

Some Practical Considerations in Restoration of Wilderness Geodiversity: Insights From Lake Pedder, Tasmania

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Abstract—Geodiversity values involve aspects of the abiotic environment that are sometimes the dominant element that imparts scenic and wilderness value, are scientifically important in their own right, and almost invariably form the essential habitat for the biodiversity that is often the main target of modern conservation policies. Given this dominance of the physical landscape over other aspects of wilderness character, the potential for restoration of degraded wilderness depends foremost on the significance and resilience of the landforms and the capacity for them to recover over an acceptable time frame. The contradiction between the expectations that wilderness is in pristine natural condition, should be available for recreational use, yet is devoid of artificial intervention in natural processes must also be addressed. This challenge looms increasingly large in a world in which virtually all wilderness areas now face anthropogenic climate change that is increasingly distorting natural processes. This paper illustrates a geomorphological approach to assessing wilderness restoration prospects by presenting a case study of potential restoration of the original Lake Pedder, a scenic glacial lake that was widely regarded as both the heart and crown jewel of the Tasmanian wilderness prior to its inundation beneath a large hydro-electric reservoir in the early 1970s. The applicability of this approach to assessing potential wilderness restoration endeavours elsewhere is discussed.

Introduction

Geodiversity values involve aspects of the abiotic environment that are often the dominant element that imparts scenic and wilderness value, are scientifically important in their own right, and almost invariably form essential habitat for the biodiversity that is often the main target of modern conservation policies (Gray 2003; Kiernan 1991, 1996; Sharples 1995). Geconservationists focus on protection of important geological features, landforms, soil types and natural geo-processes, aiming to safeguard specific sites deemed outstanding in some way or that are representative of geodiversity, and natural types, timing, rates and magnitude of geo-processes. Implicit in this approach is the belief that nature conservation should include a concern

with safeguarding overall environmental diversity rather than being locked into a narrow focus just on biodiversity (ACIUCN 1996).

Many of the attributes that first triggered conservation initiatives were related to landforms rather than biology. Thus, the geysers of Yellowstone, U.S.A., a small cave containing a hot spring at Banff, Canada, and the Jenolan Caves in Australia were early stimuli to later broader conservation initiatives in those areas. The original Lake Pedder was widely regarded as both the heart and crown jewel of the Tasmanian wilderness prior to its inundation beneath a large hydro-electric reservoir in the early 1970s (fig. 1). This development caused by far the greatest loss of wilderness of any single development in Tasmania (Lesslie and others 1988). The campaign against the dams played a major role in development of the modern conservation movement in Australia, giving birth to the world's first Green political party, stimulating formation of a national Wilderness Society, and laying the foundation for eventual establishment of the Tasmanian Wilderness World Heritage Area. This defining battle in the emergence of wilderness conservation in Australia was fought almost entirely on the basis of the physical attributes of the Pedder environment, the discovery of endemic species in the area occurring only late in the campaign and even then being viewed as supplementary rather than fundamental to the case against the dams.

Landforms such as Lake Pedder may be perceived as being of significance for their existence value, a recognition that they are of great worth in their own right irrespective of their utility to others. They may also be judged important for their underpinning of natural processes, including geosystem and ecosystem support. Finally, landforms may be of instrumental value to humans for spiritual, aesthetic, recreational, scientific, educational, economic and other reasons (Kiernan 1996). Many of these attributes potentially contribute to the range of values typically sought in wilderness.

There is a common misconception that any phenomenon to which the term *geo* is affixed must be made of solid rock and therefore inherently robust and require little protective management, but there are numerous examples of loss and damage to important features. Landforms composed of unconsolidated sediments are particularly vulnerable. The geomorphology of an area is defined by its contours, hence, any artificial change to those contours at whatever scale *by definition* constitutes damage to the geomorphology. The real questions concern the degree to which important values are compromised, the extent of damage, and the potential for natural or assisted recovery of damaged values. As in bioconservation, it is often necessary to safeguard all components of natural geo-systems (including palaeo-systems), such as

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In: Watson, Alan; Sproull, Janet; Dean, Liese, comps. 2007. Science and stewardship to protect and sustain wilderness values: eighth World Wilderness Congress symposium: September 30–October 6, 2005; Anchorage, AK. Proceedings RMRS-P-49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.



Figure 1—Lake Pedder beach and the Frankland Range, Southwest Tasmania (photo by author).

the catchment from which water is delivered to sustain a limestone cave. Moreover, the value of a set of landforms such as those around Lake Pedder may exceed the sum value of its individual parts (Kiernan 1991).

Inclusion of the artificial reservoir that drowned Lake Pedder within the boundaries of the Tasmanian WHA was accepted by the World Heritage Bureau in the express hope that the original Lake Pedder might one day be restored. The 1994 IUCN General Assembly in Buenos Aires passed a resolution seeking restoration. Ongoing calls for restoration of the original Lake Pedder mirror similar pressures to restore wilderness affected by dams at sites such as Hetch Hetchy and Glen Canyon, USA. The practicality of such proposals is dependent upon the capacity of the environment to recover to an acceptable degree if an impoundment is drained.

Wilderness Restoration: A Contradiction In Terms?

Pressures on the environment are increasing and there are few places that have not now felt human impact. This situation poses significant management challenges given the internal contradictions already inherent in the expectations of many wilderness advocates and some of the legislative frameworks for wilderness protection. For example, the goals specified in the U.S.A. *Wilderness Act* (1964) include preservation of natural or pristine conditions, avoidance of intentional environmental manipulation, and provision of opportunity for recreational use. The wilderness manager

is already faced with difficult trade-offs. These challenges have now been superimposed by broader-scale pollution of air and water, changes to ambient light levels (night-time increases and global dimming by day) and gross changes to geomorphological processes caused by anthropogenic climate change. While Earth history is a story of continuous natural long-term environmental change, those changes evident since the industrial revolution are inconsistent with the type, timing, rate and magnitude of earlier natural change.

Responding to on-site consequences of global environmental change or restoring a wilderness valley after removal of a dam both involve the same necessity for managers to become involved in direct environmental manipulation. That implies first making decisions about what is “natural” or “pristine” and then working to retain it or facilitate its re-creation. This is not akin to building an artificial replica of a historic house but instead involves working with the self-regenerating capacity that is possessed by many natural systems.

A very cautious approach is required when contemplating intervention in complex natural systems given limited understanding and the dangers that erroneous actions may pose for Earth’s already diminished stock of wilderness. In addition to their potential value in returning to wild condition precious places that were once wild, attempts to restore wilderness values to areas where they have been largely erased can also provide learning experiences that will better inform the inevitably much riskier intervention that will increasingly be needed in order to redress problems in areas where wilderness integrity still remains relatively high.

Wilderness Geodiversity Restoration After Decommissioning of Dams

What are the prospects for recovering geoheritage drowned beneath artificial reservoirs, the environmental diversity the landforms under-pinned, and the wilderness character that may previously have existed? Answering this question requires identification of the values the site previously contributed to overall wilderness value, followed by realistic assessment of the potential for their return. Evaluation involves a three step process: (1) inventory of the geodiversity present, (2) assessment of its significance in intrinsic, natural system support and/or human instrumental terms; and, (3) evaluation of the potential for the return of the geodiversity values.

Geodiversity significance assessment requires investigation at a number of levels:

- *System controls* — the geological, climatic/palaeoclimatic/temporal, etc., context within which landforms have evolved;
- *Landforms & landform assemblages* — analogous to biological species and communities; some landform types are common and some are rare, some are robust and some are fragile;
- *Landform contents* — sediments, archaeological material or biota dependant upon the landform in which they are contained may impart value to a landform that might not have been considered significant in its own right; and
- *Human use* — past, present, future.

From a geomorphological perspective there are four critical principals to consider in assessing the feasibility of restoration proposals.

1. *Material Resilience Principle*: Landforms composed of hard bedrock are susceptible to damage by deliberate actions such as quarrying, but they are much less susceptible to more subtle processes such as erosion by water or wind than are depositional landforms that consist of unconsolidated sediments. Dams are typically constructed in gorges eroded in robust bedrock but other surfaces surrounding and within the reservoir area may host landforms comprised of less resilient material.

2. *Impacting Forces Principle*: The impacting forces may be either the direct result of human activity, such as use of explosives, or by-products of human activity, such as erosion caused by run-off of water from a disturbed area. The duration of these forces can also be important, although typically geomorphic change is caused more by extreme events such as major floods than by prolonged moderate run-off. Direct contour change is generally localized around the actual dam-sites and associated quarries and roads, while the wider reservoir area is affected by a change to predominantly lacustrine geomorphological processes.

3. *Landform Age Principle*: An ancient landform has been through a long period of weathering and erosion such that the surviving morphology is likely to be relatively robust. Conversely, a very young landform may be at relatively higher risk of damage because it may retain considerable subtle detail. The gorges in which dams are constructed are typically relatively old features but other younger features

that were morphologically fresh prior to inundation may occur close to stream level and within the reservoir area.

4. *Genetic Process Continuity Principle*: The potential for natural healing depends upon whether the key natural processes that first formed a landform are still operating. Even if the damaging agent is removed there is limited if any potential for natural healing of a landform created by geomorphic processes that are no longer operating (for example, previous glaciation) or are operating at much changed intensity. If the gorge dammed was created by fluvial erosion that process is likely to be able to resume if the dam is removed, but there are likely to be other landforms within the reservoir area that were formed by a variety of other processes.

Case Study: Geodiversity Inventory and Geoheritage Evaluation of Lake Pedder

A review of the key attributes identified by a reconnaissance geodiversity inventory of Lake Pedder is available elsewhere (Kiernan 2001a; see also <http://www.lakepedder.org/resources/reports>) and need only be summarized here. It has shown that the geo-conservation significance of Lake Pedder at various levels of evaluation varies from global to local in scale. Note that this particular assessment relates only to geoscientific values and does not take account of existence values, ecosystem support functions or biodiversity, or non-geoscientific instrumental values to humans such as spiritual, aesthetic, wilderness or biological science.

Systems Level. The lake basin at Pedder was formed by tributary mountain glacier deposits damming a major trunk valley (the Serpentine Valley). The geographical context of Lake Pedder is globally significant. Important differences exist between the long-term climate histories of the northern and southern hemispheres and resulting glacial systems. In contrast to the northern hemisphere, the temperate southern latitudes are predominantly oceanic, reducing the potential for terrestrial evidence of past glaciation and implying glaciological differences from the continental ice sheets of Eurasia and North America. In contrast to other southern temperate glaciated areas, Tasmania is tectonically stable, allowing survival of very ancient glacial features, some of which date from the onset of glaciation in the Antarctic region over 30 million years ago. The rock types in which the glacial landforms of western Tasmania have developed are not present in the other glaciated areas of southern temperate latitudes. Nothing comparable to Lake Pedder in terms of this particular mode of genesis giving rise to a lake of similar size and character has been identified from the world geomorphological literature.

Landforms Level. Both the individual landforms and the genetically-related set of landforms were significant. The shallow (3 m) (10 ft) Lake Pedder lake basin was part of a wider landform community that included glacial features on the adjacent Frankland Range, itself an exemplar of the importance of snow-fence and shading effects on glaciation in southern temperate latitudes (Davies 1967). The individual mountain cirques are significant at a state level, which given negligible past glaciation of mainland Australia, implies national significance. The significance of the landforms produced by glacial deposition cannot be as-

sessed fully due to inundation by the reservoir. The fluvial geomorphology was also significant. Upstream of Lake Pedder and the smaller Maria Lakes lagoon system on its eastern margin the drainage system in the trunk valley comprised strongly braided channels. In contrast, the Serpentine River, which drained the lake and regulated lake level, occupied a highly sinuous single channel, its character being genetically influenced by past glaciation in a manner not apparently recorded elsewhere in the world literature.

Lake Pedder was also a nested set of component landforms, many of which were the result of ongoing post-glacial processes. They included lake margin features such as beaches, barriers, spits and bars. The main beach, formed partly of pink quartz sand and up to 600 m (656 yards) wide in summer, was more extensively developed than any comparable freshwater system in Australia (Bayly and others 1972; Timms 1992). Barriers or offshore bars are otherwise rare in Australian lakes, and the only others are in very different environments. The bar featured spectacular mega-ripple structures (fig. 2) that projected into the lake for over 400 m (437 yards) beyond the beach and which differed in form from the nearest analogues identified in the world literature. A major lunette bounding the beach was noteworthy for its

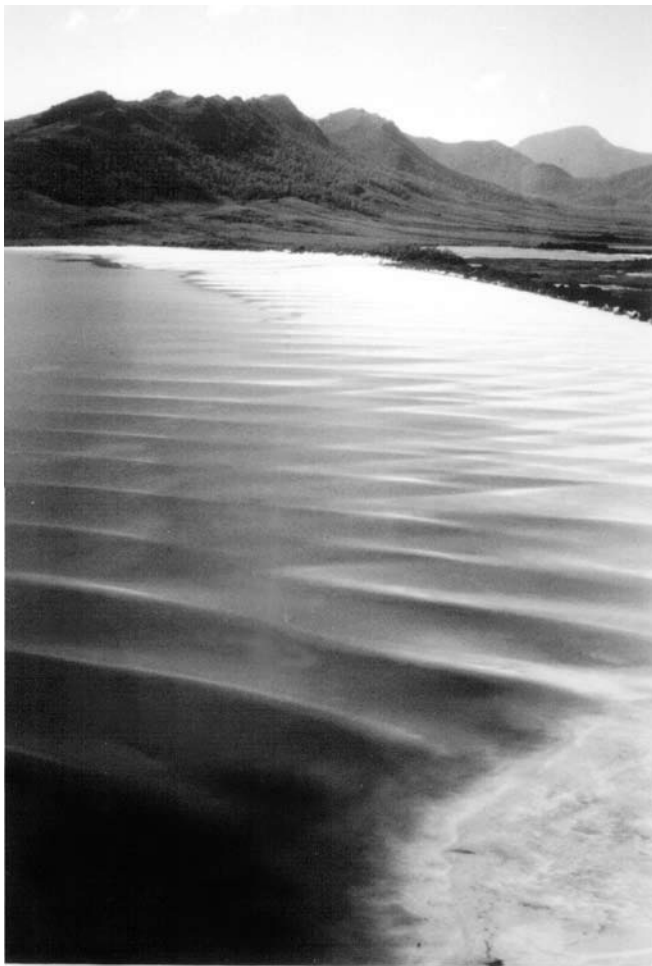


Figure 2—Aerial view of the Lake Pedder megaripple system (photo by author).

very humid environmental setting. It was also by far the largest “dune” on an Australian glacial lake.

Landform Contents Level. From a geoscientific perspective the most significant known attributes at this level were planar concretions of iron with minor manganese formed around pebbles to produce what were known as Pedder Pennies. Their character was very different from related phenomena found at a handful of other Tasmanian sites (Tyler and Buckney 1980). They were morphologically similar to some related features recorded from the Gulf of Finland but genetically more similar to forms in some Canadian freshwater lakes, although the iron content was much higher and manganese content very much less at Pedder than in Canada.

Human Use Level. In addition to its great inspirational and recreational value, from a geoscientific perspective, the Pedder area was important to development of some early concepts in Tasmanian glacial research, and its significance is compounded by an association with at least one notable geoscientist. Damming has precluded capitalizing on its geo-scientific assets, but the area remains a storehouse of untapped evidence concerning environmental history and change, and geodiversity-biodiversity relationships.

Prospects for Restoration

Direct contour change due to construction activity did not occur within several kilometres of Lake Pedder itself, hence the principle changes are those associated with superimposing a much larger artificial water body on the landscape. The principals enunciated earlier coupled with observations made as the reservoir filled and insights obtained from other temporarily drained Tasmanian reservoirs, provide the principal sources for conclusions on landform recoverability, together with some observations made by bathymetry and diving.

That the lake basin and Serpentine outlet remain intact has been proven by bathymetric surveys (Tyler and others 1996). There has been negligible sediment infill (either minerogenic or organic) with diving and grab sampling having revealed that no more than a few millimetres of organic sediment have accumulated. Sand is still exposed on the original beach. All principal geomorphological features formed by past cold-climate processes are known to remain intact (Kiernan 2001b).

The other landforms nested within the lake basin also appear to be mostly intact but even if they were not, the fact that they were formed by contemporary processes means the potential exists for natural healing. Features known to be intact include the megaripples and smaller ripples. Pedder Pennies have been recorded still lying on the sand. Underwater photography obtained by the Australian Broadcasting Commission revealed that even the slight indentations in the sand made by light aircraft that last landed on the beach prior to damming remain readily identifiable. Erosion of the dune system as the reservoir filled was very limited (maximum cut-back less than 5 percent of the narrowest part of the lunette). The dune face was naturally eroded as the lake level rose when the Serpentine River was unable to discharge the entire winter inflow. Sand blown from the exposed beach nourished the dune in summer. Because the

reservoir surface lays 16 m (52 ft) above the original lake and is limited to 1.5 m (5 ft) fluctuation by statute, the dunes are now too deep to be disturbed by the short wave-length wind waves.

Erosion has occurred around some parts of the wider reservoir perimeter but it is limited and discontinuous, does not significantly affect the key landforms, and would be inconspicuous from Pedder beach. Its confinement to a band usually no more than 3 to 4 m (10 to 13 ft) in vertical extent would imply visual disturbance no greater than that caused by discontinuous lengths of vehicular track that could rapidly be screened by low vegetation. Undecomposed peat on the dunes and valley floor remains intact hence it continues to protect the underlying sediments. Remnant viable seed is not out of the question. Significant weed invasion is unlikely (Balmer and Corbett 2001).

Discussion

A 1995 Australian Parliamentary enquiry concluded that the political climate was not appropriate for priority to be given to restoration of Lake Pedder but that restoration was technically achievable (Australia 1995). Many of the classic photographic images taken from the beach of Lake Pedder might be captured again almost immediately after the reservoir was drained, and few if any significant long-term technical obstacles to restoring the wilderness character of the area are likely to arise (Kiernan 2001b). Restoration would increase the integrity of the WHA by facilitating protection of the set of geodiversity values, the World Heritage Guidelines stipulating that the areas described should retain all or most of the key inter-related and interdependent elements in their natural relationships (UNESCO 1984). The progressive loss of wilderness documented as development intruded (Lesslie and others 1988) would be reversed by restoration of Lake Pedder and rehabilitation of dam-building roads, reducing a major re-entrant into the boundaries of the WHA and attendant management difficulties.

To what extent might a similar framework for assessing the feasibility of restoring wilderness geodiversity be useful elsewhere—what initial guidance might be available from the first principles of: Material Resilience, Impacting Forces, Landform Age and Genetic Process Continuity? There are always several key questions. What are the values that contributed to wilderness character, and to what degree did they involve geodiversity? To what extent has that geodiversity been compromised? What level of intervention is required and considered acceptable in order to return (a worthwhile proportion of) those values?

Hetch Hetchy

Construction of the O'Shaughnessy dam in Yosemite National Park (USA) was approved in 1913 and 10 years later the 7.8 km² (3 miles²) reservoir commenced filling. The project was strongly opposed by some for its destruction of the scenically spectacular "twin" to Yosemite Valley. That it seems to have been a site important for glacial geodiversity conservation does not appear to have been recognized explicitly in early debates.

The Material Resilience Principle is important here because the trough walls against which the reservoir laps have been carved primarily in solid granite, hence, there is a high probability of minimal damage to them. Directly Impacting Forces associated with construction activity were not confined to the dam-site but included other disturbance inside the reservoir perimeter (Riegelhuth and others 1988). Because the reservoir is 100 m (328 ft) deep, landforms on its floor are safely beyond the reach of its short wind waves. A light-colored watermark ("bathtub ring") formed where lichen on the granite has been killed by inundation can be anticipated to restore naturally, Riegelhuth and others (1988) estimating a likely time frame of up to 100 years. Those authors also report that areas of the reservoir floor exposed by draw-down in 1977 had been covered by no more than 250 mm (10 inches) of sediment in the half century since the reservoir was filled.

Landform ages vary at Hetch Hetchy. At least some of the valley-floor landforms are young and hence might be vulnerable to loss of morphological detail but for the depth of their inundation. Draw-down of the reservoir in 1977 revealed that the upper 6.4 km (4 miles) of the river was still contained in its original channel. Although the present form of Hetchy Hetchy Valley is largely the product of glacial processes that are no longer active, the only potentially vulnerable landforms appear to be those on the reservoir floor that were formed by similar processes to those that prevail in the general area today, hence there is ample potential for their natural healing in the unlikely event of damage having occurred.

Glen Canyon

The 216 m (709 ft) high Glen Canyon dam on the Colorado River (USA) was completed in 1963, the reservoir extending 300 km (186 miles) up-river and having a total shoreline length of over 3,200 km (1,988 miles). In addition to its intrusion on a wild and scenic place, the dam also had implications for geodiversity conservation, drowning well developed landforms produced by running water, the area being an exemplar of active fluvial processes and canyon formation. Key morphological and process attributes were canyons and a very heavy sediment load. Adverse impacts of the dam extend downstream through the Grand Canyon.

The dam traps about 85 percent of the 60 to 180 million tons of sediment that previously moved through Grand Canyon annually, hence the situation contrasts dramatically with the very limited sediment accumulation at Lake Pedder and Hetch Hetchy. Controlled water releases only allow sediment already downstream of the dam to be moved around with no new sediment being introduced into the system.

The canyon walls are solid bedrock and resilient, with softer sediment landforms mainly confined to the reservoir floor. From the perspective of Impacting Forces, only a tiny part of the area has been affected by direct excavation for engineering works, the predominant change being the transformation of a very high-energy fluvial environment into a low energy lacustrine environment. Over relatively recent geological time at least 11 natural dams have previously formed along this part of the Colorado River (Hamblin 1994) and, in a sense, the river system is essentially adjusted

to such occasional obstructions, their ultimate removal, and effective evacuation of the sediment that accumulated behind them. The key natural fluvial processes responsible for the Glen Canyon landscape are still potentially operating, but for the intervention of the present artificial dam. With the reservoir level down to 37 percent of full as of January 1, 2005, due to drought, exposure of more than 60 km (37 miles) of the Colorado and San Juan rivers and hundreds of kilometres of side canyons, has revealed that a high level of geomorphological integrity remains, with rapid flushing of accumulated sediments, the "bathtub ring" rapidly being covered in desert varnish, and vegetation up to 7 m (23 ft) high having re-established. Ongoing sediment accumulation behind Glen Canyon dam implies increasing costs the longer decommissioning is delayed, particularly with respect to greater adverse consequences downstream the more accumulated sediment has to be dealt with (Miller 2000).

Conclusions

The four principles enunciated earlier can usefully be employed to approximate restoration prospects in general terms, and provide a framework within which to identify site-specific considerations. In all three cases reviewed here, restoration appears technically feasible, but this will not always be the case, particularly where the dominant landforms are relict but relatively young and are formed from unconsolidated materials.

Physical scars created during dam construction are a greater issue at Hetch Hetchy than at Lake Pedder due to the greater degree of construction disturbance within the reservoir perimeter at Hetch Hetchy. The proportion of the Glen Canyon reservoir area affected by construction disturbance is very much smaller than either in the Lake Pedder area or at Hetch Hetchy. The consequences of inundation will also vary from reservoir to reservoir. Negligible sediment accumulation in the Lake Pedder and Hetch Hetchy reservoirs contrasts with massive accumulation in the Glen Canyon reservoir.

In all three cases reported here, those landforms produced by geomorphological processes that are no longer active have survived inundation. The only landforms that might have sustained any damage are the product or processes that would be reactivated by removing the reservoirs and which have the capacity to naturally heal any damage, but this fortuitous circumstance is unlikely to always be the case.

In all three cases reviewed here, the "bathtub ring" appears no impediment to restoration, although its origin is sometimes different, varying from a line of dead moorland, eroded soft sediment or redeposited sand at Lake Pedder, to killing of rock-encrusting algae at Hetch Hetchy. But even in a situation where a ring did appear likely to persist, would that be of such consequence as to outweigh the other benefits of restoration? If some means of intervention to remove it were feasible, would that be consistent with the wilderness ethic?

The issues that arise during reservoir draw-down and subsequent re-vegetation are likely to vary significantly between different sites and require differing levels of intervention as natural processes reclaim local environments. For example, while only minimal risk of invasion by exotic weeds exists at

Lake Pedder (Balmer and Corbett 2001) the potential for invasion appears to be far greater at Hetch Hetchy (Riegelhuth and others 1988). Such concerns require value judgements regarding levels of intervention considered consistent with concepts of wilderness and the typically conflicting agenda contained within wilderness statutes.

Emergence of the western wilderness ethic greatly post-dates a long and often under-recognized history of human presence that has included a long history of traditional land stewardship and harvesting in such places as the floor of Hetch Hetchy. Restoration projects are not inconsistent with such histories of human influence. If adopted, they may not only return precious places to the wild, but may usefully inform less dramatic intervention elsewhere that will increasingly be required to safeguard wilderness values in a world where no place remains beyond the globalized environmental damage caused by human population growth and associated economic development.

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