumne River Plan categorized the Tuolumne Meadows area into four visibility zones. This analysis (NPS, Torgerson and Schaible 2007e) is described in greater detail under “Site Planning Considerations” in chapter 8. Most existing structures are in low to moderate visibility zones. Sources of artificial light at Tuolumne Meadows are still very low (NPS, Duriscoe 2005a). Draft outdoor lighting guidelines have been developed to protect night skies in Tuolumne Meadows from artificial light associated with visitor and administrative activities (NPS 2008b). The important visual relationships between the natural features of Tuolumne Meadows and its adjacent developed areas remain largely intact (NPS 2007h).

Management Concerns

Views into and away from Tuolumne Meadows are being encroached upon by roadside parking, which has increased since the 1997 flood destroyed the Cathedral Lakes parking area. Lodgepole pines are also encroaching into views. This encroachment may be a response to changes in average precipitation and other factors (see “Biological Values,” above).

View Corridor through the Grand Canyon of the Tuolumne

Condition at the Time of Designation

The Tuolumne Wild and Scenic River Study (USFS and NPS 1979) found that the area's unspoiled condition, its variety of landscape types, its vegetation, and its backcountry values ranked that portion of the river at least as high as the national forest portion (which had been studied and given a high aesthetic rating compared with other rivers).

Current Condition

Views from the trail through the Grand Canyon of the Tuolumne continue to have high aesthetic value. At Glen Aulin, infrastructure associated with the High Sierra camp, including a utility shed with a small solar panel and water pipes, is visible from some locations in the river corridor.

Management Concerns

There are no foreseeable management concerns associated with the condition of scenic value in the Grand Canyon of the Tuolumne. As in all areas in the wild segments of the river (also located in designated wilderness), scenic values will continue to be dominated by natural processes.



Peaceful pools and plunging waterfalls follow the length of the river through the Grand Canyon. Photo Courtesy of Ron Stork

Recreational Value

Wilderness-Oriented Recreational Opportunities

Condition at the Time of Designation

Abundant wilderness-oriented recreational and educational opportunities were available at the time of designation. They included day hiking, overnight backpacking, swimming, wading, fishing, camping, climbing, horseback riding, picnicking, artistic pursuits (e.g., painting, writing, photography, sketching), sightseeing, nature study (e.g., studying wildflowers, wildlife viewing, enjoying scenery, etc.), and skiing and snowshoeing in winter. Tioga Road offered excellent opportunities for scenic driving. The Tuolumne Wild and Scenic River Study (USFS and NPS 1979) noted that Tuolumne Meadows contained one of the largest campgrounds in the national park system and served as a major trailhead into the spectacular Yosemite backcountry. It noted that the number of visitors in the Tuolumne Meadows area reached 3,000 per day during the peak summer season.

As the popularity for backpacking boomed in the late 1960s and 1970s, campsites proliferated throughout Yosemite's backcountry. Some areas had hundreds of campsites, with documented impacts such as vegetation loss, soil compaction, firewood depletion, and informal trail formation. The Yosemite wilderness trailhead quota system was developed in the 1970s in response to this change (van Wagtenonk and Coho 1980 and 1986). The backcountry area of the park was divided into travel zones. For each zone a capacity was set based on the number of acres and miles of trails and desired sociological densities for campsites and trails. These values were then adjusted downward to account for ecological factors. Those zones with ecosystems that were rare or vulnerable (such as those with subalpine meadows, like those in the Tuolumne River corridor), or that did not have a high potential to recuperate or be repaired (such as those with alpine meadows), had capacities reduced. While this research took place more than thirty years ago, the ecological and social factors that the capacities are based on are little changed (NPS, Fincher 2010d).

By the time the river was designated (the same time that the Yosemite Wilderness was designated), the trailhead quotas were limiting the number of overnight visitors in the wilderness, and thus limiting the number of campsites. Requiring a wilderness permit also allowed the NPS staff to have a face-to-face educational contact with every party spending the night in the wilderness. Leave-No-Trace education and low-impact camping practices were beginning to better protect wilderness and river values. Campers were instructed in how to minimize or avoid impacts to water quality, sensitive resources, and wildlife: to camp in existing sites, minimize trips to water to avoid informal trailing, properly dispose of human waste and dishwater, leave artifacts where they found them, store food to prevent feeding wildlife, etc.

The quota system was not designed to work by itself in limiting these impacts. Monitoring and restoration of wilderness campsites were also key components. Campsite monitoring and restoration of backcountry campsites started in the 1960s. Wilderness rangers and wilderness restoration crews began to restore campsites close to water, while leaving those in more durable locations and encouraging visitors to camp in those existing sites. All these efforts were starting to improve ecological conditions in the backcountry, and the associated wilderness experience, at the time of the Tuolumne River's designation.

Current Conditions

Abundant wilderness-oriented recreational and educational opportunities remain available in the river corridor. These opportunities have not changed since the time of designation (see above), with the exception that the number of campsites in the Tuolumne Meadows campground has been reduced from

about 600 sites (USFWS and NPS 1979) to 304 sites to provide better site separation and protection of natural features. As shown in table 5-1 sightseeing and day hiking are the most-often reported primary activities of Tuolumne area visitors, and about a third of visitors report spending at least one night in the corridor (Littlejohn et al. 2005; Le et al. 2008). Winter activities include cross-country skiing, trans-Sierra ski trips, snowshoeing, winter camping, overnight accommodations at the Tuolumne Meadows hut, and some day use and overnight use below Hetch Hetchy Reservoir. Shoulder season activities, including cycling and more accessible cross-country skiing, occur along the Tioga Road, depending on seasonal weather.

Table 5-1. Tuolumne Visitor Activities

	% Participating in Activity	% Identifying Activity as Their Primary Activity
Sightsee/take a scenic drive	91.9	60.0
Visit visitor center	58.9	0
Paint/draw/take photographs	54.1	4.4
Day hike	51.6	18.7
View wildlife/birdwatching	44.7	1.8
View roadside/trailside exhibits	44.3	0.4
Shop in park (other than park bookstore)	44.3	0
Eat in park restaurant	43.5	0
Picnic	37.8	0.4
Shop in park bookstore	33.3	0
Visit museum	26.4	0
Camp in developed campground	16.3	4.0
Other	14.6	4.9
Stay in park lodging	12.6	0
Attend ranger-led programs	8.9	0.4
Climbing	7.3	1.2
Overnight backpack	4.5	3.6

Public comments speak to the current value of recreation within the Tuolumne River corridor (NPS 2006c):

Tuolumne Meadows has the feeling of being a wilderness outpost of the park, and not as heavily visited an area as other parts of Yosemite. People can slow down and remember the essentials of living, breathing, relaxing. And the variety of trails with varying topography, offers so many different opportunities to challenge oneself or to just enjoy the day sitting along the Tuolumne River.

(Individual, Yosemite, CA, Comment #352-8)

My dream is to be able to continue to share this area with my children and grandchildren. Through hiking, backpacking and playing in the river, I hope to be able to teach them about conservation, minimum impact and respect of nature so that they can grow up feeling passionate and invested in saving this incredible, awe inspiring and special place!!!!

(Individual, Lake Forest, CA, Comment #185-20)

Wild Segments (Designated Wilderness)

The wild segments of the Tuolumne River corridor continue to offer a wide spectrum of opportunities for solitude and self-sufficient recreation, with visitors enjoying the same activities they did in 1984. Use in designated wilderness remains largely unconfined, relying on the current wilderness trailhead quota system, restrictions on camping in sensitive areas, and group size limitations to protect river values. Monitoring of resource conditions has led to adjustments in the wilderness trailhead quotas, and, by extension, the zone capacities themselves. In 1984, for example, the quota for Lyell Canyon was 50 people per day. The quota has since been lowered to 40 people per day to reduce impacts from camping to an acceptable level. Other management responses to unacceptable impacts discovered through this monitoring have included site-specific regulations (such as fire prohibitions), increased patrol, and major restoration efforts. Lyell Canyon, in particular, has seen extensive restoration of campsites since 1984. In contrast, at Glen Aulin, where camping impacts were found to be unacceptable, the management response was to establish a designated backpacker campground and require people camping in the area to stay there. As a result more people could be accommodated with less physical impact, and the quota was raised from 25 to 35 people per day (NPS, Fincher 2010d).

Many different variables are monitored to determine the effectiveness of the quota system, such as water quality, meadow health, formal trail conditions, informal trails, day use levels, encounters, people at one time, and campsite numbers and condition. Monitoring of wilderness campsites provides a good example of observed trends. Campsite numbers and conditions were first inventoried by Daniel Holmes in 1972 (NPS, Holmes 1972). In the 1980s they were inventoried again using the Wilderness Inventory and Monitoring System (WIMS) (Sydoriak 1986). In the 1990s, and again in the 2000s, a sample of wilderness campsites was assessed (WIMS 2 and WIMS 3). Analysis of these four data sets (spread over 35 years) shows a positive trend and steady improvement over time. The total number of campsites is decreasing, sites with large impacts are being restored, and overall impacts continue to show a significant decrease with each round of monitoring. An example of this trend at a specific location is provided by Pate Valley. When Pate Valley was surveyed in 1984 (the year the



Backpackers along the Grand Canyon of the Tuolumne. NPS photo by Kristina Rylands

Tuolumne Wild and Scenic River was designated), 18 campsites were recorded, while a 2006 survey recorded only 9 campsites there. In 1984 five of the sites were within 25 feet of water; in 2006 only one site was that close (NPS, Fincher 2010d).

The monitoring data indicate that with the quota system in place, people’s overnight wilderness experiences are protected from crowding and perceptions of human disturbance. However, this limitation on access temporarily denies some individuals access to a particular location on a particular date if the quota is already filled. Overnight wilderness visitors’ attitudes about their wilderness experience were studied in 2001-2002 (Newman 2002). Respondents were asked not only to trace their daily route of travel, but to make evaluative judgments concerning qualities that contribute to a positive wilderness experience. The study found that when considering how best to manage visitor use to protect wilderness experiences, the following factors are relatively important: (1) signs of human use at camping sites; (2) numbers of people encountered per day when hiking; (3) encountering stock or signs of stock use; (4) regulation of camping; (5) the chance of obtaining a wilderness permit; and (6) the opportunity to camp out of sight/sound of other groups. The study findings suggest that Yosemite Wilderness visitors are willing to trade-off freedoms, such as camping regulation and some degree of access, in order to obtain a high quality recreation experience (Newman 2002).

While overnight visitation to the Yosemite wilderness has decreased substantially since the quota system was instituted, demand for wilderness permits in the Tuolumne River corridor remains well above the quotas. Thus the quota system is still vital in protecting river values from the potential threats listed above.

According to Pettebone and others (2008), at least a third to more than a half of all use on the three major trailheads originating in Tuolumne Meadows (Glen Aulin, Cathedral Lakes, and Twin Bridges along the Lyell Fork) is day use (see figure -10).

Therefore, it is not surprising that increasing day use levels are contributing to increased perceptions of crowding on trails within a day hike of Tuolumne Meadows trailheads, particularly on the trail segment following the river from Tuolumne Meadows to Glen Aulin. The standard of no more than 8 encounters with other parties per hour 80% of the time was exceeded in 2010 on the trail to Glen Aulin (NPS, Broom and Hall 2010).

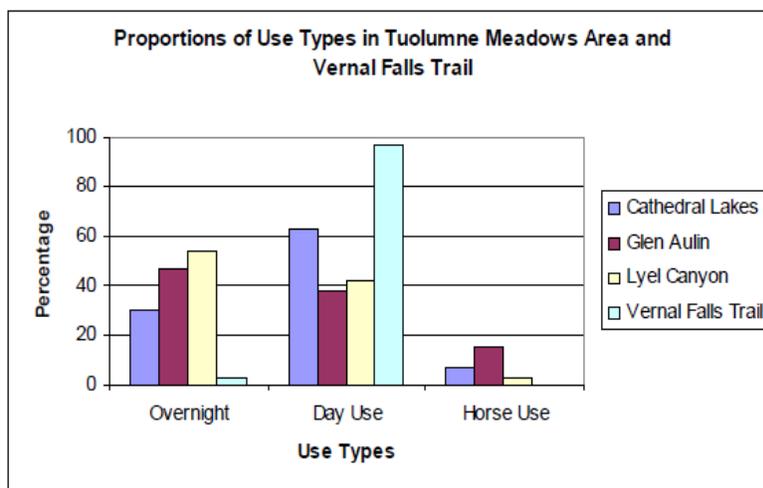


Figure 5-10. Mean Hourly Visitation on Three Primary Tuolumne Meadows Trailheads (Pettebone and Newman 2008)

Tuolumne Meadows and the Tioga Road Corridor

Visitors to Tuolumne Meadows continue to find a great diversity of recreational and educational opportunities easily accessible to people of various ages and abilities. Access to the meadows and river within the Tuolumne Meadows area remains largely unrestricted. Visitors park wherever they can,

often along the shoulders of Tioga Road and other access roads, and walk out into the meadows and along the river shoreline at will, creating many informal trails. People play games in the meadows, and picnickers spread blankets over meadow vegetation. Although visitors are satisfied with this level of accessibility (see below), the cumulative impacts of current patterns and levels of use are contributing to changes in meadow habitats, as described under “Biological Values,” above.



Twin Bridges along the Lyell Fork (above, below) is a popular short day hike. NPS photos by Kristina Rylands

According to public scoping comments and comments received throughout the Tuolumne River planning process, visitors agree they have easy access to important park sites and attractions, they connect with the natural environment, they experience a sense of freedom, it is easy to access scenic overlooks/vistas, and they can go “where they want, when they want” (NPS 2006c; White 2010). However, they also express some dissatisfaction with vehicle congestion, crowding at popular spots along the river and in the meadow, and the frequency of encounters along trails. The demand for the 304 campsites in the campground and the 69 tent cabins at the Tuolumne Meadows Lodge is high, and some visitors are not able to access these facilities during peak use periods.



The ability to enjoy the sounds of nature is a part of the recreation value throughout the Tuolumne River corridor. Natural soundscapes are an inherent part of habitats and important to many wildlife species. They are also important to people seeking solitude in wilderness or otherwise seeking to connect with nature through traditional cultural activities, nature study, or outdoor recreation. In 2006, a study was conducted to identify the types of sounds heard by park visitors during their visit to Tuolumne Meadows, along with visitor perceptions of those sounds and their frequency (Newman et al. 2006). The study found that natural soundscapes remain dominant in the meadows, even at popular destinations, but that unnatural noise is a common occurrence (Newman et al. 2006). In-park sources of unnatural sound are vehicle noise along the Tioga Road and administrative roads, and other human-caused sounds (e.g., voices and activity) close to visitor service and administrative areas, the campground, and popular destinations, such as the Soda Springs complex.

Current visitor use levels are estimated at over 4,000 people at one time in Tuolumne Meadows (based on cars parked in day and overnight parking, including parking at the campground). No comparative data are available for the time of designation. However, there has been a 42% increase in visitation parkwide since the Tuolumne was designated (total park visitation reported by the NPS Public Use Statistics Office was 2.74 million in 1984, compared with 3.9 million in 2010).

Visitor use patterns are changing parkwide, as more day users visit the park. A study conducted in 2006 (DEA 2007) found that the overall average parking duration at Tuolumne Meadows was only 1.3 hours, with the majority (69%) of vehicles parking for less than one hour (see figure 5-11). This indicates that day users with only a short time to spend in the area comprise a significant part of the visitor population.

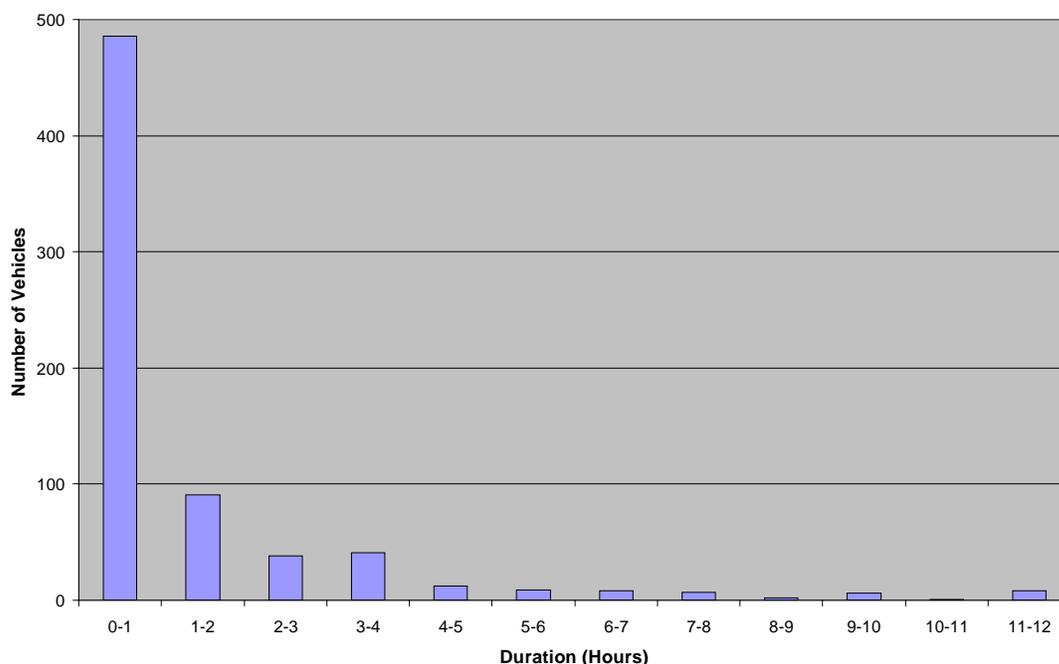


Figure 5-11. Overall Vehicle Parking Occupancy by Facility Type (DEA 2007)

Management Concerns

Internal, tribal, and public scoping produced more comments about the nature of the visitor experience than any other general topic (NPS 2006c). It is fair to say that many people are passionate about the kinds of experiences they desire along the Tuolumne, but that they sometimes see other people's desired experiences conflicting with their own (NPS 2006c).

As previously noted, the wilderness overnight trailhead quota system, inaugurated in 1977 and adjusted periodically based on updated information, remains an effective tool for preserving wilderness character and opportunities for primitive, unconfined recreation and solitude in most parts of the river corridor (NPS, Fincher 2010d). Monitoring has shown that impacts to river values from wilderness camping under the existing capacities are within acceptable limits. However, as noted previously, wilderness trails within the first few miles of Tuolumne Meadows trailheads are receiving increasingly large amounts of day use, which is not covered by the overnight trailhead quota system.

Public comments, supported by research, indicate that stock use can affect a visitor's wilderness experience either positively or negatively, depending on their wilderness values. Some people think stock use enhances the cultural or historic feeling of a wilderness experience, while others dislike the aesthetic effects, such as manure and urine on trails. Commercially supported stock use is seen by some as a nonessential service in wilderness, where self-reliance is a valued part of the wilderness experience. Similarly, some people commented during public scoping that nonmotorized recreational boating should be allowed on the Tuolumne, while others commented that it should continue to be prohibited (NPS 2006c).



RV parked along Tioga Road in Tuolumne Meadows. NPS photo by Kristina Rylands

Most of the concerns related to recreational values focus on the Tuolumne Meadows area. As the popularity of the area has increased, crowding and congestion—particularly vehicle congestion and crowding at popular spots along the river and in the meadows—have begun to change the visitor experience. As described above, some visitors have expressed dissatisfaction with vehicle congestion and crowding. The potential for further increases in visitation would be expected to increase visitor dissatisfaction in the future without management action to protect the wilderness-oriented visitor experience.

The outstanding recreational value of the Tuolumne River corridor is the opportunity it affords for wilderness-oriented recreation, where dramatic scenery, the sounds of nature, and opportunities for relative solitude shape the experience. This value could, and does, mean different things to different people, as they expressed during public scoping. For many visitors, including the majority of visitors who commented during public scoping, a traditional park experience, including family camping and lodging, is what they value most about their visit to Tuolumne. With changing use patterns, however, the majority of visitors now are day visitors, with only a short time to spend near the river. Site development at Tuolumne Meadows has not changed substantially over the past 50 years, when most visitors came to spend several days in the area. Opportunities oriented to a growing preponderance of day users are needed to create more meaningful experiences for these visitors.



Tuolumne Interpretive Ranger Carl Sharsmith shares the joy of stream crossing along the Tuolumne River with park visitors, circa 1970. He once said, "The more you see, the more you know." NPS Photo

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