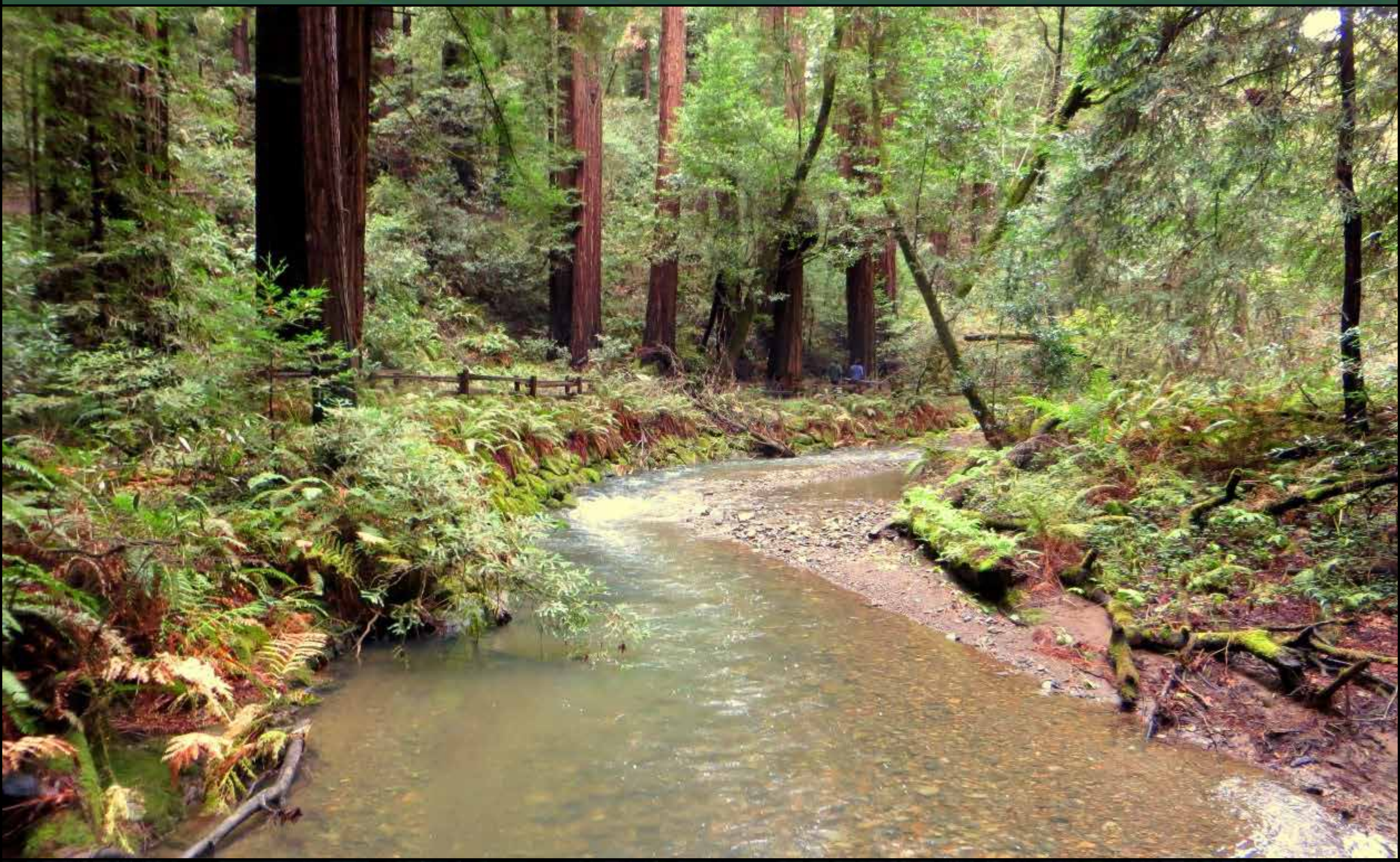
Muir Woods National Monument
California

US Department of the Interior
National Park Service

Salmon Habitat Enhancement and Bridge Replacement Project at Muir Woods

DRAFT ENVIRONMENTAL ASSESSMENT



April 2017

NATIONAL PARK SERVICE

Salmon Habitat Enhancement and Bridge Replacement Project at Muir Woods Environmental Assessment

Prepared for

National Park Service
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April 2017

National Park Service. 2017. Salmon Habitat Enhancement and Bridge Replacement Project at Muir Woods Draft Environmental Assessment. Print Check Draft. March. Prepared by Horizon Water and Environment. (HWE 16.039) Oakland, CA.

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Acronyms and Abbreviations

A

ABAAS	Architectural Barriers Act Accessibility Standard
APE	area of potential effect

B

BAAQMD	Bay Area Air Quality Management District
BMP	best management practice
Br.	bridge

C

CCC	Civilian Conservation Corps
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CEQ	Council on Environmental Quality
CH_4	Methane
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CGS	California Geological Survey
CNPS	California Native Plant Society
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CWA	Clean Water Act
CY	cubic yard(s)

D

dBA	Decibel
DBH	diameter at breast height
DPS	distinct population segment
DS	Downstream

E

EA	environmental assessment
EIS	environmental impact statement
EO	Executive Order

ESA	Endangered Species Act
ESU	evolutionarily significant unit
F	
FEMA	Federal Emergency Management Agency
FIRM	flood insurance rate map(s)
FWCA	Fish and Wildlife Coordination Act
G	
GGNRA	Golden Gate National Recreation Area
GHGs	greenhouse gases
GMP	general management plan
I	
IRMA	Integrated Resource Management Applications
L	
LF	linear feet
LWD	large woody debris
M	
MWNM	Muir Woods National Monument
MT	metric ton
N	
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHE	Northern Hydrology and Engineering
NHPA	National Historic Preservation Act
NHTSA	National Highway Traffic Safety Administration
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxides
NPCA	National Parks Conservation Association
NPS	National Park Service
NRCS	National Resources Conservation Service
NRHP	National Register of Historic Places
NTU	nephelometric turbidity units
P	

PM	particulate matter
R	
RWQCB	Regional Water Quality Control Board
S	
SJVAPCD	San Joaquin Valley Air Pollution Control District
SOD	sudden oak death
SWPPP	stormwater pollution prevention plan
SFAN	San Francisco Bay Area Network
T	
t/y	tons per year
U	
US	Upstream
USACE	United States Army Corps of Engineers
USC	United States Code
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
V	
VOC	volatile organic compound
W	
WRCC	Western Regional Climate Center

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Chapter 1
PURPOSE AND NEED FOR ACTION

1.1 Introduction

Designated a national monument in 1908, Muir Woods National Monument (MWNM) has a rich cultural and natural history. MWNM protects old growth redwood forest, as well as the portion of Redwood Creek that flows through the park. During the 1930s, the Civilian Conservation Corps (CCC) placed rock armoring (riprap) along the banks of Redwood Creek. This riprap is now understood to interfere with natural channel processes, which are important for habitat creation and ecological health of the creek and nearby forest. Additionally, for much of the 20th century, the National Park Service (NPS) removed fallen logs from the creek. Although this practice ended by about the late 1980s, the rate of large-diameter wood in the channel is still significantly below that in unaltered channels in old growth redwood forests. Channel processes have been altered for many decades, and watershed-level issues have resulted in channel incision in Redwood Creek. Four existing non-historic wooden pedestrian bridges that cross Redwood Creek within MWNM function to provide a visitor experience of the creek and connect to trails on hillslopes on both sides of the creek. These bridges are aging and constraining the stream channel, and are in need of replacement.

All life stages of Coho salmon (*Oncorhynchus kisutch*) occur in Redwood Creek; juvenile abundance has been low overall in Redwood Creek in recent years, but is lowest in MWNM. The Central California Coast evolutionarily significant unit (ESU) of Coho has been listed as endangered under the federal Endangered Species Act (ESA). Improvements to Coho habitat within MWNM would likely improve juvenile survivorship. Steelhead trout (*O. mykiss*) (steelhead) are also present in Redwood Creek. The Central California Coast Distinct Population Segment (DPS) is listed as threatened under the federal ESA. Project actions would benefit steelhead as well.

NPS is proposing to enhance juvenile Coho habitat within Redwood Creek through removal of riprap and placement of large woody debris (LWD). NPS also proposes to replace the four existing pedestrian bridges. These activities are collectively referred to as the Salmon Habitat Enhancement and Bridge Replacement at MWNM, and are referred to in this environmental assessment (EA) document as the Proposed Action. Figure 1-1 displays the location of the Proposed Action. All proposed activities would occur within MWNM, with the exception of site access, which would occur through areas adjacent to MWNM.

Both creek restoration and bridge replacement actions were identified in the General Management Plan (GMP) and were analyzed programmatically in the GMP Environmental Impact Statement (EIS) (NPS 2014). This EA analyzes a specific plan to complete these actions.

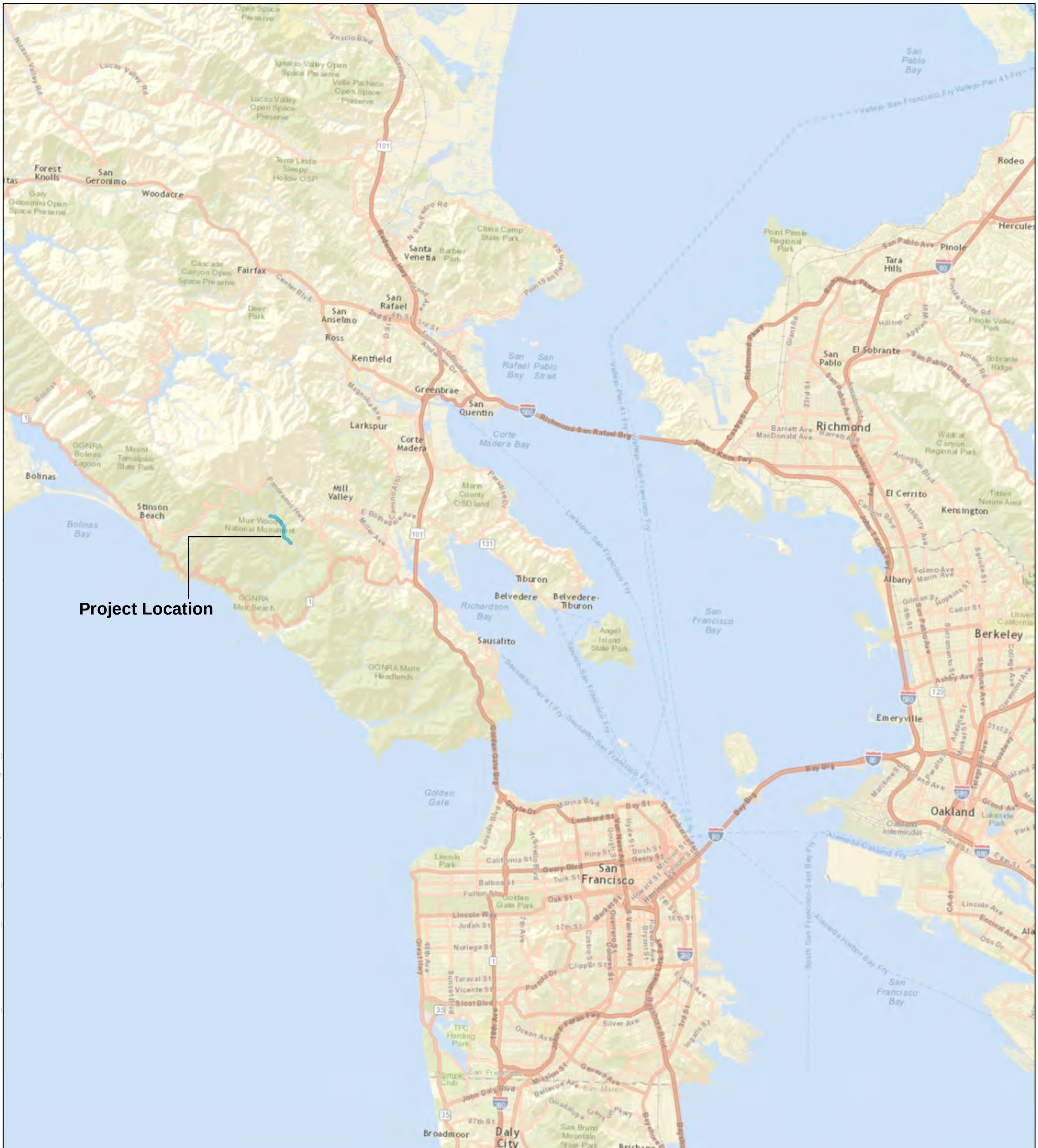

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Figure 1-1
Proposed Action Location

Project Location

N

0 2 4
Miles

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

1.2 Purpose

The purpose of this action is to enhance habitat for juvenile Coho salmon and natural stream processes, as well as to replace four aging pedestrian bridges across Redwood Creek. Although some trail realignment or removal may occur as part of the Proposed Action, this document is not intended as a comprehensive master trail plan for MWNM. Future trail adjustments may be made that would reduce impacts on channel function, but those trail modifications would not entail in-stream actions. All proposed trail relocations are those needed to meet the goals of the proposed action.

1.3 Need

The Project is needed to address low juvenile Coho abundance in Redwood Creek and bridges that are deteriorating. Coho salmon are at risk of extirpation within Redwood Creek (Fong et al. 2016). Data collected over some 15 years by NPS demonstrates that the in-stream action that is most likely to support the Coho salmon population consists of improving juvenile Coho salmon habitat within MWNM. There are two critical life stage weak points for Coho in Redwood Creek: the number of returning spawning adults and the survival rate of fry to juveniles. The Proposed Actions address the survival rate of fry to juveniles.

The decline of Coho salmon habitat has occurred due to multiple factors of many decades. The legacy of CCC riprap placement and past removal of LWD are two of the many factors that have led to poor habitat conditions for juvenile Coho in the MWNM reach of Redwood Creek. While Redwood Creek in MWNM has relatively high numbers of spawners, juvenile rearing is low in this reach (Fong et al. 2016). This reach has low numbers of channel pools, which are important for juvenile rearing (Fong et al. 2016). Pools associated with LWD provide high-quality juvenile habitat, as shown in Figure 1-2. Increased juvenile habitat in MWNM (near spawning grounds) would increase survival of juvenile Coho. Other actions, particularly the Redwood Creek Coho Salmon Captive Rearing Project, are addressing the number of returning adults in the short-term. Even if the numbers of adult spawners are increased in Redwood Creek, the creek still needs better habitat for survival of fry to the juvenile stage. The proposed action is highly complementary to the other management actions undertaken in the watershed, including the extensive restoration project undertaken at Big Lagoon, restoration in the Banducci Reach of Redwood Creek, and other ongoing NPS management actions to protect Coho salmon. Removal of riprap and placement of LWD within the channel would increase rearing habitat for juvenile salmon by increasing habitat complexity and supporting pool formation. Enhancing natural stream processes within Redwood Creek would also have a beneficial impact on the primeval redwood forest, which is important for future visitor experience of MWNM.

The CCC-era riprap is considered a contributing element to the cultural landscape in MWNM, which is listed in the National Register of Historic Places (Auwaerter and Sears 2006). Three dams that also date to the CCC era are located within MWNM, and which continue to function today as grade control within Redwood Creek. One of the dams, Log Check Dam, retains sufficient integrity to be a contributing element to the NRHP-eligible cultural landscape. These features represent erosion control practices and fine workmanship conducted by the CCC.

Figure 1-2. Juvenile salmonid use of wood jams

This wood jam occurs downstream of MNWM (downstream of the Dipsea crossing). In a March 2017 snorkeling survey, it had the highest count of juvenile coho and steelhead in or near MWNM. Juvenile salmon prefer the deeper water and cover provided by wood jams.

In addition, pedestrian bridges in MWNM (Bridges 1 through 4 crossing Redwood Creek) are reaching the end of their useful life due to degrading structural integrity. The bridges, particularly Bridges 2 and 3, are restricting natural stream flow and have been damaged by woody debris and high water. Bridges 2 and 3 can only currently accommodate the 2-year flow, and are flooded at larger storm flows (NHE 2016a). Bridge 1 can currently accommodate the 25-year flow, while Bridge 4 can accommodate the 50-year flow (NHE 2016a). The bridges' abutments constrain the channel, and the ability to pass LWD is limited. Replacement of the bridges with longer spans, higher elevations, and a rustic design would enhance and support habitat restoration goals, improve visitor safety and accessibility, ensure long-term structural integrity and decrease maintenance needs, and enhance the rustic character of the monument through bridge design. Longer spans are needed to meet the both flood-flow conveyance and pedestrian accessibility goals. MWNM is committed to meeting Architectural Barriers Act Accessibility Standard (ABAAS) for outdoor areas in the bridge designs.

1.4 Goals

The four goals of the Proposed Action are defined below.

1. Enhance winter/spring habitat for Coho fry and juveniles and summer habitat for Coho and steelhead juveniles through in-stream actions, floodplain enhancement and bank revegetation.

2. Mitigate and minimize adverse effects to the cultural resources to the extent possible while also allowing an updated understanding of conservation to be achieved for the health of the channel, salmon populations, and redwood forest.

3. Restore natural geomorphic processes where possible, given constraints to channel function such as the existing trail system and the need to maintain much of the channel bank revetment as a cultural resource.

4. Replace pedestrian bridges with new designs that improve projected channel function, accommodate visitor access for all users, and enhance the rustic character of MWNM.

1.5 Summary of Public Scoping Comments

A public scoping meeting about this project was conducted on September 20, 2016, and public scoping comments were accepted through October 21, 2016. Fourteen comment letters were received from private citizens, environmental organizations, and nonprofits including People for a Golden Gate National Recreation Area; Sierra Club; Marin Conservation League; Save our Seashore; Watershed Alliance of Marin; National Parks Conservation Association; Environmental Action Committee of West Marin; and Mount Tam Task Force. The majority of comments focused on increasing the extent of habitat enhancement in the Proposed Action. Other major themes addressed in the comments include effects on trails, details of bridge designs and locations, timing of the project, impact analysis and mitigation, as well as the overall National Environmental Policy Act of 1969 (NEPA) process. In addition, several public agencies participated in field visits and provided input on the potential actions, including National Marine Fisheries Service (NMFS), Regional Water Quality Control Board (RWQCB), California Department of Fish and Wildlife (CDFW), California State Parks, and U.S.

Army Corps of Engineers (USACE). Comments and other input were used to refine the alternatives presented in Chapter 2 of this EA.

1.6 Scope of the Environmental Assessment

This EA will analyze the No Action and Proposed Action alternatives and their respective potential impacts on the environment. This EA has been prepared in accordance with the NEPA, as amended, and implementing regulations, 40 Code of Federal Regulations (CFR) Parts 1500–1508: Protection of Environment, 43 CFR Part 46: Implementation of the National Environmental Policy Act of 1969, Director's Order 12: Conservation Planning, Environmental Impact Analysis, and Decision-making (NPS 2011) and its handbook (NPS 2001, 2015a), Section 106 of the National Historic Preservation Act of 1966 (NHPA), and section 7 of the ESA.

1.7 Environmental Topics Dismissed from Further Analysis

Three resource topics have been eliminated from further analysis based on the nature and scope of the Proposed Action. A brief summary and description of each of these resource topics is provided below.

Nightsky

Night work would not occur during implementation of the Proposed Action, thus there would be no impact on nightskies. Therefore, the topic was dismissed from further analysis in this document.

Socioeconomics

The Proposed Action would generate economic activity from minimal increases in employment during construction, creating beneficial economic effects; however, such effects would be small due to the short-term nature of construction. As such, the Proposed Action would not be anticipated to meaningfully affect the local economy or community character. Therefore, the topic was dismissed from further analysis in this document.

Environmental Justice

The Proposed Action would not result in disproportionate health or environmental effects on minorities or low-income populations or communities. Therefore, this topic was dismissed from further analysis in this document.

Land Use Impacts Related to Population and Housing Growth

The Proposed Action would not affect local or regional land use or controls of the adjacent area, including growth of population or housing because the project will only consist of creek restoration actions and bridge replacement within MWNM. The project would also not displace housing or anyone within the MWNM or the adjacent local area. Therefore, this topic was dismissed from further analysis in this document.

1.8 Environmental Topics Retained for Further Analysis

Air Quality and Greenhouse Gas Emissions

The removal of riprap, removal of existing bridges, and construction of new bridges would result in localized emissions at the monument because of temporary construction activities. Therefore, this impact topic is carried forward for detailed analysis.

Cultural Resources

To comply with Section 106 of the NHPA, NPS must "take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register [of Historic Places]." MWNM was entered into the National Register of Historic Places (NRHP) in 2008, excluding a 50-acre parcel added in 1974. The Final GMP/EIS identified trail modifications and targeted riprap removal along Redwood Creek as a minor adverse cultural resource impact (NPS 2014). This document concluded that, when combined with the preservation of other elements, the Section 106 determination of effect on historic structures, districts and cultural landscapes for MWNM would be no adverse effect (NPS 2014). Several trails are contributing elements to the NRHP-eligible property. The riprap along Redwood Creek, constructed between 1934 and 1938, is also considered a contributing element to the NRHP-eligible property. Therefore, this impact topic is carried forward for detailed analysis.

Threatened or Endangered Species

The Proposed Action is intended to improved habitat for Coho salmon as well as steelhead trout. Northern spotted owl (*Strix occidentalis caurina*) is an additional species which may be impacted by the Proposed Action. Critical habitat for marbled murrelet (*Brachyramphus marmoratus*) is located on California State Park property immediately surrounding MWNM, but is not located within the monument itself. Therefore, this impact topic is carried forward for detailed analysis.

Geology: Soils and Bedrock

Placement of LWD would have an impact on soils through the use of the cable grip hoist method of log movement. Rerouting of trails would also have an impact on soil resources. The Final GMP/EIS identified targeted riprap removal as a long term moderate beneficial impact on geologic resources and soils (NPS 2014). Therefore, this impact topic is carried forward for detailed analysis.

Visitor Use and Experience

One of the basic purposes of the NPS is to provide visitors opportunities to enjoy the parks. Implementation of the Proposed Action would impact visitor use and experience during construction due to construction activities and temporary closures of portions of some trails. The Project as a whole is intended to improve visitor experience and would contribute to the goal of presenting MWNM as a contemplative outdoor setting where visitors experience the primeval forest and learn about the monument's place in U.S. conservation history (NPS 2014). Therefore, this impact topic is carried forward for detailed analysis.

Soundscapes

Anthropogenic noise would temporarily increase during implementation of the Proposed Action because of construction activities, equipment, vehicular traffic, and crews. Acoustic impacts from construction would be temporary and would have temporary effects on visitors, employees, or natural soundscape conditions. Therefore, this impact topic is carried forward for detailed analysis.

Transportation

The Proposed Action could affect local transportation during riprap removal and bridge removal and construction due to increased truck traffic in the vicinity of MWNM. Therefore, this impact topic is carried forward for detailed analysis.

Wildlife Habitat

The Proposed Action would have short-term construction-related effects on wildlife and wildlife habitat, and long-term effects on habitat due to changes in hydrology and geomorphology within Redwood Creek. Therefore, this impact topic is carried forward for detailed analysis.

Water Resources and Hydrologic Processes

The Proposed Action would take place within and across waters of the United States, and would affect hydrology. The different alternatives would have different effects on these resources. Also, the Proposed Action may have effects on sedimentation. Therefore, this impact topic is carried forward for detailed analysis.

Vegetation

Implementation of the Proposed Action would have an effect on vegetation within the monument. These effects would be both short term due to construction and longer term based on changes in the channel due to removal of riprap and future channel evolution. Revegetation of channel banks where riprap is removed would occur. Additionally, sensitive plant species including locally rare species are located within MWNM. Therefore, this impact topic is carried forward for detailed analysis.

Climate Change

The Proposed Action is anticipated to have minimal effects on climate change, due to the release of greenhouse gas emissions during construction. Climate change would also have an effect on the Project. Therefore, this impact topic is carried forward for detailed analysis. This impact topic will be addressed within each relevant impact topic and will not be addressed under its own section. For example, climate change impacts on biological resources will be addressed in the biological resources impact topic.

Visual Resources

Creek restoration activities and bridge replacement would both have long-term effects on visual resources within MWNM. Creek restoration activities would result in a channel that is more similar to conditions occurring in unaltered old-growth forests. Visual conditions near the channel would be more complex, with increased large wood in the channel and a less manicured visual condition. Visitors would experience a greater range of old-growth forest characteristics along Redwood Creek. Replacement of existing bridges would result in visitors encountering longer, higher bridges. Construction activities would also have a temporary effect on visual resources within the monument. Therefore, this impact topic is carried forward for detailed analysis.

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Chapter 2
ALTERNATIVES

2.1 Introduction

This chapter describes alternatives for the various elements of the Proposed Action (Creek Restoration and Bridge Replacement), consistent with the purpose of, and need for, action. As the different project elements are somewhat independent of one another, they are described as element alternatives. For actions described as occurring on the right or left bank of Redwood Creek, these directions are relative to the view looking downstream.

The Proposed Action must provide for both visitor use and resource protection (NPS 2006). The Final GMP/EIS for Golden Gate National Recreation Area and MWNM National Monument (2014) states that "portions of the main trail and bridges could be relocated to allow for creek and floodplain restoration and improvements to the integrity of the redwood forest ecosystem" and "the historic creek stabilization rock work could be removed in targeted areas to restore natural creek functions important to forest health." Removal of all historic riprap in Redwood Creek was not considered as an alternative, as it does not meet the GMP guidance of targeted riprap removal. The elements described below represent a range of reasonable and feasible approaches to achieve these goals. These elements are also in line with NPS management policies regarding watershed and stream processes (NPS 2006).

Modifications to trails identified as part of Creek Restoration and Pedestrian Bridge Replacement Alternatives do not represent the full set of possible trail modifications that could benefit channel function. These alternatives identify trail modifications that are needed to remove riprap and replace bridges. These trail changes are intended to keep existing trail corridors accessible to visitors. Other future trail modifications may be possible and may allow further improvements in channel or forest function but would not require additional riprap removal or other in-stream actions.

2.2 No Action Alternative

Under the No Action Alternative, no actions would be taken to improve habitat for salmonids or to encourage more natural geomorphic processes. No riprap would be removed, no LWD would be installed, and the four pedestrian bridges would either not be replaced or be replaced in-kind (same location, same material, same size). Under this scenario, it could be assumed that some trees may still fall in the channel intermittently. The trails network within MWNM would not change.

2.3 Creek Restoration Alternatives

Because all of the creek restoration alternatives focus on restoring habitat complexity within Redwood Creek, all would be guided by the same strategy, and all would have certain key project elements in common. To avoid redundancy, the following section describes the project elements that would be implemented with all creek restoration action alternatives. Table 2-1 summarizes elements in each Creek Restoration Alternative.

Actions Common to All Creek Restoration Alternatives

- NPS would conduct revegetation on creek banks and areas of the forest floor impacted by implementation. Revegetation on creek banks would only use native species, and would include species that would provide overhanging branches for cover for fish.
- Grade control would be installed in a small incised tributary on the east side of the creek just downstream of Bridge 3. Broken pieces of riprap removed during other project actions would be installed by hand in a series of check dams extending over approximately 150 linear feet (LF) of the tributary. Slash may be placed in the tributary between the check dams to help trap sediment. The purpose of the grade control is to help reverse the incision that has occurred in this reach and potentially raise groundwater elevations on a very localized scale, which may help protect instream flows. The check dams may also capture sediment behind them and. This is a small-scale experimental action.
- Heavy equipment would be used to excavate pools and build adjacent bars/riffles at wood jams. These actions would create immediate summer rearing habitat (pools) and enhance winter rearing depth as well as velocity.
- An undermined bank adjacent to the entrance boardwalk extending approximately 20 LF will be filled with riprap to prevent erosion or further undermining. A sewer line under the adjacent boardwalk will remain in place even after other segments of the sewer line will be moved further from the creek, and the entrance boardwalk is essential infrastructure for visitor resources. The rock will be placed so as to remain in a smooth line with other riprap both upstream and downstream of this feature.
- Erosion control methods may integrate the use of existing rock backing material (the 6-12-inch rock behind the riprap) to protect bank slopes without the use of erosion control fabric where there is sufficient banking material and the bank slope is adequate.
- Any toe material that occurs as part of a riprap segment will be removed along with the other riprap rock and the creek bed will be rebuilt to the existing grade with suitable native material.

Creek Restoration Alternative 1

This alternative consists of in-stream actions mostly upstream of Bridge 3, with some actions upstream of Bridge 1 to enhance Coho habitat by removing riprap and installing large woody debris, as identified in *Salmon Habitat Restoration at Muir Woods Site Analysis, Conceptual Designs and Impact Analysis* (Northern Hydrology and Engineering [NHE] 2016) and further refined in 2017 conceptual design revisions (NHE 2017a and 2017b). The 2016 NHE report identifies riprap segments that would be most suitable for removal, with the goal of improving juvenile rearing habitat for Coho as well as improving overall forest and riverine ecology. This alternative includes removal of 1,123 LF of riprap (33 percent of total riprap) over approximately 1 mile of channel and relocation of approximately 32 to 50 existing downed trees from upland areas into the channel into 17 locations (Figure 2-1). Pools near LWD installation would be excavated in some areas to provide immediate salmonid habitat.

This alternative would result in an increase in summer habitat of approximately 15 percent and an increase in winter/spring Coho habitat of approximately 24 m^2/100m. To reduce potential erosion after riprap removal, banks where riprap has been removed would be treated based on conditions at each specific location. Approximately 58% of banks are expected to be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have substantial mature root structures behind existing riprap, and since the roots can be very effective at resisting erosion, added treatments are not expected to be needed in those locations. Most actions would be conducted as part of Phase 1 implementation (mostly upstream of Bridge 3), and about 70% of the Phase 1 areas would have such bank erosion control, while the rest appear to have existing adequate root structure. Construction phases are described in detail in Section 2.5.

At riprap segment L10, which would be removed, base rock remains in the top of bank where an asphalt trail was removed by NPS in 2000. Since the base rock has prevented reestablishment of native plant cover, it would be removed from the former trail alignment (about 6 inches below the surface) to allow plant reestablishment that will better stabilize the bank after riprap removal. To maintain the same elevation of the ground surface, excess soil generated when some banks are sloped will be placed on the top of bank where the rock was removed. A layer of 6-inch rock occurs behind riprap segment R10 and extends about 4 to 5 feet behind the riprap to the valley wall. Most of this segment cannot be removed without cutting all the way up to the valley wall, which could lead to future hillslope destabilization. Approximately 30 LF at the downstream end of riprap R10 segment would be removed since section does not have buried rock behind it. This removal will be dependent on future investigations.

The upstream half of segment L11 (L11A) would be re-stabilized, with its downstream end keyed into the bank well. This would provide long-term protection to the trail while allowing riprap removal at the downstream end of this segment (L11B). It would be re-stabilized using typical hand/mechanical methods to recreate a wall as it originally appeared. It will not consist of a newly engineered bank stabilization.

While all riprap upstream of Bridge 3 will be removed without the need to close trails within MWNM, the removal of a segment R6 just upstream of Bridge 2 will require temporary closure of the trail on the east side of the creek. Visitors will still have access upstream of Bridge 2 via the trail on the west side of the creek

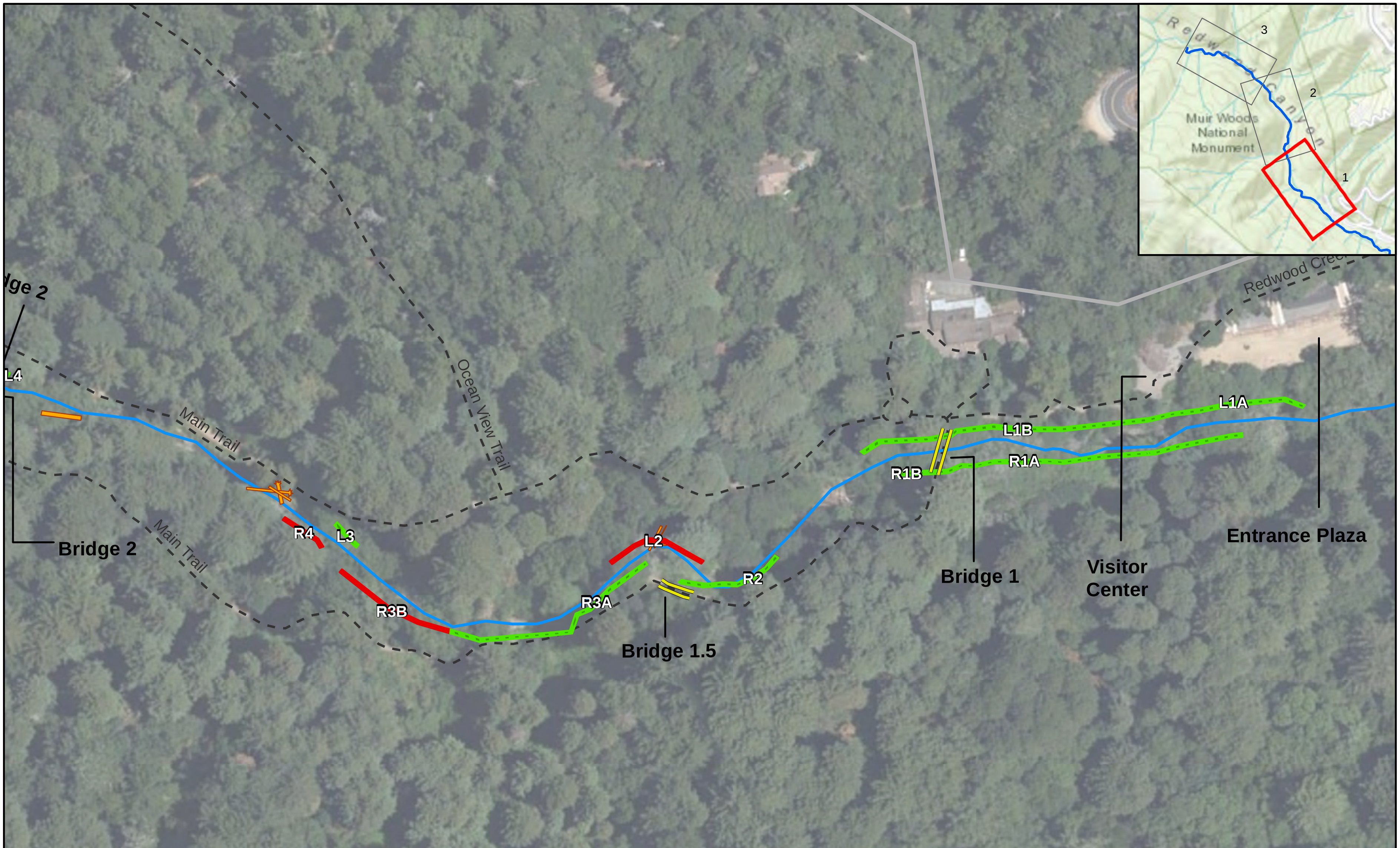
Creek Restoration Alternative 2

This alternative consists of all actions in Creek Restoration Alternative 1, plus additional habitat enhancement through riprap removal at the Plaza, and removal of a portion of trail and an additional riprap segment in Cathedral Grove (Figure 2-2). This alternative includes removal of 1,461 LF (43 percent) of riprap, representing an increase of 338 LF compared to Creek Restoration Alternative 1. The 140 LF segment riprap (L7) in Cathedral Grove would be removed. As part of this action, the western side of the asphalt loop trail (approximately 350 LF) on the top of bank at Cathedral Grove would be removed prior to riprap removal.

Table 2-1. Summary of Creek Restoration Alternative Elements

	Creek Restoration Alternative 1	Creek Restoration Alternative 2	Creek Restoration Alternative 3	Creek Restoration Alternative 4	Creek Restoration Alternative 5 *(Preferred Alternative)*
Minimum Riprap Removal Area	Mostly upstream of Bridge 3, but not including Cathedral Grove. One segment upstream of Bridge 2, and three segments upstream of Bridge 1.			Mostly upstream of Bridge 3, including Cathedral Grove. One segment upstream of Bridge 2, and five segments upstream of Bridge 1.	
Riprap Removal Area at Plaza	None	Downstream of Bridge 1 (adjacent to Plaza)			
Additional Riprap Removal Area	None			Two locations where advance trail relocation is required: Between Bridges 1 and 2 and near Fern Creek	
Total Riprap Removal and % of All Riprap	**1123 LF (33%)**	**1461 LF (43%)**	**1461 LF (43%)**	**1731 LF (51%)**	**1731 LF (51%)**
Percent of All Visible Riprap Removed	40	50			
Special Habitat Treatments:	None		Lower the right bank at Plaza to floodplain elevation	Add alcove near Bridge 1.5 Area	Add Alcove near Bridge 1.5 Area and lower the right bank at Plaza to floodplain elevation
Minimum Trail Alteration	None	Remove one side of loop trail at Cathedral Grove (350 LF)			
Additional Trail Alteration	None			Relocate up to 440 LF on right bank near Bridge 1.5 and remove Bridge 1.5; relocate 115 LF on left bank near Fern Creek	
Large Woody Debris – Locations	US of Br. 3 - @ 12 US of Br. 2 - @ 4 US of Br. 1 - @3 **Total: @ 19 Locations**		US of Br. 3 - @ 12 US of Br. 2 - @ 4 US of Br. 1 - @3 DS of Br. 1: @3 **Total: @ 22 Locations**	US of Br. 3 - @ 12 US of Br. 2 - @ 4 US of Br. 1 - @3, Plus Alcove Area: @1 DS of Br. 1: @3 **Total: @ 23 Locations**	

	Creek Restoration Alternative 1	Creek Restoration Alternative 2	Creek Restoration Alternative 3	Creek Restoration Alternative 4	Creek Restoration Alternative 5 *(Preferred Alternative)*
Large Woody Debris Logs: Estimated Number and % of Fallen Logs on Floodplain, Hillslopes			40–55 / 9 to 15%		
Approximate Number of Imported Logs (for Plaza Area Only)	None			50	



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Bridge

Redwood Creek

trails

MWNM Boundary

Large Woody Debris

Proposed Riprap Treatments

No Action

Remove

Figure 2-1
Creek Restoration Alternative 1
Sheet 1 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
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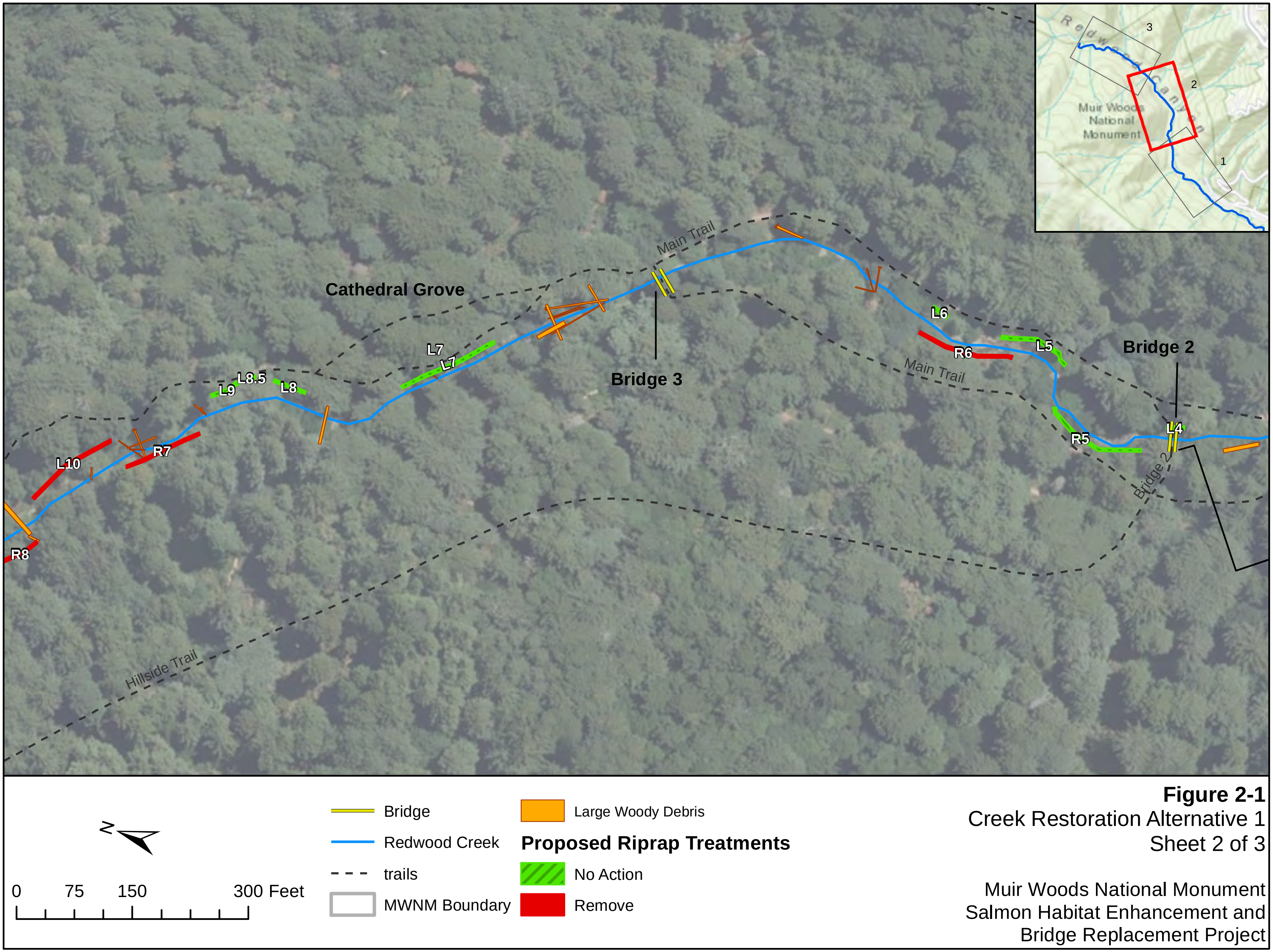
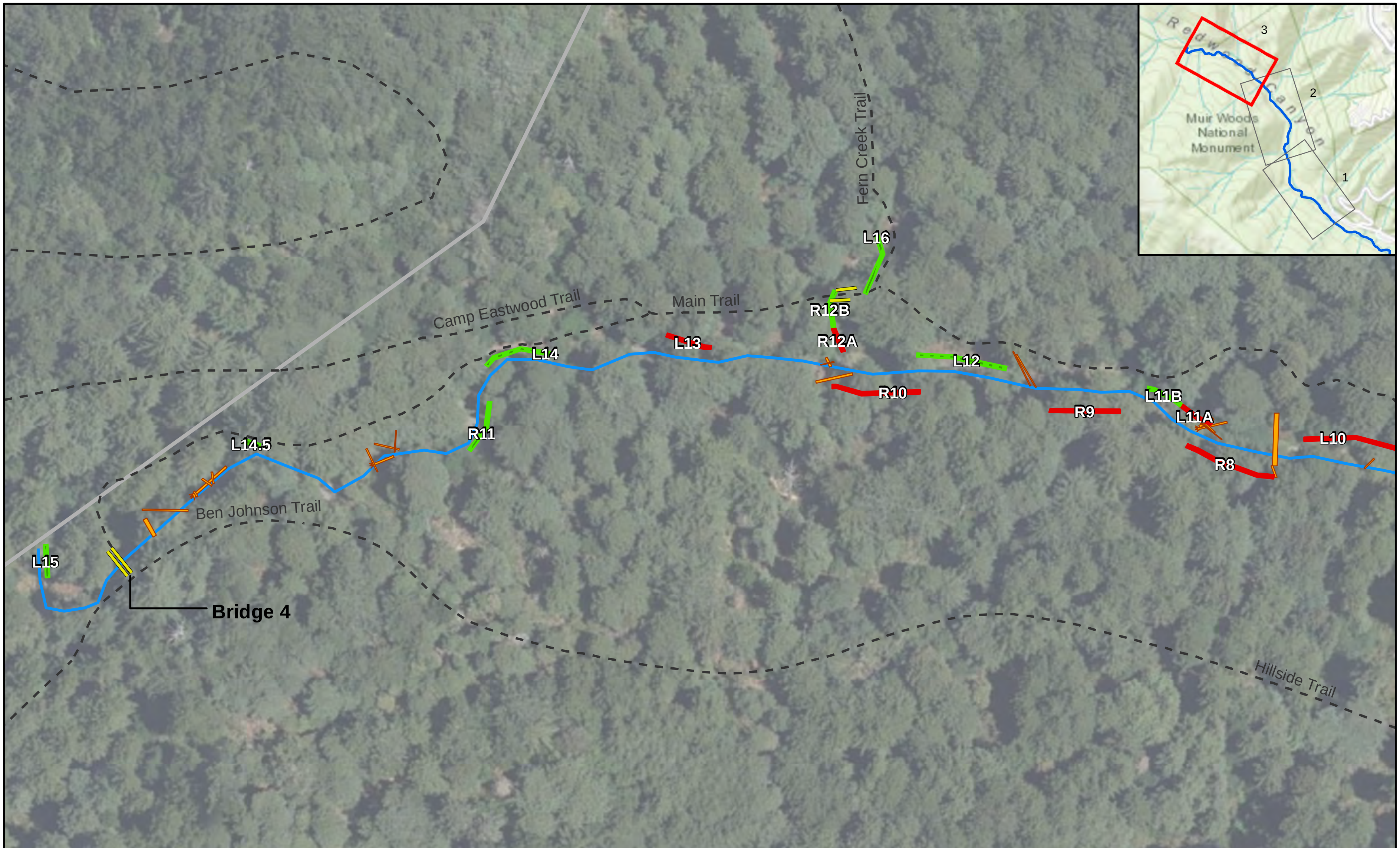


Figure 2-1
Creek Restoration Alternative 1
Sheet 2 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project



N

0 75 150 300 Feet

Bridge
Redwood Creek
trails
MWNM Boundary

Large Woody Debris

Proposed Riprap Treatments

No Action
Remove

Figure 2-1
Creek Restoration Alternative 1
Sheet 3 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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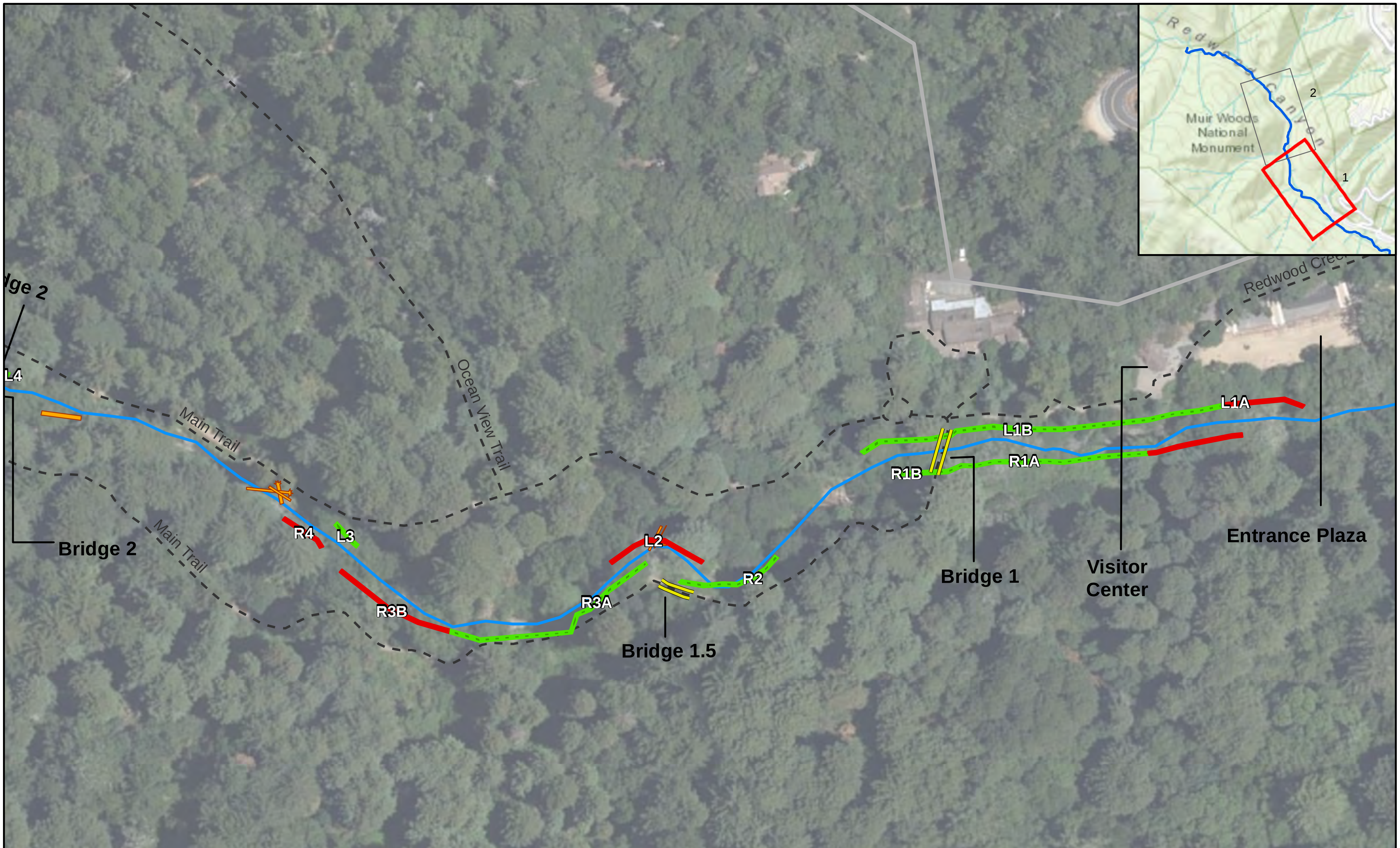

Bridge
Redwood Creek
trails
MWNM Boundary
Large Woody Debris
Trail Removal

Proposed Riprap Treatments

No Action
Remove

0 75 150 300 Feet

Figure 2-2
Creek Restoration Alternative 2
Sheet 1 of 2

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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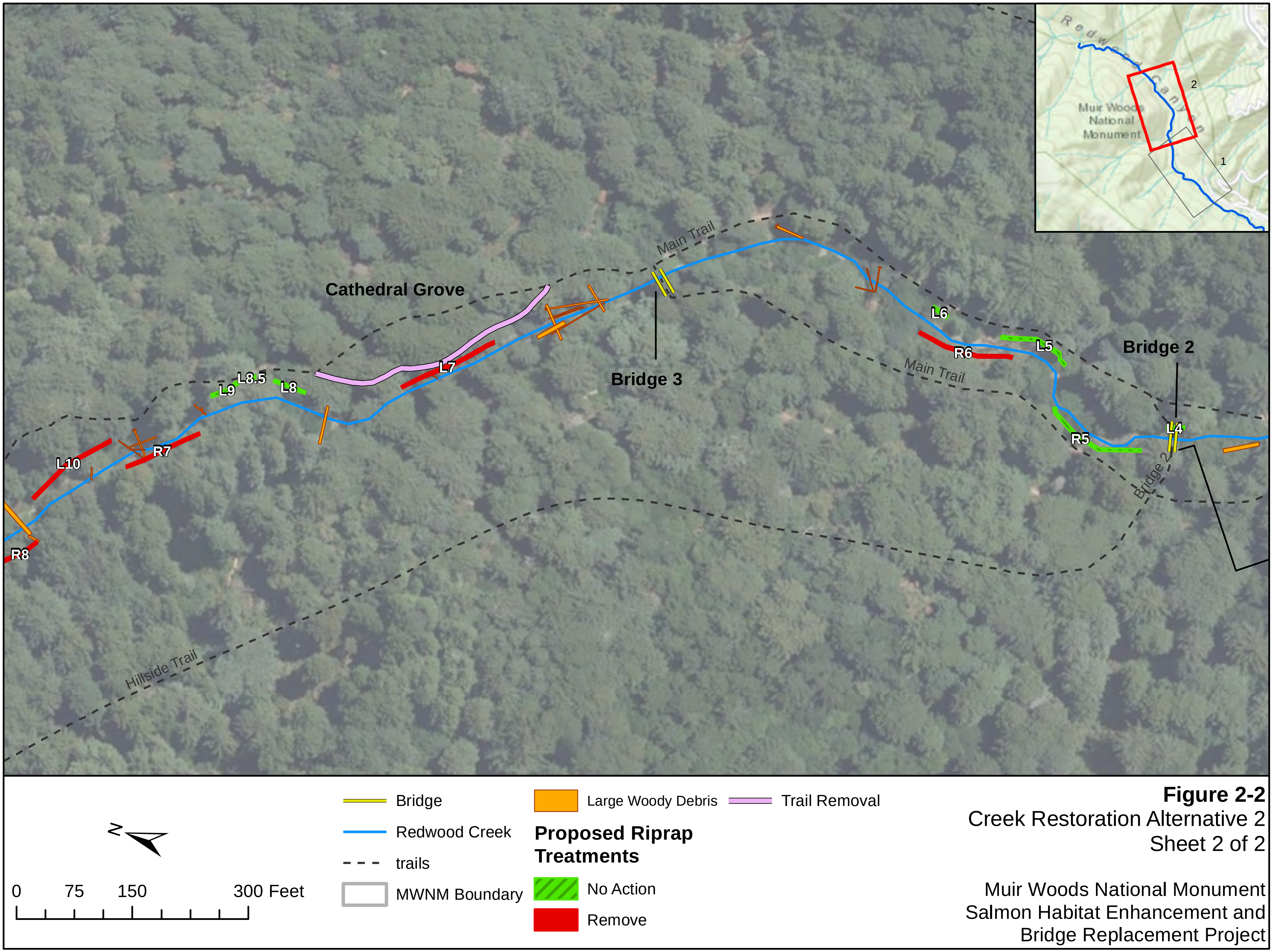

Figure 2-2
Creek Restoration Alternative 2
Sheet 2 of 2

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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With an existing split trail through Cathedral Grove, the main (eastern) leg of the trail would remain in place. A new trail configuration and gathering area in Cathedral Grove would be planned and implemented as part of a separate planning process. To reduce potential erosion after riprap removal, banks would be treated based on conditions at each specific location. About 45% of banks are expected to be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have substantial mature root structures behind existing riprap, and since the roots can be very effective at resisting erosion, added treatments are not expected to be needed in those locations. Most actions would be conducted as part of Phase 1 activities (mostly upstream of Bridge 3), and about 60% of the Phase 1 riprap removal areas would have such bank erosion control, while the rest appear to have adequate root structure. Construction phases are described in detail in Section 2.5. This alternative expands the geographic area of improvements to Coho habitat throughout more of the project reach, and would increase both summer and winter/spring Coho habitat.

Creek Restoration Alternative 3

This alternative consists of all actions in Creek Restoration Alternative 2, plus additional habitat enhancement through terracing of the right floodplain and installation of three engineered log jams in the channel adjacent to the Plaza (Figure 2-3). Bank treatments to reduce erosion described in Creek Restoration Alternative 2 would be used. Approximately 5,400 square feet would be terraced at two elevations, with a low terrace at about a 1-year flood elevation and a higher terrace at about a 1.5- to 3-year flood elevation. The existing landscape on the right bank consists of a high bench that does not function as floodplain. No redwood trees occur in the footprint of the proposed terracing. Approximately four to five mature alders are rooted between the top of the bank and the channel. These alders may be affected, or terracing may be able to protect them in place. Approximately 400 cubic yards (CY) of material would be excavated and would be off-hauled or, if possible, reused on site as part of re-contouring. The engineered log jams would be constructed using approximately 50 large diameter logs (anticipated to be eucalyptus [*Eucalyptus* spp.]) imported from a separate project within the Redwood Creek watershed. The root tissue of the eucalyptus logs would be manually ripped prior to installation to prevent eucalyptus from resprouting; this method has been used successfully before in other projects in Redwood Creek. The jams would be large structures with interwoven logs to provide cover, create scour, and trap sediment and would be persistent. Structures located against the right bank would be designed to encourage creation of secondary channels and lift flows onto the terraces.

These proposed actions are intended to address some of the channel incision in this reach by reconnecting a channel with its floodplain and encouraging storage of sediment on both the new floodplain and in the channel. The added cover, low velocity refuge, and formation of scour pools and secondary channels would enhance habitat for juvenile salmonids.

Creek Restoration Alternative 4

This alternative consists of all actions in Creek Restoration Alternative 2, plus additional habitat enhancement via installation of three engineered log jams near the Plaza, excavation of an alcove and installation of LWD in the vicinity of Bridge 1.5, and additional riprap removal that would require modification of two trail segments as follows (Figure 2-4). This alternative would result in removal of 1,731 LF (51 percent) of riprap, representing an increase of 608 LF compared to Creek Restoration Alternative 1, and an increase of 270 LF compared to Creek Restoration Alternatives 2 and 3. To reduce potential erosion after riprap removal, banks will be treated based on conditions at each specific location. About 45% of banks are expected to be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have substantial mature root structures behind existing riprap, and since the roots can be very effective at resisting erosion, added treatments are not expected to be needed in those locations. Most actions (73% of all riprap removal proposed in this alternative) would be conducted as part of Phase 1 activities (mostly upstream of Bridge 3), and about 60% of the Phase 1 riprap removal areas would have such bank erosion control, while the rest appear to have adequate existing root structure. Construction phases are described in detail in Section 2.5. These actions provide more complex habitat for Coho as well as increased summer and winter/spring habitat.

The implementation of these actions is dependent upon completion of new trail segments routed through the forest further from the channel. All of the forested areas proposed for new trail segments are flat, extend more than a channel width from the top of the bank, can avoid impacts to redwood trees, and present good options for smooth connections to the existing trail alignment.

Approximately 33 LF of riprap segment R2 and approximately 148 LF of segment R3a would be removed on the west side of Redwood Creek upstream of Bridge 1. Approximately 60 to 80 LF of asphalt trail on the top of the west bank, including the small footbridge referred to informally as "Bridge 1.5," would also be removed. A drainage area at Bridge 1.5 would be enhanced as an alcove. The relocated trail segment would extend up to 440 LF.

Approximately 88 LF of riprap (segment L12) on the east side of the creek just downstream of Fern Creek would be removed. There is a buried rock drain lens in the center of this riprap segment. It is approximately 15 feet wide and extends about 20 feet from the riprap to the existing trail. Additional investigation of this drain lens would be conducted to identify any treatments related to its removal. Prior to removing this segment, approximately 115 LF of asphalt trail on the east side of the creek just downstream of Fern Creek would be relocated further away from the channel.

Creek Restoration Alternative 5 (Preferred Alternative)

Creek Restoration Alternative 5 includes all actions in Creek Restoration Alternative 4, plus the floodplain terracing described in Alternative 3 (Figure 2-5). Bank treatments to reduce erosion described in Creek Restoration Alternative 4 would be used. This alternative provides the maximum amount of improvements to Coho habitat. It includes the maximum extent of riprap removal that can be conducted without affecting infrastructure, existing grade controls, or existing LWD structures. Infrastructure that is protected includes the sewer line under the entrance boardwalk, trails not modified, and a water line along some areas of the left bank up to Fern Creek Trail. Several riprap segments are not proposed for removal because of the risk of the channel outflanking existing grade control, including two cascades and six historic channel-spanning log grade controls.

Bridge
Redwood Creek
trails
MWNM Boundary
Large Woody Debris

Proposed Riprap Treatments

No Action
Remove
Floodplain Grading
Disposal Area
Engineered LWD

Figure 2-3
Creek Restoration Alternative 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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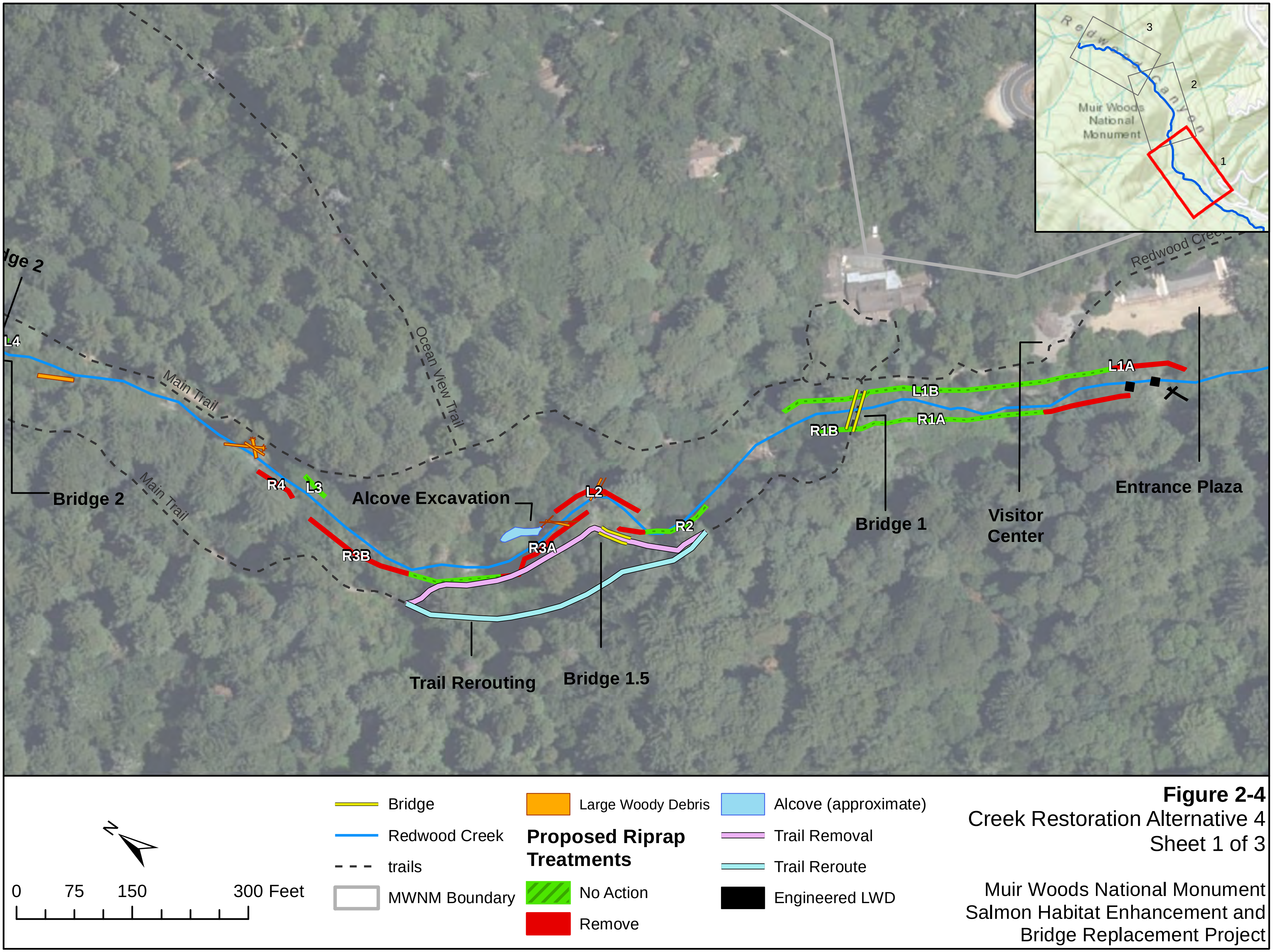

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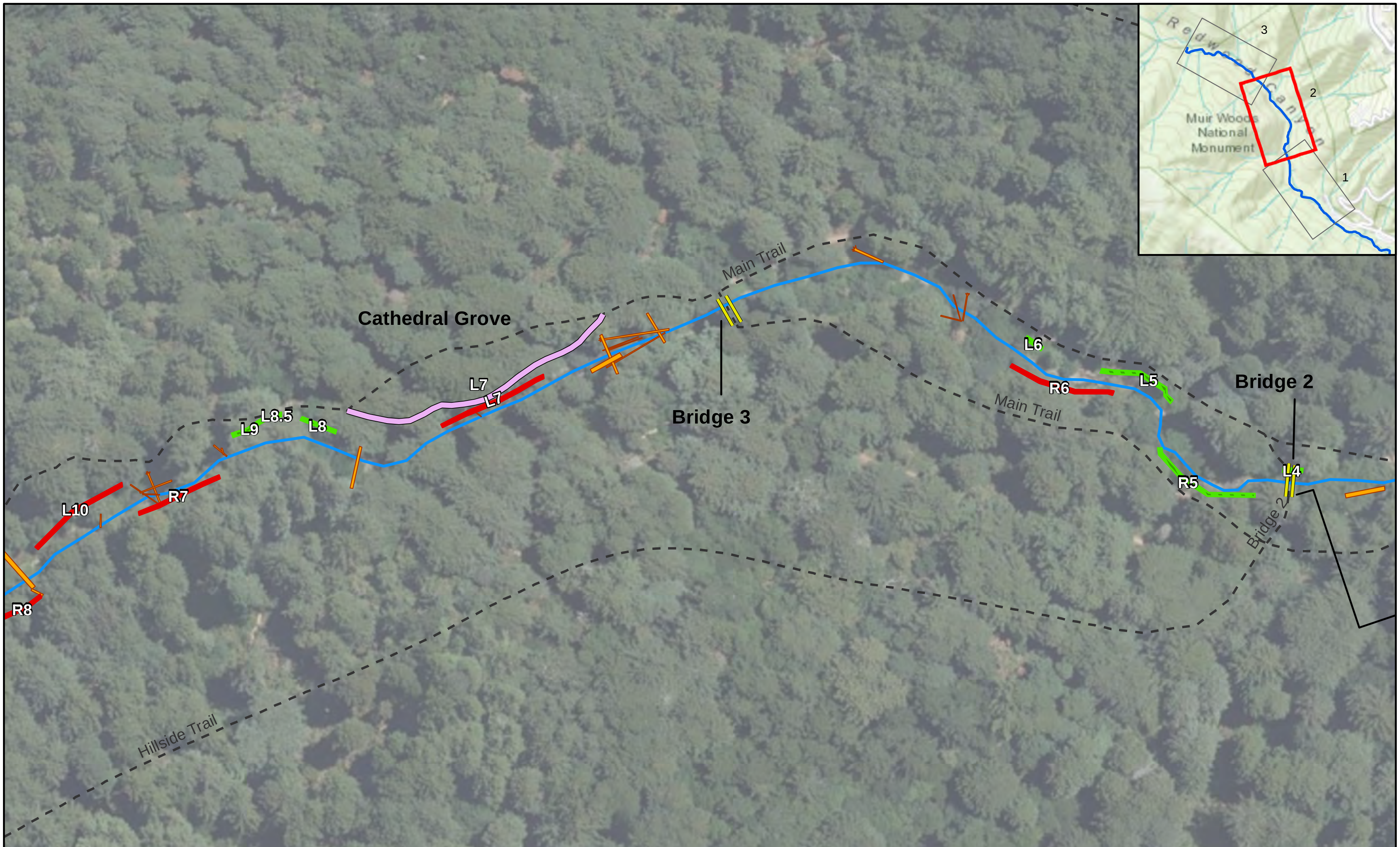
Figure 2-4
Creek Restoration Alternative 4
Sheet 1 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project



Bridge
Redwood Creek
trails
MWNM Boundary

Large Woody Debris

Proposed Riprap Treatments

No Action
Remove

Alcove (approximate)
Trail Removal
Trail Reroute
Engineered LWD

N

0 75 150 300 Feet

Figure 2-4
Creek Restoration Alternative 4
Sheet 2 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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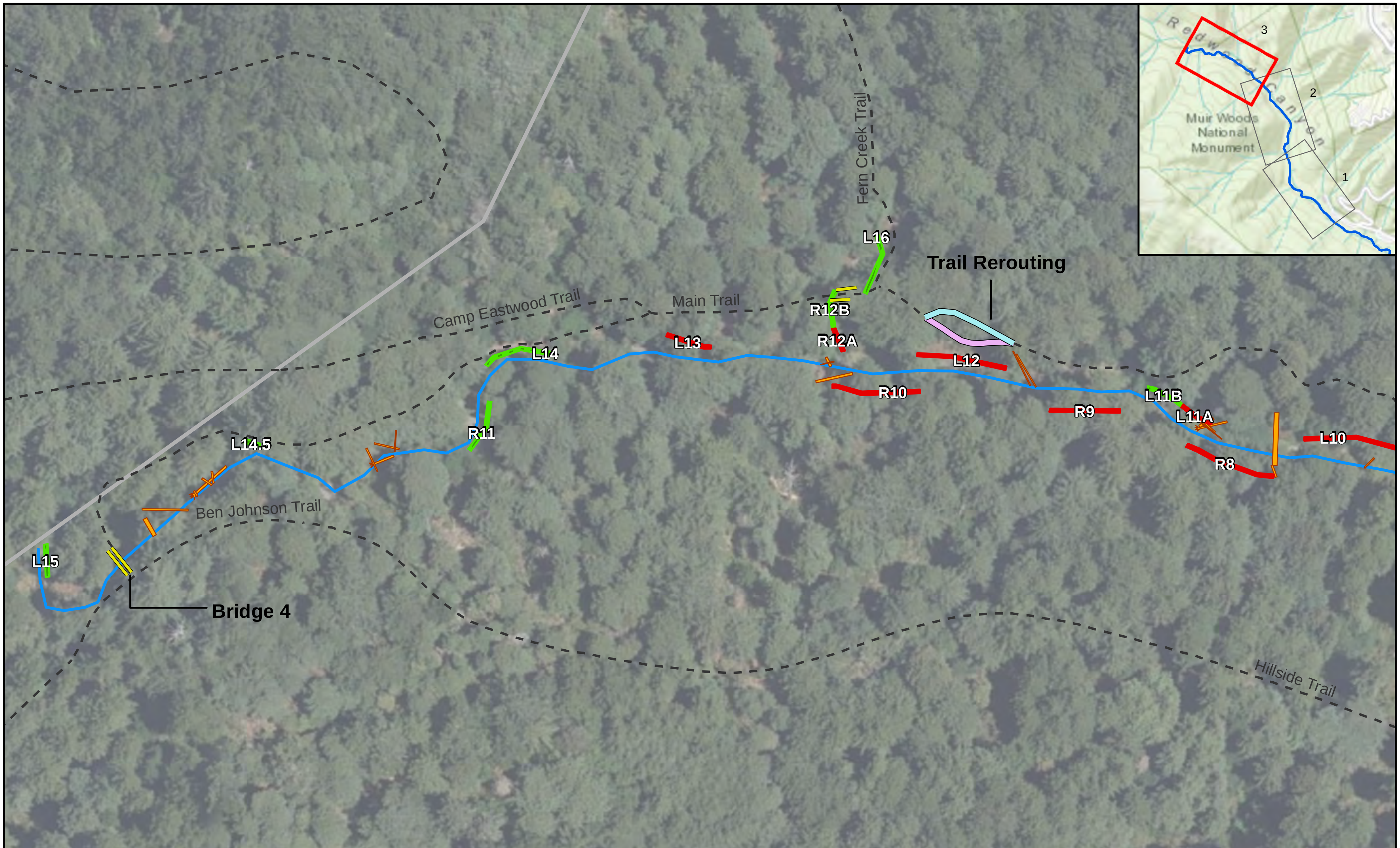


N

0 75 150 300 Feet

- Bridge
- Redwood Creek
- trails
- MWNM Boundary
- Large Woody Debris

Proposed Riprap Treatments

- No Action
- Remove
- Alcove (approximate)
- Trail Removal
- Trail Reroute
- Engineered LWD

Figure 2-4
Creek Restoration Alternative 4
Sheet 3 of 3

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

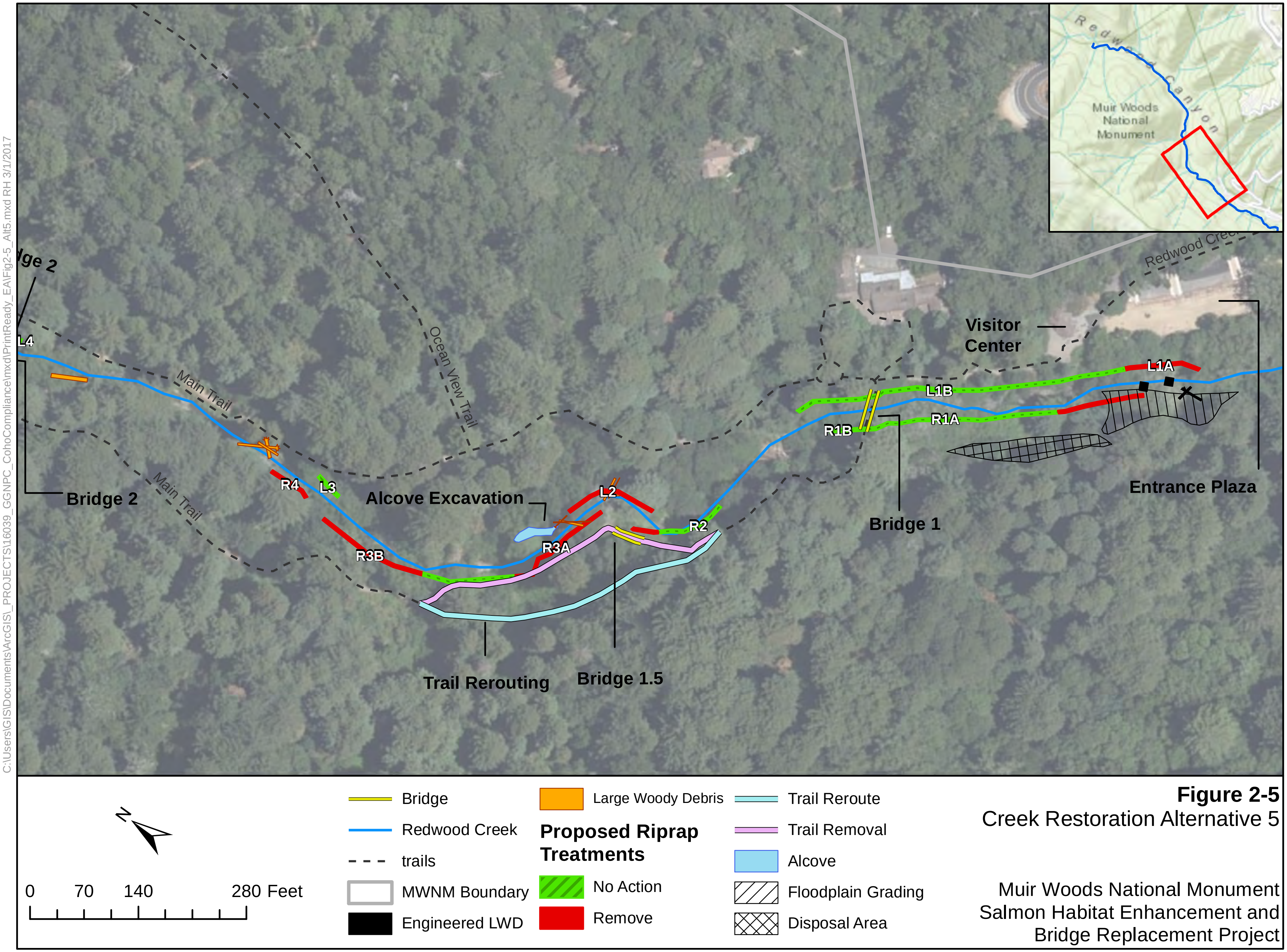


Figure 2-5
Creek Restoration Alternative 5

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

2.4 Pedestrian Bridge Replacement Alternatives

Four existing pedestrian bridges in MWNM are deteriorating due to age, and would be replaced by bridges which would be designed to provide improved flood conveyance while enhancing the rustic and historic character of MWNM. Designs for Bridges 2 and 3 would require trail rerouting, while designs for Bridges 1 and 4 would not. All alternatives would have certain key project elements in common. All of the forested areas proposed for new trail segments are flat, extend more than a channel width from the top of the bank, can avoid impacts to redwood trees, and present good options for smooth connections to the existing trail alignment. Table 2-2 summarizes elements in each Pedestrian Bridge Replacement Alternative.

Actions Common to All Pedestrian Bridge Replacement Alternatives

- NPS would replace Bridges 1 and 4 to pass a 100-year storm flow. This action would require minor increases to bridge span to ensure passage of a 100-year storm flow with 18 inches of freeboard (Figure 2-6). Bridge 1 would have an approximately 50 LF span and Bridge 4 would have an approximately 45 LF span.
- Bridge 2 would have an approximately 52 LF span and Bridge 3 would have an approximately 45 LF span. The height for these bridges would vary depending upon the alternative.
- Bridges would be of a clear span design over the stream channel, able to accommodate from 25- to 100-year flood flows (based on existing channel conditions). New abutments would be relocated farther from the creek but still in the 100-year floodplain.
- The approaches to all new bridges would be designed to connect the existing trail network with the new bridges.

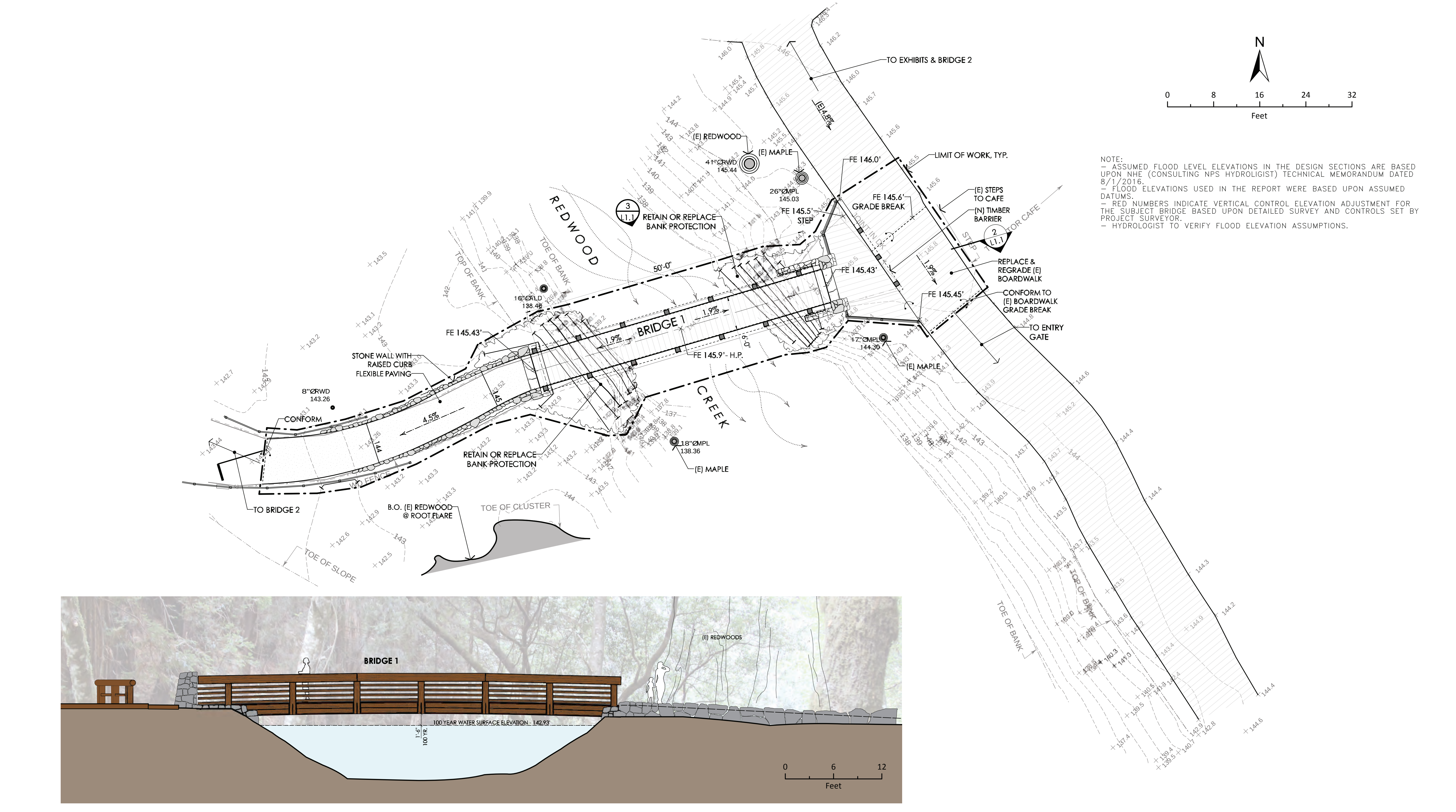
  Existing abutments for Bridges 1 through 4 would be removed. Historic riprap surrounding the Bridge 1 abutments and riprap in the vicinity of the Bridge 2 left bank abutment would not be removed. Non-historic riprap surrounding the Bridges 2, 3, and 4 abutments would be retained, replaced in-kind, or replaced with other bank protection measures.
- Bridge designs and associated redesigned trail approaches will meet ABAAS for outdoor areas and all grades will aim to be less than 5%.
- Bridges would be a steel stringer design with wood decking and guardrails (Figure 2-7). Guardrails are needed to comply with current safety codes. Bridges 1 and 4 would include a minor arched camber. Bridges 2 and 3 would include a more significant arched camber.
- New/rerouted trails would either be boardwalk or flexible paving, which could include asphalt, compacted shale, or other materials. The lengthened boardwalks/transitions between bridge and trails may require piers placed within the 100-year floodplain.
- Areas of existing trail removal would be decompacted, restored, and revegetated with native plants.

Table 2-2. Summary of Pedestrian Bridge Replacement Alternative Elements

	No Action Alternative	Alternative A: Bridges 2 & 3 – 25-year	Alternative B: Bridges 2 & 3 – 100-year	Alternative C: Bridge 2 – 25 year and Bridges 3 – 100-year (Preferred Alternative)
Bridge 1	Bridge would be replaced in kind. Accommodates 25-year storm	50 LF span Accommodates 100-year storm, 18 inches freeboard		
Bridge 2	Bridge would be replaced in kind. Accommodates 2-year storm	52 LF span Accommodates 25-year storm, 15 inches freeboard at peak of arch	52 LF span Accommodates 100-year storm, 14 inches freeboard at peak of arch	52 LF span Accommodates 25-year storm, 15 inches freeboard at peak of arch
Bridge 3	Bridge would be replaced in kind. Accommodates 2-year storm	45 LF span Accommodates 25-year storm, 12 inches freeboard at peak of arch	45 LF span Accommodates 100-year storm, 13 inches freeboard at peak of arch	
Bridge 4	Bridge would be replaced in kind Accommodates 50-year storm	45 LF span Accommodates 100-year storm, 18 inches freeboard		
Trail Rerouting	No changes to trails will occur	No trail reroutes for Bridges 1 and 4. Approaches to bridges would require minor new trail construction and adjusted grades within existing alignment. At Bridge 2, approx. 120 LF of new boardwalk to be installed on east side of creek and 20 LF of new boardwalk on west side of creek. At Bridge 3, approx. 120–160 LF of new trail and 30 LF of boardwalk	No trail reroutes for Bridges 1 and 4. Approaches to bridges would require minor new trail construction and adjusted grades within existing alignment. At Bridge 2, approx. 140 LF of new boardwalk to be installed on east side of creek and 40 LF of new boardwalk on west side of creek. At Bridge 3, approx. 120–160 LF of new trail and 50 LF of boardwalk	No trail reroutes for Bridges 1 and 4. Approaches to bridges would require minor new trail construction and adjusted grades within existing alignment. At Bridge 2, approx. 120 LF of new boardwalk to be installed on east side of creek and 20 LF of new boardwalk on west side of creek. At Bridge 3, approx. 120–160 LF of new trail and 50 LF of boardwalk

	No Action Alternative	Alternative A: Bridges 2 & 3 – 25-year	Alternative B: Bridges 2 & 3 – 100-year	Alternative C: Bridge 2 – 25 year and Bridges 3 – 100-year (Preferred Alternative)
		would be installed on east side of creek. 35 LF of new boardwalk on west side of creek Total = Approx. 205 LF boardwalk, approx. 120–160 LF trail	would be installed on east side of creek. 50 LF of new boardwalk on west side of creek Total= Approx. 280 LF boardwalk, approx. 120–160 LF trail	would be installed on east side of creek. 50 LF of new boardwalk on west side of creek Total= Approx. 240 LF boardwalk, approx. 120–160 LF trail
Grades	No changes to trails will occur	Bridge gradient and redesigned trails to bridges would meet ABAAS. All grades would be under 5%		
Bridge Abutments	No changes to abutments will occur	Existing abutments would be removed. New abutments would be installed during construction.		
Bridge Design	No changes to design will occur	Steel stringer bridge with guardrails. Bridges 1 and 4 would include a minor arched camber. Bridges 2 and 3 would include a more significant arched camber.	Steel stringer bridge with guardrails. Bridge 1 and 4 would include a minor arched camber. Bridges 2 and 3 would include a more significant arched camber. Bridge 2 would require a 10-foot-long guardrail on each side of bridge on the boardwalk.	Steel stringer bridge with guardrails. Bridges 1 and 4 would include a minor arched camber. Bridges 2 and 3 would include a more significant arched camber.
Gathering Area	No changes to existing gathering areas will occur	Bridge 2 would have small, approximately 20x20-foot gathering area on east side of creek.	Bridge 2 would not include a gathering area.	Bridge 2 would have small, approximately 20x20-foot gathering area on east side of creek.

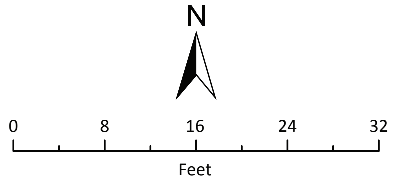
	No Action Alternative	Alternative A: Bridges 2 & 3 – 25-year	Alternative B: Bridges 2 & 3 – 100-year	Alternative C: Bridge 2 – 25 year and Bridges 3 – 100-year (Preferred Alternative)
Restoration Area	No changes will occur	Gathering area and existing trail alignment at Bridge 2 would be restored. Trail on east side of Bridges 2 and 3 would be restored.	Gathering area and existing trail alignment at Bridge 2 would be restored. Trail would be outside of 100-year floodplain. Trail on east side of Bridges 2 and 3 would be restored.	



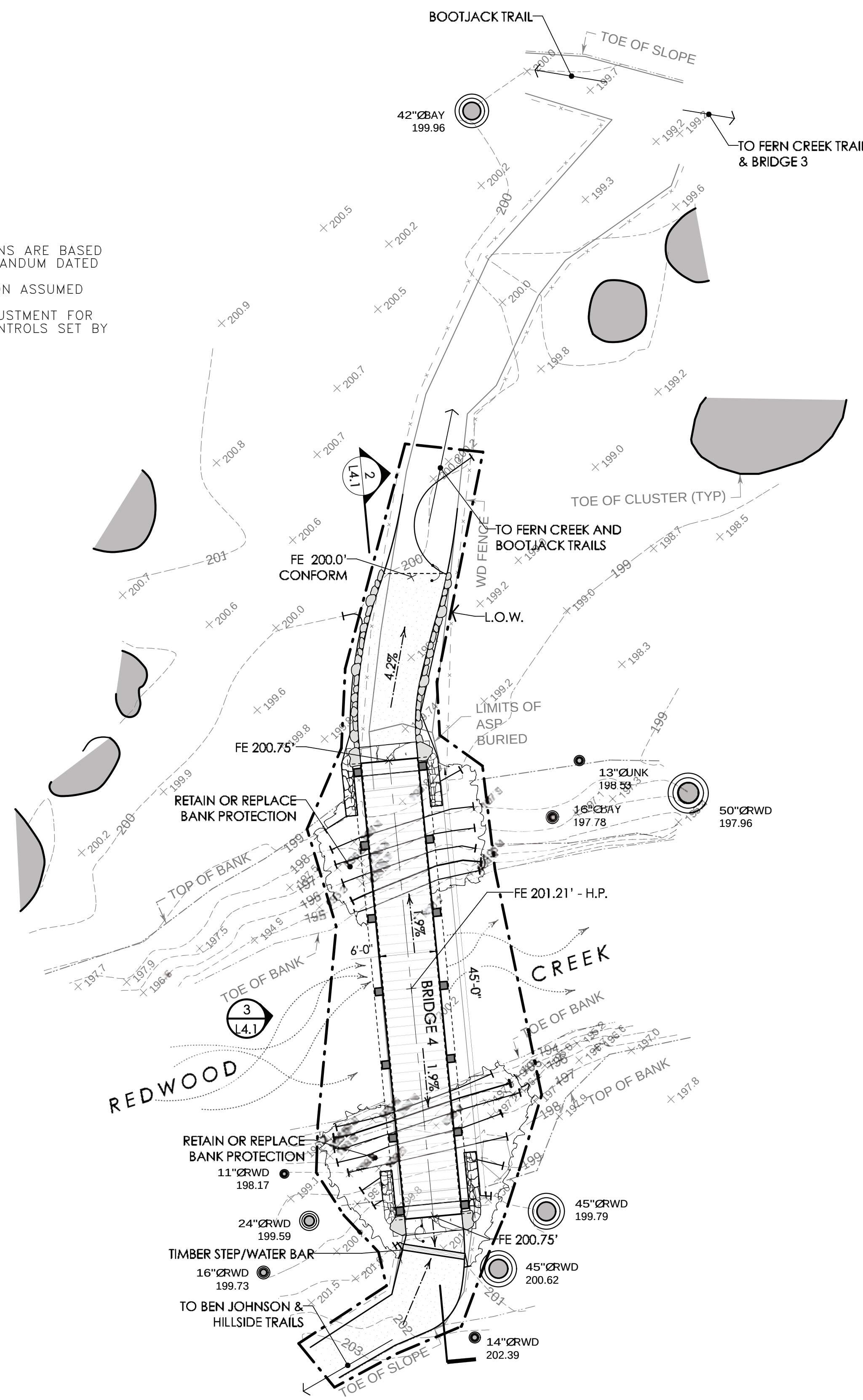
Source: Roth LaMotte 2017

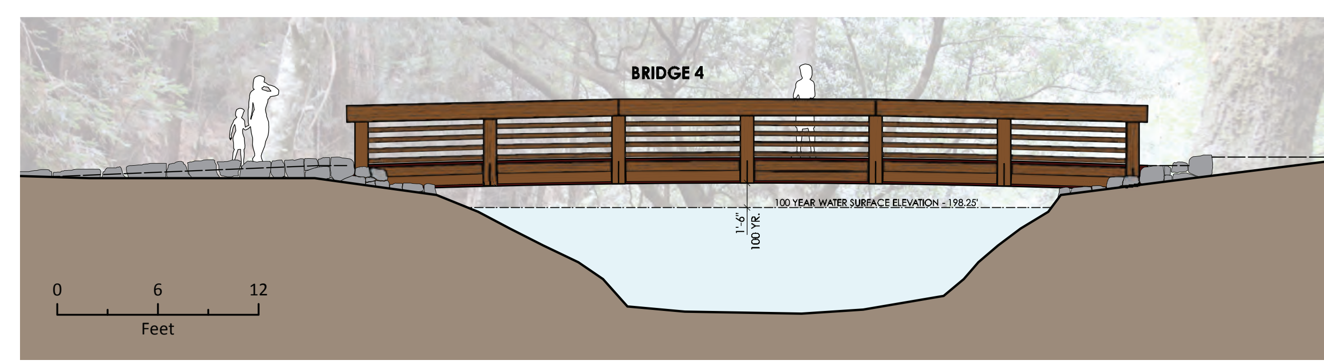
Figure 2-6, Sheet 1 of 2.
Actions Common to All Pedestrian Bridge Alternatives

Salmon Habitat Enhancement and Bridge Replacement Project Environmental Assessment



NOTE:
– ASSUMED FLOOD LEVEL ELEVATIONS IN THE DESIGN SECTIONS ARE BASED UPON NHE (CONSULTING NPS HYDROLIGIST) TECHNICAL MEMORANDUM DATED 8/1/2016.
– FLOOD ELEVATIONS USED IN THE REPORT WERE BASED UPON ASSUMED DATUMS.
– RED NUMBERS INDICATE VERTICAL CONTROL ELEVATION ADJUSTMENT FOR THE SUBJECT BRIDGE BASED UPON DETAILED SURVEY AND CONTROLS SET BY PROJECT SURVEYOR.
– HYDROLOGIST TO VERIFY FLOOD ELEVATION ASSUMPTIONS.





Source: Roth LaMotte 2017

Figure 2-6, Sheet 2 of 2.
Actions Common to All Pedestrian Bridge Alternatives

Salmon Habitat Enhancement and Bridge Replacement Project Environmental Assessment

Horizon WATER and ENVIRONMENT

Pedestrian Bridge Replacement Alternative A

Under this alternative, spans for Bridges 2 and 3 would be lengthened and the clearance under the bridge would be raised to pass a 25-year storm event (Figures 2-8 and 2-9). Bridge 2 would have 15 inches of freeboard at the peak of the arch in a 25-year storm event, while Bridge 3 would have 12 inches of freeboard at the peak of the arch in the same event. Existing abutments would be removed and new abutments would be placed farther from the creek channel.

For Bridge 2, this alternative replaces the asphalt trail on either side of the bridge with a boardwalk to connect to the main trail network to improve visitor experience, safety, and reduce maintenance needs. Approximately 120 LF of new boardwalk would be installed on the east side of the creek, and approximately 20 LF of new boardwalk on the west side of the creek. Approximately 80 LF of asphalt trail on the east side of the trail would be removed and restored. The existing large paved area on the east side of the bridge would be removed and areas closest to the creek would be restored. Bridge 2 would have a small approximately 20-by-20-foot gathering area on the east side of Redwood Creek.

For Bridge 3, this alternative replaces the asphalt trail with a new boardwalk and flexible paving trail to connect to the main trail network. Approximately 120 to 160 LF of new trail and approximately 30 LF of boardwalk would be installed on east side of creek, and approximately 35 LF of new boardwalk on the west side of the creek. This would result in new disturbance for re-alignment of trail, but also restoration where the approximately 130 LF of existing asphalt trail would be removed.

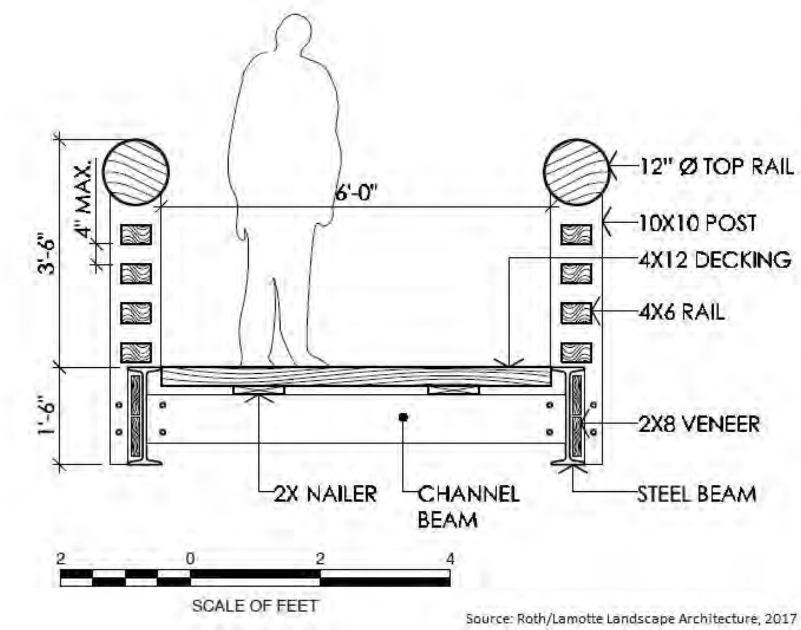
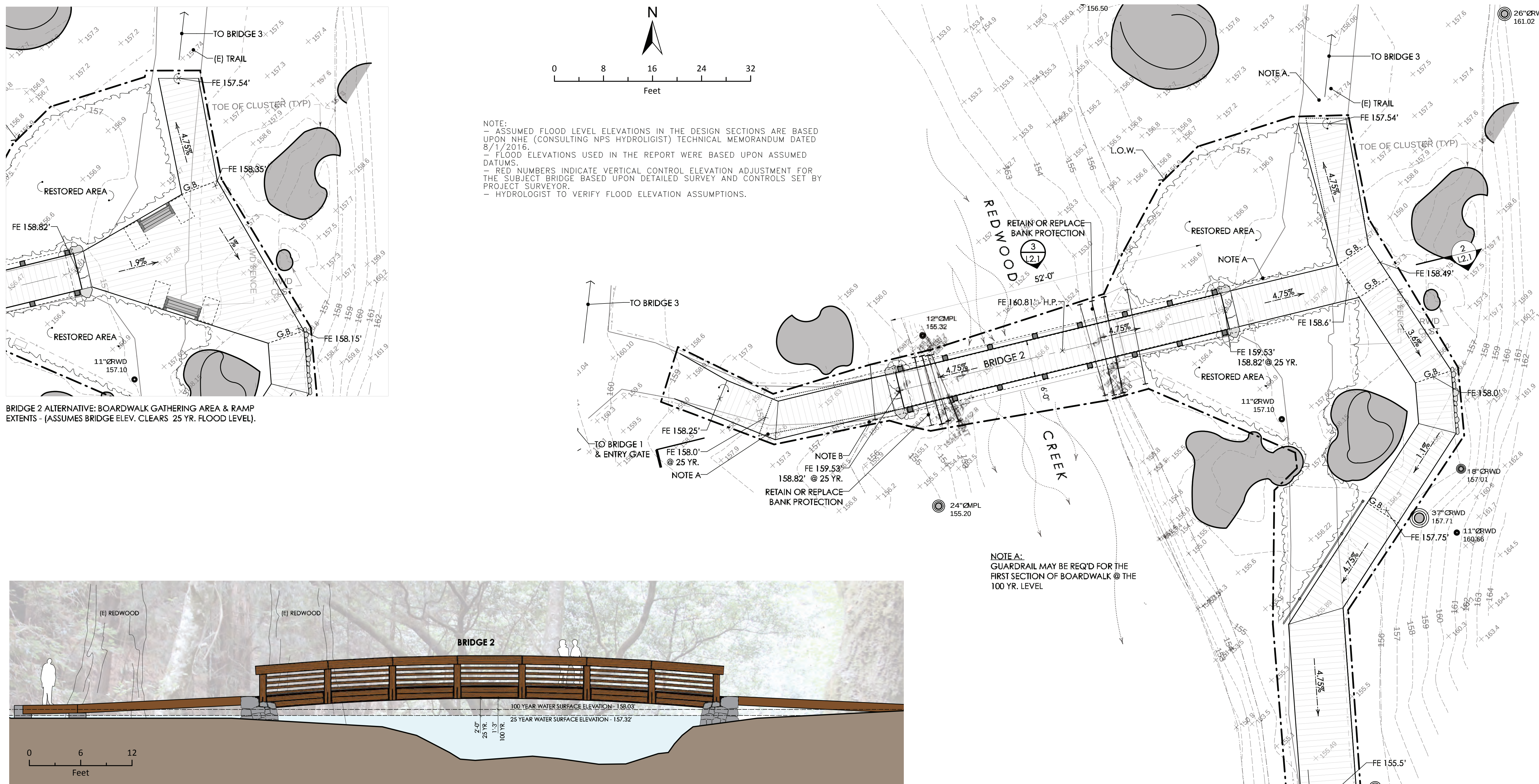


Figure 2-7. Typical Bridge Cross section

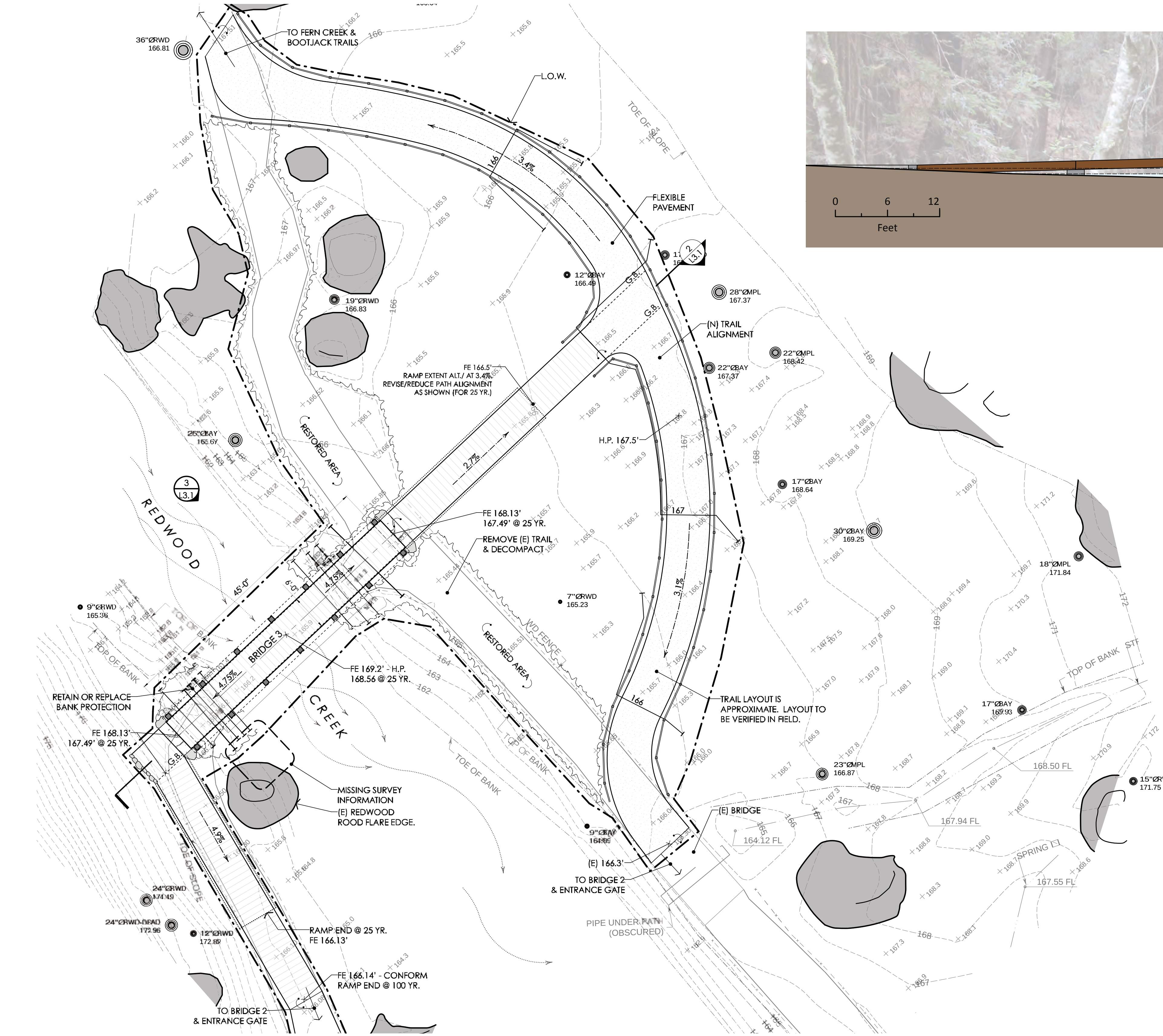
Pedestrian Bridge Replacement Alternative B

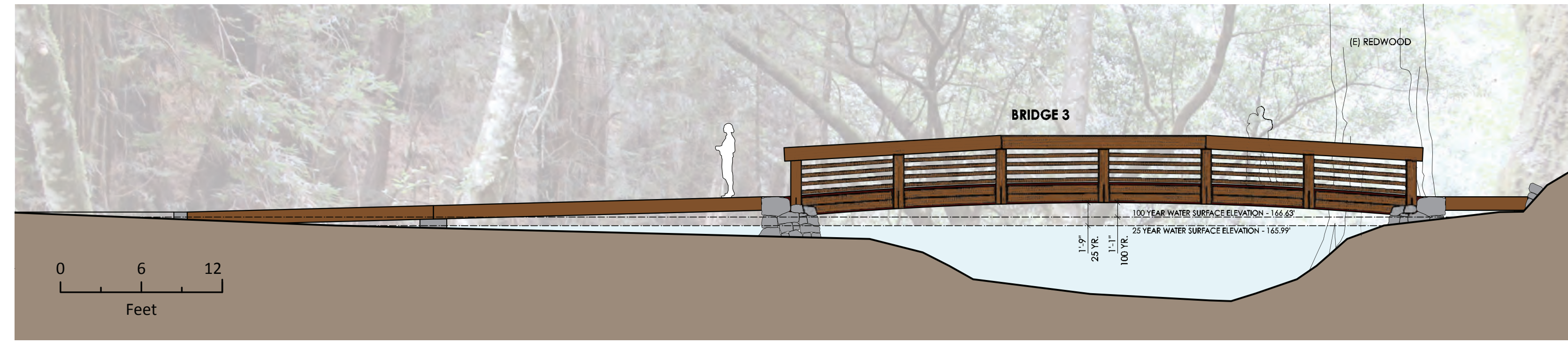
Under this alternative, spans for Bridges 2 and 3 would be the same length as under Pedestrian Bridge Replacement Alternative A but would be raised 9 inches (Figures 2-8 and 2-9). They would be designed to pass a 100-year storm event. Bridge 2 would have 14 inches of freeboard at the peak of the arch in a 100-year storm event, while Bridge 3 would have 13 inches of freeboard at the peak of the arch in the same event. Existing abutments would be removed and new abutments would be placed farther from the creek channel.

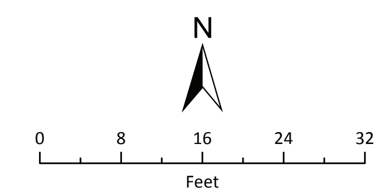


Source: Roth LaMotte 2017

Figure 2-8
Bridge 2 Alternatives







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– FLOOD ELEVATIONS USED IN THE REPORT WERE BASED UPON ASSUMED DATUMS.
– RED NUMBERS INDICATE VERTICAL CONTROL ELEVATION ADJUSTMENT FOR THE SUBJECT BRIDGE BASED UPON DETAILED SURVEY AND CONTROLS SET BY PROJECT SURVEYOR.
– HYDROLOGIST TO VERIFY FLOOD ELEVATION ASSUMPTIONS.

Source: Roth LaMotte 2017

Figure 2-9
Bridge 3 Alternatives

For Bridge 2, approximately 140 LF of new boardwalk would be installed on the east side of the creek and approximately 40 LF of new boardwalk would be installed on the west side of the creek. This would result in new disturbance for re-alignment of trail, but also restoration where approximately 80 LF of existing asphalt trail and the informal gathering area would be removed. The rerouted trail would be outside of the 100-year floodplain. This alternative would require approximately 10 LF of guardrail on the boardwalk approaches to Bridge 2 for safety and accessibility reasons, and would not include a gathering area at Bridge 2.

For Bridge 3, this alternative would require trail rerouting involving approximately 120 to 160 LF of new trail and installation of approximately 50 LF of boardwalk installation on the east side of the creek and approximately 50 LF of new boardwalk on the west side of creek. As with Pedestrian Bridge Replacement Alternative A, approximately 130 LF of existing asphalt trail would be removed and restored. This would require an area of new disturbance for the rerouted trail, but allows the trail to be pulled back from the stream with restoration of existing paved trail area. This would also provide different visitor experience through a wooded area, which is not generally provided on the valley floor.

Pedestrian Bridge Replacement Alternative C (Preferred Alternative)

Under this alternative, the span of Bridge 2 would be lengthened and designed to pass a 25-year storm event and Bridge 3 would be lengthened and designed to pass a 100-year storm event (Figures 2-7 and 2-8). Bridge 2 would have 15 inches of freeboard at the peak of the arch in a 25-year storm event, while Bridge 3 would have 13 inches of freeboard at the peak of the arch in a 100-year storm event. Under this alternative, the gathering area at Bridge 2 is retained. Habitat benefits of the longer span at Bridge 3 are significantly greater than habitat benefits for the longer span at Bridge 2. Additionally, this alternative requires less rerouting and replacement of existing trails at Bridge 2 than Alternative B.

For Bridge 2, this alternative would have the same design as described in Pedestrian Bridge Replacement Alternative A. For Bridge 3, this alternative would have the same design as described in Pedestrian Bridge Replacement Alternative B.

2.5 Construction Methods

There are many constraints to traditional construction methods at MWNM. Equipment access is limited by two extensive boardwalks that would not support heavy equipment. The forest floor is sensitive, due to both redwood root systems and understory vegetation. Visitor use is heavy within the park, and visitors use trails 7 days per week. Additionally, there are multiple biological constraints and work windows, including the salmonid spawning season, northern spotted owl nesting season, songbird nesting season, and marbled murrelet nesting season.

Revegetation during the first phase of creek restoration actions is anticipated to be largely salvaged or transplanted material from within MWNM, while revegetation in later years would also consist of nursery stock grown from locally collected materials. All plants for restoration will be grown by or under guidance of NPS's native plant nurseries. Revegetation for bridge replacement actions may consist of both salvaged and nursery stock.

Preparation of a stormwater pollution prevention plan (SWPPP) is anticipated for this project. Erosion control and sedimentation best management practices (BMPs) would be conducted per the SWPPP and would be implemented in each phase.

NPS would prepare a detailed plant protection plan based on specific areas to be impacted by any proposed actions. NPS would thoroughly review potentially impacted areas in advance and identify either any special-status or locally rare species as well as native plants that would be protected (more details on rare plant surveys are provided in BMPs BIO-11 through BIO-13) (see Table 2-3 in Section 2.7, *Best Management Practices*). This plan would also identify invasive species that should be controlled prior to implementation of proposed action (more detail in BMP-7). Based on the species and potential impacts, a plan would be made to either (a) avoid the area if necessary to the presence of a sensitive species; (b) salvage plants if they are salvageable; (c) trim branches/leaves if the plants would easily resprout, (d) cover with plywood or other protective materials, or (e) other types of activities. Salvaged plants would be removed either immediately before impact or possibly approximately 1 month in advance. These plants would be either replanted in other disturbed areas immediately or stored in an area with a water source, and then replanted either immediately after work is completed in a specific zone or during the typical winter planting period. All BMPs described in Table 2-3 would be implemented.

Creek Restoration

Some construction activities, such as staging, stockpiling, and transport of materials would take place on California State Parks land. These include use of the Alice Eastwood campground, hauling up Alice Eastwood Road to Panoramic Highway, and the work at the Plaza. Figure 2-10 shows the park boundaries and the location of State Park land.

Construction is anticipated to be conducted in two or more phases. The riprap removal work located upstream of Bridge 2 is anticipated to be conducted first, and the riprap removal work downstream of Bridge 2 is anticipated to be conducted in a later year.

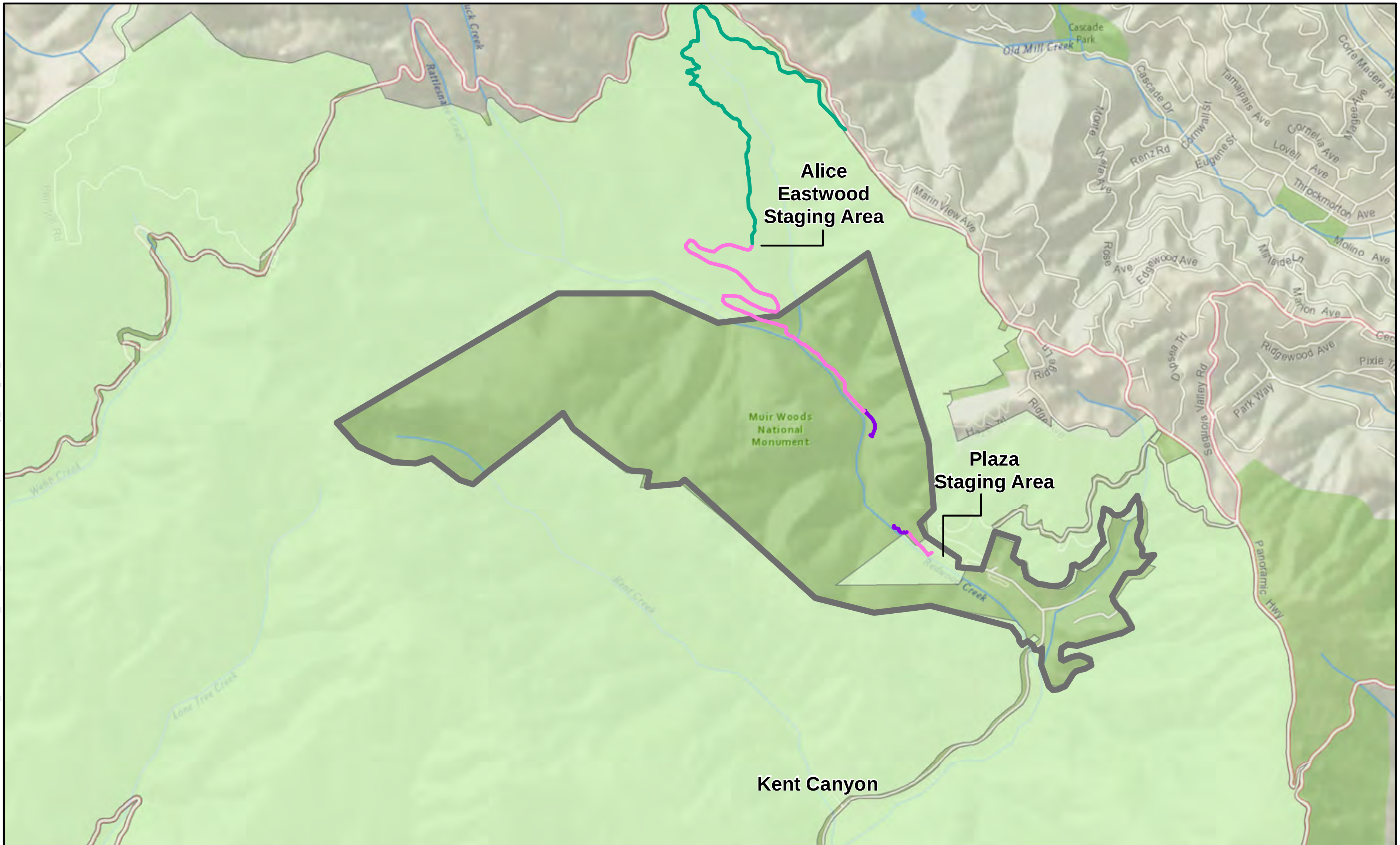
The methods described in this section are divided by phases and geographic areas of the Proposed Action and are not specific to the alternatives described above. Thus, riprap selected for removal under any of the Creek Restoration Alternatives would be removed using the methods described below based on its location within Redwood Creek. Phase 1 riprap removal consists of riprap removal between Bridge 2 and Bridge 4. Installation of LWD in this work area may or may not be concurrent with Phase 1 riprap removal, depending on funding, crew availability, limited work window, timing of contract award, or other factors. Riprap segment R4 could potentially be removed during either Phase 1 or Phase 2. This segment consists of small rocks which can be removed by hand. Both removal and off-haul of this segment would use hand methods such as wheelbarrows.

The Phase 2 work zone would include all actions downstream of Bridge 1, as well as any riprap removal, alcove construction, or LWD installation identified in the Bridge 1.5 area. Installation of LWD between Bridge 1.5 and Bridge 2 could occur in either phase.

Upstream of Bridge 2

Phase 1 Riprap Removal (Excluding Segment R6)

Equipment would be mobilized to the California State Parks Alice Eastwood Group Camp, where a staging area would be established. The staging area would be delineated by fencing such as orange environmentally sensitive area fencing and/or temporary 6-foot-high chain-link fencing.



N

0 625 1,250 2,500 Feet

Primary Route for Large Excavator

Route On Trail

Alice Eastwood Road

MWNM boundary

California State Park Land

Figure 2-10
State Park Lands and Staging Areas

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

Equipment mobilized for in-channel work upstream of Bridge 2 would use Alice Eastwood Road, to the Camp Eastwood Trail, to the intersection with the main trail at MWNM (see Figures 2-10 and 2-11). Alice Eastwood Road is on California State Parks property. From the intersection with Panoramic Highway, the upper segment of Alice Eastwood Road is paved and leads to the California State Parks Alice Eastwood Group Camp. The lower segment of the road is dirt from the Alice Eastwood Group Camp to MWNM. The dirt segment has numerous gullies, and the gullies would be treated as needed for mobilization and hauling by the construction crew prior to use to reduce long-term sediment delivery. These gullies were recognized as a source of sediment in the Pacific Watershed Associates (PWA) 2002 sediment source survey and were evaluated as medium and medium low priorities for treatment. The gully on the dirt segment of the Alice Eastwood Road currently washes sediment to the asphalt trail at Muir Woods, within 25 feet of the creek. Any damage to Alice Eastwood Road would be repaired following the completion of hauling.

Prior to any heavy equipment entering the channel, the work area would be dewatered and fish and wildlife removed following the steps described in Section 2.7, *Best Management Practices*. A cofferdam (either traditional sandbag/polyethylene design or a water-filled cofferdam) would be installed at approximately creek station 2000. The pump bypass would be installed at near the Camp Eastwood trail junction with the Main Trail, and the discharge pipe would be located just upstream of Bridge 3 to maintain clean flows at the same natural flow rate downstream of the work zone. Once the pump is turned on, it would need to run continuously 7 days per week to prevent water from flowing through the work zone. Discharge from Fern Creek would also need to be rerouted or plugged to avoid draining into the work zone; it is conceivable that if flows are higher than usual at the time that another pump could be needed, but it is likely that these flows will be able to be rerouted without the use of an additional pump. If any small tributaries are actively draining at the time of work, their flows will also be rerouted or plugged to avoid draining into the work zone.

To provide equipment access to the channel, a ramp would be constructed between the main trail and Redwood Creek, near the cofferdam. Removal of small areas of fencing and minor clearing and grubbing could occur at the ramp location. Fencing would be rebuilt at the completion of the project. The ramp design is anticipated to consist of high strength woven geotextile fabric (e.g. Mirafi 500X) with a layer of geogrid (e.g. Mirafi BX1200) capped with 6 to 8 inches of aggregate. The aggregate design mix would be constrained by the choice of geo-grid used for the ramp or whether geo-grid is used at all. The ramp, including all materials used for its construction, would be removed after activities in the channel are completed; and the forest floor would be decompacted using the same method described for asphalt trail removal below. Approximately 450 haul cart loads are anticipated to exit the channel using this ramp. This ramp will also be used daily for access to the channel for all personnel and equipment during work in this area.

Once reaching MWNM, the equipment would cross approximately 100 feet of forest floor to enter Redwood Creek via the ramp. The route would then be located within the creek, extending from this upstream point in the creek down to the Cathedral Grove reach, a distance of approximately 1,400 LF of channel. All riprap from the Cathedral Grove area (riprap segment L7) to the upstream-most riprap segment proposed for removal (L13) would be removed using this route.

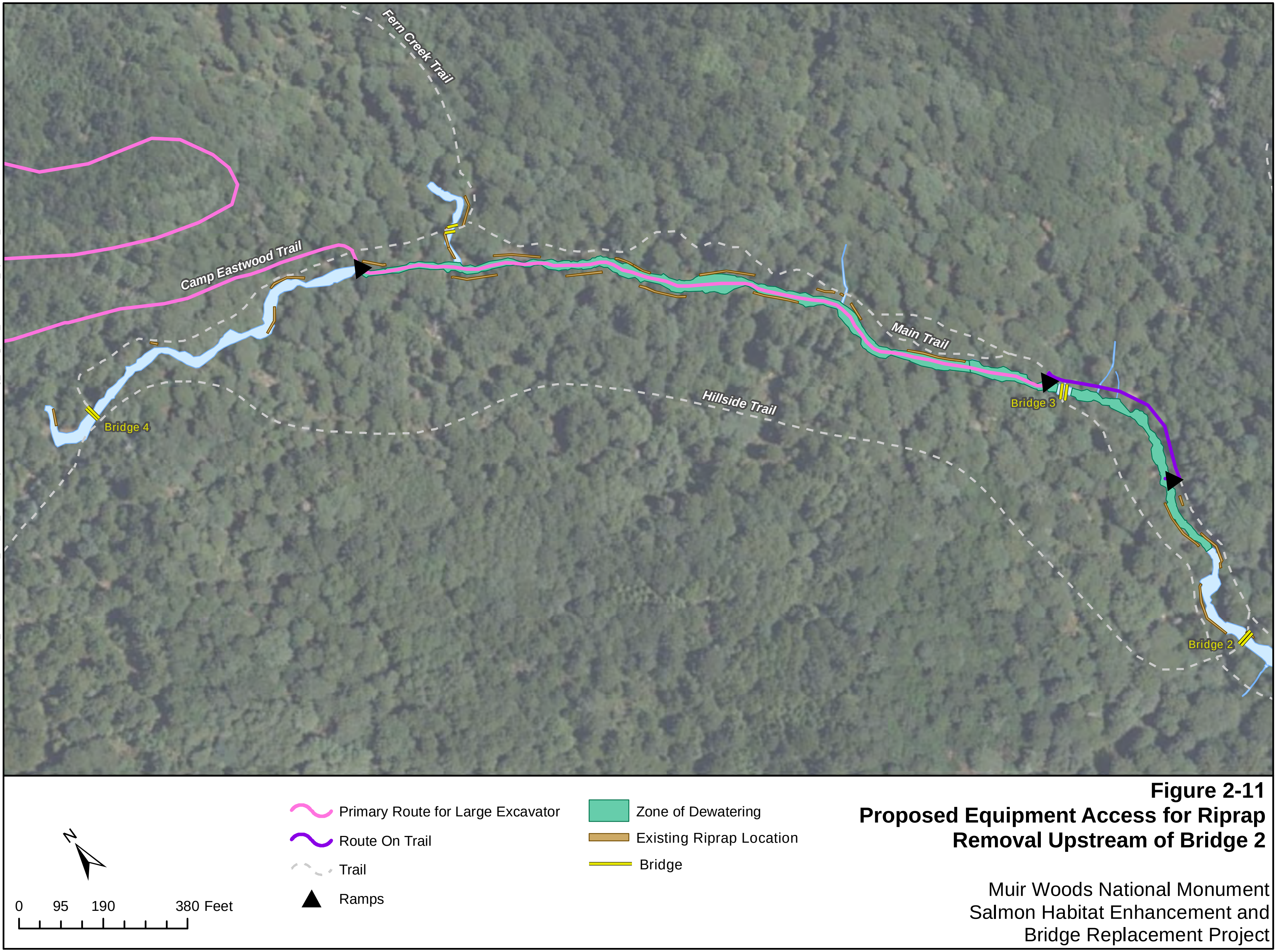


Figure 2-11
Proposed Equipment Access for Riprap Removal Upstream of Bridge 2

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

The channel in this route is straight and has no wood jams to dismantle. There are a few small-diameter logs spanning the channel from top of bank to top of bank, but these do not extend to the water and can be picked up and replaced or relocated to a location that will function more effectively for habitat. The bed material is mostly cobble. One large-diameter instream log occurs near this area but it will not need to be moved. It is located downstream of the area where heavy equipment would be operating.

The equipment anticipated to be used in this area would be three mid-sized excavators, two to four haul carts (e.g., Wacker DW50), a skid steer, a hydraulic hammer (at least one for the mid-sized excavator and/or skid steer). A minimum of two laborers is anticipated. It is anticipated that much of the rock in this area can be removed without being broken up; however, some may need to be broken up before removal and hauling. The excavator would operate throughout the channel reach to remove the large 1- to 2-ton boulders and load them into haul carts. Each cart would drive back up the channel, up the Camp Eastwood Trail and then to Alice Eastwood Road, drive up the road to the Alice Eastwood Group Camp and unload at the Alice Eastwood Group Camp parking lot. After exiting the channel, the one-way haul distance between the Camp Eastwood Trailhead to the Alice Eastwood Group Camp parking lot is 4,412 LF. A 20-ton excavator would load the boulders into 10-CY trucks at that location. About three trucks are estimated to be running daily throughout the majority of the Phase 1 riprap removal.

This access route was selected because it is the fastest and most efficient route and would have the fewest impacts on the forest or on visitor access. All the riprap in this area can be removed in a single working season. This route allows access by a sizeable excavator and the use of an off-haul cart with a capacity of 3 to 4 CY per trip, substantially reducing off-haul time and number of trips. This approach also allows for a greater range of actions:

1. Vegetation on banks can easily be salvaged by equipment. Vegetation would be removed, set aside during the work, then replaced in the bank by the equipment.

2. Notches in banks could be created for placement of logs or holes in the channel could be pre-dug to embed the logs in the channel, providing added stability.

3. Pools can be excavated prior to wood placement. Although pool configurations may change in the long term during winter events, configurations would provide some near-term juvenile habitat.

4. Any excavated pool material can be placed at an in-stream bar. Again, although this geomorphic configuration will change, it may help to jump start the desired creation of in-channel complexity.

Phase 1 Riprap Removal (Segment R6)

For riprap segment R6, which is upstream of Bridge 2 but downstream of Bridge 3, the riprap removal method would be as described below.

A cofferdam, similar to that described above, would be installed just upstream of Bridge 3. A third cofferdam may be necessary to prevent bypass water from migrating upstream into the work area and will be assessed further prior to the final design. A secondary pump and bypass would be constructed in this area, with the terminal end of the discharge pipe located downstream of segment R6. This area would be dewatered as described in Section 2.7, Best Management Practices. Dewatering of this portion would be conducted for a shorter period of time. An overlap in operation of this dewatering pump and the upstream dewatering pump would occur because the segment R6 riprap would be offhauled using the dewatered portion of the channel described above.

Two ramps would be constructed to allow equipment access to segment R6. These ramps would be located at Bridge 3 and slightly upstream of segment R6. They would be constructed and removed similarly to the ramp at creek station 2000, but would be less substantial because they would be used for a shorter period of time.

A smaller excavator would travel down the channel using the Alice Eastwood Road and the primary channel route described above. The excavator would drive out of the channel at the Bridge 3 ramp to the main trail. It would then drive down the main trail on the east side of the channel to re-enter the channel using the ramp located slightly upstream of segment R6. A smaller excavator is required because the trail is narrow in this area. Since the excavator would be smaller than the one used further upstream, it is likely that the segment R6 rocks would have to be broken up in order to load them into the carts. Hydraulic and/or pneumatic equipment would be used to break down the rock.

The excavator would load rocks into carts on the trail. The carts would travel back up the main trail to the downstream end of Cathedral Grove, and re-enter the main channel haul route back up to Alice Eastwood Road. The same carts would be used in this area that would be used upstream. The longer haul time would result in a slower rate of work in this area.

Asphalt Trail Removal

This methodology is also applicable to asphalt trail removal downstream of Bridge 2. Removal of asphalt trail and any base rock would be conducted by an excavator or other small equipment using methods that would not disturb the ground surface below the base rock. Equipment would scrape in shallow movements to avoid impacts to possible roots beneath the trail. Removal of all of the base rock is very important or the area will not easily develop vegetative cover. Material would be off-hauled using the same creek off-haul route as described above.

The subsurface would then be decompacted using hand methods to avoid potential impacts to tree roots Shovels would be inserted into the ground surface about 1-foot deep in multiple directions at 1-foot centers throughout the area. The ground would then be heavily covered with organic debris from the forest floor, with mulch a minimum of 4 to 6 inches thick. Surface water would be allowed to infiltrate over the next year before planting. This method would be repeated about 6 months to 1 year later, prior to planting.

Existing Water Line at Muir Woods

The route of an existing water line which extends from the Alice Eastwood area and likely along the left bank of Redwood Creek requires investigation prior to construction. This line once served drinking fountains that have since been removed, but the line has been retained for fire protection. The investigation is needed to ensure proposed actions would not interfere with this line.

Existing Water Line at Alice Eastwood

A water line extends down the center of the paved Alice Eastwood Road from Panoramic Highway to the campground. It is an old line that is at a shallow elevation and prone to breaking. Prior to implementation, the route of the water line will be marked on the road by a professional company. A preconstruction water pressure test will be conducted to identify any existing leaks in the line. A contractor will be required to repair any leaks that occur during their use and will conduct a post- construction water pressure test to demonstrate the system is in good working order prior to closing out. This method will also be used for any bridge construction in which heavy trucks use the Alice Eastwood Road.

Hauling and Location of Rock Disposal

Rocks are expected to be stockpiled at the Kent Canyon storage area for reuse either by NPS or State Parks in the future. Kent Canyon is on lower Muir Woods Road, approximately 1 mile downstream from the MWNM entrance (Figure 2-9). To access the storage area, trucks would drive from the intersection of Alice Eastwood Road and Panoramic Highway to Upper Muir Woods Road, then past the entrance to MWNM, and about 2 miles down to Kent Canyon. This trip would be approximately 5 miles one way. Driving time for a haul trip could be slowed by visitor traffic at MWNM if hauling is done during peak visitor hours. It may be possible to haul during off-peak hours.

Due to the use of the large excavator, it is likely that many of the 1- to 2-ton rocks can be stockpiled intact and will therefore be more valuable for potential future reuse. It is possible some rocks might be delivered to other currently unidentified locations.

Trail Closures

Alice Eastwood Road from the Alice Eastwood Group Camp would be closed during Phase 1 hauling activities, for pedestrian safety. Other nearby routes such as Fern Creek Trail would remain open. Signs informing visitors that the area is being used for construction access would be installed during construction. However, LWD installation may be occurring at the same time as riprap removal, and LWD installation would require trail closure. Trail closure may be focused on selective areas for LWD installation, instead of broad areas of trail closure. Signage and alternative routes would be provided for any trail closures.

Campground Closure

The Alice Eastwood group campground would be closed by State Parks during the Phase 1 implementation while the area is used as a staging area to load rocks into trucks. State Parks may make the determination to close the campground on both weekdays and weekends or only on weekdays. The work will be conducted either entirely after Labor Day or will minimize any disruptions prior to Labor Day to minimize any closures during the summer period when the campground is used frequently during weekdays.

LWD Installation

Installation of LWD in the channel would occur both within and outside of the routes identified for riprap removal. See Figure 2-1 for detail on location and movement direction for logs proposed for LWD installation. LWD would be installed using a combination of methods, including a cable hoist and drag method as well as the use of heavy equipment.

The primary method of LWD installation will entail the use of a cable and grip hoist system. This method lifts one end of the tree in the air while the other is dragged on the ground. Existing downed logs present in MWNM would be moved into the channel to act as LWD. In areas accessible by heavy equipment, a notch in the bank or a hole in the creek bed may be pre-dug for placement of the wood via the cable method. Backfilling of gravels around an embedded trunk tip would most likely be conducted by hand. Designs will maximize the number of log pieces in a jam, which would increase the sediment storage potential of wood jams, the roughness of the structure, the complexity of scour and fill patterns, and the length of channel that is influenced by the structure. As described above, heavy equipment would be used to excavate pools and build adjacent bars/riffles at wood jams.

The rigging uses wire rope with grip hoists. The grip hoists put the wire rope under tension. A rigging crew would set up the rigging in trees surrounding the log to be moved. A detailed rigging plan would be prepared approximately 1 to 2 months prior to LWD relocation. Crews would climb trees using a Swedish ladder (a sectional aluminum ladder) for safety. The use of spurs, which enter trees approximate 1.5 inches, would not be permitted for tree climbing. Nylon strapping would be placed around the tree to secure the rigging. Trees would be protected from damage by placing 2x4 planks between bark flutes as well as padding the area to be strapped. One end of the target log would be raised and the log would be dragged into the creek. A rut would be created as the log is dragged. This rut would be filled using shovels and rakes, following placement of the LWD. There would also likely be temporary trampling of vegetation surrounding the logs moved into the channel. For logs installed in areas where riprap will not be removed, dewatering of the channel is not anticipated. This is based on the idea that under natural recruitment of LWD into the channel, trees fall when the channel is wet and inhabited. The grip hoist method has been used by both NPS and State Parks trail crews in and near Muir Woods and is a commonly used technique in back country areas without access for equipment.

If any logs for LWD must be cut, the following method would be used to avoid leaving a visible clean cut on the end of the log. A wedge and a sledge hammer would be used to splinter the end of the log by using an existing crack in the end of the log. The exposed end would be left splintered, as it might appear after a fall. It may be feasible to first cut the log with a chainsaw and then splinter the remaining end. Duff would also be used to bury a new cut at the end of a log. Finished cuts should not appear as visible cuts but as roughened, splintered ends.

A few bay laurel (*Umbellularia californica*) trees may be removed to allow relocation of LWD. In order to incorporate two large redwood logs that fell in January 2017 into the LWD designs, two small redwood trees (less than 1 foot diameter at breast height [DBH]) would be removed and reused within the Redwood Creek channel. Two small diameter redwood trees (less than 1 foot DBH) may also be removed to allow a large diameter redwood, which fell naturally during winter storms in early 2017, to be rolled into the channel upstream of Bridge 2. They would be reused as LWD in the channel to create a complex jam.

The LWD designs call for piles of small woody debris to be placed in the channel before large logs are placed on top of them. The small woody debris would be collected from a variety of locations around MWNM where fallen or hazardous trees have been cut by the trail crew and piles of slash remain.

Phase 2 Downstream of Bridge 2

These methods pertain to the Plaza Area, which extends from Bridge 1 downstream to the Plaza, and the Bridge 1.5 area, which includes riprap segments R3, a portion of R2, and L2. Phase 2 work would be conducted in a similar manner to Phase 1 work, with a larger excavator used downstream of Bridge 1. LWD installation downstream of Bridge 1 would occur in Phase 2. Installation of BMPs required by the SWPPP would occur, and are anticipated to be similar to those for Phase 1.

Phase 2 mobilization would require a police escort for the delivery of the 20-ton excavator. The Plaza Area would be used as the staging area for this phase of work. The primary equipment access and haul route for the Plaza Area would be between Bridge 1 and the Plaza (see Figure 2-12). Large equipment can easily access this area from the Plaza. The existing sewer line in the Plaza area would not be impacted by Project actions.

A cofferdam, dewatering pump, and bypass pipe would be set up near the Bridge 1.5 area. This area would be dewatered and fish and wildlife would be removed as described in Section 2.7, Best Management Practices. It may be possible to use an electric pump in this location, but if this is not feasible a diesel pump would be used. A ramp would be constructed at in the Plaza Area and would be similar to the ramp described above at station 2000. This ramp would be the primary route for equipment entering the channel as well as off-hauling riprap. A large excavator would enter the channel from the Plaza and travel upstream to remove riprap downstream of Bridge 1. Track trucks, wheel loaders, or carts like those to be used in Phase 1 would be used to haul the rock out of the creek and up to the Plaza. The 10-yard-trucks will be loaded at the Plaza Area.

Ramps would be built at Bridge 1 and in the Bridge 1.5 area, similar to the Phase 1 ramp described at Bridge 3. The riprap in the Bridge 1.5 area would be removed by a smaller excavator (such as that described for riprap segment R6 above). It would travel from the Plaza, up the channel haul route to Bridge 1, and exit the channel on the right bank just downstream of Bridge 1. From there, it would drive on the asphalt trail along the right bank to the work zone. Much of this removal may be conducted from the bank itself; however, the excavator would also enter the channel in this area and dewatering would occur as described above. To off-haul, the carts would travel back down the asphalt trail, down the ramp on the immediate downstream side of Bridge 1, down the channel to the Plaza area, and up the ramp to the Plaza. In addition to riprap removal, the excavator would be used in the Bridge 1.5 area to excavate an alcove in an existing gravel bar along the left bank. The excavated material would be placed as part of a channel feature and would not be exported.

LWD Installation

LWD in the Plaza area would consist of imported large-diameter logs with root wads. The excavator would handle and install all of these logs.

There is some LWD proposed for installation that is outside of the riprap removal zones. As with the upstream area, the wood in these areas is expected to be mostly installed using the cable and grip hoist methods.

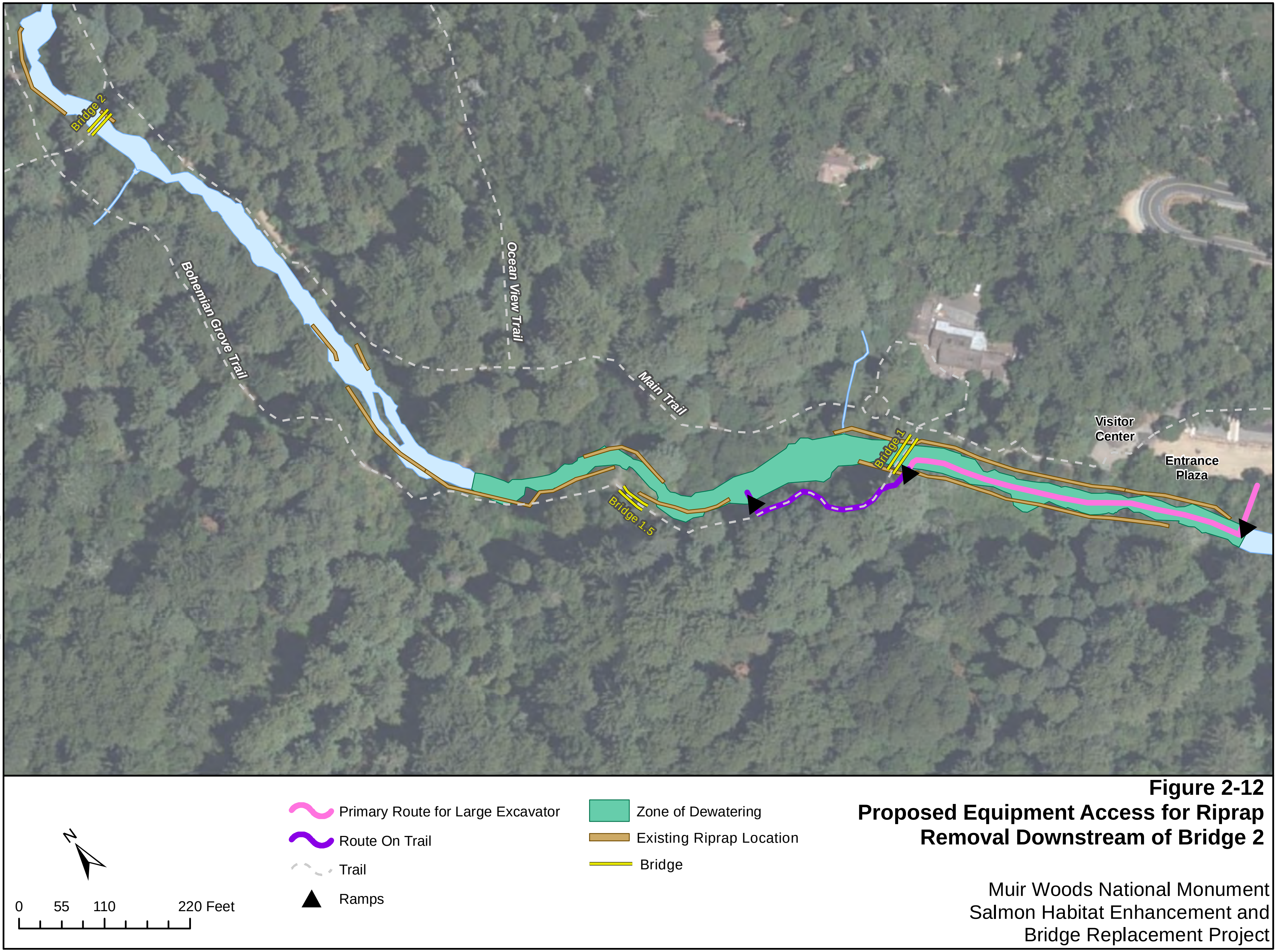


Figure 2-12
Proposed Equipment Access for Riprap Removal Downstream of Bridge 2

Muir Woods National Monument
Salmon Habitat Enhancement and Bridge Replacement Project

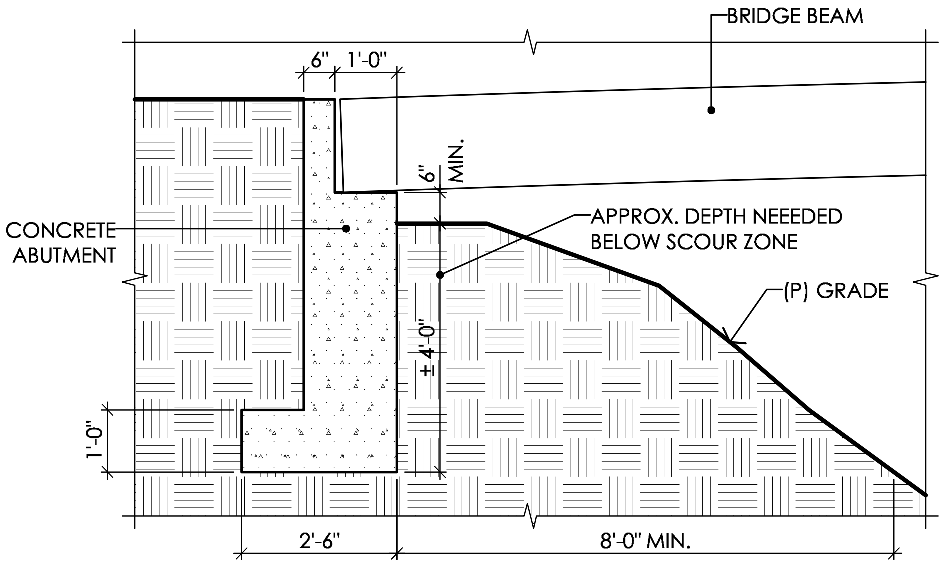
Bridge Construction

Bridge construction would have a phased approach, in which 2 bridges would be replaced in one year, and the other 2 bridges would be replaced 2 years later. Bridges 1, 2, 3, and 4 would be demolished. Temporary bridging (scaffolding) would be constructed just above the water line under and outside the footprint of the bridge alignment. The bridging would act as temporary access between banks as well as serving as a working platform. All decking would be unbolted, the glulams would be blocked up off of the scaffold and cut into pieces. Those pieces would be dragged off the platform via cable and winch and removed from the site for disposal. This approach eliminates the need for overhead lifting and protects Redwood Creek from construction debris. The existing abutments would be removed and replaced further from the creek. If dewatering is needed to remove the abutments, the same BMPs and protocols would be followed as described for the Creek Restoration Actions.

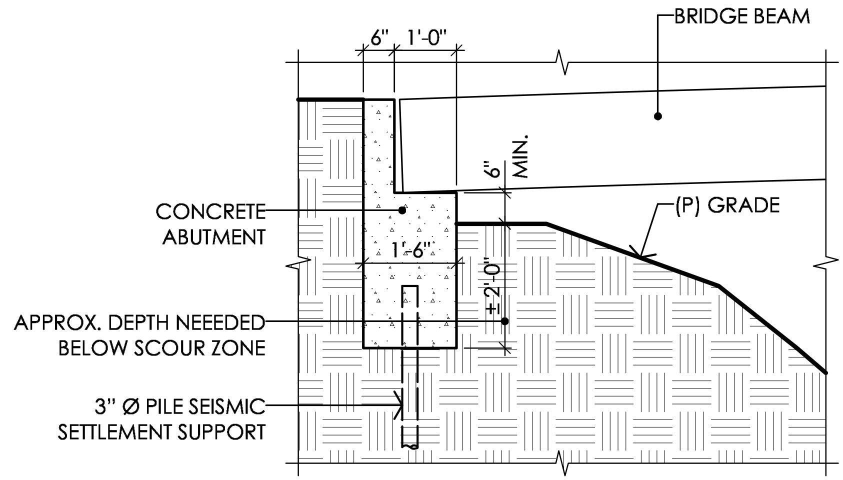
The new foundation type may vary from bridge to bridge depending upon the results of geotechnical subsurface exploration. Potential foundation types under consideration are pile cap and shallow/spread footings (Figure 2-13). These foundations would require excavation to the bottom of the cap or footing. Spoils would be offhauled or reused on site/at adjacent sites where feasible. Helical piles may be used, or micropiles. Helical piles are typically installed using relatively lightweight portable or track-mounted equipment and require a minimum of hand labor to construct. Micropile construction would entail drilling a small-diameter vertical shaft, placing a high-strength, large-diameter length of steel rebar, and then filling the excavation with neat cement grout. Micropile drilling would require high-speed pneumatic drills.

Materials for bridge construction would be staged in the laydown space at the existing parking area behind the visitor/administration building and would be coordinated with other parallel NPS construction projects. Steel beams would be transported in smaller sections from the staging areas at Camp Alice Eastwood (for Bridge 4) or the old parking area (for Bridges 1, 2, and 3) on heavy-duty dollies either rolled by hand or pulled by an excavator. Bulky and heavy materials would be transported with rubber tracked carriers. Model and type of tracked carriers may vary with materials required. For Bridges 2 and 3, portions of the existing asphalt trail would be removed. For Bridge 4, the eastern approach ramp would be constructed using excavation spoils, local stone, and local logs (if available). Beam sections would be winched across onto the platform constructed during demolition, aligned, blocked into place, and bolted together and to the beam seat. This method is intended to eliminate the need for overhead lifting. Wood railings and decking would be sourced from sustainable sources of wood and would be certified by the Forest Stewardship Council or similar certification.

Use of Alice Eastwood Road would follow procedures to protect the waterline discussed above in creek construction methods. As with this creek construction use of the campground area as a staging area, State Parks may choose to temporarily close the campground, depending on the period and duration of its use.



CONCRETE ABUTMENT - OPTION 1
SPREAD FOOTING - 50' BRIDGE, TYP.



CONCRETE ABUTMENT - OPTION 2
PILE SUPPORT - 50' BRIDGE, TYP.

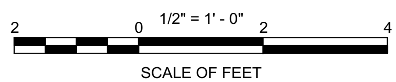


Figure 2-13
Pedestrian Bridge Abutment Options

Salmon Habitat Enhancement and Bridge Replacement Project Environmental Assessment

Disturbed areas of the streambank would be regraded and revegetated. Area where asphalt is removed for trail rerouting would be decompacted and revegetated as described for the Creek Restoration Actions. Materials from demolition of Bridges 1, 2, and 3 would be removed using the existing trail system on the east side of Redwood Creek. Bridge 4 would be removed using the Alice Eastwood Road. Materials for Bridges 1, 2, and 3 would be transported along the trails along Redwood Creek. Materials for Bridge 4 would likely be transported on Alice Eastwood Road. Precaution would be taken to protect the existing boardwalk, and when necessary the boardwalk would be replaced in kind if damaged.

During construction of each bridge, visitors would be rerouted along alternate access routes such as the trails on the west side of Redwood Creek, Hillside Trail, portions of the trails on the east side of Redwood Creek, and Canopy View Trail during construction of each bridge.

Schedule

Creek restoration actions could begin as early as fall 2017 if compliance is complete, but is most likely to be conducted in fall 2018. . Phase 1 riprap removal is anticipated to occur over about an 8-week on-the-ground work period, and Phase 2 is anticipated to occur over a similar duration in a later year.

Bridge construction is scheduled to start in 2019 and 2021 with two bridges removed and replaced each of the construction years. Construction is anticipated to occur over an approximately 4.5-month period within each construction year.

Equipment

Equipment that is anticipated to be used for the Proposed Action consists of the following items.

<u>Creek Restoration</u>

- Tracked excavators (Cat 308, John Deer160, and Komatsu PC88 or similar, see Figure 2-14)
- Articulated haul carts (DW60 Wheel Dumper or similar, see Figure 2-15)
- Tracked haul carts (CanyCom S25A or similar)
- Noise-attenuated dewatering pumps for dewatering (6-inch diesel, as well as potentially electric for the Phase 2 pump)
- Hydraulic and/or pneumatic equipment to break rock when removing riprap segment R6 boulders.
- Diesel 375 cfm compressor
- Supplemental hand tools

Figure 2-14. Cat 308

Figure 2-15. DW60 Wheel Dumper

- Tracked loader (Mustang MTL 50, Komatsu CK35, or similar)
- 10-CY dump trucks

Bridge Replacement

Bridge replacement equipment may vary, depending on the method of bridge anchoring.

Helical piles would require a small excavator or a hydraulic pump on a small trailer. Micropile installation would require a small drill rig or possible hydraulic portable drill rig. Shallow spread footings could be hand-dug or may require the use of a small excavator.

Other equipment would include:

- Diesel compressor
- Tracked haul carts
- Cable and winch
- Hand tools

2.6 Operations and Maintenance Activities

Rerouting of trails in the Bridge 1.5 and the Fern Creek area would result in decreased future trail maintenance, as trails would be relocated further from the creek and thus would be less prone to flooding.

Routine maintenance of pedestrian bridges will continue. Replacement of the pedestrian bridges would result in less long-term maintenance, as the bridges would be subject to less water and debris damage, compared to the current bridges. Replacement of the current glulam bridges with steel stringer bridges with wood decks would also result in less future maintenance due to the superior durability of these materials. Additionally, the new bridge design would allow for easier replacement of parts than existing glulam bridges. The decking and railing materials sit on top of the steel stringer frame that supports the bridge. These bridge components can be replaced if damaged and would not require replacement of the entire bridge structure. Replacement of some portions of asphalt trail with boardwalk would result in increased future maintenance, as part of ongoing trail maintenance in MWNM.

2.7 Best Management Practices

Table 2-3 lists best management practices that would be implemented during construction of the project.

Table 2-3. Best Management Practices

Number	BMP Description
Channel Bed BMPs	
BMP-1	The work zone and the potential area of dewatering will be defined.
BMP-2	Following implementation of measure BIO-5, the work zone will be dewatered. Dewatering entails setting up a pump and piping along the work zone. The pump must operate continuously. A noise-attenuated diesel pump will be used to reduce noise. Supplemental methods of attenuating noise will be added as necessary, such as surrounding the pump with rice straw bales. All water will be piped to the downstream channel to maintain instream flows there throughout the work. A set of strict BMPs will be implemented to ensure that no turbid water is piped into the channel (or enters the downstream area through other means.) These may include the use of desiltation devices at the terminal end of the discharge pipe, the use of sandbags to disperse the outflow so it does not stir up turbidity, avoiding foot traffic in the intake zone that would stir up turbidity, construction of a cofferdam at the downstream end of the dewatered zone to prevent turbid water from infiltrating upstream, and taking daily turbidity measurements to evaluate effectiveness and modify measure as necessary to eliminate any observed turbidity due to construction activities. If an auxiliary fuel tank is needed for the dewatering pump, NPS will work with the contractor to identify a suitable location and identify site-specific BMPs.
BMP-3	The small number of existing channel pools will be lined with fabric and then gravel will be placed on top of them. The gravel and fabric will be removed following the completion of construction, re-exposing the pool. This allows the form of the pool to be completely reoccupied after construction.
BMP-4	A. All vehicles and equipment will be kept clean and in proper working order. Excessive build-up of oil and grease will not be accepted. B. All equipment used for in-channel work will be inspected for leaks each day prior to initiation of work. Action will be taken to prevent or repair leaks, prior to use. C. Incoming equipment will be checked for leaking oil and fluids. Leaking equipment will not be allowed on site. D. No heavy equipment will operate in a live stream. E. No equipment servicing will be done in the channel or immediate floodplain, unless equipment stationed in these locations cannot be readily relocated (i.e., pumps and generators). F. Spill kits would be readily available.

Number	BMP Description
	G. If necessary, all servicing of equipment done at the job site will be conducted in a designated, protected area to reduce threats to water quality from vehicle fluid spills. Designated areas will not directly connect to the ground, surface water, or the storm drain system. The service area will be clearly designated with berms, sandbags, or other barriers. Secondary containment, such as a drain pan, to catch spills or leaks will be used when removing or changing fluids. Fluids will be stored in appropriate containers with covers and properly recycled or disposed of offsite. H. No large fuel storage containers will be allowed. Fuel will be delivered to the site only in pick-up trucks designed for fuel hauling, but it will not be otherwise stored on site. I. If emergency repairs are required in the field, only those repairs necessary to move equipment to a more secure location will be conducted in the channel or floodplain. J. All on- and off-road vehicles, boots, equipment, and tools must be power washed to remove soil and plant fragments before entering GGNRA property to avoid spreading pathogens or exotic/invasive species. Equipment also must be cleaned when moving between work zones. K. Vehicle and equipment washing can occur on site only as needed to prevent the spread of sediment, pathogens, or exotic/invasive species and only in defined site which would be identified in the SWPPP. No runoff from vehicle or equipment washing is allowed to enter water bodies, including channels and storm drains, without being subjected to adequate filtration (e.g., vegetated buffers, hay wattles or bales, and silt screens). L. All boots, equipment, and tools must be disinfected using a 10% bleach solution, 70% isopropyl alcohol, or other NPS-approved disinfectant method prior to entering the site, as well as between work areas, to prevent pathogen spread.
BMP-5	Biodiesel will be required to the extent possible.
Forest Floor BMPs	
BMP-6	Where feasible, downed wood slated for movement or in the travel path will be searched to remove and relocate any amphibians. Worker and visitor safety is a preeminent concern, and searching for and relocating amphibians will not be conducted in instances where safety might be threatened.
BMP-7	NPS will identify invasive plants, particularly panic veldt grass (*Ehrharta erecta*), within the work and access route areas prior to Project implementation. A qualified vegetation ecologist or botanist will plan treatments to prevent the spread of invasive species, and implementation of these treatments will be under the supervision of a qualified vegetation ecologist or botanist. The location of invasive species and the treatment plan will be documented in a plant protection plan. The final treatment prior to Project implementation will occur close to initiation of Project work.

Number	BMP Description
BMP-8	Identify a route which avoids understory vegetation where possible and gives sufficient space to redwood trunks.
BMP-9	Minimize disturbance to vegetation.
BMP-10	Place protective mats, if necessary, on the haul route to disperse the load.
BMP-11	Tie back, trim, or remove vegetation (in order of preference) in the route prior to use, and replant after work is completed.
BMP-12	Evaluate compaction both before and after work and de-compact using hand methods, if needed.
BMP-13	Padding may be wrapped around trunks, if needed, for extra protection in areas where there is a risk of equipment hitting a trunk.
Bridge Construction BMPs	
BMP-14	Debris from demolition of existing bridges or construction of new bridges will not enter the channel. Bridge construction will follow channel bed BMPs outlined above.
Air Quality and Greenhouse Gas BMPs	
BMP-15	Idling time of equipment when not in use will be avoided and low emission producing equipment will be used when feasible.
Cultural Resources	
CR-1	Deep excavation (including bank terracing and potentially bridge construction) will be monitored by an archeologist who meets the U.S. Secretary of the Interior's professional qualification standards. Riprap removal and LWD installation will not be monitored by an archaeologist.
CR-2	Not all cultural resources are visible on the ground surface. If any cultural resources, such as structural features, unusual amounts of bone or shell, flaked or ground stone artifacts, historic-era artifacts, human remains, or architectural remains, are encountered during any Project construction activities, work will be suspended immediately at the location of the find and within an appropriate radius of at least 50 feet, and the NPS archeologist will be notified immediately. The unanticipated discovery will be treated according to the guidelines outlined in 36 CFR 800.13.
CR-3	In the unlikely event that human remains are discovered during construction activities, all work will stop within 50 feet of the discovery, and the NPS archeologist will be contacted immediately. Furthermore, as required by law, the requirements of California Health and Human Safety Code Section 7050.5 will be followed and the Marin County coroner will be notified. If the human remains are determined to be of

Number	BMP Description
	Native American origin, NPS will follow the provisions outlined in the Native American Graves Protection and Repatriation Act (1990).
CR-4	The project prioritizes retaining the most visible segments of CCC rock work. Actions to mitigate the loss of historic fabric may include an interpretive program at MWNM to highlight the work done by the CCC, as well as extensive documentation of historic features adversely affected by the project. In addition, trail features constructed by the CCC throughout Muir Woods will be thoroughly documented and treatment guidelines will be developed to preserve or rehabilitate as warranted and archeological surveys will be conducted to ensure identification of and proper treatment measures for any as-yet unknown resources.
Biological Resources	
BIO-1	Prior to any construction-related activities, a training session will be required for all contractors, partners, and NPS staff participating in Project-related activities in the Project area. Training will be conducted by a qualified biologist to familiarize personnel about sensitive resources in the Project area. Personnel will be provided with a brief life-history and physical description of Coho salmon, steelhead, northern spotted owl, marbled murrelet, and other sensitive wildlife in the area. Training will include staff resource contact information, identification of sensitive resources, the limits of the work area, general BMPs, and appropriate actions to take upon encountering species status species or other wildlife. All attendees will sign an attendance sheet along with their printed name, company or agency, email address, and telephone number.
BIO-2	No construction activities will occur at night or during dawn or dusk to minimize impacts on wildlife that are most active during these times, such as the northern spotted owl.
BIO-3	The contractor will be required to keep all waste and contaminants contained and remove them daily from the work site. Wildlife-proof trash receptacles will be used.
BIO-4	Access and/or construction below ordinary high water will be limited to June 15 to October 31, unless conditions to allow the start of salmon spawning do not occur by October 31 and continued work is approved by or otherwise permitted by regulatory agencies, to minimize potential adverse effects to salmonid spawning and movement. The actual work window could be adjusted slightly and will depend upon the current water year, creek conditions, and timing of salmonid migrations.
BIO-5	In areas to be dewatered, NPS will set up fish exclusion fences at the outer boundaries of the work zone and remove all fish and wildlife from the work zone as described below, although the details may be revised per guidance from NMFS. A. All pumps used to divert live stream flow, outside the dewatered work area, will be screened and maintained throughout the construction period to comply with the NMFS Fish Screening Criteria

Number	BMP Description
	for Anadromous Salmonids (NMFS 1997). Pump intakes will be covered by 3/32-inch mesh and placed inside housing with sufficient area to prevent impingement of fish. Pump intakes will be checked periodically to ensure impingement is not occurring. B. The channel will be blocked by placing fine-meshed nets or screens above and below the work area to prevent fish from entering the work area. Exclusion screening will be placed in low velocity areas to minimize impingement. Screening or nets will be oriented so that approach velocities do not exceed established criteria for fry or fingerling (NMFS 1997). Chosen criteria will be based on field observations of smallest salmonid. To minimize entanglement, appropriately sized mesh diameter will be used depending upon minimum fish size in the area (either 1/8 or 1/4inch). The bottom edge of the net or screen will be secured into the channel bed to prevent fish from passing under the screen. Screens will be checked periodically and cleaned of debris to permit free flow of water. C. Fish Protection Measures: i. Fish relocation activities must be performed only by qualified fisheries biologists with experience with fish capture and handling. NPS will ensure that all biologists working on this Project be qualified to conduct fish collections in a manner that minimizes all potential risks to salmonids. Electrofishing, if used, will be performed by a qualified biologist and conducted according to the NMFS Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act (NMFS 2000) ii. A qualified biologist will monitor the construction site during placement and removal of channel diversions and cofferdams to ensure that any harm or loss of salmonids is minimized and documented. The biologist will be on site during all dewatering events to ensure that all listed species are captured, handled, and relocated safely. iii. Captured fish will be handled with extreme care and kept in water to the maximum extent possible during relocation activities. The details of a salmonid relocation plan will be developed based on a pre-project survey and an NMFS biological opinion, but will likely include the following elements: All captured fish will be kept in cool, shaded, aerated water protected from excessive noise, jostling, or overcrowding any time they are not in the stream and fish will not be removed from this water except when released. To avoid predation, the biologist will have at least two containers and segregate young-of-year fish from larger age-classes and other potential aquatic predators. Captured salmonids will be relocated, as soon as possible, to a suitable instream location in which habitat conditions are present to allow for survival of transported fish and fish already present.

Number	BMP Description
	iv. If any salmonids are found dead or injured, the biologist will contact the NOAA Fisheries North Central Coast Office. The purpose of the contact is to review the activities resulting in take and to determine if additional protective measures are required. All salmonid mortalities will be retained, placed in an appropriately-sized sealable plastic bag, labeled with the date and location of collection, fork length measured, and be frozen as soon as possible. Frozen samples will be retained by the biologist until specific instructions are provided by NOAA Fisheries. The biologist may not transfer biological samples to anyone other than the NOAA Fisheries North Central Coast Office without obtaining prior written approval from the North Central Coast Office, Supervisor of the Protected Resources Division. Any such transfer will be subject to such conditions as NOAA Fisheries deems appropriate. v. NPS will provide a written report to NOAA Fisheries within three months of the completion of the respective construction season. The report will contain, at a minimum, a description of the location from which fish were removed and the release site, including photographs; the date and time of the relocation effort; a description of the equipment and methods used to collect, hold, and transport salmonids; if an electroshocker was used for fish collection, a copy of the logbook must be included; the number of fish relocated by species; the number of fish injured or killed by species; and a brief narrative of the circumstances surrounding ESA-listed fish injuries or mortalities. D. All temporary fill, cofferdams, pumps, pipes and sheet plastic will be removed from the stream upon completion of each Project phase, as well as upon Project completion.
BIO-6	The following measures will be implemented to minimize potential adverse effects to northern spotted owls: ▪ If construction commences between February 1 and July 31, NPS will conduct pre-construction surveys for northern spotted owls in suitable nesting habitat; ▪ If northern spotted owl nests are detected during pre-construction surveys, no work that raises noise levels above ambient background levels will be conducted within ¼-mile of an active nest; ▪ Within northern spotted owl habitat, disturbance to native trees greater than 10 inches in diameter at breast height will be avoided where feasible.
BIO-7	The following measures will be implemented to minimize potential adverse effects to marbled murrelet: ▪ If construction activities that would increase noise levels above ambient background levels within 1/4 mile of nest sites or unsurveyed suitable habitat commences between March 15 and September 15, NPS will conduct inland pre-construction surveys for within ¼ mile of potential marbled murrelet nesting habitat. Surveys will be conducted in accordance with *Methods for*

Number	BMP Description
	Surveying marbled murrelets in Forests: A Revised Protocol for Land Management and Research (Evans Mack et al. 2003). ▪ If marbled murrelet breeding activity is detected during pre-construction surveys, no work that raises noise levels above ambient background levels will be conducted within ¼ mile of an active nest.
BIO-8	The following measures will be implemented to minimize potential adverse effects to non-federally listed nesting birds. ▪ If vegetation clearing or ground disturbing activities commence between March 1 and July 31, a qualified biologist will conduct a survey for nesting birds within 5 days prior to starting work. If a lapse in Project-related work of 1 week or longer occurs, another focused survey will be conducted before Project work can be initiated. Surveys will cover a minimum of a 1/4-mile radius around the construction area. ▪ If nesting birds are found, a buffer will be established around the nest and maintained until the young have fledged. Appropriate buffer widths are 300 feet for non-listed raptors and 100 feet for non-listed passerines. A qualified biologist may identify an alternative buffer based on a site-specific evaluation. Work will not commence within the buffer until fledglings are fully mobile and no longer reliant upon the nest or parental care for survival.
BIO-9	Prior to Project-related activities, a qualified biologist will conduct pre-construction surveys for dusky-footed woodrat (*Neotoma fuscipes*). Identified woodrat houses will be avoided to the maximum extent practicable. If houses are unavoidable, NPS will implement informal NPS protocol of dismantling of woodrat houses.
BIO-10	Prior to determining final trail reroute locations, a qualified bat biologist will conduct surveys of tree hollows adjacent to the proposed new trail location. If bat maternity colonies are detected adjacent to the proposed trail location, the trail location will be designed so the entrance to the hollow does not face the trail.
BIO-11	Within 1 year prior to commencement of ground disturbing activities, a qualified botanist will perform surveys for special-status and locally rare plant species within areas that could potentially be disturbed by the Proposed Action. Floristic surveys will be performed according to the *Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities* (California Department of Fish and Game 2009 or current version). If special-status or locally rare plants are detected within the construction zone or within a 50-foot radius of the construction zone, NPS will implement BIO-12. Additionally, any invasive plant species within or adjacent to the construction zone will be identified.

Number	BMP Description
BIO-12	If special-status plants are detected within the construction zone or within a 50-foot radius of the construction zone, NPS will adjust the construction footprint or establish an exclusion area to avoid impacts to the plants. Locations of special-status plant populations will be clearly identified in the field by staking, flagging, or fencing prior to the commencement of activities that may cause disturbance. A qualified botanist will determine whether direct and/or indirect impacts will occur. If the botanist determines that impacts will not be completely avoided, BIO-13 will be implemented.
BIO-13	If avoidance is not feasible, NPS will implement measures to minimize the impact on the species. Minimization measures will be evaluated on a case-by-case basis for local rarity and extent of impacts. Minimization measures may include transplanting perennial species, seed collection and dispersal for annual species, and other conservation strategies that will protect the viability of the local population. If minimization measures are implemented, monitoring of plant populations will be conducted by a qualified botanist to assess the mitigation's effectiveness. The performance standard for the mitigation will be no net reduction in the size or viability of the local population.
BIO-14	NPS will prepare a detailed plant protection plan based on specific areas potentially impacted by any proposed actions. NPS will thoroughly review areas of likely impact in advance and identify either any sensitive species or native species that will be protected or invasive species that will be controlled. Based on the potential impact and the species, a plan will be made to either (a) avoid the area if necessary to the presence of a sensitive species; (b) salvage plants if they are salvageable; (c) trim branches/leaves if the plants will easily resprout, (d) cover with plywood or other protective materials, or (e) other types of activities. Salvaged plants will be removed either immediately before impact or possibly up to 1 month in advance. They will be stored in area where there will be an easy water source (i.e.: such as the former nursery area) and replanted either immediately after work is completed in a specific zone or during the typical winter planting period.
BIO-15	All areas where vegetation is disturbed by project work, including rip rap removal, log installation, bridge replacement, trail re-routes and access, will be restored following project work with native plants propagated in the park nurseries, and the removal of invasive plants.
BIO-16	A biological monitor will be present during implementation of the creek restoration work. The biological monitor will ensure that any unanticipated impacts to natural resources are avoided.
BMP = best management practice CFR = Code of Federal Regulations ESA = Endangered Species Act GGNRA = Golden Gate National Recreation Area	

Number	BMP Description
LWD = large woody debris NMFS = National Marine Fisheries Service NPS = National Park Services NOAA = National Oceanic and Atmospheric Administration	

2.8 Alternatives Considered and Dismissed from Further Analysis

Grade Control of Other Tributaries

All creek restoration alternatives include installing grade control at an incised tributary near Bridge 3. Installation of grade control on other incised tributaries was not considered as an alternative because the overall treatment of tributaries was considered to be outside the scope of this project. Some tributaries have grade control at the confluence with the mainstem of Redwood Creek. Actions were considered to remove this grade control to provide better off-channel winter habitat for salmon; however, this action was dismissed because of the risk of inducing further incision in the existing tributaries.

Grade Control within Redwood Creek

NPS considered an action to install grade control in the Redwood Creek channel to address the long-term effects of incision. The intent of such an action would be to reactivate the channel with its floodplain and, possibly, increase groundwater elevations to better maintain instream flows during the dry season. The action could have consisted of reusing removed riprap to build grade control structures that would capture sediment and aggrade the channel 1 to 2 feet, depending on the structure.

This action was dismissed because there are not appropriate locations to install such structures. They would require stable, reinforced banks on either side to prevent outflanking by high flows, and no such location was identified. If the intent were to allow banks to erode to generate sediment to be trapped behind the grade control, the approach would be ineffective because there are no channel banks other than those identified in the preferred alternative where bank erosion could occur without affecting existing infrastructure (including a sewer line under the entrance boardwalk, a water line extending along the left bank to Fern Creek, boardwalks, and trails). A single grade control structure, depending on a height of 1 to as much as 2 feet, would have extended its effect only 80 to 100 LF upstream given the channel gradient, so up to as many as 30 to 40 structures would have been needed in the mile-long reach to aggrade the whole channel. The effect would be a highly-engineered system that is not suited for MWNM.

Muir Woods is identified in the GMP as a Cultural Landscape with historic significance, and it is protected as such as part of the NPS mission. The range of actions which can be conducted under the GMP that may alter the landscape consist of "targeted riprap removal" and some trail relocation to improve channel function. The GMP does not accommodate the significant change in the landscape that might be expected with a large number of rock grade control structures and extensive bank erosion. Instead, the preferred alternative addresses incision through a long-term approach, by adding wood to significantly increase the sediment storage capacity of the channel and to use angled channel-spanning logs where possible. A moderate approach to reusing some boulders mid-channel will be employed in the preferred alternative without building channel-spanning grade controls.

Removal of Bridge 1

Removal of the existing Bridge 1 without replacement was initially considered as an alternative. However, removal of Bridge 1 would likely require major changes to trails and visitor experience in MWNM. This alternative would limit opportunities for an accessible loop and would concentrate visitor use of the boardwalk and trails on the east side of the creek. It would eliminate the most heavily used loop through the woods, which extends from the entrance on the east side of the creek to Bridge 2 or 3 and back on the west side of the creek. This would also eliminate access and unique views around Bohemian Grove on the west side of the creek. The GMP supports the use of side trails in the woods in order to avoid concentrating visitors on the main trail. It also encourages the development of thematic interpretive trails to experience different parts of the park. Thus Bridge 1 removal would be more properly considered under a comprehensive trail plan, which is outside the scope of this EA.

Removal of Bridge 3

Removal of the existing Bridge 3 without replacement, and removal of the trail segment between Bridges 2 and 3 on the west side of Redwood Creek, were initially considered as an alternative. Bridge 3 is heavily used by visitors as it provides a 1-mile loop through the woods. Bridge 3 allows for more trail options for visitors. It also provides NPS with management flexibility when trails must be closed to due to hazards such as a tree falling over a trail. The trail segment between Bridges 2 and 3 also helps distribute visitors throughout the woods rather than keeping them all along one trail. Removal of Bridge 3 would result in a major, permanent effects on use patterns and visitor opportunities within MWNM. For these reasons, this action was dismissed as an alternative.

Chapter 3
AFFECTED ENVIRONMENT

3.1 Introduction

This chapter presents information about the existing environment at MWNM. Issues and impact topics discussed in this chapter include cultural resources, threatened and endangered species, visitor use and experience, geology and soils, transportation wildlife habitat, vegetation, water resources and hydrologic processes, visual resources, and climate change (where applicable within the impact topics). Two recent EAs describe the affected environment in and around MWNM (NPS 2015b, NPS 2016a) and were utilized in authoring the affected environment for this EA.

3.2 Cultural Resources

Area of Potential Effects

The implementing regulations for Section 106 of the National Historic Preservation Act (NPHA) of 1966, found at 36 CFR 800, require that an area of potential effects (APE) must be established to determine and define the "geographic area or areas within which an undertaking may directly or indirectly cause alterations to the character or use of historic properties, if such properties exist and is influenced by the scale and nature of an undertaking. It encompasses both those areas where proposed actions might occur that would directly impact cultural resources, as well as adjacent areas that contain resources that might be indirectly affected" (36 CFR 800.16(d)).

To assess the effects of this undertaking on all historic resources that might be affected, the general APE includes the entire Muir Woods Historic District. The areas that the project would directly affect (the Direct APE) include the channel and both banks of Redwood Creek for approximately 5,110 LF, from the vicinity of the restrooms at the Entry Plaza, upstream to just above Bridge 4; a small portion of Fern Creek (approximately 125 LF), upstream from its confluence with Redwood Creek, is also in the Direct APE. The Direct APE encompasses portions of the Main Trail and Bridges 1 through 4. Also included in the Direct APE are potential trail relocations, areas of potential disturbance from dragging logs to the creek channel, and access routes for equipment to be used for project actions in the creek channel. A detailed map of the Direct APE, including known resources (trails, riprap, and bridges), is shown in Figure 3-1.

N

0 25 50 100 Feet

Design Log
Log to be relocated
Other Logs

Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 1 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

Design Log
Log to be relocated
Other Logs

Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

N

0 25 50 100 Feet

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 2 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

Design Log
Log to be relocated
Other Logs

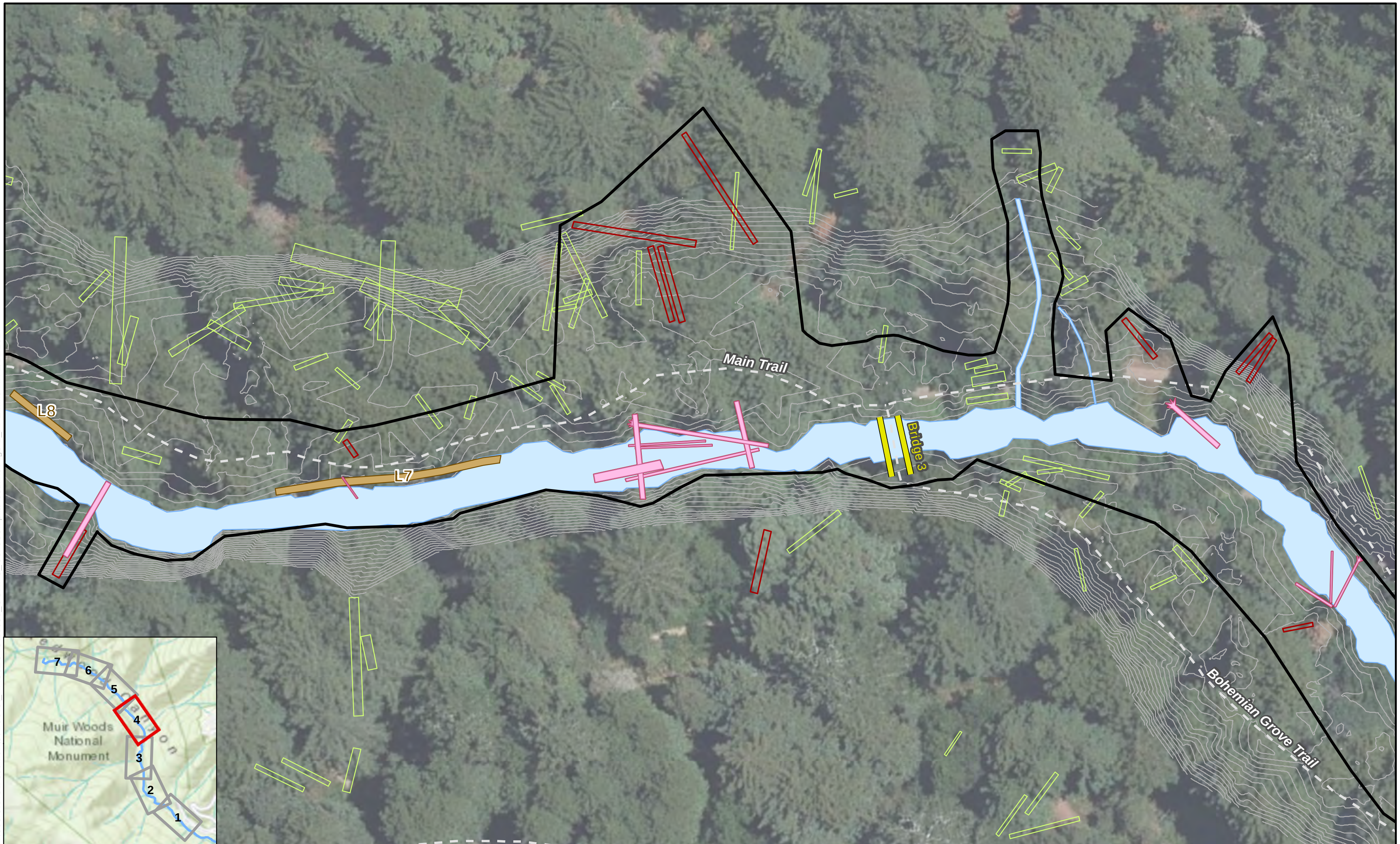
Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

N

0 25 50 100 Feet

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 3 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project



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N

0 25 50 100 Feet

Design Log
Log to be relocated
Other Logs

Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 4 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

Design Log
Log to be relocated
Other Logs

Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

N

0 25 50 100 Feet

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 5 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

N

0 25 50 100 Feet

Design Log
Log to be relocated
Other Logs

Direct APE
Existing Riprap Location
Bridge
1-foot elevation contour

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 6 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

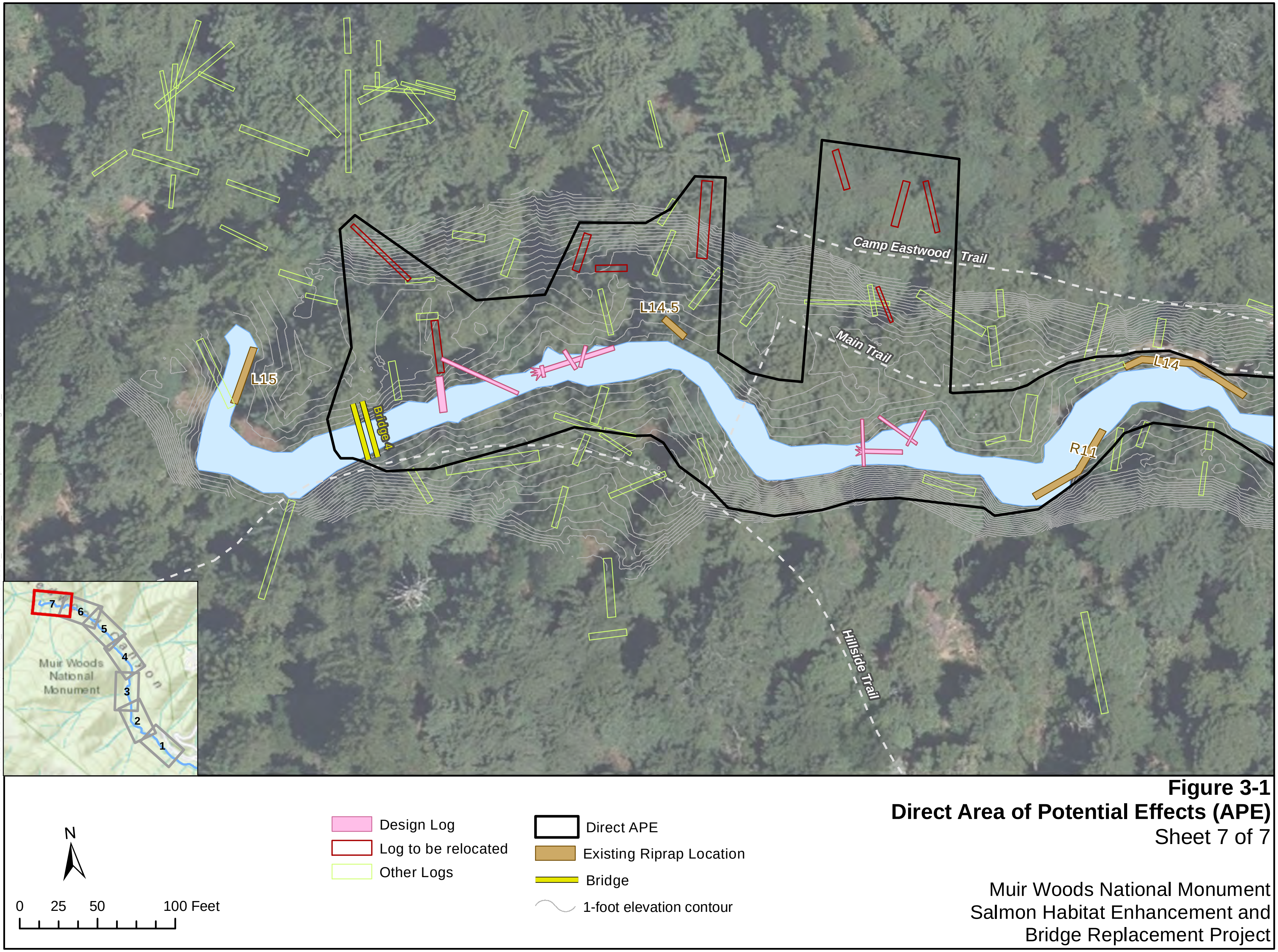

Figure 3-1
Direct Area of Potential Effects (APE)
Sheet 7 of 7

Muir Woods National Monument
Salmon Habitat Enhancement and
Bridge Replacement Project

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Properties Listed in the National Register of Historic Places

Muir Woods National Monument. The monument is one of the great examples of the early development of the conservation movement in the late 19th and early 20th centuries to preserve an old-growth forest of coast redwoods. Theodore Roosevelt declared it a national monument in 1908 under the provisions of the Antiquity Act of 1906. The portion of MWNM as it existed at the end of the period of significance (1907–1947) was entered into the national register in 2008 as a historic district. For a property to be eligible for the NRHP, it must meet at least one of four main criteria, as listed under 36 CFR 60.4:

- **Criterion A.** The property is associated with events that have made a significant contribution to the broad patterns of our history; or
- **Criterion B.** The property is associated with the lives of persons significant in our past; or
- **Criterion C.** The property embodies the distinctive characteristics of a type, period, or method of construction, or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components may lack individual distinction; or
- **Criterion D.** The property has yielded or may be likely to yield, information important in prehistory or history.

The monument was found to be nationally significant under criterion A and criterion C for the contributions of William Kent and the conservation movement, its use of rustic park architecture, and as an example of Emergency Conservation Work/Civilian Conservation Corps programs in the 1930s, as well as its association with the signing of the United Nations Charter in 1945 (Auwaerter and Sears 2006). Five buildings and 22 structures (dating 1922–1940) are significant under criterion C as representative examples of pre-World War II-era rustic design characteristic of NPS buildings built during that era. Contributing elements to the monument within the Direct APE include the following (see Figure 2-1 for locations):

- Main Trail
- Ben Johnson Trail
- Cathedral Grove
- Redwood Creek riprap (referred to as stone revetment [Auwaerter and Sears 2006])

Cathedral Grove (named for visitors' experience of the grove as a sacred space) is historically significant as the location for the United Nations Conference on International Organization's memorial service for President Franklin D. Roosevelt, who had died just weeks before his planned participation in the conference. United Nations Conference on International Organization held the memorial service in Roosevelt's honor on May 19, 1949 (Auwaerter and Sears 2006).

Archeology

NPS conducted an archeological survey of the Project's Direct APE in December 2016 (Gavette, personal communication 2016). In addition to conducting an inspection of the ground surface, 15 auger borings were placed throughout the Direct APE to evaluate the potential for buried archaeological remains. The depth of the auger borings varied, ranging in depth from 23 centimeters to 90 centimeters. No cultural materials were identified in the Direct APE as the result of the surface inspection and subsurface auger borings.

Riprap Assessment

Horizon Water and Environment Architectural Historian Kara Brunzell performed a field visit to document historic riprap along Redwood Creek on November 10 and December 27, 2016 (Brunzell 2017). This riprap is considered locally significant for criteria C. GGNRA staff have categorized the riprap within MWNM into 34 sections for the purposes of the Proposed Action. Visibility of riprap segments from public trails was previously assessed by NPS. All sections of riprap, totaling 3351 LF, were inspected, photographed, and recorded. Letter grades for condition were assigned in the field to each numbered section (where a variety of conditions were present within a single numbered section, multiple grades were utilized). The condition assessment key developed for the evaluation is provided below. A narrative description of each numbered section is provided in the Conditions Assessment Report included in Appendix A. The results of the assessments are presented in Table 3-1.

<u>Condition Assessment Key</u>

A – excellent condition: *Intentionally placed, tightly fitted rocks; few or no missing rocks; appears stable.*

B – good condition: *Intentionally placed rocks range from loosely to tightly fitted; some missing rocks or apparently unstable areas; overall appears stable.*

B-/C+ – fair condition: *intentionally but loosely stacked rocks, or tightly stacked with missing rocks.*

C – poor condition: *Rocks appear jumbled or randomly stacked; portions missing or fallen into the creek; areas appear unstable.*

D – not present or not visible: *Section has either fallen away completely or is fully embedded in creek bank.*

Table 3-1. Riprap condition and visibility

Left or Right Bank (Facing Downstream)	Riprap Segment (starting downstream)	Condition of Riprap	Visible from Trail?	Approximate Length (LF)	Creek Restoration Alternative 1	Creek Restoration Alternative 2	Creek Restoration Alternative 3	Creek Restoration Alternative 4	Creek Restoration Alternative 5 (*Preferred Alternative*)
L	1-A	C-	Not Visible	151	no	yes[1]	yes[1]	yes[1]	yes[1]
R	1-A	B-	Visible	111	no	yes[2]	yes[2]	yes[2]	yes[2]
L	1-B	C+	Slightly Visible	397	no	no	no	no	no
R	1-B	B-	Visible	344	no	no	no	no	no
Bridge 1									
L	2	B	Visible	128	yes	yes	yes	yes	yes
R	2 (downstream segment)	A-	Not Visible	33	no	no	no	yes	yes
R	2 (upstream segment)	A-	Not Visible	18	no	no	no	no	no
L	3	C-	Not Visible	39	no	no	no	no	no
R	3-A (downstream segment)	B+	Not Visible	148	no	no	no	yes	yes
R	3-A (upstream segment next to grade control)	B+	Not Visible	105	no	no	no	no	no
R	3-B	C+	Visible	151	yes	yes	yes	yes	yes
R	4	C	Visible	13	yes	yes	yes	yes	yes

Left or Right Bank (Facing Downstream)	Riprap Segment (starting downstream)	Condition of Riprap	Visible from Trail?	Approximate Length (LF)	Creek Restoration Alternative 1	Creek Restoration Alternative 2	Creek Restoration Alternative 3	Creek Restoration Alternative 4	Creek Restoration Alternative 5 (*Preferred Alternative*)
Bridge 2									
L	4	C-	Visible	46	no	no	no	no	no
L	5	B-	Visible	79	no	no	no	no	no
R	5	A	Visible	135	no	no	no	no	no
L	6	C-	Visible	23	no	no	no	no	no
R	6	A-	Visible	128	yes	yes	yes	yes	yes
Bridge 3									
L	7	B-/B	Visible	141	no	yes	yes	yes	yes
R	7	A-	Visible	118	yes	yes	yes	yes	yes
L	8	C+	Not Visible	55	no	no	no	no	no
R	8	A	Visible	108	yes	yes	yes	yes	yes
L	8.5	D	Not Visible	49	no	no	no	no	no
L	9	C+	Not Visible	23	no	no	no	no	no
R	9	A-	Visible	82	yes	yes	yes	yes	yes
L	10	B+	Visible	131	yes	yes	yes	yes	yes
R	10	A-	Not Visible	104	yes	yes	yes	yes	yes
R	11	B	Visible	49	no	no	no	no	no
L	11 - A	C-	Visible	59	yes	yes	yes	yes	yes
L	11 - B	B	Visible	26	no	no	no	no	no
L	12	A-	Not Visible	104	no	no	no	yes	yes
R	12 - A	C	Visible	39	yes	yes	yes	yes	yes

Left or Right Bank (Facing Downstream)	Riprap Segment (starting downstream)	Condition of Riprap	Visible from Trail?	Approximate Length (LF)	Creek Restoration Alternative 1	Creek Restoration Alternative 2	Creek Restoration Alternative 3	Creek Restoration Alternative 4	Creek Restoration Alternative 5 (*Preferred Alternative*)
R	12 - B	B-	Visible	26	no	no	no	no	no
L	13	B+	Visible	62	yes	yes	yes	yes	yes
L	14	C-	Not Visible	79	no	no	no	no	no
L	14.5	B-	Not Visible	20	no	no	no	no	no
L	16	C+	Visible	72	no	no	no	no	no
BRIDGE 4									
[1]Approximately 112 feet would be removed from the downstream end of this segment [2]Approximately 98 feet would be removed from this segment									

Pedestrian Bridges

Four existing non-historic bridges cross Redwood Creek in the Direct APE. NPS constructed these bridges in the 1990s to replace older bridges. The current bridges are constructed of glulam, a modern engineered wood product. The glulam is deteriorating, and the bridges will need to be replaced within the next few years. At least two of the bridges obstruct the flow of the creek during floods. In addition, because of their streamlined design and modern materials, the design of the existing bridges is not compatible with the rustic historic character of MWNM, which is an NRHP-listed historic district. Existing bridge locations align with the trails along Redwood Creek.

Tribal Consultation

To date, the Federated Indians of Graton Rancheria have not indicated that properties of traditional cultural values are associated with this Proposed Action or within the Direct APE exist.

3.3 Threatened or Endangered Species

Three species federally listed as threatened or endangered are present within MWNM: Coho salmon, steelhead, and northern spotted owl. Additionally, MWNM contains potentially suitable habitat for the marbled murrelet, which is federal listed as threatened. These species are described below.

Coho Salmon

Coho salmon in Redwood Creek belong to the Central California Coast ESU, which was upgraded from threatened to endangered in June 2005 (70 CFR 37160). Critical habitat for this ESU is present within Redwood Creek and includes the creek and adjacent riparian habitat (70 CFR 52488).

Habitat characteristics required for successful Coho salmon development include (1) clean loose gravels free of fine sediment, needed for spawning and egg development; (2) adequate pools and natural instream cover for juveniles; (3) connected alcoves and off channel habitats for juveniles to survive winter flows; (4) clean cool water; and (5) unimpaired passage to and from the ocean (NOAA 2012). Redwood Creek within MWNM provides spawning and limited rearing habitat for this species. As described above, habitat for juvenile Coho salmon has deteriorated over the years due to past management practices such as installation of riprap along the channel and removal of LWD which resulted in loss of pools in the stream (Fong et al. 2016). CDFW (formerly California Department of Fish and Game [CDFG]) identified Redwood Creek as a priority restoration area for the recovery of this species (CDFG 2004).

Coho are at risk of extirpation from the Redwood Creek watershed (Fong et al. 2016). Population levels for all three cohorts (age classes) of Coho salmon are well below recovery targets set by NMFS (Fong et al. 2016). Coho salmon need pools for summer rearing habitat, when water levels in the creek are low, particularly pools deeper than 1.6 feet. MWNM is dominated by low water habitats. Fong et al. (2016) found that average residual water depths for flatwater habitats during summer 2015 for Reach 6 of Redwood Creek in MWNM was 0.4 feet. These shallow water depths may be suitable habitat for stream invertebrates and juvenile steelhead, but are not conducive summer rearing habitat for juvenile Coho salmon

(Fong et al. 2016). The number of pools and the amount of LWD in the reach of Redwood Creek in MWNM are lower than other reaches of the creek outside of MWNM, and the lack of pools has been recognized since 1976 (Fong et al. 2016). Figure 3-2 shows the percentage of habitat by length across Redwood Creek reaches, with Reach 6 (MWNM) showing the lowest percentage of pool habitat. Additionally, there is a significantly lower percentage of pools deeper than 1.6 feet in MWNM compared to other reaches (Fong et al. 2016). A study in the Redwood Creek watershed concluded that lack of summer habitat provided by deep pools (i.e., greater than 0.5 meters with complex cover combined with low late-summer and fall flows in the lower creek was the primary factor limiting Coho salmon production in the watershed during dry years (Smith 2001).

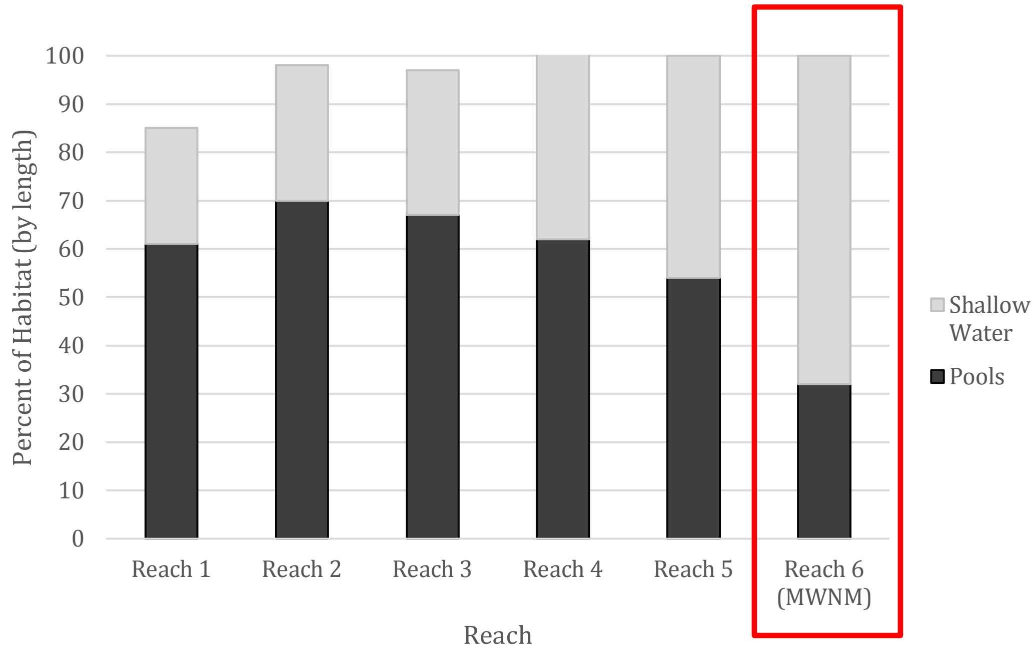

Figure 3-2. Percent of pool and shallow water habitats in Redwood Creek between 1995 and 2015 for Reaches 1-6. Reach 6 (outlined) contains the Proposed Actions.

Juvenile Coho are typically associated with low velocity pools or off-channel habitats with complex cover, especially that provided by LWD (Shirvell 1990; Bustard and Narver 1975; Nickelson et al. 1992). The frequency of LWD within Redwood Creek is low overall, and the lowest densities have been reported within MWNM (NHE 2016). Compared to streams in undisturbed old-growth forests, Redwood Creek in MWNM has less large diameter woody debris, and fewer long (>15 meter) pieces of LWD (NHE 2016). The lowest density of LWD within the Proposed Action area occurs between Bridge 3 and Bridge 4 (Fong et al. 2016). The riprap has prevented channel migration and thus limited natural recruitment of LWD into the creek (NHE 2016). The pedestrian bridges, which are undersized for stream flow, have also limited the transport of LWD in this reach of Redwood Creek.

A 3-year Coho salmon captive rearing program was initiated to address poor adult survivorship. This program entails capturing a portion of the juvenile Coho Salmon present in Redwood Creek and rearing them in captivity at Warm Springs Fish Hatchery, located at Lake Sonoma. Captive rearing is a temporary measure to prevent extirpation of Coho salmon in Redwood Creek. Juvenile Coho salmon were collected from Redwood Creek in 2014, 2015, and 2016. Three- to four-year-old adults will be released into Redwood Creek to spawn; the first round of adults was released into Redwood Creek in winter 2015-16, and a second larger release was conducted on December 8, 2016. The last planned release will be in the winter of 2018. This program is a collaboration between CDFW, the NMFS, the U.S. Army Corps of Engineers, the California Department of Parks and Recreation, NPS, the Golden Gate National Parks Conservancy, and the Friends of Lake Sonoma.

Steelhead

Steelhead within the Redwood Creek watershed belong to the Central California Coast Distinct Population Segment (DPS) (NOAA 2015). This DPS was originally federally listed as threatened in 1997 (63 FR 32996) and reaffirmed as threatened in 2006 (71 FR 834). Critical habitat for this DPS is present within Redwood Creek, encompassing the lateral extents of the creek up to the ordinary high water line (70 FR 52488).

Habitat requirements for juvenile steelhead are similar to those of Coho salmon (NPS 2005).

Northern Spotted Owl

The northern spotted owl is federally listed as threatened in Washington, Oregon, and California (55 CFR 26114). This species is known to occur within MWNM (Gardali and Geupel 2000). Marin County is the southernmost limit of this species range (USFWS 2011) No critical habitat for northern spotted owl is present in MWNM. The nearest designated critical habitat is north of Highway 1, approximately 0.7 mile north of the project area.

Through the majority of their range, northern spotted owls are mainly found in old-growth coniferous forests, but in Marin County they inhabit a variety of forest types including second-growth and old-growth Douglas fir (*Pseudotsuga menziesii*), coast redwood (*Sequoia sempervirens*), bishop pine (*Pinus muricata*), mixed conifer-hardwood, and evergreen hardwood forests (Ellis and Harrigan 2016). Range expansion of Barred Owl (*Strix varia*) is a threat to northern spotted owl (USFWS 2011). Barred Owls were first documented to breed in MWNM in 2007 (Ellis and Harrigan 2016). In 1999, two pairs of northern spotted owls occupied MWNM, but since 2010 northern spotted owls have not established an activity center within the boundaries of MWNM (Ellis and Harrigan 2016). Other threats to northern spotted owl in Marin County include habitat loss, structural changes in forest heterogeneity due to Sudden Oak Death (SOD), genetic isolation, disturbance from human recreational pressures, and West Nile virus (Press et al. 2010).

Marbled Murrelet

The marbled murrelet is federally listed as threatened in Washington, Oregon, and California (57 FR 45328), and is listed as endangered under CESA. This species is a seabird which spends the majority of its life on the ocean, but nests in old-growth forests up to 50 miles inland (USFWS 1997). Portions of Mt. Tamalpais State Park and County-owned land directly adjacent MWNM are designated critical habitat for this species. However, the designated critical habitat for marbled murrelet does not include MWNM.

In 1997 and 1998 systematics surveys for marbled murrelet were conducted in MWNM and no marbled murrelet were observed (Gardali and Geupel 2000). Studies assessing offshore distribution of marbled murrelet did not observe this species in the ocean waters adjacent to MWNM (Briggs et al. 1987, Ralph and Miller 1995, as cited in Gardali and Geupel 2000).

Additionally, eggshell surveys in 1999 did not identify any marbled murrelet eggshells, and relatively few trees within MWNM appear to provide suitable nesting habitat for this species (Gardali and Geupel 2000).

3.4 Geology: Soils and Bedrock

MWNM is located in southern Marin County, west of San Francisco Bay, within the northern Coast Range of California's geomorphic provinces. The physical landscape and topography of the Mt. Tamalpais and Muir Woods area reflect a history of tectonic forces, active since the Mesozoic Era initiation of plate collision and subsequent subduction of the Pacific Plate beneath the North American Plate (California Geological Survey [CGS] 2002). Regionally, the northwestern trending ranges of southern Marin run generally parallel to the northwest/southeast trending San Andreas Fault, located in the Pacific Ocean just off-shore the Marin Headlands (CGS 1991). However, more locally in the Mt. Tamalpais area, ridges and crestlines radiate around the mountain peak in all directions, with MWNM located in the Redwood Creek watershed southeast of the Mt. Tamalpais peak.

Proximity to the San Andreas Fault Zone results in a high degree of bedrock fracturing and deformation. At MWNM, most of the underlying rock is of the Franciscan assemblage, a highly deformed mixture of sedimentary, metamorphic, and igneous rocks of late Jurassic and Cretaceous marine origin that reflect the tectonic compressional and subduction processes of the region (Wahrhaftig 1994 and Blake et al. 2000 as cited in NPS 2011). More specifically within the MWNM, incoherent shale and sandstone dominate the monument, with relatively steep slopes that tend to be highly susceptible to mass wasting (Graymer et al. 1991).

Soil is the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants (U.S. Department of Agriculture [USDA], National Resources Conservation Service [NRCS] 2017). Soils are influenced by several environmental factors including climate (precipitation, temperature, available moisture, etc.), macro- and microorganisms, topographic relief, parent rock material, land use practices, and time.

Bedrock is overlain with loam to very gravelly loam soils from the Centissima-Barnabe complex (USDA, NRCS 2016). The Centissima-Barnabe complex primarily derives from weathered soft sandstone, shale, and chert. This soil is typically the most commonly encountered soil type within the monument and supports all of the slope redwood stands (McBride and Jacobs 1978). Soils generally range in thickness from 20 to 33 inches above bedrock. This soil unit exhibits high runoff and a moderate susceptibility to erosion. The Redwood Creek streambed is characterized by a mix of gravel and cobble with some areas of oversized rock riprap with few fine materials.

Settlement and development in the watersheds draining Mt. Tamalpais and MWNM began as early as 1841 (Auwaerter and Sears 2006). Intensification of land uses in the watershed for logging and agricultural purposes in the 19th century changed vegetation and land cover conditions resulting in other hydrologic and geomorphic effects. Erosion and sediment transport increased with these land use changes and the creeks likely enlarged or incised to accommodate increased runoff and sediment loads (Stillwater Sciences 2004).

Substantial development for access roads and visitor amenities for Muir Woods began in the mid-1880s (Auwaerter and Sears 2006). Expanding public use led to further road improvements and other developments during the first half of the 20th century, resulting in continued soil disturbance and increased erosion within Muir Woods and the Action Area.

More recently, a natural resources assessment completed in 2011 ranked the soil conditions at MWNM as fair because of historic logging, grazing, farming, residential development, and compaction from pedestrians (NPCA 2011). In recent years, efforts have been made to restore and improve soil conditions by removing paved trails in favor of raised boardwalks and fencing sensitive areas prone to erosion to protect soil from compaction from pedestrian traffic.

3.5 Visitor Use and Experience

Title 54 of the United States Code, states that one of the purposes of the National Park Service is providing for visitor "enjoyment of scenery, natural and historic objects, and wildlife" while leaving these resources "unimpaired for the enjoyment of future generations" (54 USC 100101(a)). According to the GMP EIS, the purpose of MWNM "is to preserve the primeval character and ecological integrity of the old-growth redwood forest for scientific values and inspiration" (NPS 2014). The GMP also established a visitor experience goal of fostering "the visitor's deep personal connection to the monument and discovery of the values and enjoyment of the natural environment." Visitors come to experience the immensity of the redwoods, the sights and sounds of nature, and the history of the monument. Visitor use and experience at MWNM is influenced by high visitation levels that lead to adverse impacts on transportation to and from the monument, parking, as well as walking within the monument. Large crowds generate noise and detract from the overall experience in the monument. With the implementation of the first phase of the Reservation System (anticipated in late 2017 or early 2018), days with extremely high daily visitation levels (>4,500) would be minimized or eliminated, visitation would be more evenly distributed over the course of a day, and, numbers of visitors per hour during peak times of the day would be reduced (NPS 2015b). These changes would reduce the effects of crowding on visitors.

The trails in the monument, particularly those between the Entrance Station and Bridges 1 and 2, are heavily-trafficked, especially in the summer months. The bridges in the monument connect trails on both sides of Redwood Creek and provide visitors with the ability to walk loops of varying lengths and to see more of the monument. Trails on both sides of Redwood Creek also help disperse crowds.

3.6 Transportation

High visitation rates and limited parking and road capacity have adversely impacted transportation to and within MWNM resulting in traffic congestion, illegal parking, and unsafe conditions for pedestrians. During peak visitation times, traffic can back up along Muir Woods Road, Panoramic Highway, Highway 1, and onto Highway 101. As part of a plan to address this, in 2015, shoulder parking areas on upper and lower Muir Woods Road were fenced off to prevent parking and an additional parking lot was added at lower Conlon Avenue. The upcoming implementation of a parking reservation system (NPS 2015b) and the Sustainable Access Project (NPS 2016a) will enable NPS to better manage visitation rates, parking availability, and transportation options in the monument.

3.7 Wildlife Habitat

Several types of wildlife habitat are present within the areas where the Proposed Action may occur, including aquatic habitat in Redwood Creek, riparian habitat along the creek, redwood forest, and wetland habitat adjacent to the creek.

Redwood Creek provides habitat for invertebrates, fish, amphibians, and reptiles; mammals also use the creek as a source of prey and water. Currently, habitat complexity within the creek is limited due to the presence of riprap lining the channel (ESA 2014) and past removal of LWD. Aquatic invertebrates are an important food source for juvenile salmonids. Kimball and Kondolf (2002) found that aquatic invertebrate abundance and family diversity were significantly greater in non-riprapped portions of Redwood Creek in MWNM compared to riprapped portions of the creek.

Amphibians such as California giant salamander (*Dicamptodon ensatus*) and Pacific chorus frog (*Pseudacris regilla*) are present in MWNM (Stillwater and Horizon 2011). California giant salamander larvae are found in a variety of aquatic habitats, and adults are found in surface litter in terrestrial habitats, as well as underground (Fong and Howell 2006). Although California red-legged frogs (*Rana draytonii*) are present approximately 1.6 miles south of MWNM (CDFW 2016), they are not expected within MWNM itself as there have been no documented adults or juveniles in upper Redwood Creek and suitable breeding habitat is not present in MWNM (Stillwater and Horizon 2011).

The monument provides nesting and foraging habitat for many bird species. The bird species most commonly observed in MWNM include Pacific-slope Flycatchers (*Empidonax difficilis*), Pacific Wrens (*Troglodytes troglodytes*), Chestnut-backed Chickadees (*Parus rufescens*), Goldencrowned Kinglets (*Regulus satrapa*), Brown Creepers (*Certhia americana*), and Dark-eyed Juncos (*Junco hyemalis*) (Gardali and Geupel 2000). Wilson’s Warbler (*Wilsonia pusilla*), a neotropical migrant warbler, also nests in MWNM (Gardali and Geupel 2000).

Bats are known to both forage and roost in MWNM (Heady and Frick 2004). Bat species detected in MWNM include California myotis (*Myotis californicus*), Yuma myotis (*Myotis yumanensis)* silver-haired bat (*Lasionycteris noctivagans*), big brown bat (*Eptesicus fuscus*), western red bat (*Lasiurus blossevillii*), hoary bat (*Lasiurus cinereus*), and Townsend's big-eared bat (*Corynorhinus townsendii*) (Heady and Frick 2004). Most bat activity occurs in the riparian corridor (Heady and Frick 2004). In a study by Heady and Frick (2004), silver-hair bats have been captured in the redwood habitats in MWNM but not in the downstream hardwood riparian habitat, while Yuma myotis showed an opposite pattern of being present in hardwood riparian habitat and absent in redwood grove. Several species of bats have been observed using redwood hollows as maternity roosts, day roosts, or night feeding roosts, and bats also use other features such as bark crevices as roosting habitat (Heady and Frick 2004). The majority of the species detected in MWNM are found there year-round (Heady and Frick 2004).

3.8 Water Resources and Hydrologic Processes

Watershed and Topography

MWNM lies within the 8.8-square-mile Redwood Creek watershed U.S. Geological Survey [USGS] 2016a). The headwaters of Redwood Creek include the Fern Creek, Spike Buck Creek, and upper Redwood Creek tributaries that originate on the steep southern slopes of Mt. Tamalpais (elevation of 2,571 feet). The headwater tributaries flow south and southeastward coalescing at the confluence of Redwood Creek and Fern Creek at approximate elevation of 230 feet. Downstream of this confluence point, Redwood Creek flows at the bottom of Redwood Canyon, a northwest trending gorge characterized by steep, densely wooded slopes and a relatively narrow fluvial floodplain. Redwood Creek runs adjacent to the Redwood Creek Trail toward the main gate and entrance to MWNM. Topography in the Action Area generally slopes toward Redwood Creek, perpendicular to the flow direction of the creek. The Action Area ranges in elevation from approximately 140 to 300 feet above mean sea level (USGS 2015).

Downstream of MWNM, Redwood Creek arcs to a more southwest flow direction as it opens up to Frank Valley, which is a wider riparian corridor and alluvial floodplain than the more confined creek alignment found upstream in the MWNM. Kent Creek joins Redwood Creek 0.9 miles downstream of the MWNM. Downstream of Santos Meadow, approximately 0.7 miles downstream of the Kent Creek confluence, Redwood Creek bends to a more southerly alignment as it heads towards the Big Lagoon estuary and the Muir Beach river mouth at the Pacific Ocean.

The Redwood Creek watershed is largely undeveloped, with protected forest land managed by the Marin Municipal Water District, California State Parks (Mt. Tamalpais State Park), and NPS (MWNM and the Golden Gate National Recreation Area [GGNRA] at Muir Beach) (Stillwater and Horizon 2011). The contributing watershed area upstream of the Action Area is approximately 1.9 square miles (USGS 2016a).

Climate

The Action Area has a Mediterranean climate characterized by cool, wet winters and warm, dry summers. Average temperatures range from 40 degrees Fahrenheit (°F) to 70 °F throughout most of the year, and temperatures below freezing are extremely rare (Stillwater and Horizon 2011). Annual precipitation at MWNM varies greatly year to year, but averages 37.4 inches, mostly occurring October through May, with November through March being the wettest period (Western Regional Climate Center [WRCC] 2016). Fog drip is estimated to provide an additional 10 to 20 inches of water to vegetation annually, or 10 to 40 percent of the annual water supply for vegetation, but exact volumes have not been measured in the Redwood Creek Watershed (Weeks 2006 and Dawson and Siegwolf 2007, as cited in Stillwater and Horizon 2011).

Hydrology

Redwood Creek is the primary hydrologic feature and resource in the Action Area (Marin Coastal Hydrologic Unit, Fern Creek Hydrologic Unit 2201300003). As described above, the creek's headwaters originate approximately 2.5 miles northwest of the action area on the southwestern slopes of Mt. Tamalpais. As Redwood Creek enters MWNM, the longitudinal profile of the creek flattens considerably, with bed slope decreasing to less than 2 percent slope.

Streamflows in Redwood Creek vary greatly. During the spring and summer dry season, flows are shallow and low magnitude. During the late fall, winter, and early spring months, flows can be quite large responding to winter precipitation events. Baseflow, the flow in the creek fed by groundwater and deeper soil moisture and not specifically related to a single storm event, generally increases over the wet season months and then recedes into the spring and summer.

Measurements taken in the late-1980s and 2003–2004 at the Redwood Creek Bridge located at the downstream end of the action area, showed summer flows of less than 1 cubic foot per second (cfs) and peak winter flows of approximately 30 to 170 cfs occurring with different storm events (Stillwater and Horizon 2011). More recent measurements from a monitoring station on Redwood Creek approximately 1.5 miles downstream from the action area showed the daily discharge ranged from periods of no flow to a maximum of 431 cfs (USGS 2016b); older records show a high flow of 2,150 cfs (USGS peak flow data Station No. 11460150 1962-1973 as cited in Cooprider 2004).

A hydrologic assessment estimated potential flood flows at the four existing bridges in the Action Area and the Fern Creek/Redwood Creek confluence (NHE 2016a). The flow magnitude-frequency relationships are summarized in Table 3-2, where peak discharges for different return intervals are provided at these locations. Bridges 2 and 3 have the least flood capacity and are only able to effectively pass the 2-year peak-flood flow (NHE 2016a). Bridge 1 can pass the 2-, 5-, 10- and 25-year peak-flood flows, while Bridge 4 can pass all peak-flood flows except the 100-year event (NHE 2016a).

Table 3-2. Summary of flood-frequency estimates at the four bridge sites and Fern Creek confluence with Redwood Creek within Muir Woods.

Return Interval (year)	Chance Exceedance (%)	Bridge 4 (cfs)	Fern Creek (cfs)	Bridge 3 (cfs)	Bridge 2 (cfs)	Bridge 1 (cfs)
2	50	240	368	397	401	426
5	20	427	651	699	707	750
10	10	541	822	883	892	947
25	4	672	1,016	1,091	1,103	1,170
50	2	766	1,157	1,242	1,255	1,331
100	1	864	1,303	1,398	1,413	1,498
500	0.2	1,080	1,623	1,741	1,759	1,864

Source: NHE 2016a

As discussed in Chapter 1, the CCC installed check dams and rock revetments along approximately 57 percent of the creek channel within MWNM during the 1930s (NPS 2014). These physical modifications altered the channel shape and form, creating a wider channel, and restrained geomorphic processes of bank erosion, channel migration, and resulting recruitment of LWD into the channel. However, it is noted that the baseline hydrologic condition in Redwood Creek at the time these channel modifications were made was already severely altered due to land use practices, vegetation removal, and soil compaction since the 19th century. In other words, runoff response to rainfall events was very likely increased and amplified due to the past land use alterations in the watershed that reduced the ability for the watershed to infiltrate rainfall. The check dams, grade control structures, and rock revetments placed in the 1930s likely reduced the increased or exacerbated erosion from high runoff conditions (Stillwater and Horizon 2011). The check dams have since been removed but the revetments and many grade control structures remain on portions of the creek. Although some natural processes have returned, the creek has more shallow water including riffle and flatwater habitats and less deep water pool habitat than would naturally occur within a similarly sloped stream, and less large woody debris (Fong 2002, as cited by NPS 2014; Stillwater and Horizon 2011).

Groundwater

MWNM is underlain by Franciscan bedrock. Although groundwater may percolate and fill fractures, joints, and shear zones, Franciscan rocks are considered impermeable and non-water bearing. This results in a "perched" groundwater table where water contained in the soil and weathered rock pools above the bedrock, accumulating during the wet season and diminishing during the dry season. Some of this water may eventually percolate downwards into the bedrock or flow laterally along the top of the bedrock until finding water-bearing sedimentary units or until daylighting in the banks or bed of creeks, ponds, springs, or other surface waters. As such, there are no operating groundwater wells in MWNM; however, springs located upstream of the MWNM supply water for use by the Marin Municipal Water District (NPS 2014).

Water Quality

The San Francisco Bay Basin (Region 2) Water Quality Control Plan (Basin Plan) describes water quality standards for regional waterbodies (San Francisco Bay RWQCB 2015). The standards include beneficial uses of waterbodies and the water quality objectives that protect these beneficial uses. Redwood Creek has multiple possible beneficial uses including, but not limited to, agricultural, municipal, and domestic supply; freshwater replenishment; coldwater and warmwater habitat, fish migration and spawning, wildlife habitat, and preservation of rare and endangered species; shellfish harvesting; and contact or noncontact water recreation (San Francisco Bay RWQCB 2015). These uses are for the entire length of the creek, not just the reach in the Action Area.

The San Francisco Bay Area Network (SFAN) Inventory and Monitoring Program monitors two sites close to the Action Area, Fern Creek and the mainstem of Redwood Creek downstream of the MWNM entrance under the Muir Woods Road bridge. The Fern Creek sampling location is off of the Fern Creek Trail just upstream of the confluence with Redwood Creek. The program measures water temperature, dissolved oxygen, pH, specific conductance, turbidity, nitrogen, and bacteria.

Water temperature in Redwood Creek was generally within the optimal temperature range for juvenile Coho salmon (10 degrees Celsius [°C] to 15.6°C) with just a few short-term exceedances (Armour 1991 as cited by Wallitner 2016). Water temperature in Redwood Creek were comparable but slightly cooler, ranging from 8.5°C to 15.7°C with a median of 12.8°C. Temperatures in Fern Creek were comparable but slightly cooler, ranging from 8.2°C to 15.0°C and a median of 12.1°C. (Wallitner 2016).

All dissolved oxygen measurements for the 2013–2014 water-year sampling exceeded the RWQCB established dissolved oxygen minimum of 7 milligrams per liter (mg/L) (RWQCB 2015). Redwood Creek had a wider range of dissolved oxygen measurements (7.53 mg/L to 11.43 mg/L) than those in Fern Creek (9.05 mg/L to 11.81 mg/L) (Wallitner 2016).

Measurements of pH for both streams were well within the standard of 6.5 to 8.5, and ranged from 7.09 to 8.08 (Wallitner 2016).

The RWQCB does not specify criteria for specific conductance; however, to support diverse aquatic communities in freshwater streams, specific conductance should be below 500 microsiemens per centimeter (μS/cm) (Behar 1997, as cited by Wallitner 2016). Specific conductance values ranged from 121.3 μS/cm to 264.9 μS/cm in Redwood Creek and 88.4 μS/cm to 199.9 μS/cm in Fern Creek.

Turbidity levels of up to 41.1 nephelometric turbidity units (NTU) and 35.8 NTU have been recorded in Redwood Creek and Fern Creek, respectively, and exceeded the 25 NTU ecological objective (NPS 2016c; Wallitner 2016). However, high turbidity levels do not persist over long periods with the median values much lower at 0.46 NTU for Redwood Creek and 0.47 NTU Fern Creek. These turbidity measurements occurred during a period when the natural bank erosion rate is approximately 0.0015 $m^3m^{-1}a^{-1}$ (Stillwater Sciences 2004).

The RWQCB has not established a numeric water quality criterion for nitrate; however, an ecological threshold of 0.30 mg/L is frequently used as the threshold to limit eutrophication in streams (Roche et al. 2013, as cited by Wallitner 2016). Nitrate as nitrogen was low in Redwood Creek and Fern Creek sampling locations, approximately 80 percent of the samples reporting levels below the detection limit (Wallitner 2016).

Chemical analysis of samples collected during the 2015 and 2016 water-years generally characterize the chemical signature of Redwood Creek (NPS 2016b). Samples collected in the Action Area at Bridge 1 showed high levels of magnesium and moderate to low concentrations of other metals, including calcium, sodium, iron, nickel, and potassium. Aluminum, arsenic, and chromium were also detected at very low levels. These metals likely occur naturally and several of these elements were not detected during smaller flow events. Naturally occurring hydrocarbons were occasionally detected in low concentrations at Bridge 1 during the 2015 and 2016 sampling events (NPS 2016b). No polycyclic aromatic hydrocarbons were detected in Redwood Creek in the Action Area in the 2015 and 2016 samples.

Floodplains

The Action Area historically contained more overbank floodplain and terrace areas that would be inundated by larger streamflows on a more frequent basis than under current conditions (ESA 2014; Ryan 2016). Channel inundation of historic overbank areas of Redwood Creek within MWNM has been reduced through modification of the channel shape, removal of in-channel LWD, streambank stabilization structures, dams, and placement of fill (NPS 2014). These have contributed to historic channel incision. Redwood Creek is held within more rigid banks by these structures and not allowed to meander and flood historic overbank areas (ESA 2014; NPS 2014). Streambed incision has also contributed to the creek being hydrologically disconnected from its historic floodplains, which are now located on terraces above the stream channel (ESA 2014; Ryan 2016).

According to Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRMs), no floodplains have been identified within MWNM (FEMA 2009). However, some areas are designated as “areas in which flood hazards are undetermined, but possible” (FEMA 2009). Hydraulic analysis indicates that the current channel generally contains 10-year peak-flood flow in most of the Action Area with limited overbanking occurring near Bridge 3, Bridge 2, and adjacent the Entry Plaza (NHE 2016b). Under 100-year peak flood flow, flooding is extensive throughout the Action Area. Various climate models predict either increases or decreases in regional precipitation by 2080; however, there is a consensus that storm intensity and frequency, as well as flood events would be expected to increase, including scouring events (Stillwater and Horizon 2011, 2014; Walsh et al. 2014 as cited in NPS 2016a).

Geomorphic Processes

The sediment budget refers to the mass balance of sediment generated, stored, and transported through a watershed. In general, sediment source areas are more typically found in upslope and watershed headwater areas. Sediment is typically transported downstream into mid-watershed locations where it is variably stored or further transported downstream. Lower watershed areas are typically more depositional in receiving sediment loads from the watershed upstream. Though these general tendencies exist, at any given time, at any location in a watershed, sediment can be variably eroded, transported, deposited, or just stored in relative quiescence.

A sediment budget was developed for Redwood Creek using watershed models, field assessments of sediment sources, dendrochronology, channel surveys, sediment transport models, and sediment yields from neighboring watersheds (Stillwater Sciences 2004). Under the existing condition, the bank erosion at Muir Woods is below what is considered to be the current natural bank erosion rate in the watershed because of the extensive bank revetment (Stillwater Sciences 2004). Common to other watersheds from the region, sediment delivery from basin slopes occurs through a combination of fluvial processes such as sheetwash erosion and runoff and also by mass movement processes such as slumps, earthflows, landslides, and debris flows. The Stillwater 2004 sediment budget estimated that 46 percent of the basin slopes have been mapped as landslide prone areas. The estimate annual bank erosion immediately downstream of MWNM is 0.015 $m^3a^{-1}a^{-1}$. The current sediment production within Muir Woods has been very limited by the presence riprap. Stillwater Sciences provided context for sediment production rates in Redwood Creek. They reported, 'Sediment production rates are higher than a large, mainly lowland urban watershed in Washington State, equitable with those derived in the neighboring Lone Tree Creek, lower than those in the nearby agricultural Bolinas watershed, and far lower than the steeper and wetter watersheds of north coastal California subject to commercial forestry disturbances.' (Stillwater Sciences 2004).

Development of MWNM also included alteration of the natural environment and Redwood Creek itself. As described in Chapter 1, the CCC armored much of Redwood Creek in the Action Area with rock riprap to control streambank instability, bank erosion, and overbank flooding. The placed riprap provides additional shear strength to the streambanks and reduces the degree of physical channel processes such as channel migration, bank erosion, and the release and transport of sediment and input to the downstream creek system. Channel migration is a geomorphic process that occurs as streams adjust their morphology as they work toward a dynamic equilibrium to reflect watershed runoff and sediment conditions. Since the riprap prohibits channel widening and migration, channel sinuosity in the Action Area remains low, resulting in relatively high flow velocity unconducive for the deposition of sediment and development of instream bars and pool-riffle morphology. This solidified channel form hinders natural recovery from historic incision. In addition, with channel migration is hindered, this may obstruct development of habitat for aquatic organisms and terrestrial species in the channel corridor.

In addition to the bank riprap, the CCC also installed several instream grade control structures. The CCC riprap bank lining and grade control structures were in response to basin-wide logging and grazing disturbance, and downstream channelization for—all resulting in significant channel incision throughout the watershed and extending into MWNM. Since the 1900s, Redwood Creek in MWNM experienced several periods of incision resulting in the lowering of the streambed by approximately 10 feet in some areas (ESA 2014. Historic floodplain elevations of approximately 4 and 10 feet above the present creek elevation provide evidence of this process. In areas outlined for work under Creek Restoration Alternative 1, there is not a 10-foot difference between the creek bed and the floodplain. The constructed grade control structures in MWNM may limit the effects of incision compared to downstream reaches. The primary grade control in MWNM is a constructed rock cascade adjacent the Entry Plaza, which provides about 10 feet of vertical drop, and is where the incision is the most pronounce in the project area (ESA 2014).

3.9 Vegetation

Redwood Forest

Redwood forest is the dominant plant community in MWNM. Coast redwoods are the dominant tree species, covering approximately two-thirds of the land area (Schirokauer et al. 2003). The largest redwood trees in MWNM grow along the valley floor of Redwood Canyon (Steers et al. 2014). In addition to redwood trees, Douglas fir, California bay laurel (*Umbellularia californica*), and tanoak (*Notholithocarpus densiflorus*) are also common in the redwood forest (Steers et al. 2014). The herbaceous understory in the redwood forest is dominated by various ferns including western sword fern (*Polystichum munitum*) and lady fern (*Athyrium filix-femina* var. *cyclosorum*), and redwood sorrel (*Oxalis oregana*). Old-growth redwood forests have been found to store more carbon aboveground than any other forest type (Van Pelt et al. 2016).

Riparian Forest

Red alder (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*) are found bordering Redwood Creek within the monument (Steers et al. 2014). Vegetation adapted to wet conditions such as giant horsetail (*Equisetum telmateia* var. *braunii*) is also common here.

Special Status Plants

The only CNPS-ranked plant known to occur within MWNM is California bottlebrush grass (*Elymus californicus*) (Integrated Resource Management Applications [IRMA] 2005). This species has a California Rare Plant Rank of 4.3, a rank described as “Plants of Limited Distribution” with a threat rank of “Not very threatened in California (less than 20 percent of occurrences threatened / low degree and immediacy of threat or no current threats known)” (California Native Plant Society [CNPS] 2017). This species is known to occur near Redwood Creek, but not along its banks. Locally rare plants are present along Redwood Creek, and may be present within the project area. These species include western burning bush (*Euonymus occidentalis*), coastal brookfoam (*Boykinia occidentalis*), Indian hemp (*Hoita macrostachya*), western azalea (*Rhodedendron occidentale*), and leopard lily (*Lilium pardilinum* spp.

pardilinum) (IRMA 2005; pers. comm. Forrestel 2017). Leopard lily has no federal, state, or CNPS listing, but is of concern to MWNM natural resource management staff because they believe it was more widespread in MWNM in the past (Steers 2013). Some locally rare or special-status plants may be present within the project area.

Invasive Species

A total of 86 non-native plants are listed as present or probably present within MWNM (IRMA 2005) however park staff have documented at least 125 non-native, invasive plants in the park. Invasive plants within MWNM include broadleaved forget-me not (*Myosotis latifolia*), panic veldt grass (*Ehrharta erecta*), and English ivy (*Hedera helix*) (IRMA 2005, NPS 2016). Panic veldt grass is of particular concern for spread during construction projects due to its rapid life cycle, presence within the project area, and affinity for disturbed areas. Volunteer and staff removal efforts have reduced the presence of invasive plants within MWNM (NPS 2016c).

Plant Pathogens

Plant pathogens within the genus *Phytophthora* are known to occur within MWNM. The pathogen *Phytophthora ramorum* causes the plant disease SOD and is known to occur within MWNM (Davidson et al. 2003). The pathogen results in SOD in tanoak and several oak species, and also causes twig and foliar diseases in other species including California bay laurel, Douglas-fir, and redwood (Davidson et al. 2003). California bay laurel appears to be a major reservoir of *P. ramorum* inoculum (Davidson et al 2003). Of the known hosts of *P. ramorum,* tanoak is the most susceptible to SOD (Davidson et al. 2003). Spores of *P. ramorum* can be found in soil and water in addition to plant material (California Oak Mortality Task Force 2004). SOD has caused extensive tanoak mortality as well as some coast live oak mortality within MWNM.

Soil-born species of *Phytophthora* have been identified in both GGNRA nurseries and in the wild (Shor 2016). Soil-born *Phytophthora* species are common in nursery and agricultural settings and some species, such as *P. cinnamomi*, have the potential to cause extensive plant mortality in wildland settings. NPS is working to limit the spread of these plant pathogens. GGNRA has identified a variety of *Phytophthora* species both on nursery stock and on wild plants in the park and is working to limit the spread of these plant pathogens through improved sanitation practices in the park nurseries, during project implementation and by staff.

3.10 Visual Resources

Visual resources are a major part of the visitor experience at MWNM, with the primary draw being views of towering redwoods. In addition to trees and other vegetation, from the monument's trails, visitors take in views of Redwood Creek and its tributaries, wildlife, and manmade features including bridges, boardwalks, benches, historic markers, and riprap revetments installed by the CCC that give the creek a less natural, more manicured appearance (NPS 2006).

3.11 Soundscapes

The current MWNM soundscape includes both natural and manmade sounds. Natural sounds from flowing water, wildlife, and wind are generally perceived as pleasing and a positive part of the visitor experience, while manmade noise from vehicles, people talking, etc. is typically perceived negatively. Research conducted in MWNM showed that large percentages of visitors were exposed to, and annoyed by, visitor-caused noises such as loud groups and children (Manning et al. 2009). Ambient noise levels in MWNM are typically low, with summer season daytime averages ranging from roughly 30 dBA in the more remote backcountry areas to 40 dBA near the road and Entry Plaza (U.S. Department of Transportation [USDOT] 2011). Due to higher rainfall and streamflows, winter season daytime averages are a bit higher at approximately 40 and 55 dBA for backcountry and entrance area, respectively. Noise levels at night tend to be lower. In quieter areas of the monument, noise from manmade sources like aircraft is more noticeable. During the summer, in the less busy sections of the monument, natural soundscapes devoid of aircraft, vehicle, or other manmade noises are audible about a third of the time, while in the busier areas of the monument near the road, noise from other visitors and vehicles is audible most of the time and largely natural soundscapes are only audible a small percent of the time. Natural sounds are more predominant during the less busy winter months (USDOT 2011).

The park has implemented “quiet zones” in an attempt to improve soundscapes in certain areas, such as in Cathedral Grove. Upcoming changes to parking and transportation at the monument may decrease manmade noise levels in the monument as well.

3.12 Air Quality and Greenhouse Gas Emissions

Air Quality

In the San Francisco Bay Area, the main air pollutants of concern are ozone and particulate matter, though clean air from the Pacific Ocean generally helps keep air pollution levels low along the Marin County coast (BAAQMD 2016). Based on data collected at Point Reyes National Seashore, MWNM likely has relatively high nitrogen deposition and estimated acid pollutant exposure compared to other parks in the Inventory and Monitoring Program, but has a low ranking for ozone (Sullivan 2016). Compared to other parks, Point Reyes National Seashore (and by extension, MWNM) has “relatively high background haze and low natural background visibility” though visibility has improved over the last 25 years (Sullivan 2016; Interagency Monitoring of Protected Visual Environments [IMPROVE] 2016). It should be noted that due to the dense forest and steep canyon walls found in MWNM, such background haze and visibility most likely does not affect views within the monument.

Under US National Ambient Air Quality Standards (NAAQS), Marin County is in marginal non-attainment for ozone, moderate non-attainment for PM 2.5, and maintenance/ moderate non-attainment for carbon monoxide (U.S. Environmental Protection Agency [USEPA] 2016a). De minimis emission levels for the county have been set at 100 tons per year (t/y) for nitrous oxides (NOx), PM 2.5, and carbon monoxide, and 50 t/y for volatile organic compounds (VOCs) (USEPA 2016b).

Greenhouse Gas Emissions

Climate Change and Greenhouse Gases

Climate change is impacting California resources: warmer air and surface water temperatures, different precipitation patterns, rising sea levels, and ocean acidification are all examples of this change. Human influence on climate change is clear and human-caused emissions of greenhouse gases (GHGs) are the highest in history. Because GHGs (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide) persist and mix in the atmosphere, emissions anywhere in the world affect the climate everywhere in the world.

Global climate change is already affecting ecosystems and societies throughout the world. Climate change adaptation refers to the efforts undertaken by societies and ecosystems to adjust to and prepare for current and future climate change, thereby reducing vulnerability to those changes. Human adaptation has occurred naturally over history; people move to more suitable living locations, adjust food sources, and more recently, change energy sources. Similarly, plant and animal species also adapt over time to changing conditions; they migrate or alter behaviors in accordance with changing climates, food sources, and predators.

In 2014, total California GHG emissions were 441.54 million metric tons of carbon dioxide equivalents (MT CO_2e) (CARB 2016a). This represents a 2.7 million metric ton decrease in total GHG emissions from 2013 and an overall decrease of approximately 9.4 percent since peak levels in 2004. Overall trends in the inventory demonstrate that the carbon intensity of California's economy is declining (the amount of carbon per million dollars of gross domestic product) representing a 28 percent decline since 2001 (CARB 2016b).

In 2014, the transportation sector of the California economy was the largest source of GHG emissions, accounting for approximately 36 percent of the total emissions (CARB 2016a). On-road vehicles accounted for most of the emissions in the transportation sector. The industrial sector accounted for approximately 21 percent of the total emissions, and emissions from electricity generation were about 20 percent of the total. The rest of the emissions are made up of various sources (CARB 2016a).

Federal Policy

At the federal level, USEPA has developed regulations to reduce GHG emissions from motor vehicles and has developed permitting and reporting requirements for large stationary emitters of GHGs. On April 1, 2010, USEPA and the National Highway Traffic Safety Administration (NHTSA) established a program to reduce GHG emissions and improve fuel economy standards for new model year 2012–2016 cars and light trucks. On August 9, 2011, USEPA and the NHTSA announced standards to reduce GHG emissions and improve fuel efficiency for heavy-duty trucks and buses. In August 2016, the USEPA and NHTSA jointly finalized Phase 2 Heavy-Duty National Program standards to reduce GHG emissions and improve fuel efficiency of medium- and heavy-duty vehicles for model year 2018 and beyond (USEPA 2017).

On October 5, 2009, Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, was issued by the Council on Environmental Quality (CEQ). The EO required federal agencies to set a 2020 GHG emissions reduction target within 90 days, increase energy efficiency, reduce fleet petroleum consumption, conserve water, reduce waste, support sustainable communities, and leverage federal purchasing power to promote environmentally responsible products and technologies.

On August 1, 2016, the CEQ released final guidance on the consideration of GHG emissions and climate change in NEPA review (CEQ 2016). This is an update to guidance issued in draft form in February 2010 and December 2014. The guidance encourages agencies to include a quantitative assessment of GHG emissions. The guidance states that the assessment of direct and indirect climate change effects should account for upstream and downstream emissions and includes guidance on biogenic sources of GHG emissions from land management actions.

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Chapter 4
ENVIRONMENTAL CONSEQUENCES

4.1 General Methodology for Assessing Impacts

Direct, indirect, and cumulative impacts are described in accordance with CEQ regulations (40 CFR 1502.16), and the context and intensity of impacts are assessed (40 CFR 1508.27). Where appropriate, BMPs that would reduce potential adverse impacts are also described and incorporated into the evaluation of impacts. A full list of BMPs can be found in Table 2-3 in Chapter 2, Alternatives. Appendix B provides a checklist which has been prepared to support any necessary evaluation of the project pursuant to the California Environmental Quality Act (CEQA) by relevant lead and responsible agencies with discretionary approval authority over some or all of the project.

4.2 Cumulative Impacts Analysis Methodology

Cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions" (40 CFR 1508.7/8). The temporal scale for the cumulative impacts analysis includes past actions through reasonably foreseeable future actions.

Cumulative impacts are determined for each impact topic by combining the impacts of the alternative being analyzed and other past, present, and reasonably foreseeable actions that would also result in beneficial or adverse impacts. Some of these actions are in the early planning stages, so the evaluation of cumulative impacts is based on a general description of the projects. Unless cited otherwise, the information regarding other projects was derived from the Muir Woods Sustainable Access Project EA (NPS 2016). The remainder of this section discusses other projects that are planned in the immediate vicinity of MWNM.

Muir Woods Reservation System

The MWNM Reservation System project is divided into two phases. Phase 1 was completed in February 2016 and included the establishment of a parking barrier system along Muir Woods Road. To improve traffic safety and to prevent parking along the shoulder, approximately a mile of posts and cables were installed along the Muir Woods Road shoulder. Additionally, erosion and sediment control measures were installed.

Phase 2 of the reservation system includes management of motor vehicle access and parking changes, which would reduce peak visitation levels. Reservations for private vehicles and the Muir Woods Shuttle would occur through a third-party-operated system. A separate system would be used for reservation of commercial vehicle parking spots. This system would reduce the number of vehicles parked on the Muir Woods Road shoulder (NPS 2015b).

Muir Woods Road Bridge Replacement Project

Muir Woods Road bridge, which is located just south of the MWNM boundary, has been identified for replacement by Marin County due to structural deficiencies, bridge alignment and safety issues, as well as undermining of the bridge due to scour. Improvements associated with the bridge replacement are anticipated to extend along Muir Woods Road from approximately 400 feet west of the bridge to 600 feet east of the bridge, and would involve realigning the road in this area and moving the bridge slightly downstream. Access to MWNM would be maintained throughout implementation of this project. Construction is anticipated to begin in 2019.

Muir Woods Road Rehabilitation Project

The Muir Woods Road Rehabilitation Project would repair damage from landslides and flooding, as well as resurfacing 2.4 miles of asphalt road. It would also repair or replace culverts, which would ameliorate drainage issues and reduce sediment inputs to Redwood Creek. Completion of planning for the project is anticipated in 2017, and construction is expected to begin in 2019 (County of Marin 2016).

Muir Woods Water/Wastewater Line Replacement

Starting in 2017 and ending in 2018, NPS plans to repair and enhance water and wastewater lines as well as portions of the potable water and wastewater collection systems in MWNM. The relocation of the sewer line that currently extends along the bank of Redwood Creek will protect the creek water quality from a potential spill.

Muir Woods Sustainable Access Project

This project would improve the entry area of MWNM. NPS would modify the configuration of the Entry Plaza and several parking lots, but would maintain the same number of parking spaces for privately owned vehicles as currently exists within the monument. NPS would remove all parking from the Entry Plaza, although administrative vehicular access would remain. A new pedestrian bridge would be installed at the Dipsea Trail crossing of Redwood Creek. The existing restrooms in the Entry Plaza would be relocated, and a second restroom would be constructed. The two wastewater lift stations would be replaced. Existing roadside parking would be eliminated on Muir Woods Road and disturbed areas between Conlon Avenue and the Muir Woods Road Bridge would be revegetated with plants native to MWNM (NPS 2016a).

4.3 Cultural Resources

Methodology and Assumptions

This analysis on potential impacts to cultural resources is based on the results of an archaeological survey of the Proposed Action's Direct APE (Gavette, personal communication 2016) and a conditions assessment of the riprap that lines Redwood Creek (Brunzell 2017). The riprap is a contributing element to the NRHP-listed Muir Woods National Monument Historic District. The analysis was guided by the criteria of adverse effect provided in the implementing regulations of Section 106 of the NHPA under 36 CFR 800.5, Assessment of Adverse Effects.

The conclusion section of each of the action alternatives addresses three topics: (1) NEPA impacts to individual historic features within MWNM, such as the historic riprap; (2) NEPA impacts to MWNM as a whole; and (3) impacts to MWNM under Section 106 of the National Historic Preservation Act.

Impacts of the No Action Alternative

Analysis

Under the No Action Alternative, existing management would continue and no actions would be taken to improve habitat for salmonids or to encourage more natural geomorphic processes. No riprap would be removed, no LWD would be installed, and the four pedestrian bridges would either not be replaced or be replaced in-kind (same location, same material, same size). The trails network within Muir Woods Historic District would not change. Public use of the trails and pedestrian bridges would continue, but there would be no new adverse or beneficial impacts on cultural resources in these areas, including the Main Trail, Ben Johnson Trail, and Redwood Creek riprap, all of which are contributing elements to the Muir Woods Historic District.

Conclusion

Under the No Action Alternative, there would be no new adverse or beneficial impacts on cultural resources. Consequently, the No Action Alternative would have no adverse effects.

Creek Restoration Alternatives

Impacts of Actions Common to All Creek Restoration Alternatives

Analysis

Since creek banks are often considered archeologically sensitive, an adverse impact on previously unidentified subsurface archeological resources could occur from ground disturbance during removal of the riprap. However, the earth-disturbing activities would also be monitored to minimize any impacts on archeological resources, per BMP CR-1.

Grade control in the form of check dam construction would similarly have a beneficial long-term impact by slowing erosion and preserving historic riprap.

Conclusion

Under all creek restoration alternatives, impacts on cultural resources would be direct, short- and long-term, and minor. Minor adverse impacts would be mitigated or offset by corresponding beneficial impacts.

Impacts of Creek Restoration Alternative 1:

Analysis

Under Creek Restoration Alternative 1, habitat restoration activities would result in removal of about 1,123 LF of historic riprap. Sections targeted for removal under Creek Restoration Alternative 1 constitute about 33 percent of the riprap, causing major short- and long-term adverse impact to the historic riprap, which is a contributor to the Muir Woods Historic District.

Adverse impacts to historic riprap will be partially addressed by preservation of some of its most visible sections, the careful recordation of the riprap, and rehabilitation of CCC features on Muir Woods trails per BMP CR-4. Roughly 60 percent (about 1336 of 2533 LF) of visible riprap would be preserved under Creek Restoration Alternative 1.

Construction activities would result in additional minor short-term impacts to trails that are contributors to the Muir Woods Historic District. These impacts would be mitigated by locating staging and stockpiling areas away from trails that are contributors to the Muir Woods Historic District.

Conclusion

Under Creek Restoration Alternative 1, impacts on historic riprap would be direct, long-term, and major. Historic riprap would be permanently destroyed by habitat restoration activities; therefore, Creek Restoration Alternative 1's adverse impacts cannot be fully mitigated. However, because the erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, when combined with actions common to all alternatives, Creek Restoration Alternative 1's impacts to historic resources would be long-term, minor, and adverse. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

<u>Impacts of Creek Restoration Alternative 2:</u>

Analysis

Under Creek Restoration Alternative 2, one leg of the trail in Cathedral Grove (a contributor to the Muir Woods Historic District) would be removed, resulting in major short- and long-term adverse effect on the trail as a contributor to the Muir Woods Historic District. Additional historic riprap (totaling roughly 1,461 LF constituting 43 percent of total riprap) would be removed resulting in major short- and long-term adverse effect on the riprap as a contributing feature to the Muir Woods Historic District.

Adverse impacts to historic riprap will be partially mitigated by preservation of some of its most visible sections, the careful recordation of the riprap, and rehabilitation of CCC features on Muir Woods trails per CR-4.. Roughly 50 percent (about 1,080 of 2,355 LF) of visible riprap will be preserved under Creek Restoration Alternative 2.

Construction activities would result in additional minor short-term impacts to trails that are contributors to the Muir Woods Historic District, including erosion. These impacts would be mitigated by locating staging and stockpiling areas away from trails that are contributors to the Muir Woods Historic District.

Conclusion

Under Creek Restoration Alternative 2, impacts on historic riprap and trails would be direct, long-term, and major. Historic riprap would be permanently destroyed by habitat restoration activities and one side of the loop of the historic trail in Cathedral Grove (a contributor to the

Muir Woods Historic District) would be destroyed; therefore, Creek Restoration Alternative 2's adverse impacts cannot be fully mitigated. However, because the trails and erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, when combined with the actions common to all alternatives and the actions taken under Creek Restoration Alternative 1, Creek Restoration Alternative 2's impacts to historic resources would be long-term, minor, and adverse. Although the impacts of Creek Restoration Alternative 2 are larger than those under Creek Restoration Alternative 1, 10 percent more of the visible riprap (which is most important as a cultural resource) will be removed. Therefore, the difference between impacts for the two alternatives is moderate. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Impacts of Creek Restoration Alternative 3:

Analysis

Under Creek Restoration Alternative 3, the same amount of historic riprap would be removed as in Creek Restoration Alternative 2, resulting in major short- and long-term adverse effect on the riprap as a contributing feature to the Muir Woods Historic District. This alternative also includes creek bank terracing, which may have adverse impacts on archeological resources that may potentially be discovered in archeologically sensitive creek banks. Such potential impacts will be mitigated by archeological monitoring, as described in BMP CR-1.

Conclusion

Under Creek Restoration Alternative 3, impacts on historic riprap and trails would be direct, long-term, and major. Historic riprap would be permanently destroyed by habitat restoration activities, a leg of the historic trail in Cathedral Grove (a contributor to the Muir Woods Historic District) would be destroyed; therefore, Creek Restoration Alternative 3's adverse impacts cannot be fully mitigated. However, because the trails and erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, when combined with the actions common to all alternatives and the actions taken under Creek Restoration Alternatives 1 and 2, Creek Restoration Alternative 3's impacts to historic resources would be long-term, minor, and both beneficial and adverse. Because additional floodplain terracing does not result in adverse effects to historic resources, there is no difference between impacts for Creek Restoration Alternative 2 and Creek Restoration Alternative 3. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Impacts of Creek Restoration Alternative 4

Analysis

Under Creek Restoration Alternative 4, two sections of trails that are contributors to the Muir Woods Historic District would be rerouted, resulting in major short- and long-term adverse effects on the trails as contributors to the Muir Woods Historic District. Habitat restoration activities will result in additional 270 LF of riprap removal, resulting in major short- and long-term adverse effects on the riprap as a contributing feature to the Muir Woods Historic District. None of the additional riprap removed, however, is visible; therefore, the difference between the creek restoration alternatives is minor in terms of impacts to cultural resources. The adverse impacts to the trails and riprap, as discussed above, will be partially addressed by preservation of some of its most visible sections, the careful recordation of the riprap, and rehabilitation of CCC features on Muir Woods trails by implementing BMP CR-4.

Conclusion

Under Creek Restoration Alternative 4, impacts on historic riprap and trails would be direct, long-term, and major. Historic riprap would be permanently destroyed by habitat restoration activities, a leg of the trail in Cathedral Grove (a contributor to the Muir Woods Historic District) would be destroyed, and up to 555 LF of other trails (also contributors to the Muir Woods Historic District) would be rerouted; therefore, Creek Restoration Alternative 4's adverse impacts cannot be fully mitigated. However, because the trails and erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, Creek Restoration Alternative 4's impacts to historic resources would be long-term, minor, and adverse. Because additional trails and riprap will be removed under Creek Restoration Alternative 4, its impacts are moderately greater than Creek Restoration Alternatives 2 and 3. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Impacts of Creek Restoration Alternative 5

Analysis

Under Creek Restoration Alternative 5, riprap removal, trail removal, and trail relocation would be the same as under Alternative 4. This alternative also includes creek bank terracing, which may have adverse impacts on archeological resources that may potentially be discovered in archeologically sensitive creek banks. Such potential impacts will be mitigated by archeological monitoring, as described in BMP CR-1.

Conclusion

Under Creek Restoration Alternative 5, impacts on historic riprap and trails would be direct, long-term, and major. Historic riprap would be permanently destroyed by habitat restoration activities, and a leg of the trail in Cathedral Grove (a contributor to the Muir Woods Historic District) would be destroyed; therefore, Creek Restoration Alternative 5's adverse impacts cannot be fully mitigated. However, because the trails and erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, when combined with the actions common to all alternatives and the actions taken under Creek Restoration Alternatives 1 through 4, impacts to historic resources would be long-term, minor, and adverse. Because additional floodplain terracing does not result in adverse effects to historic resources, there is no difference between impacts for Creek Restoration Alternatives 1 through 5. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives

Analysis

Under all pedestrian bridge replacement alternatives, replacement of the four pedestrian bridges across Redwood Creek is likely to require the use of heavy equipment. Motorized heavy equipment used could include bulldozers and trucks, which could cause erosion and thus may result in an adverse effect to historic riprap or trails. The four bridges are non-contributors to the historic district, and therefore bridge replacement would not result in an impact to a historic resource. Historic riprap protecting the Bridge 1 abutments and Bridge 2's left bank abutment would not be removed. There is no historic riprap in the vicinity of Bridge 3 and Bridge 4, so removal of their abutments would not impact a historic resource. Since creek banks are often considered archeologically sensitive, an adverse impact on subsurface archeological resources could occur from ground disturbance during removal of the abutments and excavation of bridge foundations. However, the earth-disturbing activities would also be monitored per BMP CR-1 to minimize any impacts on previously unidentified archeological resources.

Under all pedestrian bridge replacement alternatives, design of replacement bridges would be in keeping with the rustic historic character of MWNM. A prior footbridge design study identified incompatibility with the rustic aesthetic as a negative feature of the current bridges (Haesloop 2014). Bridge decks would be steel stringers, which will give the structures a profile with a slight arch (<5 percent) that would not be highly visibly noticeable and that blends into the natural environment. The simplicity of the design (which has often been used for vernacular rural bridges) is also compatible with the rustic aesthetic. Hand rails and seating would be either log construction or wood veneer, materials that are more compatible with the historic setting than the modern manufactured wood product of the current bridges. Earthen ramps and natural stone accents would also complement the natural and historic settings. Existing bridges are of modern design and appearance and a departure from the romanticized rustic aesthetic that characterized the landscape during the historic period; the new bridges will enhance the historic character of MWNM.

Conclusion

Under all pedestrian bridge replacement alternatives, impacts on cultural resources would be direct, short- and long-term, and minor. However, because the trails that are contributors to the historic district are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, actions common to all pedestrian bridge replacement alternatives, impacts to historic resources would be long-term, minor, and adverse. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Impacts of Pedestrian Bridge Replacement Alternative A

Analysis

Under Pedestrian Bridge Replacement Alternative A, spans for Bridges 2 and 3 would be lengthened and designed to pass up to a 25-year peak-discharge event with 15- and 12-inch freeboard at the peak of the arch, respectively (Figures 2-7 and 2-8). Existing abutments would be removed and new abutments would be placed at a distance farther from the creek (Figures 2-7 and 2-8). For Bridge 2, approximately 80 LF of existing asphalt trail would be removed and 120 LF of new boardwalk would be installed on the east side of creek and 20 LF of new boardwalk on the west side of the creek, and a small approximately 20- by 20-foot boardwalk gathering area would be built on the east side of the creek. For Bridge 3, approximately 130 LF of existing asphalt trail leading to the east side of the crossing would be removed and the trail would be relocated and replaced with approximately 120 to 160 LF of flexible paving. The approaches to the bridge would require approximately 30 LF of boardwalk on the east side of the creek and approximately 35 LF of boardwalk on the west side of the creek.

Conclusion

Under Pedestrian Bridge Replacement Alternative A, impacts on trails that are contributors to the historic district would be direct, long-term, and minor. Trails that are contributors to the historic district would be permanently altered by bridge lengthening and alterations to approaches; therefore, Pedestrian Bridge Replacement Alternative A's adverse impacts cannot be fully mitigated. However, because the trails are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, when combined with actions common to all alternatives, Pedestrian Bridge Replacement Alternative A's impacts to historic resources would be long-term, minor, and adverse. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

<u>Impacts of Pedestrian Bridge Replacement Alternative B:</u>

Analysis

Under Pedestrian Bridge Replacement Alternative B, the spans for Bridges 2 and 3 would be lengthened and designed to pass up to a 100-year peak-discharge event with 13- and 14-inch freeboard at the peak of the arch, respectively (Figures 2-7 and 2-8). Existing abutments would be removed and new abutments would be placed farther from the creek. For Bridge 2, on the east side of the creek approximately 80 LF of existing asphalt trail would be removed and replaced with approximately 140 LF of new boardwalk and approximately 40 LF of new boardwalk would replace asphalt trail on the west side of creek. For Bridge 3, approximately 130 LF of existing asphalt trail leading to the east side of the crossing would be removed and the trail would be relocated and replaced with approximately 120 to 160 LF of new flexible paving trail. The approaches to the bridge would require approximately 50 LF of new boardwalk on the east side of the creek and approximately 50 LF of new boardwalk on the west side of creek. The rerouted trail would be to be pulled back from the channel.

Conclusion

Under Pedestrian Bridge Replacement Alternative B, the bridge approaches are slightly longer than under Pedestrian Bridge Replacement Alternative A, so the impacts to trails that are contributors to the historic district are greater than under Pedestrian Bridge Replacement Alternative A. However, the difference between bridge approach length is minor. Therefore, adverse impacts to historic resources under Pedestrian Bridge Replacement Alternative B would be similar to potential impacts discussed above for

Pedestrian Bridge Replacement Alternative A. Under this alternative, the Section 106 determination of effect on the whole Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Under Pedestrian Bridge Replacement Alternative C, the impacts associated with Bridge 2 would be as described for Pedestrian Bridge Replacement Alternative A, and Bridge 3 impacts would be as described in Pedestrian Bridge Replacement Alternative B.

Conclusion

Under Pedestrian Bridge Replacement Alternative C, some bridge approaches are slightly longer than under Pedestrian Bridge Replacement Alternative A and others are the same, so the impacts to trails that are contributors to the historic district are greater than under Pedestrian Bridge Replacement Alternative A but less than Pedestrian Bridge Replacement Alternative B. However, the difference between bridge approach length is minor. Therefore, adverse impacts to historic resources under Pedestrian Bridge Replacement Alternative C would be similar to potential impacts discussed above for Pedestrian Bridge Replacement Alternative A. Under this alternative, the Section 106 determination of effect on Muir Woods Historic District as a whole would be no adverse effect, as this action would not render MWNM ineligible for listing in the NRHP.

Cumulative Impacts

Continued public use of the trails would potentially result in heavy use of the Main Trail and/or Ben Johnson Trail. Muir Woods is extremely popular and experiences heavy visitation year-round, with daily average visitation rates ranging from a low of approximately 1,500 in January to a high of approximately 4,700 in July (NPS 2015b). Daily visitors to Muir Woods can number in the thousands in a single day, and the majority of these visitors walk on park trails, potentially creating overuse, particularly on unpaved paths such as the Ben Johnson Trail. Public use is unlikely to result in an adverse effect to historic riprap, since visitors are not allowed to enter the creek bed.

Previous studies have not revealed archeological sites in the creek channel or on the creek banks; therefore, no adverse impacts to archeological resources are anticipated. However, ground disturbance resulting from construction activities could potentially reveal the existence of currently unknown archeological sites. Earth-disturbing activities should, therefore, be monitored for cultural resources. If any resources were discovered, construction would be stopped, and the NPS would follow the procedures outlined in 36 CFR 800.13 (Post-Review Discoveries). If no resources are discovered and if the procedures outlined in 36 CFR 800.13 are followed, construction should not result in adverse impacts to archeological resources.

Implementation of the Muir Woods Reservation System will reduce peak visitation levels at MWNM by limiting access and parking for motorized vehicles. These actions would reduce peak use of the Muir Woods Historic District and would, therefore, have a beneficial effect.

The Muir Woods Road Bridge Replacement Project will replace a bridge on Muir Woods Road outside of the Muir Woods Historic District. Replacement of the bridge would have no effect on the Muir Woods Historic District.

The Muir Woods Road Rehabilitation Project will involve repairs and resurfacing work along parts of Muir Woods Road, as well as repair or replace culverts. No archeological resources are known to exist within the project area. While the project is in an area potentially sensitive for archeological remains, the Road Rehabilitation Project will have no adverse impacts on cultural resources, as NPS will monitor the work and will follow the procedures for post-review discoveries, pursuant to 36 CFR 800.13, if archeological materials are uncovered during construction.

The Muir Woods Water/Wastewater Line Replacement includes the repair and enhancement of water and wastewater lines, along with portions of the potable water and wastewater collection systems and two lift stations in MWNM. These actions will involve ground disturbance and excavations that have the potential to uncover archeological remains, although no archeological resources have been discovered in the project area. Similar to the Road Rehabilitation Project, this project will be monitored in archeologically sensitive areas and follow the procedures under 36 CFR 800.13 if archeological materials are discovered during construction. Therefore, the Water/Wastewater Line Replacement should have no adverse effect on cultural resources.

The Muir Woods Sustainable Access Project would modify the configuration of the Entry Plaza and several parking lots, remove all parking from the Entry Plaza except for administrative parking, install a new pedestrian bridge at the Dipsea Trail crossing of Redwood Creek, relocate the existing restrooms in the Entry Plaza, and construct a second restroom. This project will have no adverse effect on cultural resources because (1) known archeological sites will be avoided; (2) 36 CFR 800.13 will be followed if archeological materials are discovered during construction; and (3) the new Dipsea Trail bridge and restrooms will be designed to meet the Secretary of the Interior's Standards for the Treatment of Historic Properties.

Impacts on cultural resources would be direct, short- and long-term, and minimal because known archeological sites would be avoided, areas of archeological sensitivity would be monitored, and new structures would be designed to follow the Secretary of the Interior's Standards for the Treatment of Historic Properties. Several of these projects would include ground disturbance in the vicinity of areas identified as archeologically sensitive but cumulatively would have no adverse effect on cultural resources as known sites will be avoided, sensitive areas will be monitored, and 36 CFR 800.13 will be followed if archeological materials are discovered during construction. Similarly, replacement of the Dipsea Trail Bridge, and construction of new bathrooms would follow the Secretary of the Interior's Standards for the Treatment of Historic Properties and thus have no adverse impact on the Muir Woods Historic District.

In conclusion, multiple projects planned in the area of the Proposed Action will have direct, short- and long-term, and minimal impacts because known archeological sites would be avoided, areas of archeological sensitivity would be monitored, and new structures would be designed to follow the Secretary of the Interior's Standards for the Treatment of Historic Properties.

Overall Impacts

Considering the creek restoration and pedestrian bridge replacement alternatives as a whole, the Proposed Action would result in direct, long-term, and major adverse impacts that cannot be mitigated to historic riprap, and minor potential adverse impacts to trails and archeological resources that can be mitigated. However, because the trails and erosion-control rock revetments are among many cultural landscapes, buildings, and structures that are considered contributors to the historic district, there would be no adverse effect on the Muir Woods Historic District.

Impacts to riprap and trails are summarized for each alternative in Tables 2-1 and 2-2 in Chapter 2.

4.4 Threatened or Endangered Species

Methodology and Assumptions

This analysis examines the potential for actions associated with each of the alternatives to affect threatened or endangered species or their habitats at MWNM. Chapter 3 described federally threatened and endangered species known to occur or potentially occurring at the monument. The area of analysis includes all habitats within the boundary of MWNM, as well as downstream reaches of Redwood Creek which could potentially be impacted by water quality and sedimentation changes.

The marbled murrelet has not been documented at MWNM or at the adjacent State Parks areas around the Alice Eastwood campground or road, and is not expected to be impacted under the Proposed Action. If marbled murrelet were to be present, effects would be similar to those described for northern spotted owls. Implementation of BMP BIO-7, which requires pre-construction surveys for this species, would further reduce the potential for impacts. Because no impacts to marbled murrelet are expected to result from the Proposed Action, this issue is not discussed further.

Impacts of the No Action Alternative

Analysis

Coho Salmon. The No Action Alternative would result in continued poor rearing conditions for juvenile Coho within MWNM. Under the No Action Alternative, no LWD would be added to Redwood Creek, although some natural recruitment of LWD could potentially occur. However, the historic removal of LWD from MWNM means that there would continue to be a low level of LWD in the creek.

In-kind replacement of pedestrian bridges would result in construction impacts to Redwood Creek such as sedimentation and disturbance of bank vegetation, but it would be expected that standard BMPs such as those described in Chapter 2 would be employed to minimize impacts on Coho salmon.

Steelhead. Impacts on steelhead under the No Action Alternative would be the similar to those described for Coho salmon because of the habitat overlap between the two species. However, steelhead are not considered at risk of extirpation from Redwood Creek.

Northern Spotted Owl. Construction activities to replace the pedestrian bridges in-kind would result in indirect short-term impacts to northern spotted owls due to increased noise from construction equipment.

Conclusion

Under the No Action Alternative, Coho salmon and steelhead critical habitat would continue to be affected by poor rearing conditions as a result of historic management practices. Direct and indirect adverse impacts would persist over the long term. Northern spotted owl would be temporarily affected by construction activities for bridge replacement. Overall, the No Action Alternative is likely to adversely affect threatened or endangered species.

Creek Restoration Alternatives

Unless otherwise noted, evaluations of impacts are based on NHE's 2016 report, *Salmon Habitat Restoration at Muir Woods*.

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All alternatives would result in removal and translocation of juvenile Coho salmon and steelhead from the areas to be dewatered within Redwood Creek and temporary loss of low quality rearing habitat. This would require a take authorization from NMFS. Revegetation of disturbed creek banks would result in overhanging branches that would provide cover for Coho salmon and steelhead. Under all stream action alternatives, there would be a beneficial increase in stream habitat complexity for listed salmonids over the No Action Alternative with removal of riprap and addition of LWD. The presence of new LWD would help with retention of small woody debris, as well as pool formation and maintenance. Impacts of riprap removal and LWD addition are analyzed in more detail in each Creek Restoration alternative below. Installation of grade control to reduce incision in a tributary to Redwood Creek would be conducted during the summer when the tributary is dry. This work period, combined with the BMPs identified in Chapter 2, would eliminate or reduce the potential for sediment to wash into Redwood Creek. Installation of grade control would reduce erosion, indirectly benefitting salmonids due to decreased sedimentation in spawning areas. Grade control also has the potential to locally raise groundwater elevations at the base of the drainage area and to store more water that becomes available to the channel later in the season, which could have minor long-term beneficial impacts on salmonids. Grade control installation would be by hand and would not be expected to significantly increase temporary noise in the vicinity of the installation, and thus is not anticipated to impact northern spotted owls.

Conclusion

Removal of juvenile salmon from areas to be dewatered would result in minor, short-term adverse impacts on juvenile Coho salmon and steelhead. Revegetation of disturbed areas would result in long-term minor beneficial impacts on Coho salmon and steelhead. Installation of grade control on the tributary to Redwood Creek would have minor, long-term beneficial impacts on salmonids, and is not anticipated to impact northern spotted owl.

Impacts of Creek Restoration Alternative 1:

Analysis

Coho Salmon. Creek actions including removal of riprap and placement of LWD would result in changes in stream habitat that would be beneficial to Coho salmon. Channel migration would result in undercut tree root systems, which creates deep undercut banks that serve as velocity refuge and cover essential for rearing fish (NHE 2016a). Implementation of the actions proposed in Creek Restoration Alternative 1 could result in short-term adverse impacts to Coho salmon through sedimentation caused by channel migration; however adverse effects such as downstream reductions in spawning habitat and downstream increases in turbidity will be minimized through revegetation and restoration of banks per BMP BIO-15. Dewatering of the channel and the presence of heavy equipment in the channel could also result in short-term impacts to Coho salmon, which would be avoided or reduced by the BMPs described in Chapter 2, specifically BMP-1, -2, -4, -5 and BIO-1, -2, -4, and -5. These BMPs require measures such as defining the work area and dewatering area, removing fish from the dewatering area, dewatering the work area, implementing measures to reduce equipment impacts, using biodiesel, biological training of workers, and limiting the in-water work window to June 15 to October 31. Impacts to specific Coho salmon habitat types are described below.

Spawning habitat

The highest density of Coho spawning in Redwood Creek occurs in MWNM (Fong et al. 2016). While removal of riprap is not anticipated to substantially change Coho salmon spawning habitat, LWD addition is anticipated to improve spawning habitat by increasing the exchange of subsurface and surface flows (NHE 2016a). Where existing riffles are converted to pools through natural channel processes, a decrease in spawning habitat may occur (NHE 2016a). However, the channel in the Action Area has a disproportionately large area of flat planar bed compared to other reaches of Redwood Creek and the conversion of some of this area to more natural features would not be anticipated to have a large impact on the availability of spawning habitat. Spawning habitat also occurs in Redwood Creek downstream of MWNM (Fong et al. 2016). Mobilization of stream banks would result in increased sediment load into Redwood Creek (see Section 4.5, *Geology* and Section 4.9, *Water Resources and Hydrology* for a more detailed discussion). Detailed long-term observation of spawning habitat within Redwood Creek has not shown burial of spawning gravel from other sediment sources (such as eroding banks) (Mike Reichmuth, NPS, personal observation, Feb. 1, 2017). In addition, sedimentation will be minimized by restoring and revegetating disturbed banks through implementation of BMP BIO-15. For these reasons, the additional fine sediment generated from restoration activities is not anticipated to have adverse impacts on downstream spawning habitat.

Summer Rearing Habitat

The number of pools within MWNM would increase, as would habitat complexity associated with LWD. Increased rearing habitat in proximity to spawning habitat reduces time and energy that young fish expend seeking out suitable habitat following emergence (NHE 2016a). Good rearing habitat created adjacent to high quality spawning habitat creates well-connected habitats that will increase overall rearing habitat capacity in the watershed. Under current poor habitat conditions, young salmon are displaced downstream where they are either eaten or potentially they over-saturate existing habitats. Increased rearing habitat in MWNM also provides better spatial distribution of juveniles throughout the watershed and minimizes risk to population from catastrophic events that affect certain segments of the creek (e.g., drought impacts affecting lowest part of creek)

This alternative has the most limited area of direct action, and has the least benefit of the alternatives. Riprap removal and LWD installation under Creek Restoration Alternative 1 would result in increases in summer rearing habitat between Bridge 1 and Bridge 4 from the existing mean of 32 percent of the channel length to approximately 47 percent, an increase of approximately 15 percent. LWD installation would result in summer habitat creation after flows are sustained at sufficiently high levels to mobilize the bed and scour pools. This would result in long-term beneficial impacts on Coho salmon.

Winter/Spring Rearing Habitat

Coho rear in areas that are adjacent to cover, have water low velocities, and have sufficient depth for the specific life stage. Shallow water habitats supported much lower numbers of juvenile Coho salmon and steelhead than pools during winter 2017 snorkel surveys. Fish that emerge (fry) during high flows can be swept downstream and mortality can increase if refugia from velocity are not readily available (Lestelle 2007). Fry prefer shallow, low velocity water in backwater pools and along channel margins adjacent to bank cover which may include woody debris, undercut banks and roots (Lestelle 2007). Under all creek restoration alternatives the revegetation of creek banks and incorporation of LWD should increase the amount of available habitat for coho fry. As described in Chapter 3, Affected Environment, the highest density of spawning in Redwood Creek occurs in MWNM (Fong et al. 2016), and the presence of pools and complex habitat in proximity to spawning habitat would likely increase juvenile abundance in MWNM. Currently, winter/spring rearing habitat is 11 m^2/100m. Under Creek Restoration Alternative 1, winter/spring rearing habitat would increase to approximately 45 m^2/100m. This would result in long-term beneficial impacts on Coho salmon.

Steelhead. Steelhead and Coho salmon can use similar habitat, but steelhead will also use more large rock cover. As temperatures drop, steelhead are also known to use loose rock substrates for cover from 10 to 490 cm in diameter in proportion to their body size (Bustard and Narver 1975; Hartman 1965). Loss of interstitial space in riprap would be offset by other habitats (such as LWD). Impacts on steelhead under Creek Restoration Alternative 1 would be similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Creek Restoration Alternative 1, noise and the presence of equipment and crews during construction activities could result in direct, short-term impacts on northern spotted owls. Implementation of BMP measures BIO-1, -2, -3, and -6 would reduce the potential for adverse impacts on northern spotted owls. These measures include biological training of workers; no Proposed Action activities at night, dawn, or dusk; removal of waste; and pre-construction surveys for this species. Long-term indirect adverse effects could occur if channel migration causes loss or degradation of occupied habitat (e.g., nest trees, prey resources); however, this is considered a negligible impact.

Conclusion

Implementation of Creek Restoration Alternative 1 would result in major long-term beneficial impacts to Coho salmon, steelhead, and their critical habitat within the Action Area. Temporary adverse impacts to these species would be reduced by implementation of BMPs described in Chapter 2, specifically BMP-1, -2, -4, -5 and BIO-1, -2, -4, and -5. These BMPs require measures such as defining the work area and dewatering area, removing fish from the dewatering area, dewatering the work area, implementing measures to reduce equipment impacts, using biodiesel, biological training of workers, and limiting the in-water work window to June 15 to October 31.

This alternative could result in short-term temporary adverse impacts on northern spotted owl due to construction noise. Implementation of BMPs BIO-1, -2, -3, and -6, would reduce the potential for adverse impacts on this species. These measures include biological training of workers; no Proposed Action activities at night, dawn, or dusk; removal of waste; and pre-construction surveys for this species. Long-term adverse impacts to northern spotted owl would be negligible.

Impacts of Creek Restoration Alternative 2:

Analysis

Coho Salmon. Under Creek Restoration Alternative 2, effects on Coho salmon would be similar to those described under Creek Restoration Alternative 1. The geographic area of habitat enhancement would be expanded to include the Entry Plaza area and Cathedral Grove. Both summer and winter/spring rearing habitat would increase, due to the development of pools from the removal of the additional 338 LF of riprap. Summer habitat would increase to 49 percent of the channel length and winter/spring rearing habitat would increase to 48 m^2/100m (NHE 2016a). This increase in habitat would result in greater beneficial impacts compared with Creek Restoration Alternative 1.

Steelhead. Effects on steelhead under Creek Restoration Alternative 2 would be similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Creek Restoration Alternative 2, effects on northern spotted owl would be similar to those described under Creek Restoration Alternative 1.

Conclusion

Implementation of Creek Restoration Alternative 2 would result in additional long-term beneficial impacts in the Action Area to Coho salmon, steelhead, and their critical habitat compared to Creek Restoration Alternative 1.

This alternative could result in short-term temporary adverse impacts on northern spotted owl due to construction noise, which would be reduced by implementation of the BMPs described in Creek Restoration Alternative 1. Long-term adverse impacts to northern spotted owl would be negligible.

Impacts of Creek Restoration Alternative 3:

Analysis

Coho Salmon. Under Creek Restoration Alternative 3, effects on Coho salmon would be similar to those described under Creek Restoration Alternative 2 but with additional benefits. This alternative addresses incision in the area of the creek that is most incised. Both summer and winter rearing habitat would increase, due to the development of pools from the removal of the additional riprap segments and the installation of engineered log jams in the Entry Plaza area. Summer habitat would be created in the form of large, deep pools in the vicinity of the constructed wood jams, and would increase 2 percent compared to Creek Restoration Alternative 2 (NHE 2016a). However, the increased value of the created jam pools is much higher than the arithmetic increase would suggest. In winter 2017, the four existing log jam pools in MWNM had on average 17 Coho salmon and 12 steelhead per pool. A mean number of two Coho salmon and six steelhead juveniles were observed in all other pools. Winter/spring habitat will be expanded throughout the reach due to increased velocity refuge, expanded cover, and increase depth where new pools are formed. The terracing of the right bank at the Plaza would add approximately 5,380 square feet of inset floodplain to this reach of river corridor which would result in an immediately larger area and wider variety of winter rearing habitat compared with Creek Restoration Alternative 2. The changes would result in an increase of 3 $m^2/100m$ compared to Creek Restoration Alternative 2 (NHE 2016a). This increase in habitat would result in greater beneficial impacts compared with Creek Restoration Alternative 2.

Steelhead. Effects on steelhead under Creek Restoration Alternative 3 would be the similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Creek Restoration Alternative 3, effects on northern spotted owl would be similar to those described under Creek Restoration Alternative 2.

Conclusion

Implementation of Creek Restoration Alternative 3 would result in additional long-term beneficial impacts in the Action Area to Coho salmon, steelhead, and their critical habitat compared to Creek Restoration Alternative 2.

This alternative could result in short-term temporary adverse impacts on northern spotted owl due to construction noise, which would be reduced by implementation of the BMPs described in Creek Restoration Alternative 1. Long-term adverse impacts to northern spotted owl would be negligible.

Impacts of Creek Restoration Alternative 4:

Analysis

Coho Salmon. Under Creek Restoration Alternative 4, effects on Coho Salmon would be similar to those described under Creek Restoration Alternative 2. Both summer and winter/spring rearing habitat would increase, due to the development of pools from the removal of the additional riprap segments. The excavation of an alcove in the Bridge 1.5 drainage area would immediately increase both summer and winter rearing habitat. Summer habitat is anticipated to increase to approximately 53 percent of the channel length, an increase of 2 percent compared to Creek Restoration Alternative 4. Winter/spring rearing habitat would increase by approximately

3 m^2/100m compared to Creek Restoration Alternative 3. Relocating up to 555 LF of trail further from the channel in two areas and gaining creek-side vegetation in these areas would also be beneficial. This increase in habitat would result in greater beneficial impacts compared with Creek Restoration Alternative 2.

Steelhead. Effects on steelhead under Creek Restoration Alternative 4 would be the similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Creek Restoration Alternative 4, effects on northern spotted owl would be similar to those described under Creek Restoration Alternative 2.

Conclusion

Implementation of Creek Restoration Alternative 4 would result in additional long-term beneficial impacts in the Action Area to Coho salmon, steelhead, and their critical habitat compared to Creek Restoration Alternative 1. Temporary adverse impacts to these species would be reduced by implementation of BMPs described in Creek Restoration Alternative 1.

This alternative could result in short-term temporary adverse impacts on northern spotted owl due to construction noise, which would be reduced by implementation of measure BMPS described in Creek Restoration Alternative 1.

Impacts of Creek Restoration Alternative 5:

Analysis

Coho Salmon. Under Creek Restoration Alternative 5, effects on Coho salmon would be similar to those described under Creek Restoration Alternative 4; however, terracing of the right bank would add approximately 5,380 square feet of inset floodplain to this reach of river corridor which would result in an immediately larger area and wider variety of winter/spring rearing habitat compared with Creek Restoration Alternative 4. Summer habitat would be similar to Creek Restoration Alternative 4, while winter/spring rearing habitat would increase by 3 m^2/100 m compared to Creek Restoration Alterative 4. Creek Restoration Alternative 5 provides the maximum habitat enhancements for Coho salmon.

Steelhead. Effects on steelhead under Creek Restoration Alternative 5 would be the similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Creek Restoration Alternative 5, effects on northern spotted owl would be similar to those described under Creek Restoration Alternative 4.

Conclusion

This alternative provides the most habitat benefit to Coho salmon, steelhead, and their critical habitat. Short-term adverse impacts to northern spotted owl would be similar to Creek Restoration Alternative 4. Temporary adverse impacts to these species would be reduced by implementation of BMPs described in Creek Restoration Alternative 1.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives

Analysis

Coho Salmon. Replacement of Bridges 1 and 4 with bridges that accommodate the 100-year flood flow with 18 inches of freeboard could have temporary adverse effects on Coho salmon due to construction-related effects such as dewatering (if required), sedimentation, or disturbance of existing in-channel habitat. Long-term minor beneficial effects could result from improving in-channel habitat conditions by removing flow restrictions.

Steelhead. Impacts on steelhead under Actions Common to all bridge alternatives would be similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under actions common to all Bridge Alternatives, noise and the presence of equipment and crews during construction activities could result in direct, temporary impacts on northern spotted owls.

Conclusion

Implementation of actions common to all pedestrian bridge replacement alternatives could result in temporary adverse impacts to Coho salmon and steelhead which would be reduced by implementation of BMPs described in Chapter 2, specifically BMP-1, -2, -4, -5 and BIO-1, -2, -4, and -5. These BMPs require measures such as defining the work area and dewatering area, removing fish from the dewatering area, dewatering the work area, implementing measures to reduce equipment impacts, using biodiesel, biological training of workers, and limiting the in-water work window to June 15 to October 31. Minor long-term benefits to Coho salmon and steelhead would also result. These actions would also result in short-term temporary adverse impacts on northern spotted owl due to construction noise, which would be reduced by implementation of measures BIO-1, -2, -3, and -6. These measures include biological training of workers; no Proposed Action activities at night, dawn, or dusk; removal of waste; and pre-construction surveys for this species.

Impacts of Pedestrian Bridge Replacement Alternative A

Analysis

Coho Salmon. Replacement of Bridges 2 and 3 with bridges that span the 25-year flood could have temporary minor adverse effects on Coho salmon due to construction-related effects such as sedimentation or the presence of heavy equipment in the channel. Long-term beneficial effects could occur due to the lengthening of the spans to accommodate high flood flows and improve transport of LWD within Redwood Creek.

Steelhead. Impacts on steelhead under Pedestrian Bridge Replacement Alternative A would be the similar to those described for Coho salmon because of the habitat overlap of the two species.

Northern Spotted Owl. Under Pedestrian Bridge Replacement Alternative A, noise and the presence of equipment and crews during construction activities could result in direct, temporary impacts on northern spotted owls.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative A would result in temporary adverse impacts to Coho salmon and steelhead from construction which would be reduced by implementation of BMPs described in *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. It would also result in minor long-term habitat improvements for these species. Pedestrian Bridge Replacement Alternative A would result in short-term minor temporary adverse impacts on northern spotted owl due to construction noise, which would be reduced by implementation of BMPs described in Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Impacts on threatened and endangered species resulting from implementation of Pedestrian Bridge Replacement Alternative B would be similar to impacts from Pedestrian Bridge Replacement Alternative A. The larger span of Bridges 2 and 3 would have potentially minor enhanced benefit to salmonids relative to Pedestrian Bridge Replacement Alternative A. Rerouting of trails would have potential minor adverse effects on northern spotted owl if prey resources (such as woodrats) are impacted.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative B would result in temporary adverse impacts to Coho salmon and steelhead from construction which would be reduced by implementation of BMPs described in *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. It would also result in long-term habitat improvements for these species due to the improved stream function and LWD transports compared to Pedestrian Bridge Replacement Alternative A. Pedestrian Bridge Replacement Alternative B would result in short-term minor temporary adverse impacts on northern spotted owl due to construction noise which would be reduced by implementation of BMPs described in *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Impacts on threatened and endangered species of implementation of Pedestrian Bridge Replacement Alternative C would be intermediate to the impacts described in Pedestrian Bridge Replacement Alternatives A and B. Habitat benefits of the longer span at Bridge 3 are significantly greater than the habitat benefits of having the longer span at Bridge 2.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative C would result in temporary adverse impacts to Coho salmon and steelhead from construction which would be reduced by implementation of BMPs described in *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. It would also result in minor long-term habitat improvements for these species. Pedestrian Bridge Replacement Alternative C would result in short-term minor temporary adverse impacts on northern spotted owl due to construction noise which would be reduced by implementation of BMPs described in *Impacts of Actions Common to all*

Pedestrian Bridge Replacement Alternatives. These impacts would be between those for Pedestrian Bridge Replacement Alternatives A and B in terms of severity.

Cumulative Impacts

Cumulative adverse impacts from other past, current, and future projects in MWNM include noise and water quality impacts. Phase 1 of the Muir Woods Reservation System caused indirect long-term beneficial impacts to Coho salmon and steelhead by reducing sedimentation and improving water quality. Effects on northern spotted owl are not anticipated from this project. Phase 2 is anticipated to also result in long-term indirect beneficial impacts on Coho salmon and steelhead.

Construction-related sedimentation and temporary disturbance of Redwood Creek from the Muir Woods Road Bridge Replacement Project would result in indirect, short-term adverse impacts on Coho salmon and steelhead. Noise disturbance during construction would result in indirect, short-term adverse impacts to northern spotted owl. The Muir Woods Road Rehabilitation Project and the Muir Woods Water/Wastewater Line Replacement would have similar adverse impacts on threatened and endangered species. However, the Muir Woods Road Rehabilitation Project would also have long-term beneficial impacts on Coho salmon and steelhead by reducing sedimentation in Redwood Creek.

The Muir Woods Sustainable Access Project could result in indirect, short-term impacts on Coho salmon and steelhead from sedimentation and water quality degradation during construction. Construction of the Dipsea Trail footbridge over Redwood Creek, revegetation of disturbed areas, and improvements to stormwater management infrastructure could have direct and indirect, long-term, beneficial impacts on Coho salmon and steelhead as a result of improved water quality and reduced habitat disturbances associated with foot traffic on the Dipsea Trail at the Redwood Creek crossing. Northern spotted owls could potentially be affected by noise and other disturbances associated with construction activities.

Taken as a whole, construction of these projects would have short-term adverse impacts to Coho salmon, steelhead, and northern spotted owls, but would result in long-term benefits to Coho salmon and steelhead.

Overall Impacts

Completing the maximum amount of work for the actions described in the alternatives above would result in short-term adverse effects on Coho salmon and steelhead, which would be reduced by implementation of BMP-1, -2, -4, -5 and BIO-1, -2, -4, and -5. These BMPs require measures such as defining the work area and dewatering area, removing fish from the dewatering area, dewatering the work area, implementing measures to reduce equipment impacts, using biodiesel, biological training of workers, and limiting the in-water work window to June 15 to October 31. It would result in a substantial increase in summer and winter rearing habitat for these species, resulting in a major long-term beneficial impact. This added habitat may increase survival of fry and juvenile Coho salmon and steelhead.

The Proposed Action is not anticipated to substantially increase the amount of fine sediment entering the creek through bank erosion. Detailed long-term observation of spawning habitat within Redwood Creek has not shown burial of spawning gravel from other sediment sources; thus, additional fine sediment is not anticipated to have adverse impacts on downstream spawning habitat. In addition, downstream sedimentation and turbidity will be minimized by restoring and revegetating disturbed banks through implementation of BMP BIO-15.

Construction noise impacts on northern spotted owl would be similar to those described in Creek Restoration Alternative 1, with an increase in duration due to implementation of Proposed Action elements. This would result in short-term adverse effects on these species, which would be reduced by implementation of BIO-1, -2, -3, and -6. These measures include biological training of workers; no Proposed Action activities at night, dawn, or dusk; removal of waste; and pre-construction surveys for this species. Long-term impacts to northern spotted owl would be negligible.

4.5 Geology: Soils and Bedrock

Methodology and Assumptions

This analysis considers the impacts of each alternative on geologic resources including: soil removal; soil erosion; potential for mass wasting that would affect soil resources; and the relative disturbance of the Action Area as compared to existing conditions. Activities that may result in impacts on soils include riprap removal, placement of large woody debris, bridge installation, and rehabilitation or revegetation of disturbed areas. Impacts to geologic resources were assessed by examining soil information and mapping for the Action Area. For the purposes of this discussion, soil is considered the unconsolidated earth material outside of the immediate stream channel. A stream channel is a more dynamic environment, where mineral and organic material and deposits are found, but these are considered as sediment versus soil. The discussion of instream sediment and geomorphic processes and the potential effects to instream conditions are discussed in Section 4.9, *Water Resources and Hydrologic Processes*.

No Action Alternative

Analysis

Under the No Action Alternative, existing and ongoing recreational use would continue. No riprap would be removed or LWD installed. The four pedestrian bridges would be maintained or replaced in-kind (i.e., same location and similar design, material, and size) at some point in the future; in a worst-case scenario, the replacement would be in response to a bridge failure. During replacement of the pedestrian bridges, impacts would be short-term, direct, and adverse due to construction activities, including ground disturbance and excavation of soils around the bridge. Bridge failure would be anticipated to result in similar but greater impacts due to the uncontrolled nature of the failure.

Conclusion

The No Action Alternative would not significantly alter geology, soils, or streambed resources in the Action Area from existing conditions. However, minor adverse impacts would occur from the presence, maintenance, replacement, and potential failure of existing facilities (e.g., bridges and trails) and visitor use. These impacts would be long-term and would occur throughout MWNM.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

Under all Creek Restoration Alternatives, soils would be stabilized through the revegetation of the creek banks and areas of the forest floor impacted during implementation of the Proposed Action. The proposed actions do not include removal of a segment of riprap (R11) at the base of a steep hillslope to avoid the possibility of hillslope slumping or slides in that location. The proposed actions for LWD also avoid the use of fallen trees on steep hillslopes to avoid potential development of gullies at such locations.

Construction activities necessitate vegetation removal in some areas for channel access and riprap removal. Required equipment and methods vary depending on the location and extent of the construction activities. However, workers and equipment would utilize existing trails and access points to the greatest extent feasible. In addition, gullying and structural instabilities on the existing dirt road segment (i.e., Alice Eastwood Road) would be repaired by the construction crew prior to use (and after use, if needed). These gullies have been identified as a sediment source to Redwood Creek (PWA 2002). Repairs to Alice Eastwood Road would take into account that this is a historic road. Potential impacts to soil resources would be avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Conclusion

Planting and revegetation activities have the potential to improve soil resources over the long-term through increasing organic matter in the soil from vegetative litter and duff, encouraging micro-organisms in the soil, and improving the physical soil structure through rooting. Vegetation removal during construction periods would be short-term, direct, and adverse. Maintaining riprap segment R11 would avoid the potential for landslides or slumps in that area. Likewise, not using logs on steep slopes for LWD reduces the potential for adverse impacts to soil resources. Repair of the existing Alice Eastwood Road (dirt road) would be beneficial by reducing erosion.

Impacts of Creek Restoration Alternative 1:

Analysis

Actions associated with Creek Restoration Alternative 1 include the installation of approximately 40 to 55 existing downed trees from upland areas into the channel at 19 locations and removal of 1,123 LF of riprap from the banks of Redwood Creek. Movement of logs for LWD is planned using the grip-hoist method. As described above, logs on steep slopes have not been selected for use as LWD to avoid potential impacts to soil resources. This would reduce the potential for long-term impacts on soil resources. The grip-hoist method results in one end of the log being dragged along the ground, which would result in a rut along the ground surface where the log is dragged. These ruts would be decompacted and refilled using hand methods described in Section 2.5, *Construction Methods*. Construction activities would result in an increase to minor localized, direct, adverse impacts to soil during construction activities and equipment usage. Potential impacts to soil resources would be further avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Remnant base rock from a previously removed trail along the top of bank next to riprap segment L10 would be removed to allow better revegetation there for bank stability. An asphalt trail in this area was removed in 2000, but the remnant base rock about 6 inches below the surface has restricted plant cover despite numerous outplanting events. This would have a beneficial impact on soil resources.

Conclusion

Under Creek Restoration Alternative 1, the impacts on soil resources from LWD placement would be minor and short-term. Removal of remnant base rock would be a minor long-term beneficial impact on soil resources.

<u>Impacts of Creek Restoration Alternative 2:</u>

Analysis

Creek Restoration Alternative 2 includes actions described in Creek Restoration Alternative 1, as well as an additional 338 LF of riprap removal. Additional riprap removal would be in the vicinity of Cathedral Grove and in the Plaza area. These activities would result in an increase to localized, direct, adverse impacts to soil during construction activities and equipment usage. Potential impacts to soil resources would be avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Approximately 350 LF of asphalt trail on the top of the left bank at Cathedral Grove would be removed, soils would be decompacted, and the area would be revegetated. Removal and revegetation of impervious or compacted surfaces would increase infiltration rates and reduce the runoff and surface erosion potential of these areas. These activities are considered beneficial.

Conclusion

In addition to the impacts of Creek Restoration Alternative 1, Creek Restoration Alternative 2 would have larger adverse short-term impacts to soil resources due to a greater use of equipment. The removal of asphalt along the trail and replacement with soil and vegetation planting represents a short-term and long-term benefit in those areas affected.

<u>Impacts of Creek Restoration Alternative 3:</u>

Analysis

Creek Restoration Alternative 3 consists of all actions under Creek Restoration Alternative 2, plus installation of three engineered log jams near the Plaza and terracing of the right bank between the channel and the floodplain (Figure 2-3). Implementation of Creek Restoration Alternative 3 would require site grubbing, grading, and off-haul of a significant volume of bank and floodplain material. During site excavation, soils would be exposed and subject to compaction and increased erosion. Graded and disturbed areas would be revegetated. These impacts would be considered short-term, direct and indirect, and adverse. Potential impacts to soil resources would be avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Conclusion

Creek Restoration Alternative 3 would have similar impacts as Creek Restoration Alternative 2. Construction activities to implement the terracing on the right bank would be considered a short-term, direct and indirect, adverse impact.

Impacts of Creek Restoration Alternative 4:

Analysis

In addition to the actions described in Creek Restoration Alternative 2, Creek Restoration Alternative 4 would excavate an alcove and add additional woody debris in the Bridge 1.5 area, and would relocate up to 555 LF of two asphalt trail segments which would be replaced with a combination of boardwalk and flexible paving farther from the channel. This action would also remove a small existing footbridge (Bridge 1.5). The former trail alignments would be decompacted, restored and replanted. The relocation of the trail segments would have a long-term, moderately beneficial impact to soil resources by reducing the impervious surface area near the channel thereby reducing erosion by necessitating stormwater runoff travel a greater distance and increasing the likelihood of infiltration before entering surface waters. Potential impacts to soil resources would be avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Conclusion

The relocation of asphalt trail farther from the creek would be considered a beneficial long-term impact.

Impacts of Creek Restoration Alternative 5:

Analysis

Creek Restoration Alternative 4 would include all action described in Creek Restoration Alternative 4, plus the left bank terracing described in Creek Restoration Alternative 3.

Conclusion

In addition to the impacts of Creek Restoration Alternative 4, construction activities to implement the terracing on the right bank would be considered a short-term, direct and indirect, adverse impact.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives:

Analysis

All Pedestrian Bridge Replacement Alternatives would involve the replacement of the existing bridges with a clear span design across the channel with new abutments farther from the creek. The existing bridge abutments would be removed. Excavation activities to remove the old bridges and construct the new abutments would cause localized, short-term, direct, and adverse impacts on soil resources during bridge construction. Applicable BMPs, listed in Section 2.7, would avoid and minimize any potential adverse impacts by reducing areas of disturbance and erosion and limiting potential runoff.

The approaches to Bridges 1 and 4 would be designed to connect the existing trail approaches with the new bridges with only minor trail/grade adjustments.

Conclusion

Excavation and removal of soil for new bridge abutments/foundations would be relatively minor, adverse, long-term permanent on soil resources. Some short-term, direct and indirect, adverse impacts are associated with construction activities; however, most impacts would be avoided or minimized through the implementation of applicable BMPs.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Under Pedestrian Bridge Replacement Alternative A, spans for Bridges 2 and 3 would be lengthened and designed to pass up to a 25-year peak-discharge event with 15 and 12-inch freeboard at the peak of the arch, respectively (Figures 2-7 and 2-8). Existing abutments would be removed and new abutments would be placed at a distance farther from the creek (Figures 2-7 and 2-8). For Bridge 2, 120 LF of new boardwalk would be installed on the east side of creek and 20 LF of new boardwalk on the west side of the creek, and a small approximately 20- by 20-foot boardwalk gathering area would be built on the east side of the creek. The existing gathering area and asphalt trail alignment at Bridge 2 would be restored. For Bridge 3, approximately 130 LF of existing asphalt trail leading to the east side of the crossing would be relocated and replaced with approximately 160 LF of flexible paving. The approaches to the bridge would require approximately 30 LF of boardwalk on the east side of the creek and approximately 35 LF of boardwalk on the west side of the creek. Soil underlying the previous trail alignments on the east side of the creek would be decompacted, and the area revegetated.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative A would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts would be long-term, direct and indirect, and beneficial by allowing larger flows to pass unimpeded thereby reducing scour around the bridge abutments. Installation of 205 LF (approximately) of boardwalk would replace hardscape (asphalt) trail and be considered a short- and long-term beneficial impact on soil resources by reducing runoff rates.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Under Pedestrian Bridge Replacement Alternative B, the spans for Bridges 2 and 3 would be lengthened and designed to pass up to a 100-year peak-discharge event with 13- and 14-inch freeboard at the peak of the arch, respectively (Figures 2-7 and 2-8). Existing abutments would be removed and new abutments would be placed farther from the creek. For Bridge 2, approximately 80 LF of trail segments would be rerouted and replaced with approximately

140 LF of new boardwalk on the east side of the creek and approximately 40 LF of new boardwalk on the west side of creek. For Bridge 3, approximately 130 LF of trail segments would be rerouted and replaced with approximately 160 LF of new flexible paving trail. The approaches to the bridge would require approximately 50 LF of new boardwalk on the east side of the creek and approximately 50 LF of new boardwalk on the west side of creek. The rerouted trail would be pulled back from the channel. The previous trail alignments on the east side of the creek would be restored and revegetated.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative B would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts associated with Pedestrian Bridge Replacement Alternative B would have larger long-term, direct and indirect, beneficial impacts than Pedestrian Bridge Replacement Alternative A since both Bridges 2 and 3 would accommodate 100-year flood flows. In addition, 280 LF (approximately) of boardwalk would be installed replacing hardscape (asphalt) trail and be considered a short- and long-term beneficial impact on soil resources by reducing runoff rates.

<u>Impacts of Pedestrian Bridge Replacement Alternative C:</u>

Analysis

Under Pedestrian Bridge Replacement Alternative c, the span for Bridge 2 would be lengthened and designed to pass up to a 25-year peak-discharge event with 15-inch freeboard at the peak of the arch and the span for Bridge 3 would be lengthened and designed to pass up to a 100-year peak-discharge event with 14-inch freeboard at the peak of the arch.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative C would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts associated with Pedestrian Bridge Replacement Alternative C would have slightly larger long-term, direct and indirect, beneficial impacts than Pedestrian Bridge Replacement Alternative A, but slightly lower long-term, direct and indirect, beneficial impacts than Pedestrian Bridge Replacement Alternative B. Pedestrian Bridge Replacement Alternative C would replace 240 LF (approximately) of boardwalk would be installed replacing hardscape (asphalt) trail and would be considered a short- and long-term beneficial impact on soil resources by reducing runoff rates.

Cumulative Impacts

Cumulative adverse impacts from other past, current, and future projects in MWNM include soil removal, soil erosion, and continued sedimentation into Redwood Creek near the Muir Woods Visitors Center, at parking lots, and along Muir Woods Road. As listed in Section 4.1 above, several ongoing and future projects would result in beneficial impacts (i.e., reduced erosion and reduced runoff) of the lower portion of the Proposed Action area. Many aspects of the other cumulative effects protect or enhance soil resources and erosion through the elimination of roadside parking in unpaved areas, improved stormwater facilities and infrastructure, installation or replacement of compromised road culverts, realignment or removal of existing dirt trails, and an improved creek crossing at the Dipsea Trail. In general, construction-related impacts on soil resources would be limited.

Overall Impacts

Construction of the various aspects of the Proposed Action would result in soil disturbance and potential for soil erosion. Short-term, adverse impacts from construction would be reduced through revegetation and implementation of erosion control BMPs, such as BMP-10, restoration of affected pathways (ex. BMP-12), and adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel). Soil erosion from channel migration would be minimized by revegetating disturbed banks per BMP BIO-15. Other aspects of the Proposed Action would result in beneficial effects on soils, including the removal of some trail segments and conversion of others to boardwalks.

4.6 Visitor Use and Experience

Methodology and Assumptions

The analysis of visitor use and experience focused primarily on visitor access to trails and bridges. Aspects of visitor experience relating to views and manmade noise and air pollution from project activities are discussed in more detail in the *Visual Resources*, *Soundscapes*, and *Air Quality* sections, respectively.

Impacts of the No Action Alternative

Analysis

To analyze the impacts associated with this alternative, the long-term impacts of taking no action or replacing bridges in-kind were compared to the benefits discussed in the Project goals. With no action, in the near term, visitors would continue to experience the monument much as they have since no bridge replacements or trail closures would occur. Over the longer term, visitors may be adversely impacted by experiencing aging bridges (and in a worst-case scenario, bridge failures), and the bridges would ultimately require replacement to ensure public safety, which would have many of the same impacts as the Pedestrian Bridge Replacement Alternatives. Visitors would also experience impacts relating to fish watching and redwood viewing which the Proposed Action seeks to address by improving hydrology and fish habitat within the monument.

Conclusion

Under the No Action Alternative, no creek improvement or bridge replacement work would be done and no temporary or permanent closure of trails would take place. Adverse impacts to visitor use and experience from construction associated with the Proposed Action, such as trail closures and noise, would be avoided; however, future similar impacts may result from in-kind bridge replacement, maintaining deteriorating bridges, or bridges submerged or damaged during large flow events. Under this alternative, no beneficial impacts to fish watching would be realized in the long term.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All creek restoration alternatives include revegetation of any impacted creek banks or areas of forest floor and the installation of check dams in a tributary near Bridge 3. In addition, all alternatives include at a minimum the work discussed for Creek Restoration Alternative 1 whose impacts are discussed below. Visitor use during these activities may be temporarily impacted by the presence, sight, and sound of equipment operating nearby. In the long-term, the restoration activities would preserve and enhance habitat quality and ecosystem resilience, which would beneficially affect user experience. Enhanced Coho habitat and viability would have a beneficial impact on visitors who enjoy fish watching.

Conclusion

Actions common to all creek restoration alternatives may have short-term adverse impacts on visitor use and experience resulting from the presence, sight, and sound of equipment operating in and near areas used by visitors. The long-term impacts of the actions would be beneficial by protecting and enhancing vegetation and creek function in the area, which are some of the monument's main attractions.

Impacts of Creek Restoration Alternative 1:

Analysis

Creek Restoration Alternative 1 involves the removal of riprap upstream of Bridge 1 and the placement of LWD in the channel. Temporary impacts to visitor use and experience would include trail closures while LWD is being moved across sections of trail plus some intermittent trail closures for equipment crossing trails to the channel or to remove a segment of riprap just upstream of Bridge 2. Some sections of trail may see increased congestion, noise, and unpleasant odors from equipment. During Phase 1 activities, the use of the Alice Eastwood group campground as a staging area may lead to closure of the campground either on weekdays only or possibly on both weekdays and weekends. Impacts will be minimized by conducting most work after Labor Day, when there is not much campground use on weekdays. Alice Eastwood Road from the campground will be closed to pedestrians for safety, but other nearby routes, such as the Fern Creek Trail, will be available. Signs will be placed and updated as needed along trail routes to provide clear information to hikers.

Conclusion

During construction of Creek Restoration Alternative 1, visitor use and experience would be impacted by temporary trail closures and increased congestion, noise, and odors on trails due to the work associated with the movement of LWD into the channel and equipment trips relating to riprap removal and hauling. Signage for alternative routes would be placed during temporary closures to limit use impacts.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 would include all of the actions described in Creek Restoration Alternative 1 as well as riprap removal in the Plaza Area and Cathedral Grove. This alternative also includes the permanent removal of the west section of trail in Cathedral Grove, which would then be inaccessible to visitors.

Conclusion

The permanent removal of the section of trail in Cathedral Grove would not have a major impact on trail continuity or visitor experience in the long term since the main leg of the trail would remain in place and a new trail configuration and gathering area in Cathedral Grove would be planned and implemented as part of a separate process. A minor impact to Visitor Use and Experience would result from the closure of the trail section as a result of changes in flow and loss of sights unique to that section. Compared to Creek Restoration Alternative 1, this alternative would have additional short-term adverse impacts from riprap removal in the Plaza Area; these are discussed in more detail in other sections below.

Impacts of Creek Restoration Alternative 3:

Analysis

Creek Restoration Alternative 3 consists of all of the actions and impacts of Creek Restoration Alternative 2, as well as installation of three engineered log jams and terracing of the right bank at or near the Entry Plaza. This work would result in temporary impacts to visitors entering and leaving the monument associated with heavy equipment operating nearby.

Conclusion

In addition to the impacts discussed in Creek Restoration Alternative 2, Creek Restoration Alternative 3 would have temporary adverse impacts on visitor use and experience in the Plaza Area where visitors enter and exit the monument. Because this is a high-traffic area, these impacts are considered moderate. In the long-term, this area would have a more natural appearance and may harbor more watchable wildlife which would be a beneficial impact.

Impacts of Creek Restoration Alternative 4:

Analysis

Creek Restoration Alternative 4 consists of all of the actions and impacts of Creek Restoration Alternative 2 along with additional riprap removal, alcove excavation, and LWD installation that would require modifications to two sections of trail (Figure 2-4). In addition to the roughly 350 LF of trail removed at Cathedral Grove, which this alternative has in common with Alternatives 2, 3 and 5, this alternative would involve the removal and rerouting of up to 440 LF of trail on the right bank near Bridge 1.5. The additional riprap and LWD work would likely proportionally increase related impacts discussed in Alternative 2. The trail modifications would involve replacing sections of trail near the creek with sections farther away, which would alter the visitor experience along those sections.

Conclusion

In addition to the impacts of Creek Restoration Alternative 2, Creek Restoration Alternative 4 would have proportionally larger temporary impacts relating to equipment usage for riprap, alcove, and LWD work. Minor long-term benefits to visitor use and experience would result from trail modifications.

Impacts of Creek Restoration Alternative 5:

Analysis

Creek Restoration Alternative 5 consists of all of the actions and impacts of Creek Restoration Alternative 4 along with the right bank terracing described in Creek Restoration Alternative 3.

Conclusion

In addition to the impacts discussed for Creek Restoration Alternative 4, Creek Restoration Alternative 5 would have temporary adverse impacts to visitor use and experience in the Plaza Area, particularly during terracing work. Minor long-term impacts to visitor use and experience would result from changes to trails.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives

Analysis

The gradient on approaches for all new bridges would be under 5 percent and all trail alterations would meet ABAAS. All bridge alternatives include replacing Bridges 1 and 4 to accommodate a 100-year storm flow. Removal and replacement of each bridge would result in temporary impacts to visitors' options for trail routes and would increase noise levels while work is being done. Bridge 1 is heavily trafficked and enables multiple options for loop routes. Bridge 4 sees less traffic, but provides access to a longer loop option and connects the Redwood Creek Trail to the Hillside Trail and Ben Johnson Trail. Signage for alternate routes and detours would be placed during construction to limit this impact.

Conclusion

Replacement of Bridges 1 and 4 would have short-term moderate adverse effects on visitor experience from construction activities and closures, but would have long-term beneficial effects from improved facilities.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

In addition to activities discussed above, Pedestrian Bridge Replacement Alternative A includes removing and replacing Bridges 2 and 3 and lengthening and elevating them to pass a 25-year storm event. Replacing Bridge 3 would require some trail rerouting with temporary impacts to visitor use during realignment and restoration activities. During removal and replacement activities, noise levels in the area would increase and trail route options would be temporarily impacted.

Conclusion

Pedestrian Bridge Replacement Alternative A would have temporary impacts on nearby noise levels and visitor access to trail routes during removal and replacement. Once the work is complete, the improved gathering area and bridges would provide long-term beneficial impacts to visitor use and experience.

<u>Impacts of Pedestrian Bridge Replacement Alternative B:</u>

Analysis

Like Pedestrian Bridge Replacement Alternative A, Pedestrian Bridge Replacement Alternative B involves replacing Bridges 2 and 3 and rerouting some portions of trail, but bridges would be designed for 100-year storm events, requiring higher and longer bridges and trail connections. This alternative would therefore require increased disturbance and rerouting of existing trails, with temporary impacts to visitor trail route options. Under this alternative, Bridge 2 would require a 10-foot-long guardrail on the boardwalks on each side of the bridge. Long-term beneficial impacts to visitor use and experience would include improved safety and a different visitor experience through a wooded area that is not generally provided on the valley floor. The elimination of an informal gathering area would have a long-term adverse impact.

Conclusion

Pedestrian Bridge Replacement Alternative B would have temporary impacts on nearby noise levels and trail route options which would be somewhat greater than Pedestrian Bridge Replacement Alternative A. Long-term beneficial impacts would also be greater than Pedestrian Bridge Replacement Alternative A, including improved visitor safety and a broader experience of the monument’s habitat types for visitors using the new bridges and sections of trail.

<u>Impacts of Pedestrian Bridge Replacement Alternative C:</u>

Analysis

Pedestrian Bridge Replacement Alternative C involves the replacement of Bridge 2 with the same span and trail adjustments as Pedestrian Bridge Replacement Alternative A and Bridge 3 with the same span and trail adjustments as Pedestrian Bridge Replacement Alternative B. Both bridges would improve conveyance of creek flows compared to their current designs, while limiting Bridge 2 to a 25-year flow standard allows for less trail rerouting and the retention of a nearby gathering area that is important to the visitor use.

Conclusion

Bridge Alternative C would have impacts falling between those of Bridge Alternatives A and B. The removal and construction of bridges would have temporary adverse impacts on visitor use and experience in terms of trail route options and accessibility. Like Pedestrian Bridge Replacement Alternative A, this alternative would have the long-term beneficial impact of retaining and improving the gathering area near Bridge 2.

Cumulative Impacts

Cumulative Impacts

Phase 2 of the Muir Woods Reservation System, which manages motorized access to the monument (parking and shuttles), will reduce peak visitation levels at MWNM by limiting access and parking for motorized vehicles. Although this project will have an adverse impact on cost to visitors, it expects to provide an overall beneficial impact on visitor experience.

The Muir Woods Road Bridge Replacement Project will replace a bridge on Muir Woods Road near the monument. Access to the monument will be maintained at all times during construction, though minor traffic control delays may have an adverse impact on some visitors traveling to the monument.

The Muir Woods Road Rehabilitation Project will involve repairs and resurfacing work along parts of Muir Woods Road. While access to MWNM will be maintained during construction, visitors to the monument could experience some minor traffic control delays.

The Muir Woods Water/Wastewater Station Line Replacement will involve the rehabilitation of two lift stations in the monument. This work will have beneficial long-term impacts to visitor use and experience by improving potable water and wastewater systems in the monument. With work anticipated to begin in 2017 and be completed in 2018, this project is likely to overlap chronologically with the Proposed Action.

The Muir Woods Sustainable Access Project would involve multiple improvements to the Entry Plaza and several parking lots including the reconfiguration of parking areas, installation of a new pedestrian bridge over Redwood Creek on the Dipsea Trail, relocation of the restroom facilities in the Plaza Area and the addition of a second restroom near the former nursery area, added interpretive media along trails from parking areas, and elimination of some roadside parking. These actions will have short-term adverse impacts on visitor use and experience during construction and implementation and long-term beneficial impacts in terms of improved pedestrian safety, reduced vehicle and pedestrian conflicts, and enhanced transportation efficiency in MWNM.

Cumulative adverse impacts to visitor use and experience from these projects in combination with the action alternatives would result from delays and difficulty in reaching the monument and would be short term. Long-term beneficial impacts include improved experience during arrival and inside the monument with less noise and congestion, and safer roads and bridges along routes in and out of the monument. Any replacement of bridges that overlaps in time with any of the other projects would lead to a minor increase in adverse impacts to visitor use and experience by temporarily creating noise and eliminating trail route options. Work on the Proposed Action is likely to overlap with the Water/Wastewater Station Line Replacement; however, the lift station work will be in an area of the monument that is not heavily trafficked by visitors and is not likely to noticeably increase the amount of construction-related noise, odors, and congestion to which visitors are exposed.

Over the long term, the action alternatives would contribute to the beneficial cumulative impacts to visitor experience that are anticipated to result from the other projects planned for MWNM.

Overall Impacts

When considering the maximum amount of work that could occur under the various alternatives, construction would have moderate impacts on visitor use and experience throughout MWNM, although such impacts would be short term and would be moderated through coordinated construction scheduling, trail rerouting, and signage describing the purpose and benefits of the actions. In the long term the actions would have moderate beneficial impacts on visitor use and experience by improving ecosystem health and climate resilience, as well as wildlife habitat, meaning healthier trees and more wildlife for visitors to experience, while ensuring new bridges fit the monument's historic setting. For some alternatives (e.g., Pedestrian Bridge Replacement Alternative B), the action would offer visitor experiences that are not currently available in the monument.

4.7 Transportation

Methodology and Assumptions

The analysis of transportation impacts focused on potential impacts to:

1. Driving to and from the monument.
2. Parking at the monument.
3. Traffic passing by the monument.
4. Driving and parking in nearby areas that may be impacted by the Proposed Action.

Impacts of the No Action Alternative

Analysis

The Proposed Action involves work on creeks, bridges, and trails inside the monument. Under the No Action alternative, none of these tasks would be undertaken, though some bridges may be replaced in-kind in the future.

Conclusion

The No Action Alternative would have a minor adverse short-term impact on transportation when/if bridges are replaced in-kind during construction.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All creek restoration alternatives include revegetation of any impacted creek banks or areas of forest floor and the installation of check dams in a tributary near Bridge 3. In addition, all alternatives include at a minimum the work discussed for Creek Restoration Alternative 1 whose impacts are discussed below. While some equipment and material used during revegetation and check dam construction would be on site already, some materials would be brought in from off site, resulting in additional road traffic.

Conclusion

Since activities associated with this alternative are temporary and would involve bringing in materials from off site, the actions common to all creek restoration alternatives would have minor short-term adverse impacts on transportation and no long-term impact.

Impacts of Creek Restoration Alternative 1:

Analysis

Creek Restoration Alternative 1 involves the removal and hauling of approximately 752 CY of riprap. Material removed upstream of Bridge 2 would be hauled out via Alice Eastwood Road and Panoramic Highway (Figure 2-9). Material from downstream of Bridge 2 would be loaded at the Plaza Area and hauled to Kent Canyon, other stockpile locations, or a landfill via Muir Woods Road (Figures 2-9 and 2-11). While underway, these activities and associated worker trips would impact parking and transportation in the Plaza Area and increase traffic on Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. The construction crew may improve the dirt section of Alice Eastwood Road prior to use. Based on use of 10-CY trucks being approximately 70 percent full, Alternative 1 would result in approximately 75 haul trips during Phase 1 and 30 haul trips during Phase 2 which would occur over separate 2-month construction periods.

Conclusion

During removal and hauling activities, Creek Restoration Alternative 1 would temporarily impact parking and transportation in the Plaza Area and slightly increase traffic on Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. Slower moving trucks and construction equipment may cause minor, short-term delays for vehicles traveling on these roads. Since activities associated with this alternative are temporary, Creek Restoration Alternative 1 would have no long-term impact on transportation.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 involves the removal of approximately 105 CY of riprap and 350 LF of asphalt trail in addition to the work described in Creek Restoration Alternative 1. These materials would be hauled out via the same routes described above and would increase temporary impacts proportionally; another 15 truck trips during Phase 2 for riprap removal and 10 additional trips to handle removed asphalt during Phase 1 would result.

Conclusion

During removal and hauling activities, Creek Restoration Alternative 2 would temporarily impact parking and transportation in the Plaza Area and slightly increase traffic on Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. In comparison to Creek Restoration Alternative 1, Creek Restoration Alternative 2 involves the removal of additional riprap and asphalt and as a result these impacts would be proportionally larger, but likely result in an average of less than one additional truck trip per day. Since activities associated with this alternative are temporary, Creek Restoration Alternative 2 would have no long-term impact on transportation.

Impacts of Creek Restoration Alternative 3

Analysis

Creek Restoration Alternative 3 would involve additional off-hauling of up to 400 CY of floodplain material from near the Entry Plaza in addition to the work described in Creek Restoration Alternative 2. Some of the excavated floodplain material may be reused on site for bank contouring. This alternative would also involve importation of approximately 50 logs for use in engineered log jams near the entry plaza. This would result in approximately 50 additional haul trips compared to Creek Restoration Alternative 2 over the Phase 2 construction period. The additional heavy equipment use and travel in the Entry Plaza area would increase temporary impacts on parking and transportation in the vicinity.

Conclusion

Compared to Creek Restoration Alternative 1 or 2, which this alternative would supplement, Creek Restoration 3 would produce additional temporary impacts to transportation near the Entry Plaza and on hauling routes.

Impacts of Creek Restoration Alternative 4:

Analysis

In addition to the work described in Creek Restoration Alternative 2, Creek Restoration Alternative 4 would include removal of additional riprap and up to 555 LF of asphalt trail and importation of materials to construct up to 555 LF of the trail reroutes, resulting in approximately 10 more trips in both Phase 1 and 2. The additional heavy equipment use and haul trips would slightly increase temporary impacts on parking and transportation in the vicinity.

Conclusion

Compared to Creek Restoration Alternative 1, 2, or 3, Creek Restoration Alternative 4 would produce additional temporary impacts to transportation on hauling routes. It would involve fewer hauling trips than Alternative 3. Since activities associated with this alternative are temporary, Creek Restoration Alternative 4 would have no long-term/permanent impact on transportation.

Impacts of Creek Restoration Alternative 5:

Analysis

In addition to work described in Creek Restoration Alternative 4, this alternative includes the floodplain terracing work described in Creek Restoration Alternative 3. Creek Restoration Alternative 5 would involve roughly 100 haul trips during each construction phase. This is more than any of the other alternatives; however, at approximately 100 more trips than Creek Restoration Alternative 1, this averages just 1 to 2 additional hauling trips per day of construction.

Conclusion

Creek Restoration Alternative 5 would have short-term adverse impacts on traffic along hauling routes that would average 1 to 2 more hauling trips per day compared to Creek Restoration Alternative 1.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Bridge Alternatives:

Analysis

All bridge alternatives include replacing Bridges 1 and 4. The material from these bridges would be hauled out and transported to a landfill and materials for the new bridges would be imported. Approximately 60 truck trips are anticipated for mobilization, demobilization, in-haul, and off-haul.

Conclusion

Importing bridge construction materials and hauling old bridge material out and transporting it to a landfill would have minor, short-term, adverse impacts on traffic along Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. The actions common to all bridge alternatives would have no long-term impact on transportation.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Pedestrian Bridge Replacement Alternative A includes the removal and replacement of Bridges 2 and 3 and some nearby asphalt. This material would be hauled out and transported to a landfill and material for the new bridges would be imported. Approximately 63 truck trips are anticipated for mobilization, demobilization, in-haul, and off-haul.

Conclusion

Importing construction materials and hauling out old bridge material and transporting it to a landfill would have minor, short-term, adverse impacts on traffic along Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. Pedestrian Bridge Replacement Alternative A would have no long-term impact on transportation.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Pedestrian Bridge Replacement Alternative B is similar to Pedestrian Bridge Replacement Alternative A, but would require the removal of additional asphalt and importation of additional material for longer bridges. Approximately 67 truck trips are anticipated for mobilization, demobilization, in-haul, and off-haul.

Conclusion

Importing construction materials and hauling out old bridge material and transporting it to a landfill would have short-term, minor adverse impacts on traffic along Alice Eastwood

Road, Panoramic Highway, and Muir Woods Road. These impacts would be proportionally larger than those for Pedestrian Bridge Replacement Alternative A based on the amount of material removed. Pedestrian Bridge Replacement Alternative B would have no long-term impact on transportation.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Pedestrian Bridge Replacement Alternative C is similar to, and in terms of scale falls between, Alternatives A and B. Approximately 65 truck trips are anticipated for mobilization, demobilization, in-haul, and off-haul.

Conclusion

Importing construction materials and hauling out old bridge material and transporting it to a landfill would have short-term, minor adverse impacts on traffic along Alice Eastwood Road, Panoramic Highway, and Muir Woods Road. These impacts would be slightly larger than those for Pedestrian Bridge Replacement Alternative A and smaller than those for Pedestrian Bridge Replacement Alternative B based on the amount of material removed. Pedestrian Bridge Replacement Alternative C would have no long-term impact on transportation. Though Alternatives A, B and C vary in size, the number of hauling trips associated with each is anticipated to average less than one per construction day.

Cumulative Impacts

The Muir Woods Reservation System will decrease the number of motorized vehicles accessing and parking at the monument during peak visitation times, resulting in long-term beneficial impacts on traffic, congestion, and safety along Muir Woods Road.

The Muir Woods Road Bridge Replacement Project will have temporary adverse impacts on Muir Woods Road during construction due to lane closures, causing delays, and the presence of construction crews and long-term beneficial impacts on transportation safety when completed.

The Muir Woods Road Rehabilitation Project will have temporary moderate adverse impacts on traffic on Muir Woods Road during construction and long-term beneficial impacts on transportation safety when completed.

The Muir Woods Water/Wastewater Line Replacement may have temporary minor adverse impacts on traffic on Muir Woods Road during construction due to worker and equipment trips.

The Muir Woods Sustainable Access Project would involve multiple improvements to the Entry Plaza and several parking lots including the reconfiguration of parking areas, installation of a new pedestrian bridge over Redwood Creek on the Dipsea Trail, relocation of the restroom facilities in the Plaza Area, and elimination of some roadside parking. These actions will have temporary adverse impacts on transportation during implementation and beneficial long-term impacts from improved operational efficiency, and reduced conflicts between vehicles and pedestrians.

The action alternatives would involve replacement of bridges which could result in additional cumulative impacts to transportation from delivery or off-hauling of bridge if it were to occur at the same time as one of the projects discussed above. In combination with the action alternatives, these projects would have temporary adverse impacts to transportation at MWNM. This would particularly be the case if project construction overlaps. Combined, the projects would have long-term beneficial impacts on transportation. Work on the Proposed Action is likely to overlap with the Water/Wastewater Station Line Replacement which would increase the scale of construction-related impacts on traffic and parking. Additional adverse impacts to traffic and congestion on Muir Woods Road would result if storage and landfill hauling trips overlap with the Bridge Replacement or Road Rehabilitation projects.

Overall Impacts

Completing all of the actions described in the alternatives would result in as much as approximately 290 construction-related offsite hauling trips which would be phased over multiple years and construction periods. Construction activity, worker trips, and hauling trips associated with this work would have adverse, short-term impacts on transportation in, around, and to the monument. Once complete, this work would not have any long-term impacts on transportation.

4.8 Wildlife Habitat

Methodology and Assumptions

Discussion of habitat for salmonids, northern spotted owl, and marbled murrelet is covered in Section 4.4, *Threatened and Endangered Species*. Impacts on other wildlife habitat are considered below.

No Action Alternative

Analysis

Under the No Action Alternative, stream habitat conditions would not be altered. As aquatic invertebrate abundance and family diversity are significantly lower in riprapped portions of Redwood Creek (Kimball 2002), these metrics would remain low. In-kind replacement of pedestrian bridges would result in construction-related noise impacts to habitat used by birds and other wildlife.

Conclusion

Under the No Action Alternative, impacts on aquatic wildlife habitat would remain adverse and long term. Bridge replacement would result in short-term construction-related adverse impacts on wildlife habitat.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

The presence of construction equipment and crews would result in noise impacts to habitat used by birds and other wildlife. Implementation of BMPs BIO-8 and -9 would reduce these potential impacts through surveys for nesting birds and woodrat houses and implementation of avoidance and minimization measures. Installation of grade control could result in temporary impacts to habitat used by California giant salamander and other amphibians. However, installation of grade control would have long-term minor beneficial effects on California giant salamander and other amphibians due to a higher water table in the treatment area. Revegetation of disturbed areas would have long-term beneficial impacts on wildlife habitat.

Conclusion

Implementation of these actions would result in temporary minor adverse noise and construction impacts to wildlife habitat, but would also result in long-term beneficial impacts to wildlife habitat.

Impacts of Creek Restoration Alternative 1:

Analysis

Removal of riprap would result in temporary adverse impacts to aquatic habitat in Redwood Creek due to dewatering. It would result in long-term beneficial impacts to aquatic habitat due to an increased instream channel sinuosity, expanded cover by streamside vegetation, and a greater allochthonous input of organic matter. The addition of LWD to the channel would result in long-term beneficial impacts to aquatic habitat by increasing cover and complexity. Removal of riprap and installation of LWD is not anticipated to impact wetland habitat. The presence of construction equipment and crews would result in noise impacts to habitat used by birds and other wildlife. Movement of equipment and logs would result in temporary disturbances to the forest floor, which could temporarily adversely impact movement of wildlife. Amphibians may be present underneath the downed logs which would be used for LWD and under downed material along skid/drag routes. Implementation of BMP-6 would reduce potential impacts on amphibians by searching for and relocating amphibians beneath downed wood disturbed by the proposed actions where feasible.

Conclusion

Implementation of Creek Restoration Alternative 1 would result in both temporary minor adverse noise and construction impacts to wildlife habitat, but would also result in long-term beneficial impacts to wildlife habitat.

Impacts of Creek Restoration Alternative 2:

Analysis

Removal of the additional riprap segments would increase the impacts (both adverse and beneficial) on wildlife habitat as described for Creek Restoration Alternative 1. Removal of the trail segment at Cathedral Grove would increase the amount of forest floor available as wildlife habitat.

Conclusion

Implementation of Creek Restoration Alternative 2 would result in both temporary minor adverse noise and construction impacts to wildlife habitat, but would also result in long-term beneficial impacts to wildlife habitat. The impacts would be proportionally greater compared to the impacts of Creek Restoration Alternative 1.

Impacts of Creek Restoration Alternative 3:

Analysis

Under Creek Restoration Alternatives 3, terracing of the right bank in the Entry Plaza area and installation of engineered log jams, would increase the impacts (both adverse and beneficial) on wildlife habitat as described for Creek Restoration Alternative 2. Increased floodplain habitat under this alternative would result in additional short-term construction impacts and additional long-term beneficial impacts on aquatic invertebrate habitat within Redwood Creek.

Conclusion

Implementation of Creek Restoration Alternative 2 would result in both temporary minor adverse noise and construction impacts to wildlife habitat, but would also result in long-term beneficial impacts to wildlife habitat. The impacts would be proportionally greater compared to the impacts of Creek Restoration Alternative 3.

Impacts of Creek Restoration Alternative 4:

Analysis

Under Creek Restoration Alternative 4, removal of the additional riprap segments would have similar but proportionally greater impacts on wildlife habitat as described for Creek Restoration Alternative 2. Construction of the alcove would result in increased aquatic habitat. Trail rerouting could have potential impacts on bat maternity colonies. Heady and Frick (2004) found that bat maternity colonies in tree hollows were not disturbed by humans as long as the entrance to the hollow faces away from the trail. Per BMP BIO-9, bat surveys will be conducted in subsequent phases of trail planning and the trail alignment would be adjusted as needed to be protective of bat maternity colonies.

Conclusion

Implementation of Creek Restoration Alternative 4 would result in temporary minor adverse noise and construction impacts to wildlife habitat, but would also result in additional long-term beneficial impacts to wildlife habitat compared to Creek Restoration Alternative 2.

Impacts of Creek Restoration Alternative 5:

Analysis

Under Creek Restoration Alternatives 5, impacts to wildlife habitat would be similar to Alternative 4 but with terracing of the right bank in the Entry Plaza area. These actions would proportionally increase impacts (both adverse and beneficial) on wildlife habitat. Increased floodplain habitat under this alternative would result in additional short-term construction impacts and additional long-term beneficial impacts on aquatic invertebrate habitat within Redwood Creek.

Pedestrian Bridge Replacement Alternatives

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

The presence of construction equipment and crews would result in noise impacts to habitat used by birds and other wildlife. Rerouting of the trail for Bridge 3 would result in minor long-term impacts to forest floor habitat, which would be offset by restoration where the existing trail would be removed.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative A would result in short-term adverse impacts on wildlife habitat and minor long-term beneficial impacts on wildlife habitat.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Impacts under Pedestrian Bridge Replacement Alternative B would be similar to those described for Pedestrian Bridge Replacement Alternative A. However, this alternative would result in increased disturbance because of the increased area of trail rerouting required.

Conclusion

Implementation of Bridge Alternative B would result in minor short-term adverse impacts on wildlife habitat and minor long-term beneficial impacts on wildlife habitat.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Impacts under Pedestrian Bridge Replacement Alternative C would be intermediate to those described for Pedestrian Bridge Replacement Alternatives A and B.

Conclusion

Implementation of Bridge Alternative C would result in minor short-term adverse impacts on wildlife habitat and minor long-term beneficial impacts on wildlife habitat.

Cumulative Impacts

Combined with past and future planned actions in the vicinity, temporary impacts to wildlife habitat through noise and presence of construction crews could occur. Over the long term, the majority of these projects would improve wildlife habitat in the vicinity of MWMN.

Overall Impacts

The combined effects of the implementation of the various actions would be similar to the impacts of each alternative, but with a difference in scale. Collectively, implementation of the Proposed Action would result in increased noise and presence of construction crews, resulting in short-term adverse impacts on wildlife habitat. Improvements to wildlife habitat would also occur, with improved aquatic habitat and greater proportion of boardwalk trails, resulting in greater long-term beneficial impacts to wildlife habitat.

4.9 Water Resources and Hydrologic Processes

This analysis considers the impacts of each alternative on water resources, including water quantity, water quality, and groundwater. This section also focuses on hydrologic and geomorphic (i.e. hydro-geomorphic) impacts within the channels such as effects on creek function; instream features; flooding; sediment erosion, transport and deposition; and changes to bed morphology within the active stream channel. Discussion of soils at the top of the streambanks outside of the active channel are discussed in greater detail above in Section 4.5, *Geology: Soils and Bedrock*. Activities that may result in impacts to water resources and hydro-geomorphic processes include riprap removal along Redwood Creek, placement of large woody debris or instream grade control in a tributary, bridge installation, and rehabilitation or revegetation of disturbed areas. Actions which may limit sedimentation and turbidity impacts to water resources include the bank treatments/revegetation on new banks where tree roots do not offer adequate bank stability. Impacts were assessed by examining literature on hydrologic and geomorphic processes, and existing studies and mapping for the Action Area.

No Action Alternative

Analysis

Under the No Action Alternative, visitor usage and the existing trail system and facilities would continue under existing conditions. Asphalt trails located on the historic floodplain near Redwood Creek would not be relocated or removed, thereby continuing to contribute water and sediment to the creek during rain events. Bridges 1, 2, 3, and 4 would be left "as is" or replaced in kind and continue to create hydrologic constrictions and disturbances during high flow events. Existing riprap lining portions of Redwood Creek would likely persist for a significant time period and continue to adversely impact hydrologic and geomorphic processes and floodplain function, including long stretches of channelization/planar bed features, a general inability to trap and store sediment, and little opportunity for the development of undercut banks or side channels that would add system complexity. Therefore, the No Action Alternative would result in direct and indirect, long-term, adverse impacts on surface water, water quality, floodplains, and hydro-geomorphic processes as a result of instream disturbances at bridge crossings, and hardened banks that prevent more natural geomorphic function. The riprap would maintain a sediment production level within MWNM that is below the normal rate observed in the channel downstream of MWNM. Existing management actions do not pollute groundwater resources or significantly impede groundwater recharge; therefore, there would be no impacts on this resources.

Conclusion

Implementation of the No Action Alternative would not substantially alter water resources or hydro-geomorphic processes in the action area from existing conditions. However, existing facilities, e.g., bridges and riprap, significantly restrict natural hydrologic functions and result in points of hydraulic constriction during high flow periods. The presence of existing facilities result in long-term, direct and indirect, adverse impacts to hydrologic functions of Redwood Creek throughout the action area.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

Under all Creek Restoration Alternatives, disturbed areas and exposed soils would be stabilized through the revegetation of creek banks and areas of the forest floor impacted during implementation of the Proposed Action. Specific actions to stabilize banks and control erosion are described within each alternative. Revegetation of exposed areas near the creek channel would help stabilize banks and improve the water quality of Redwood Creek during high flow events by reducing turbidity and sediment loads. Impacts from these actions would be long-term, indirect, and beneficial.

Proposed work areas typically have at least a full channel width between the existing bank and an existing trail. This buffer allows for significant erosion to occur before threatening trail integrity. However, if erosion appeared to be extending toward a trail system that is designated as part of the long-term plan, NPS would likely take preventive action to increase bank stability or slow erosion so as to prevent loss of the trail.

In additional, all Creek Restoration Alternatives include the installation of broken pieces of riprap removed during other actions into a series of grade control extending over approximately 150 LF of a small incised tributary on the east side of the creek just downstream of Bridge 3. Slash from fallen wood will be added between the grade controls. This would be considered fill in waters of the U.S. The purpose of the grade control is to potentially raise sub-streambed groundwater elevations on a very localized scale, which may help protect instream flows. The grade controls and slash may also capture sediment behind them and help impede the incision which has occurred in this small tributary. This would result in a long-term, direct and indirect, beneficial impact by reducing sediment loads entering the mainstem of Redwood Creek from this source.

Construction activities necessitate vegetation removal in some areas for channel access and for exposure and removal of the existing riprap. Required equipment and methods vary depending on the location and extent of the construction activities. However, workers and equipment would utilize existing trails and access points to the greatest extent feasible. BMPs would also be implemented to further avoid and minimize potential impacts to water resources. In addition, existing dirt trails segments (i.e., Alice Eastwood Road) showing gullying and structural instabilities will be repaired by the construction crew prior to and/or after use and be considered an indirect beneficial impact.

Conclusion

Planting and revegetation activities have the potential to improve water quality over the long-term by decreasing sheet and rill erosion. Installation of check dams on the adjoining small tributary would result in a long-term, direct and indirect, beneficial impact by reducing sediment loads entering the mainstem of Redwood Creek from this source and slowing continuing downcutting of the drainage. Vegetation removal during construction periods would be short-term, direct, and adverse. Repair of the existing Alice Eastwood Road (dirt road) would be moderately beneficial by reducing erosion and sedimentation into surface waters. Any short-term, direct and indirect, adverse construction-related impacts to water resources or water quality would be avoided and minimized through implementation of applicable BMPs.

The impacts of actions common to all Creek Restoration Alternatives would be long-term, indirect, and beneficial through the restoration and revegetation of disturbed or barren areas and stabilization of an incised tributary.

Impacts of Creek Restoration Alternative 1:

Analysis

Actions associated with Creek Restoration Alternative 1 include installing LWD into the channel and removing approximately 1,123 LF of riprap from the banks of Redwood Creek. To reduce potential erosion after riprap removal, about 58% of banks will be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have adequate mature root structures and will likely be effective at resisting high rates of erosion, while still providing beneficial stream features. Removing instream riprap would expose the channel banks to more natural geomorphic processes and allow for active channel movement and lateral migration. Following removal of bank armoring and with treatment of those banks that do not have obvious root structures, near-term bank erosion is anticipated to be maintained within no more than 2 to 5 times the natural erosion rate observed downstream (Stillwater Sciences 2004, NHE 2017). With a natural bank erosion rate at about 0.015 $m^3m^{-1}a^{-1}$, an increase of two to five times of the natural rate represents an overall increase in downstream areas of Redwood Creek of about 1 to 4% additional sediment, which will be virtually undetectable. The existing condition in MWNM currently produces below normal sediment due to hardened banks (SWS 2004). There may be a short term increase as processes return to a more natural condition, after which production is expected to be about that of the natural erosion rates downstream.

Several potential erosion processes may occur including: shearing flows initiating toe of bank erosion and promoting outer bend erosion; bank failure caused by flows directly hitting the bank, often caused by deflection from woody debris; bank failure caused by focused eddying and scour related to flow separation downstream of a channel obstruction such as LWD; and mass wasting of banks typically caused by rotational and block slumping following periods of elevated streamflow and bank saturation then followed by flow recession and high bank soil pore water pressure (Stillwater Sciences 2004). However, in general, old growth forests, including MWNM, typically exhibit relatively low channel migration rates occurring over the scope of hundreds of years, except where flows are deflected in the vicinity of wood jams (ESA 2014; NHE 2016a). Additionally, these erosional processes are anticipated to the substantially reduced by implementation of the bank recontouring and erosion control measures described above. Under Creek Restoration Alternative 1, initial overbank flooding would not be expected to occur substantially more frequently than under existing conditions.

Following riprap removal, the above-mentioned hydro-geomorphic processes may begin to occur during significant streamflow events. With the bank treatments, it is expected that by the time the erosion control fabric has decayed, new bank vegetation will be well established to provide stability to banks. Erosional rates would vary based on localized physical elements of the channel, bed and bank material, hydrodynamic characteristics, and the presence of bedrock, LWD, or established vegetation. In areas where trees or woody shrubs were present, erosional processes would be slowed or redirected in response to developed root systems which increase bank sheer strength. Over time, increased bank erosion would generally lead to a wider cross sectional channel area. The enlarged channel width and area would increase channel capacity and enable larger stream flows to be contained in the channel. Increased channel width and channel area would also result in lower flow depth and lower flow velocity for equal-sized discharge events, compared to the pre-project condition. At some point, the increased channel cross-sectional area and relatively lower velocities would in turn result in less erosive conditions along the streambanks and some degree of instream sedimentation as the creek channel adjusts its morphology toward a new dynamic equilibrium form. Restoration of a more natural creek channel condition is one of the goals of the project.

The precise duration of this period of channel adjustment, initiating with moderately increased erosion following riprap removal and continuing through the cycle of channel widening, declining flow velocity and instream deposition is uncertain but would likely operate on the scale of decades. Such a landform adjustment cycle is dependent on many factors including the physical conditions of the channel, woody debris supply to the creek, rainfall and water balance conditions and notably seasonal precipitation amounts and specific event based rainfall amounts and intensities, land use, vegetation and fire conditions in the watershed, etc.

Building on the process described above related to removal of the existing riprap, the Proposed Action's constructed LWD structures may further enhance or amplify these geomorphic processes by creating large debris jams that may potentially redirect flows towards streambanks or create scour pools through flow eddies. LWD is also anticipated to trap sediment upstream, reducing the downstream effects of sediment. A positive feedback process may occur whereby increased channel lateral movement and erosion in turn leads to more trees falling into the channel, further causing instream blockages and pool scouring. Slack water areas and deeper pools immediately upstream and downstream of these LWD structures also provide opportunities for sediment deposition and storage in the channel. Similar to what is described above, related to channel widening and migration as a result of riprap removal, a new dynamic equilibrium will be achieved that will then slow the channel widening and erosion process caused by increased woody debris in the channel. This is the basic cycle of how streams adjust to their changing environment.

Assessing the magnitude of the expected erosion to occur following removal of the riprap is complex and difficult, owing to the stochastic nature of these types of natural processes. There would be much spatial and temporal variability in the erosive response at different riprap removal locations. Some erosion might occur gradually with moderately sized flows, other locations may erode more substantially as pulsed or episodic events during or after large storms. As described above, over the course of years and decades following the construction of the Proposed Action, it is expected that streambank erosion rates in the project reach will be initially elevated for several years when compared to current conditions, and then gradually decline until the new equilibrium is achieved.

NHE (2017) conducted an assessment estimating the potential increase in sedimentation following riprap removal based on existing studies (i.e., Stillwater Sciences 2004; NHE 2014 and 2016b) and field observations. To determine sedimentation increases following riprap removal, the effects of bank erosion rates on the Redwood Creek sediment budget (as estimated in Stillwater Sciences 2004) were separated and assessed individually following two phases of construction, with Phase 1 removing a maximum of 1,053 LF (321 meters) and Phase 2 a maximum of 748 LF (228 meters) of riprap. The two Phases were analyzed independently of each other. NHE (2017) estimated an increased erosion rate for a period of approximately 2 to 5 years then, as bank vegetation became more established, a taper off to the estimated natural erosion rate for the Redwood Creek watershed (0.015 $m^3m^{-1}a^{-1}$ as cited by Stillwater 2004). The increased sedimentation of bank erosion in the Action Area under natural bank conditions from Phase 1 was estimated at 8.2 tonnes per acre (ta^{-1}) and 5.8 ta^{-1} following Phase 2. The initial change in sediment production in the lower watershed would be between about 1 to 4% higher than under current conditions, but that increase is expected to taper off to about a 1% increase as the project area returns to natural erosion rate (0.015 $m^3m^{-1}a^{-1}$ as cited in Stillwater Sciences 2004) and shown in Figures 4-1 and 4-2.

In addition to considering the duration and magnitude of the potential erosion impact, another key consideration is the fate of the eroded material. Some of the eroded material would be captured in the Action Area and stored in pools and depositional features of the created woody debris features. The remainder of the eroded material will be transported to downstream reaches of Redwood Creek. Material will settle and deposit according to its texture (grain size) compared to the flow energy available to maintain the material in suspension. The transport and deposition of eroded channel material downstream caused by the removal or riprap, placement of woody debris structures, and near-term bank treatments, including an increase in turbidity downstream, is considered a short-term and long-term moderate impact of the Proposed Action, given the slight increase of about 1-4% in the near term and a likely return to less than an additional 1% in sediment production over the long-term. The scale of this impact would likely diminish over time as the creek banks can respond naturally via lateral migration, the channels widens, and the system achieves its new dynamic equilibrium. Once establishing its new equilibrium, any turbidity generated in the Action Area would be considered natural and not an anthropogenic source of sediment. However, this process of increased sediment loading to Redwood Creek and return to equilibrium would likely occur over an extended time frame during which transported sediment levels downstream of MWNM could remain at an elevated level of up to an additional 2% compared to existing conditions. This restoration of natural processes is considered to be an overall beneficial impact on water resources.

Project actions would result in fill and removal of fill within waters of the U.S., a regulated activity. The addition of LWD would be approximately 2,185 square feet of fill in waters of the U.S. Riprap removal would be considered fill removal of approximately 2,810 square feet within waters of the U.S.

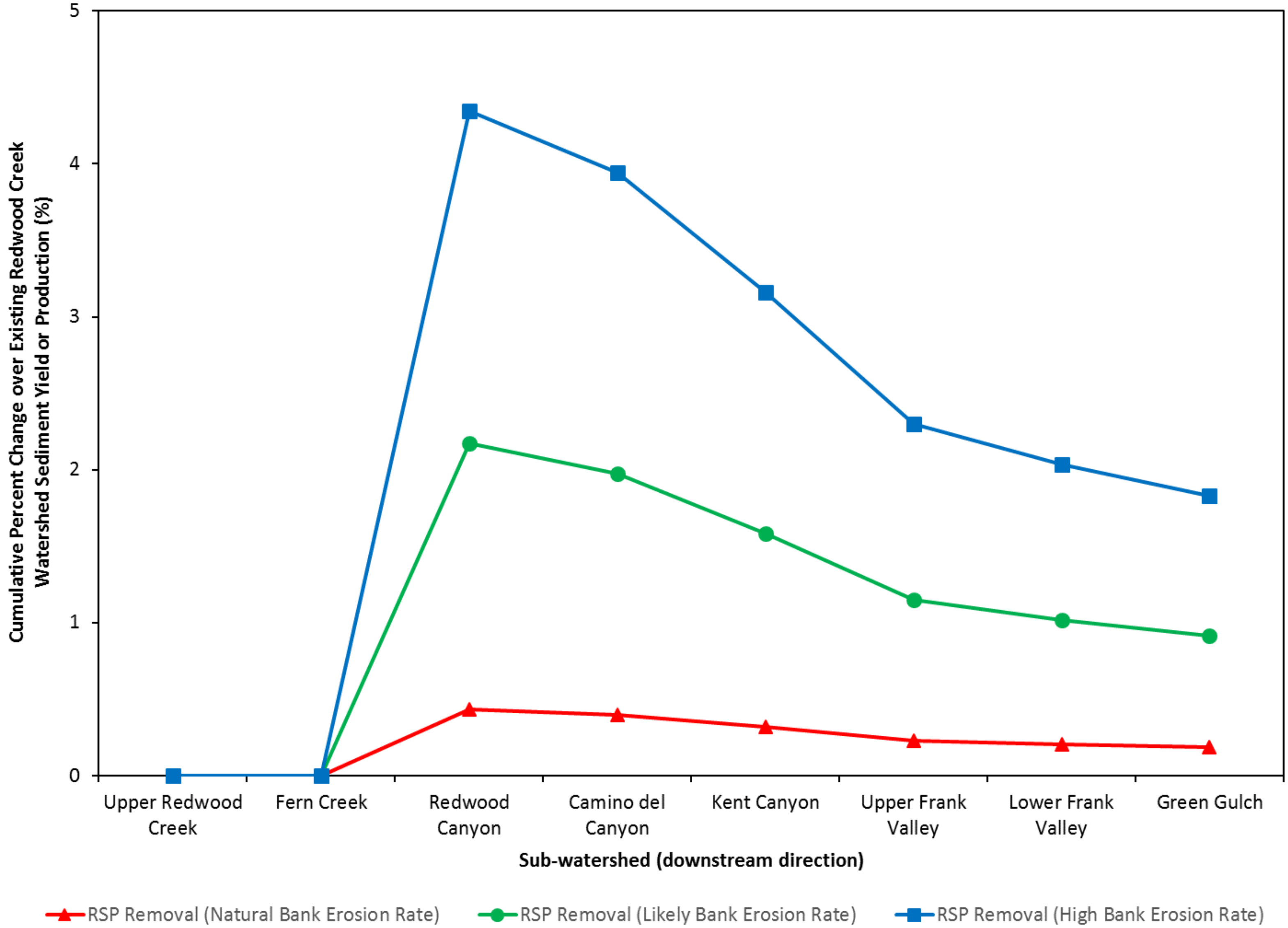

Figure 4-1. Percent change over the existing Redwood Creek watershed sediment budget (SWS, 2004) from natural, likely and high bank erosion rates from rock slope protection removal for Phase 1 of Creek Restoration Actions (figure source, NHE 2017).

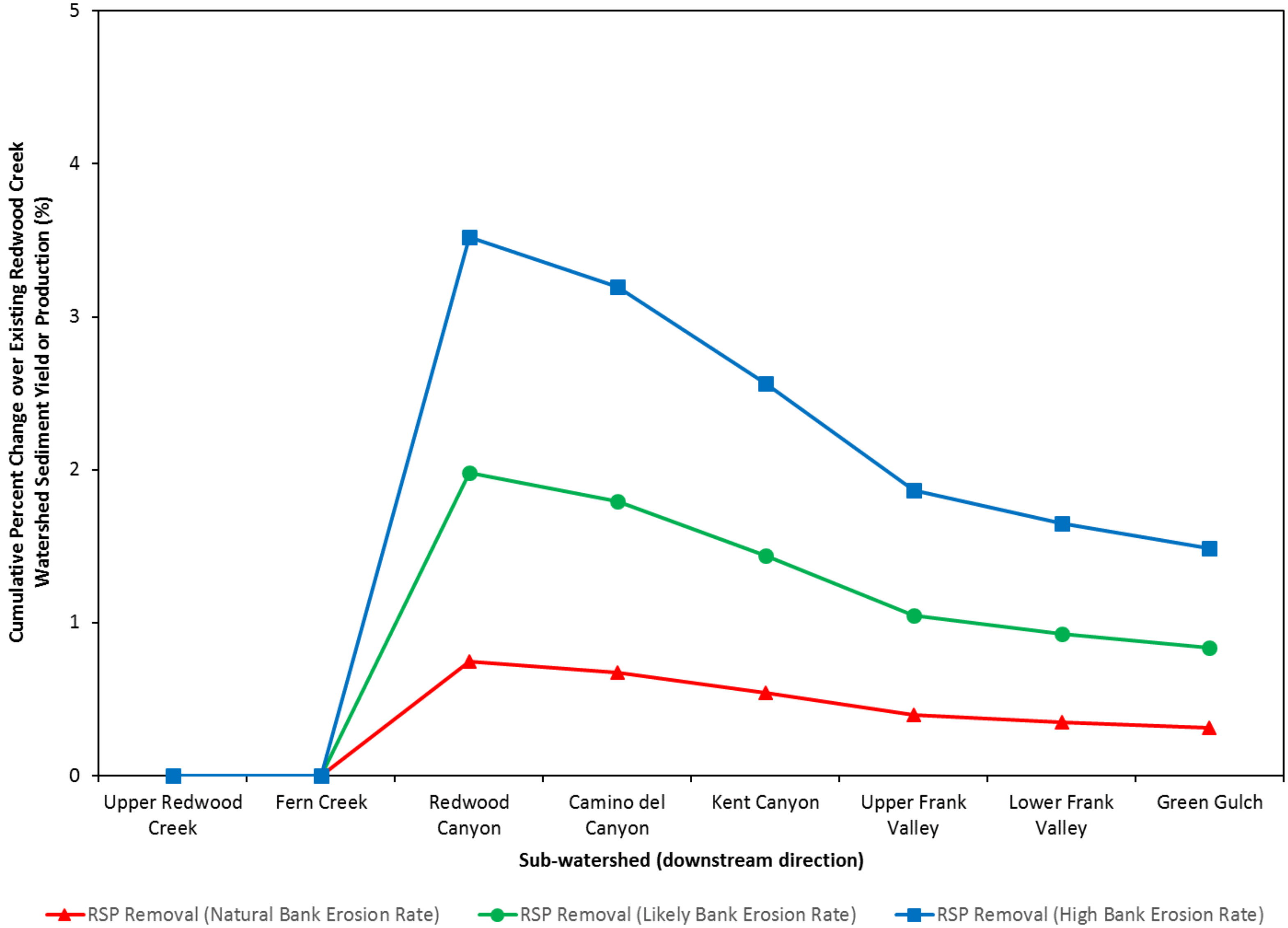

Figure 4-2. Percent change over the existing Redwood Creek watershed sediment budget (SWS, 2004) from natural, likely and high bank erosion rates from rock slope protection removal for Phase 2 of Creek Restoration Actions (figure source, NHE 2017).

Conclusion

Construction of this alternative would have the potential for short-term minor adverse effects on water quality due to ground disturbance and related erosion, as well as potential for accidental releases of fuels or other construction-related hazardous materials. These effects would be reduced through implementation of BMPs, including erosion control measures and measures to reduce the potential for an accidental spill from construction equipment.

Over the long term, the restoration of more natural geomorphic processes through riprap removal, LWD removal, and other restoration actions would represent a substantial short-term and long-term beneficial effect within the action area, as the channel would migrate, generate pools, trap sediment, develop undercut banks, and exhibit other features commonly found in natural channels.

The anticipated erosion effects of Creek Restoration Alternative 1 would represent a minor, short and long-term adverse impact on water quality, and would have a minor effect on Redwood Creek downstream of the Proposed Action. Impacts would be reduced by bank treatments after implementation to maintain sedimentation rates in the project area at no more than 2 to 5% above normal rates downstream in the near term, with long-term rates expected to return to normal rates observed downstream. The project area currently has below normal erosion rates due to the presence of riprap. As conditions normalize after implementation, even the short term increase in sediment would represent, at the worst level in the short term, an estimated 4% increase downstream over current elevations, which is most likely not even enough to be measurable. Over time, the expected increase in sediment downstream reaches is expected to be increased by about 1% (NHE, 2017). Therefore the project is not anticipated to result in downstream smothering of spawning areas, filling of instream pools or other adverse effects on instream habitat and water quality (e.g., turbidity). Detailed long-term observation of spawning habitat within Redwood Creek has not shown burial of spawning gravel from other sediment sources (such as eroding banks) (Mike Reichmuth, NPS, personal observation, Feb. 1, 2017).

In addition to the control of sediment due to bank treatments, impacts would be minimized by staging implementation of the restoration activities into two construction Phases; excavation of pools to reduce flow velocity and encourage deposition; revegetation of banks where riprap has been removed; and/or other appropriate measures to control downstream sediment migration. Impacts to other water quality parameters (e.g., temperature, contaminants, trace metals, nutrients, etc.) would likely be negligible over the long term and would remain comparable to existing levels.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 would include all of the actions described in Creek Restoration Alternative 1 as well as an additional 338 LF of riprap removal from the Plaza area and Cathedral Grove. Under this alternative, the same amount of LWD fill in waters of the U.S. would occur as under Creek Restoration Alternative 1. Additional riprap removal would add fill removal of approximately 840 square feet within waters of the U.S. compared to Creek Restoration Alternative 1. To reduce potential erosion after riprap removal, banks will be treated based on conditions at each specific location. Approximately 45% of banks are expected to be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have substantial mature root structures behind existing riprap, and since the roots can be very effective at resisting erosion, added treatments are not expected to be needed in those locations. Most actions would be conducted as part of Phase 1 activities (mostly upstream of Bridge 3), and about 60% of the Phase 1 riprap removal areas would have such bank erosion control, while the rest appear to have adequate root structure.

In addition to the removal of riprap, approximately 350 LF of asphalt trail on the top of the left bank at Cathedral Grove would be removed and revegetated. As discussed above for impacts of actions common to all Creek Restoration Alternatives, removal and revegetation of impervious or compacted surfaces would increase infiltration rates and reduce the runoff and surface erosion potential of these areas. Impacts of removing this segment of impervious asphalt are beneficial, long-term, and indirect.

Conclusion

In addition to the impacts of Creek Restoration Alternative 1, Creek Restoration Alternative 2 would have slightly larger, but still minor adverse short-term and long-term permanent impacts due to a greater anticipated erosion of upper streambank areas and increased mobilized sediment and turbidity following the removal of riprap. The removal of asphalt along the trail and replacement with soil and vegetation planting represents a short-term and long-term benefit in those areas affected.

Impacts of Creek Restoration Alternative 3:

Analysis

Creek Restoration Alternative 3 consists of all of the actions and impacts of Creek Restoration Alternative 2, as well as installation of three engineered log jams and terracing of the right bank at near the entry plaza. The right bank downstream of Bridge 1 would be terraced to connect the channel to the historic floodplain (Figure 2-3). This action would help increase the area of inundation along the channel margin under smaller flows and likely reduce the volume of bank material mobilized and transported downstream during high flow events. Creek Restoration Alternative 3 may likely shorten the duration required for this reach to achieve its geomorphic equilibrium.

Under this alternative, LWD fill in waters of the U.S. would increase approximately 380 square feet compared to Creek Restoration Alternative 2. The same amount of riprap fill removal in waters of the U.S. would occur as under Creek Restoration Alternative 2.

Implementation of Creek Restoration Alternative 3 would require site grubbing, grading, and off-haul of a significant volume of bank and floodplain material. During site excavation, soils would be exposed and subject to increased erosion. Graded and disturbed areas would be revegetated. These impacts would be considered short-term, direct and indirect, and adverse. Potential impacts to water quality would be avoided and minimized through the adherence to permit requirements (e.g., SWPPP, prepared by qualified personnel).

Conclusion

Compared to Creek Restoration Alternative 2, Creek Restoration Alternative 3 would have greater beneficial and adverse short-term and long-term permanent impacts to geomorphology and water quality, due to the additional restoration actions and a somewhat larger, but still minor volume of anticipated erosion and sediment loading into Redwood Creek following the removal of riprap. In addition, Creek Restoration Alternative 3 manually removes instream material that would be subjected to erosion and mobilization and would regrade the right bank to a more gradual angle. These actions would reduce the volume of erodible material and lower the rate of erosion in this reach, as compared to Creek Restoration Alternative 2.

Impacts of Creek Restoration Alternative 4:

Analysis

Creek Restoration Alternative 4 consists of all actions under Creek Restoration Alternative 2, plus removal of an additional 270 LF of riprap, excavation of an alcove and installation of a LWD structure in the Bridge 1.5 area. Similar to Creek Restoration Alternative 2, the removal of riprap and installation of LWD would allow for increased bank erosion, the undercutting of the banks, and a resulting increase in creek turbidity and downstream sedimentation. These actions would be an adverse short-term and long-term impacts on water quality. To reduce potential erosion after riprap removal, banks will be treated based on conditions at each specific location. About 45% of banks are expected to be regraded to a 1V:1:5H slope, covered with erosion control fabric, and aggressively replanted. Other banks already have substantial mature root structures behind existing riprap, and since the roots can be very effective at resisting erosion, added treatments are not expected to be needed in those locations. Most actions (73% of all riprap removal proposed in this alternative) would be conducted as part of Phase 1 activities (mostly upstream of Bridge 3), and about 60% of the Phase 1 riprap removal areas would have such bank erosion control, while the rest appear to have adequate existing root structure.

Creek Restoration Alternative 4 would also relocate two asphalt trail segments (up to a total of 555 LF) farther from the channel and would replace them with flexible paving. A small footbridge (Bridge 1.5) would also be removed. The former trail alignment would be decompacted, restored and replanted. The relocation of the trail segments would have a long-term, moderately beneficial impact to water quality by reducing the impervious surface area near the channel and improving infiltration and water quality conditions. Under Creek Restoration Alternative 4, a drainage area at Bridge 1.5 would also be enhanced as an alcove. This alcove would provide an off-channel, lower energy environment that would capture and store deposited sediment. Impacts with creation of the alcove would be considered a long-term, moderately beneficial impact to water quality.

Under this alternative, LWD fill in waters of the U.S. would increase approximately 70 square feet compared to Creek Restoration Alternative 3. Riprap fill removal in waters of the U.S. would increase approximately 680 square feet compared to Creek Restoration Alternative 3. Trail rerouting near Bridge 1.5 would result in fill of approximately 55 square feet of a tributary to Redwood Creek, but would also result in removal of a trail segment impacting approximately the same area of waters. Creation of the alcove would result in approximately 60 square feet of dredging within waters of the U.S.

Conclusion

The additional impacts of this alternative, both adverse and beneficial, would be similar to those of Creek Restoration Alternative 2; taken on their own, they would be proportionately smaller due to the more limited extent of activity that would be conducted under this alternative. However, because Creek Restoration Alternative 4 would include the actions of Creek Restoration Alternative 1, the overall effects (both adverse and beneficial) would be greater. Additionally, the creation of the alcove would be considered a long-term, moderately beneficial impact to water quality.

Impacts of Creek Restoration Alternative 5:

Analysis

Creek Restoration Alternative 5 consists of all of the actions and impacts of Creek Restoration Alternative 4 along with the right bank terracing described in Creek Restoration Alternative 3. Under this alternative, LWD fill and riprap fill removal in waters of the U.S. would be the same as in Creek Restoration Alternative 4.

Conclusion

In addition to the impacts of Creek Restoration Alternative 4, terracing of the right bank between the channel and the floodplain would significantly reduce the volume of mobilized sediment and the adverse short-term and long-term permanent impacts to geomorphic and water quality resources would be significantly less under Creek Restoration Alternative 5 as compared to Creek Restoration Alternative 4.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives:

Analysis

All Pedestrian Bridge Replacement Alternatives would involve the replacement of the existing bridges with a clear span design with new abutments farther from the creek. The existing bridge abutments would be removed and relocated farther from the creek channel. Excavation activities to remove the old bridges and construct the new bridge and abutments would cause localized, short-term, direct, and adverse impacts on water quality during bridge construction. Applicable BMPs, listed in Section 2.7, would avoid and minimize potential adverse impacts by reducing areas of disturbance and erosion and limiting potential runoff and contamination to surface and ground water.

Under all Pedestrian Bridge Replacement Alternatives, Bridges 1 and 4 would be designed to accommodate a 100-year peak-flood flow event with an additional 18 inches of freeboard and require minor increases to bridge span compared to the existing design (Figure 2-6). Bridge 2 and Bridge 3 may be designed for different size storm event(s), as shown in Table 4-1 below. Currently, Bridge 2 and 3 have the least flood capacity of the four bridges, and are only able to effectively pass the 2-yr peak-flood flow (NHE 2016b). Bridge 1 can effectively pass the 25-year peak-flood flow but is subject to being flooded or submerged during a 50-year or 100-year events (NHE 2016b). Bridge 4 can pass the 2-year, 25-year, and 50-year events but does not pass the 100-year peak-flow event (NHE 2016b).

Table 4-1. Flow Capacity for Bridges 1 through 4 under existing, Pedestrian Bridge Replacement Alternative A, Pedestrian Bridge Replacement Alternative B, and Pedestrian Bridge Replacement Alternative C

	Effective Capacity – Existing (peak-flood flow)	Design Capacity – Pedestrian Bridge Replacement Alternative A (peak-flood flow)	Design Capacity – Pedestrian Bridge Replacement Alternative B (peak-flood flow)	Design Capacity – Pedestrian Bridge Replacement Alternative C (peak-flood flow)
Bridge 1	25-year	100-year	100-year	100-year
Bridge 2	2-year	25-year	100-year	25-year
Bridge 3	2-year	25-year	100-year	100-year
Bridge 4	50-year	100-year	100-year	100-year

Source: NHE 2016b

The pedestrian approaches to Bridges 1 and 4 would be designed to connect the existing network of trails with the new bridges. There would be no increase in trail length for these bridges. The removal of the existing bridges would remove fill from Redwood Creek, a water of the U.S. The construction of the new bridges would result in fill in waters of the U.S. that would be similar in size to the fill removed for the existing bridges.

Conclusion

Excavation and construction of new bridge abutments would have relatively minor, adverse, short-term impacts on surface waters and water quality during construction; however, most impacts would be avoided or minimized through the implementation of applicable BMPs. Overall, replacement of the bridges would be long-term, direct and indirectly beneficial to water quality and hydrologic resources by allowing larger flows to pass unimpeded under creek crossings. Enlarging the cross-sectional area under the bridges removes potential choke points that can result in scouring and an increase in turbidity.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Under Pedestrian Bridge Replacement Alternative A, spans for Bridges 2 and 3 would be lengthened and designed to pass a 25-year peak-flood flow event with 15- and 12-inch freeboard at the peak of the arch, respectively (Figure 2-7). For Bridge 2, 120 LF of new boardwalk would be installed on the east side of creek and 20 LF of new boardwalk on the west side of the creek, and a small approximately 20- by 20-foot boardwalk gathering area would be built on the east side of the creek. The existing gathering area and asphalt trail alignment at Bridge 2 would be restored. For Bridge 3, approximately 130 LF of existing asphalt trail leading to the east side of the crossing would be relocated and replaced with approximately 120 LF of flexible paving. The approaches to the bridge would require approximately 30 LF of boardwalk on the east side of the creek and approximately 35 LF of boardwalk on the west side of the creek. The previous trail alignments on the east side of the creek would be decompacted, and the area revegetated. The removal of the existing bridge abutments would remove fill from Redwood Creek, a water of the U.S. Although ground disturbance and construction of the realigned trails would be considered a short-term, direct, adverse impact, any potential impacts to water quality would be offset through the restoration and revegetation of removed trail segments.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative A would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts would be long-term, direct and indirect, and beneficial by allowing larger flows to pass unimpeded thereby reducing scour and lowering water turbidity. Installation of 205 LF (approximately) of boardwalk would replace hardscape (asphalt) trail and be considered a short- and long-term beneficial impact by reducing runoff rates and turbidity of surface waters. Some short-term, direct and indirect, adverse impacts are associated with construction activities; however, most impacts would be avoided or minimized through the implementation of applicable BMPs.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Under Pedestrian Bridge Replacement Alternative B, the spans for Bridges 2 and 3 would be lengthened and designed to pass a 100-year peak-flood flow event with 14- and 13-inch freeboard at the peak of the arch, respectively (Figure 2-7). For Bridge 2, approximately 80 LF of trail segments would be rerouted and replaced with approximately 140 LF of new boardwalk on the east side of the creek and approximately 40 LF of new boardwalk on the west side of creek. For Bridge 3, approximately 130 LF of trail segments would be rerouted and replaced with approximately 160 LF of new flexible paving trail. The approaches to the bridge would require approximately 50 LF of new boardwalk on the east side of the creek and approximately 50 LF of new boardwalk on the west side of creek. The rerouted trail would be to be pulled back from the channel. The previous trail alignments on the east side of the creek would be restored and revegetated. The removal of the existing bridge abutments would remove fill from Redwood Creek, a water of the U.S. The amount of fill removed would be the same as for Pedestrian Bridge Alternative A.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative B would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts would be long-term, direct and indirect, beneficial by allowing 100-year flood flows to pass unimpeded. Pedestrian Bridge Replacement Alternative B has moderately more beneficial impacts than Pedestrian Bridge Replacement Alternative A since Bridges 2 and 3 would allow for larger flows and abutments would be located farther from the center of the channel, thereby reducing scour of around the bridge abutments and lowering water turbidity. In addition, 280 LF (approximately) of boardwalk would be installed replacing hardscape (asphalt) trail and be considered a short- and long-term beneficial impact on water resources by reducing runoff rates and turbidity of surface waters.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Under Pedestrian Bridge Replacement Alternative C, the span for Bridge 2 would be lengthened and designed to pass up to a 25-year peak-discharge event with 15-inch freeboard at the peak of the arch and the span for Bridge 3 would be lengthened and designed to pass up to a 100-year peak-discharge event with 14-inch freeboard at the peak of the arch.

The removal of the existing bridges abutments would remove fill from Redwood Creek, a water of the U.S. The amount of fill removed would be the same as for Pedestrian Bridge Alternatives A and B.

Conclusion

Impacts under Pedestrian Bridge Replacement Alternative C would be similar to potential impacts discussed above under *Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives*. Overall, impacts associated with Pedestrian Bridge Replacement Alternative C would have slightly larger long-term, direct and indirect, beneficial impacts than Pedestrian Bridge Replacement Alternative A, but slightly lower long-term, direct and indirect, beneficial impacts than Pedestrian Bridge Replacement Alternative B. Pedestrian Bridge Replacement Alternative C would replace 240 LF (approximately) of boardwalk would be installed replacing hardscape (asphalt) trail and be considered a short- and long-term beneficial impact on water resources by reducing runoff rates and turbidity of surface waters.

Cumulative Impacts

Cumulative adverse impacts from other past, current, and future projects in MWNM include soil removal, soil erosion, and continued sedimentation into Redwood Creek near the Muir Woods Visitors Center, parking lots, and along Muir Woods Road. As listed in Section 4.1 above, the Muir Woods Reservation System, Muir Woods Road Rehabilitation Project, and the Muir Woods Sustainable Access Project all address and reduce disturbance of soils, erosion, sedimentation, and other hardscape-related pollutant loading that degrades the quality of receiving waters. Actions applicable to improving water quality include: revegetation of bare or disturbed areas adjacent to existing facilities; elimination of roadside parking in unpaved areas; installation or repair of culverts; expansion of riparian habitat into previously developed areas; and construction of stormwater treatment facilities for visitor parking areas. Completion of these projects would result in indirect, long-term, beneficial impacts on water resources.

Construction associated with other Muir Woods projects requires some vegetation clearing, excavation, and other ground disturbing activities. This disturbance would expose soils and increase the potential for soil erosion, sedimentation of surrounding water resources, and accidental release of hazardous materials. Ground disturbance during construction could also temporarily alter localized surface water drainage. During construction, impacts on water resources and hydrologic processes would be direct, short-term, and adverse as a result of flow alterations and sediment and pollutant loading.

All of the current and future projects would implement BMPs related to stormwater, sediment and erosion control, and waste management. Dewatering would be necessary to divert flows around construction activities in the creek. Compliance and implementation of applicable BMPs would help limit erosion and reduce untreated runoff from entering surface waters. These procedures would avoid and minimize potential impacts to water resources related to construction activities.

The cumulative actions would have adverse effects on water quality and hydrology; however, these effects would be relatively limited and localized compared to the more widespread benefits from the elimination of ground disturbance and the installation of stormwater management and erosion and sediment control measures. The overall impacts from these cumulative actions would be beneficial. Under the action alternatives, during replacement of the bridges, construction activities and methods would be similar to other cumulative actions and potentially contribute to increased erosion of soils and sedimentation into Redwood Creek. These contributions may be appreciable and result in short-term, direct and indirect, adverse impacts. However, implementation of applicable BMPs would help prevent or limit erosion and reduce untreated runoff from entering surface waters and garner no long-term cumulative impacts.

In conjunction with other past, current, and future projects in MWNM, the action alternatives associated with the Proposed Action would result in adverse short-term and long-term impact on water quality in and downstream of the Proposed Action. Implementation of the Proposed Action would result in elevated levels of turbidity and downstream sedimentation in Redwood Creek. Many aspects of the other projects protect or enhance water quality through the elimination of roadside parking in unpaved areas, improved stormwater facilities and infrastructure, installation or replacement of compromised road culverts, realignment or removal of existing dirt trails, an improved creek crossing at the Dipsea Trail,. In general, construction-related impacts to surface waters and water quality would be relatively minor, adverse, and short-term. Despite increased turbidity, impacts to other water quality parameters (e.g., temperature, contaminants, trace metals, nutrients, etc.) would likely be negligible and remain comparable to existing levels.

Overall Impacts

Construction activities associated with the Proposed Action would result in short-term impacts to water quality related to ground disturbance and potential erosion, as well as the potential for accidental spills of fuels or other construction-related hazardous materials into the creek. These effects would be eliminated or reduced through use of erosion control and spill prevention BMPs.

Over the long term, the Proposed Action would result in substantial beneficial effects to geomorphology in the restored area, as a result of the restoration of natural channel processes from installation of LWD, riprap removal, widened bridges, and other proposed actions. These benefits would accrue over a period of decades as the channel migrates, new features form, and it reaches an eventual state of equilibrium.

In addition, the Proposed Action would have minor increases in sediment production due to erosion from removal of riprap, and the subsequent transport of sediment within the restored reach and downstream. Bank treatments to control erosion would reduce levels of sediment released into Redwood Creek. Project features such as the LWD installations, tributary grade control improvements, and natural features such as embedded/exposed tree roots and LWD recruitment over time, would allow for sediment storage within the Action Area. Increased sediment deposition within the Action Area would also be expected to occur once the channel widens and flow velocities are reduced, allowing for more sediment to settle out. With proposed bank erosion control treatments, initial erosion is anticipated to be slow and the system would eventually reach a dynamic equilibrium. Over a period of time, the erosion rate would approach natural erosion/sedimentation rates similar to other portions of the Redwood Creek watershed. Actual erosion and sedimentation rates depend on a multitude of factors (e.g., seasonal precipitation amounts and specific event based rainfall amounts and intensities, the physical conditions of the channel, woody debris supply to the creek, land use, vegetation and fire conditions in the watershed, etc.) but would likely be diffused over the course of several years.

Preliminary estimates predict that average rates of bank erosion following proposed actions would be on the order of 2 to 5 times the natural bank erosion rate in the project area and occur for a period of approximately 5 years, before tapering off to the natural erosion rate as the bank vegetation becomes more established (NHE 2017). This increase in sedimentation rate represents a 2 to 5 percent increase in the total watershed sediment budget during Phase 1 and a 2 to 4 percent increase during Phase 2 (NHE 2017). Increases in turbidity would likely be linked to storm and high flow events and would vary in significance based on initial hydrologic conditions, event size and duration, and bank vegetation density and composition. This rate of increase in the watershed is likely virtually imperceptible and minor.

Fate of eroded sediment would also vary widely based on pre- and post-hydrologic and hydraulic conditions of the watershed. In general, the Proposed Action area would become a source for sediment with minimal volumes stored within MWNM; most sediment in the Action Area would be mobilized and transported downstream. Conventional geomorphic principles would project the transport and storage of material (temporary and semi-permanent) in the channel and floodplains downstream of the Proposed Action area, such as the lower gradient portions of the creek at Frank Valley, Big Lagoon, and Muir Beach. That said, major improvements to general watershed function and sediment supply and deposition to areas of historic channel incision would be expected over the long term, with improved floodplain connectivity within MWNM resulting in greater long-term beneficial impacts within the Action Area and downstream.

4.10 Vegetation

Methodology and Assumptions

Impacts considered in this analysis include vegetation disturbance from trampling, revegetation of creek banks and disturbed areas on the forest floor, as well as impacts to the overall health of the redwood forest. Existing information on vegetation within MWNM was consulted. No mapping of vegetation or quantification of the area of impacts to vegetation were conducted.

No Action Alternative

Analysis

Under the No Action Alternative, riprap would remain in Redwood Creek and the existing pedestrian bridges would be replaced in-kind at some point in the future. Riprap prevents natural channel migration, and channel incision in Redwood Creek has disconnected the stream from its floodplain, reducing the amount of natural disturbance from floods on the adjacent alluvial redwood forest (NHE 2016a). Redwood forests are adapted to periodic disturbance, and the incision and lack of channel migration may have affected the redwood forest adjacent to Redwood Creek. In-kind replacement of bridges would likely result in vegetation disturbance in the vicinity of construction. Impacts on special-status or locally rare plants are not anticipated, as it is anticipated that NPS would conduct surveys and implement protective measures prior to in-kind replacement of bridges.

Conclusion

Under the No Action Alternative, the health of the alluvial redwood forest would continue to be adversely affected by historic management actions such as the installation of riprap and removal of LWD from Redwood Creek. The replacement of bridges in-kind would not address the issue of passage of LWD through the creek and would result in short-term adverse impacts on vegetation. The No Action Alternative would continue long-term adverse impacts on vegetation in MWNM.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

Revegetation of disturbed areas along banks and the forest floor would reduce the impacts of riprap removal and LWD installation on understory vegetation. Installation of grade control on the incised tributary would result in short-term impacts on understory vegetation due to trampling by construction crews. The anticipated increase in water table would result in minor long-term benefits to understory vegetation and adjacent redwoods trees.

Conclusion

Implementation of actions common to all creek restoration alternatives would result in minor short-term adverse impacts on understory vegetation due to trampling. Minor long-term beneficial impacts would occur for vegetation in the vicinity of tributary grade control.

Impacts of Creek Restoration Alternative 1:

Analysis

As noted by Save the Redwoods League, targeted removal of riprap within and addition of LWD to Redwood Creek would improve geomorphic function and natural flooding dynamics within MWNM which would have beneficial effects on the ecological health of the redwood forest (Burns, Pers. Comm. 2016). Save the Redwoods League supports the habitat enhancement actions and describes them as “critical and necessary investment to sustain the ecological health of the coast redwood ecosystem” (Burns et al. 2016). Creek restoration actions that raise the water table and thereby improve water security for redwoods in the park could boost their resilience in the face of expected climate change impacts which include higher temperature and increased aridity (Gonzalez 2016).

Redwood tree root systems influence stream channels that flow through forests (NHE 2016a). Redwood trees generally have relatively shallow root systems that can extend over 100 feet from the base of the tree. Roots of multiple trees also intertwine, increasing the stability of these trees during flood events or high winds. Thus, a redwood tree on the bank of a stream channel is far less likely to be toppled from lateral erosion than trees with localized, vertical root systems (NHE 2016a). Numerous existing undercut redwoods have persisted at MWNM for at least 15 years since they were last photographed (Shoulders personal observation, 2017).

The altered flow dynamics that are anticipated to result following riprap removal and LWD installation could potentially destabilize redwood trees in the vicinity of the channel. Under

Alternative 1, there are approximately 130 trees greater than 1-foot DBH within one channel width (approximately 33 feet) of Redwood Creek within the areas proposed for riprap removal and LWD installation. The majority of these trees are redwoods. Of these trees, approximately 23 are located between the top of bank and the active channel. Approximately 15 trees are located within the projected long term channel evolution identified by NHE in their 2016 report (NHE 2016a). Although these 15 trees are located within project channel evolution zone, as described above redwoods are less likely to be toppled than other tree species. In recent years, several redwood trees have fallen at MWNM (largely those rooted on steep slopes), but none of the partially undermined redwood trees along the channel have fallen. Even during periods of elevated erosion and channel migration such as prior to the 1930s, there is no documentation that high erosion levels led to increased toppling of old-growth redwoods along Redwood Creek due to channel erosion (NHE 2016a).

If one or more of these trees falls into the creek, it would add more beneficial LWD to the creek, as well as creating light gaps that are known to enhance riparian biodiversity as well as enhance redwood regeneration (Lorimer et al. 2009; Van Pelt et al. 2016). Tree fall due to creek movement is a natural disturbance within redwood forests, to which redwood forests are adapted (Lorimer et al. 2009). If the presence of riprap artificially hardening the banks of Redwood Creek has prevented the toppling of adjacent redwoods over the past, this may have been delaying natural processes that would have occurred in the absence of riprap. Within MWNM, current density of trees greater than 0.16-foot DBH is 430 ± 31 individuals (Steers et al. 2014). This is within goals identified for healthy forests on Mt. Tamalpais (Burns et al. 2016). As described by Save the Redwoods League, natural recruitment of riparian redwood trees or other tree species into Redwood Creek is not anticipated to significantly reduce tree density within MWNM (Burns et al. 2016).

Heavy equipment, movement of logs for LWD, and the presence of construction crews would result in trampling of understory vegetation. These would be short-term adverse impacts to understory vegetation. As described above, disturbed areas would be revegetated as part of the Proposed Action, per BIO-15.

Remnant base rock from a previously removed trail along the top of bank next to riprap segment L10 would be removed to allow better revegetation there for bank stability. An asphalt trail in this area was removed in 2000, but the remnant base rock about 6 inches below the surface has restricted plant cover despite numerous outplanting events. This would have a beneficial impact on understory vegetation.

Implementation of BMP-8 through BMP-13 would reduce the potential for adverse effects on vegetation, including redwoods. These BMPs include identification of a construction route that minimizes disturbance, placement of protective mats, salvaging of vegetation, decompaction of soil as needed, and potentially padding redwood trunks.

The presence of construction crews and heavy equipment could potentially spread non-native invasive plant species in MWNM. BMP-4 would be implemented to limit the spread of invasive plant species by construction equipment, minimizing this risk. BIO-14 requires the creation of a plant protection plan which would be protective of native plants and would limit the spread of invasive plants. BMP BIO-15 requires the removal of invasive plants in disturbed areas.

No impacts on rare plants are anticipated because a survey would be conducted prior to any construction activities and protective measures implemented if rare plants were discovered, per BIO-11, -12, and -13. These BMPs require a rare plant survey and avoidance and minimization measures for rare plants, if discovered, within 50 feet of Proposed Actions.

Conclusion

Under Creek Restoration Alternative 1, impacts to the redwood forest would be long term and beneficial. Short-term adverse and beneficial impacts to understory vegetation would occur. No impacts on rare plants are anticipated.

Impacts of Creek Restoration Alternative 2:

Analysis

Under Creek Restoration Alternative 2, removal of the additional riprap segments would have similar impacts on vegetation as described for Creek Restoration Alternative 1, with a greater benefit to forest health due to increased opportunities for channel migration associated with additional riprap removal. Trees within one channel width of actions along Redwood Creek would increase by 15. Trees located between the top of bank and active channel near actions would increase by 10 and trees within the projected channel evolution would increase by 6. This would increase the potential for trees to topple into Redwood Creek, although as described in Creek Restoration Alternative 1, this is not anticipated in the short term. Removal of the Cathedral Gove trail segment would reduce compaction to redwood roots and would result in an increased area available for understory vegetation. BMPs indicated in Creek Restoration Alternative 1 would be implemented.

Conclusion

Under Creek Restoration Alternative 2, impacts to the redwood forest would be long term and beneficial. Short-term adverse impacts to impacts to understory vegetation would occur. No impacts on rare plants are anticipated.

Impacts of Creek Restoration Alternative 3:

Analysis

Impacts of Creek Restoration Alternative 3 would be similar to those described for Creek Restoration Alternative 2. This alternative would increase the number of trees within one channel width of actions along Redwood Creek by 7, but no new trees would be within the projected channel migration zone. This action is not anticipated to result in increased likelihood of trees toppling into Redwood Creek compared to Creek Restoration Alternative 2. Additional vegetation impacts would occur with right bank terracing, which may affect five alder trees present in the terracing footprint. Protection of these trees may be possible. BMPs indicated in Creek Restoration Alternative 1 would be implemented.

Conclusion

Under Creek Restoration Alternative 3, impacts to the redwood forest would be long term and beneficial. Short-term adverse impacts to impacts to understory vegetation and alder trees in the bank terracing area would occur. Long-term beneficial impacts to the riparian forest would occur due to the increase in floodplain habitat. No impacts on rare plants are anticipated. BMPs indicated in Creek Restoration Alternative 1 would be implemented.

Impacts of Creek Restoration Alternative 4:

Analysis

Impacts of Creek Restoration Alternative 4 would be similar to those described for Creek Restoration Alternative 2. This alternative would increase the number of trees within one channel width of actions along Redwood Creek by 9, but no new trees would be within the projected channel migration zone. Additional short-term adverse impacts to understory vegetation would occur with relocation of up to 555 LF of trail. Areas where trails would be removed would be decompacted, restored, and revegetated. BMPs indicated in Creek Restoration Alternative 1 would be implemented.

Conclusion

Under Creek Restoration Alternative 4, impacts to the redwood forest would be long term and beneficial. Additional short-term adverse impacts to understory vegetation would occur due to trail rerouting. No impacts on rare plants are anticipated.

Impacts of Creek Restoration Alternative 5:

Analysis

Impacts of Creek Restoration Alternative 5 would be similar to those described for Creek Restoration Alternative 3. Compared with Creek Restoration Alternative 3, this alternative would increase the number of trees within one channel width of actions along Redwood Creek by 7, but no new trees would be within the projected channel migration zone. Additional short-term adverse impacts to understory vegetation would occur with relocation of up to 555 LF of trail. Areas where trails would be removed would be decompacted, restored, and revegetated. BMPs indicated in Creek Restoration Alternative 1 would be implemented.

Conclusion

Under Creek Restoration Alternative 5, impacts to the redwood forest would be long term and beneficial. Short-term adverse impacts to impacts to understory vegetation and alder trees in the bank terracing area would occur. No impacts on rare plants are anticipated.

Pedestrian Bridge Replacement Alternatives

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Under Pedestrian Bridge Replacement Alternative A, the presence of construction equipment and crews would result in limited trampling of understory vegetation. Replacement of portions of the existing trail with boardwalk would reduce compaction of redwood roots, resulting in minor long-term beneficial impacts to redwoods. The rerouting of the existing trail at Bridge 3 and replacement with flexible pacing would result in minor, long term adverse impacts to understory vegetation. Implementation of BMP-8 through BMP-14 would reduce the potential for adverse effects on vegetation, including redwoods. Implementation of BMP BIO-15, which requires revegetation of disturbed areas caused by project work and trail re-routes, would reduce impacts on understory vegetation. These BMPs include identification of a route that minimizes disturbance, placement of protective mats, salvaging of vegetation, decompaction of soil as needed, potentially padding redwood trunks, and creation of a plant protection plan which would be protective of native plants and would limit the spread of invasive plants.

No impacts on rare plants are anticipated because a survey would be conducted prior to any construction activities and protective measures implemented if rare plants were discovered, per BMP BIO-11, -12, and -13. These BMPs require a rare plant survey and avoidance and minimization measures for rare plants, if discovered within 50 feet of Proposed Actions.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative A would result in minor short-term adverse impacts and minor long-term impacts on understory vegetation.

<u>Impacts of Pedestrian Bridge Replacement Alternative B:</u>

Analysis

Impacts of Pedestrian Bridge Replacement Alternative B would be similar to impacts described for Pedestrian Bridge Replacement Alternative A. Increased conversion of existing asphalt trail to boardwalk would reduce compaction of redwood roots, resulting in an increase to minor long-term beneficial impacts to redwoods. Revegetation of disturbed areas caused by project work and trail re-routes, would reduce impacts on understory vegetation. BMPs indicated in Pedestrian Bridge Alternative A would be implemented.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative A would result in minor short-term adverse impacts and minor long-term impacts on understory vegetation.

<u>Impacts of Pedestrian Bridge Replacement Alternative C:</u>

Analysis

Impacts of Pedestrian Bridge Replacement Alternative C would be intermediate to impacts described for Pedestrian Bridge Replacement Alternative A and B. Revegetation of disturbed areas caused by project work and trail re-routes, would reduce impacts on understory vegetation. BMPs indicated in Pedestrian Bridge Alternative A would be implemented.

Conclusion

Implementation of Pedestrian Bridge Replacement Alternative C would result in minor short-term adverse impacts and minor long term impacts on understory vegetation.

Cumulative Impacts

Projects discussed in Section 4.2 such as the Muir Woods Road Bridge Replacement Project, Muir Woods Water/Wastewater Station Line Replacement, and the Muir Woods Sustainable Access Project would affect vegetation in and nearby MWNM. Cumulative adverse impacts from these projects would remove and degrade vegetation in the short term, resulting in short term adverse impacts on vegetation. Some projects, such as the Muir Woods Reservation System project and the Muir Woods Sustainable Access Project, would result in long-term improvements to vegetation conditions in the vicinity, resulting in indirect, long-term, beneficial impacts on vegetation. Implementation of the Creek Restoration or Pedestrian Bridge alternatives would result in minor contributions to short-term adverse impacts on understory vegetation and minor contributions to long-term benefits to the health of the redwood forest.

Overall Impacts

The combined effects of the implementation of the Proposed Action would be similar to the impacts of each alternative, but with a difference in scale. Implementation of the Proposed Action would result in trampling of understory vegetation during construction, a short-term adverse impact. Major improvements to general forest health would be expected over the long term, with improved floodplain connectivity and greater proportion of boardwalk trails, resulting in greater long-term beneficial impacts to the redwood forest. No impacts on rare plants are anticipated.

4.11 Visual Resources

Methodology and Assumptions

The analysis of impacts to visual resources took into consideration potential impacts to views of natural and manmade features. Natural features of particular interest to visitors include redwoods, streams, other vegetation, and wildlife. Historical features in the monument include riprap placed by the CCC in the 1930s.

Impacts of the No Action Alternative

Analysis

The No Action Alternative would leave existing riprap and large downed trees in place. Bridges would either be left or replaced in-kind, and no trail changes would occur.

Conclusion

The No Action Alternative would have temporary adverse impacts on visual resources during any future in-kind bridge replacement work. While in-kind bridges would be of similar size and design, new bridges would require guardrails to comply with current safety codes and thus would have minor long-term impacts on visual resources.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All creek restoration alternatives include revegetation of any impacted creek banks or areas of forest floor and the installation of grade control in a tributary near Bridge 3. The use of equipment for these actions would create minor, site-specific, short-term impacts to visual resources. Over time, the vegetation would restore the natural character of the restored creek banks. In the long-term, it is likely some tributary grade control would be visible from the trail, and this grade control may improve the water table and health of the surrounding redwood forest ecosystem.

Conclusion

The actions common to all creek restoration alternatives would have minor, site-specific, short-term adverse impacts to visual resources. Long-term impacts would include a less-channelized, more natural looking stream channel, visible check dams, and possibly beneficial impacts to the viewscape arising from improved ecosystem health and climate resilience.

Impacts of Creek Restoration Alternative 1:

Analysis

Creek Restoration Alternative 1 involves the removal of approximately 1,123 LF of historical riprap, approximately 1,019 LF of which is visible from trails in the monument. As part of this alternative, LWD would be moved from nearby locations into the channel. The transport of LWD and removal and hauling away of riprap and asphalt would have temporary adverse impacts on visual resources due to the presence of heavy equipment near and on trails. The removal of riprap and a side-trail would permanently alter some views and eliminate access to certain views, respectively. The movement and placement of LWD would create long-lasting changes in views as well. Over time, these actions would result in a more natural appearance to the creek, and improve the health and climate resilience of the local ecosystem, while leaving some historic riprap available for viewing. This would ultimately lead to improvements to the visual resources relative to the No Action Alternative, a beneficial impact. The placement of erosion control fabric on re-contoured banks would have a short-term minor adverse impact on visual resources, which would fade over time as vegetation covers it.

Conclusion

Equipment operating near and along trails to move LWD and remove riprap and placement of erosion control fabric would have temporary, site-specific, adverse impacts on visual resources. The removal of historic riprap would have permanent impacts on visual resources and access to specific views, but the overall long-term impact would be beneficial by restoring a more natural character to the creek.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 involves the removal of approximately 338 LF of riprap (in the Entry Plaza Area and near Cathedral Grove) and 350 LF of asphalt trail would be removed from Cathedral Grove in addition to the work described in Creek Restoration Alternative 1. The Plaza Area is one of the busiest locations in the monument and offers visitors their initial view of MWNM. The presence of equipment while this work is underway would create a temporary, site-specific, adverse impact to the viewscape. Since some of the riprap being removed is visible from the Plaza Area, some viewers may consider the permanent removal to be an adverse impact. However, in general, the restoration of a more natural character to the creek is considered a long-term beneficial impact.

Conclusion

The impacts of this alternative would be similar and proportionally larger than those found in Creek Restoration Alternative 1. The removal of a side-section of trail would have permanent impacts on visual resources and access to specific views, but the overall long-term impact would be beneficial by restoring a more natural character to the creek.

Impacts of Creek Restoration Alternative 3:

Analysis

Creek Restoration Alternative 3 involves installation of log jams downstream of Bridge 1 and terracing of the right bank in the Entry Plaza Area in addition to the work described in Creek Restoration Alternative 2.

Conclusion

The impacts of this alternative would be similar to those found in Creek Restoration Alternative 2. Creek Restoration Alternative 3 would have a temporary, site-specific, adverse impact on the viewscape during construction, which would be for a longer period than in Creek Restoration Alternative 2 given the additional work included.

Impacts of Creek Restoration Alternative 4:

Analysis

Creek Restoration Alternative 4 involves the removal of approximately 270 LF of riprap and rerouting of up to 555 LF of trail in addition to the work described in Creek Restoration Alternative 2.

Conclusion

The impacts of this alternative would be similar and proportionally larger than those found in Creek Restoration Alternative 2.

Impacts of Creek Restoration Alternative 5:

Analysis

Creek Restoration Alternative 5 consists of all of the actions and impacts of Creek Restoration Alternative 4 along with the right bank terracing described in Creek Restoration Alternative 3.

Conclusion

The impacts of this alternative would be similar and proportionally larger than those found in Creek Restoration Alternative 4.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives:

Analysis

The replacement of Bridges 1 and 4 are actions common to all bridge alternatives. The removal of existing abutments, addition of boardwalk, and replacement of the existing bridges with longer, higher, clear spans with guardrails would impact the sites' visual resources. Under all alternatives, new bridges would be designed to be compatible with the historic setting of MWNM, so the impact should be minor and would be beneficial.

Conclusion

During removal and replacement, the actions common to all bridge alternatives would have temporary, adverse impacts on visual resources due to the presence of equipment and temporary impacts to vegetation. In the long-term, the actions common to all bridge alternatives would have minor adverse impacts on visual resources due to the addition of boardwalk, as well as longer, higher bridges with guardrails. Long-term minor beneficial impacts to visual resources would occur due to bridge designs compatible with the historic setting.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Pedestrian Bridge Replacement Alternative A involves the removal and replacement of Bridges 2 and 3 with higher, longer, spans that would pass the 25-year flow event. The bridges would have guardrails on the span.

Conclusion

During removal and replacement of bridges, Pedestrian Bridge Replacement Alternative A would have temporary, adverse impacts on visual resources due to the presence of equipment and impacts to vegetation. In the long-term, Pedestrian Bridge Replacement Alternative A would have minor, adverse impacts to visual resources due to longer, higher spans, and guardrails. However, the bridges would be more consistent with the historic character of the park, which would be beneficial.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Pedestrian Bridge Replacement Alternative B involves the replacement of Bridges 2 and 3 with longer spans than those in Pedestrian Bridge Replacement Alternative A, and the rerouting of some portions of trail. These new trail sections would provide visitors views differing from those typically found along the valley floor. These bridges would also have guardrails on the span, and Bridge 2 would require a 10-foot-long guardrail on each side of the boardwalk approaching the bridge.

Conclusion

Pedestrian Bridge Replacement Alternative B would have temporary adverse site-specific impacts to visual resources during construction. In the long-term the new bridges would have longer and higher spans with guardrails, which would have a minor adverse impact. This alternative would have more adverse effects on visual resources compared to Pedestrian Bridge Replacement Alternative B. This which would be offset by the bridges being more consistent with the historic character of the park, and by affording more sweeping views compared to existing conditions or Pedestrian Bridge Replacement Alternative A. Rerouting the trail would also have the beneficial impact of providing visitors access to new views.

<u>Impacts of Pedestrian Bridge Replacement Alternative C:</u>

Analysis

Pedestrian Bridge Replacement Alternative C involves the replacement of Bridges 2 and 3, though unlike Pedestrian Bridge Replacement Alternative B, only Bridge 3 would be replaced with a span capable of accommodating the 100-year storm with 13 inches of freeboard. Bridge 2 would have the span described under alternative A, and would not have guardrails on the boardwalk. Both bridges would have longer, higher spans with guardrails compared to the no-action alternative.

Conclusion

Pedestrian Bridge Replacement Alternative C would have temporary adverse site-specific impacts to visual resources during construction. In the long-term, Bridges 2 and 3 would have a longer and higher spans with guardrails which would have a minor adverse impact on visual resources. This impact would be intermediate to Pedestrian Bridge Replacement Alternatives A and B. This adverse impact would be offset by the bridge design being more consistent with the historic character of the park compared to existing conditions. Rerouting the trail would also have the beneficial impact of providing visitors access to additional and different views.

Cumulative Impacts

The cumulative effects of the various projects are first described, and then considered in combination with the Proposed Action. The Muir Woods Reservation System will have minor beneficial long-term impacts on visual resources in the monument by decreasing crowding during peak visitation times and providing visitors with less obstructed views of redwoods, other vegetation, and wildlife.

The Muir Woods Road Bridge Replacement Project will have minor or no long-term impact on visual resources.

The Muir Woods Road Rehabilitation Project and the Muir Woods Water/Wastewater Station Line Replacement will have no long-term impact on visual resources.

The Muir Woods Sustainable Access Project would have long-term beneficial impacts on visual resources around the Plaza Area due to the relocation of the restroom facilities and revegetation work.

Other projects planned or recently completed in the area, in combination with the Proposed Action, would combine to have temporary moderate adverse construction-related impacts.

Other projects would have negligible or no long-term impact on visual resources in the monument, with the Proposed Action contributing long-term beneficial impacts, leading to long-term beneficial impacts overall.

Overall Impacts

Completing all of the actions described in the alternatives would have moderate adverse impacts on visual resources throughout MWNM during construction. In the long-term, these projects would have moderate, largely beneficial impacts on visual resources by restoring a more natural character to the creek, improving ecosystem health, climate resilience, and wildlife habitat, ensuring new bridges fit the monument's historic setting, and providing more diverse views from the higher bridges and new trail alignments.

4.12 Soundscapes

Methodology and Assumptions

The soundscapes analysis relied on published studies that detailed the monument's current soundscapes in addition to considering sources of noise related to the Proposed Action that may include:

1. Dewatering pumps and equipment.
2. Haul carts for transporting riprap out of the monument.
3. Cable grip and hoist system and associated heavy equipment to move logs.
4. The use of chainsaws, sledge hammers, and wedges to prepare LWD for installation.
5. Excavators, rock drills, and other equipment used in riprap removal, break-up, and transportation.
6. Equipment and activity associated with the removal and installation of bridges.
7. Equipment and activity associated with the removal of the section of asphalt trail at Cathedral Grove and subsequent soil improvement work.

The types of equipment that will be used for these activities typically produce noise levels of 70 to 80 dBA at a distance of 50 feet which could be perceived as annoyingly loud by visitors, but would not pose a risk of hearing damage over expected periods of exposure (Federal Transit Authority 2006).

Impact severity descriptions took into consideration that many areas of MWNM are typically very quiet in terms of manmade noise sources and that manmade noises have been shown to be a source of irritation for visitors hoping to experience a more peaceful, natural soundscape.

Impacts of the No Action Alternative

Analysis

Under the No Action Alternative, no work would be conducted, though some bridges may be replaced in-kind, which would cause adverse construction-related impacts at the time of replacement.

Conclusion

Any in-kind bridge replacement conducted as part of the No Action Alternative would have short-term temporary adverse impacts on soundscapes during construction. There would be no other noise impacts associated with this alternative.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All creek restoration alternatives include revegetation of any impacted creek banks or areas of forest floor and the installation of grade control in a tributary near Bridge 3. Both activities would be performed by hand and would generate negligible amounts of noise.

Conclusion

No impacts to soundscapes are anticipated from these actions.

Impacts of Creek Restoration Alternative 1:

Analysis

Creek Restoration Alternative 1 involves the removal and hauling out of approximately 1,123 LF of riprap and the relocation of approximately 34 to 50 existing downed trees into the channel. Heavy equipment and dewatering pumps and the breaking of some over-sized rocks would be used to complete this work which would have temporary, adverse impacts on soundscapes. After work is completed, this alternative would not have any long-term impact on soundscapes. Noise-attenuating pumps would be used during dewatering and additional methods of attenuating noise, such as surrounding pumps with rice straw bales, may be employed as well.

Conclusion

Creek Restoration Alternative 1 would have temporary, moderate, adverse impacts on soundscapes throughout the monument. Once work is complete, it would have no long-term impact.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 involves the removal of approximately 338 LF of riprap (in the Entry Plaza Area and near Cathedral Grove) and 350 LF of asphalt trail would be removed from Cathedral Grove in addition to the work described in Creek Restoration Alternative 1. Removal of riprap near the Entry Plaza would require the use of additional dewatering pumps. Materials would be hauled out via the same routes described earlier and would increase temporary impacts proportionally.

Conclusion

Creek Restoration Alternative 2 would have temporary, moderate, adverse impacts on soundscapes throughout the monument that would be larger than those of Creek Restoration Alternative 1 in proportion to the additional amount of work being proposed. Once work is complete, it would have no long-term impact on soundscapes.

Impacts of Creek Restoration Alternative 3:

Analysis

Creek Restoration Alternative 3 involves installation of log jams downstream of Bridge 1 and terracing of the right bank in the Entry Plaza Area in addition to the work described in Creek Restoration Alternative 2. These materials would be hauled out via the same routes described earlier and would increase temporary impacts proportionally. The Plaza is a busy area of MWNM and can have loud crowd noises; however, sound from construction equipment and operations is perceived differently from that of crowds.

Conclusion

Creek Restoration Alternative 3 would have temporary, moderate, adverse impacts on soundscapes throughout the monument that would be larger than those of Creek Restoration Alternative 1 in proportion to the additional amount of work being proposed. Once work is complete, it would have no long-term impact on soundscapes.

Impacts of Creek Restoration Alternative 4:

Analysis

Creek Restoration Alternative 4 involves the removal of approximately 270 LF of riprap, excavation of an alcove, and rerouting of 555 LF of trail in addition to the work described in Creek Restoration Alternative 2. Removal of riprap near the Bridge 1.5 area would require the use of additional dewatering pumps. These materials would be hauled out via the same routes described earlier and would increase temporary impacts proportionally.

Conclusion

Creek Restoration Alternative 4 would have temporary, moderate, adverse impacts on soundscapes throughout the monument that would be larger than those of Creek Restoration Alternative 1 in proportion to the additional amount of work being proposed. Once work is complete, it would have no long-term impact on soundscapes.

Impacts of Creek Restoration Alternative 5:

Analysis

Creek Restoration Alternative 5 consists of all of the actions and impacts of Creek Restoration Alternative 4 along with the right bank terracing described in Creek Restoration Alternative 3.

Conclusion

The impacts of this alternative would be similar and proportionally larger than those found in Creek Restoration Alternative 4.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives:

Analysis

Actions common to all bridge alternatives include removing and replacing Bridges 1 and 4. The use of heavy machinery to remove and haul away the old bridges and walkway debris and to install the new bridges would generate noise for the duration of work activity. The removal and replacement of bridge abutments would generate noise in addition to that described for in-kind bridge replacement under the No Action Alternative.

Conclusion

The actions common to all bridge alternatives would create temporary, moderate, adverse impacts for soundscapes in MWNM. No long-term impacts to soundscapes are anticipated from this alternative.

Impacts of Pedestrian Bridge Replacement Alternative A:

Analysis

Pedestrian Bridge Replacement Alternative A involves the removal and replacement of Bridges 2 and 3, construction of boardwalk approaches, and rerouting trail segments. The use of heavy machinery to perform this work would generate noise around these sites and along hauling routes for the duration of work activity. Over the long-term, while noise from walking on the boardwalk is possible, such impacts are considered minor.

Conclusion

Pedestrian Bridge Replacement Alternative A would create temporary, moderate, adverse impacts for soundscapes in the monument during construction. Long-term adverse impacts to soundscapes are anticipated to be minor due to use of the new boardwalk.

Impacts of Pedestrian Bridge Replacement Alternative B:

Analysis

Pedestrian Bridge Replacement Alternative B involves the replacement of Bridges 2 and 3 with longer spans and requires more trail rerouting than Pedestrian Bridge Replacement

Alternative A. The use of heavy machinery to perform this work would generate noise around these sites and along hauling routes for the duration of work activity.

Conclusion

Pedestrian Bridge Replacement Alternative B would create temporary, moderate, adverse impacts for soundscapes in the monument larger than those of Pedestrian Bridge Replacement Alternative A, in proportion to the amount of work proposed. No long-term impacts to soundscapes are anticipated from this alternative.

Impacts of Pedestrian Bridge Replacement Alternative C:

Analysis

Pedestrian Bridge Replacement Alternative C involves the replacement of Bridge 2 with the same span and trail adjustments as Pedestrian Bridge Replacement Alternative A and Bridge 3 with the same span and trail adjustments as Pedestrian Bridge Replacement Alternative B. The use of heavy machinery to perform this work would generate noise around these sites and along hauling routes for the duration of work activity.

Conclusion

Pedestrian Bridge Replacement Alternative C would create temporary, moderate, adverse impacts for soundscapes in the monument between than those of Pedestrian Bridge Replacement Alternative A and B, in proportion to the amount of work proposed. No long-term impacts to soundscapes are anticipated from this alternative.

Cumulative Impacts

The cumulative effects of the various projects are first described, and then considered in combination with the Proposed Action. The Muir Woods Reservation System will have long-term beneficial impacts on soundscapes throughout the monument by lowering noise due to a smaller number of visitors and reduced peak vehicular traffic.

The Muir Woods Road Bridge Replacement Project is located south of the monument, but may still have short-term adverse impacts on soundscapes in some areas of the monument during construction. It is not anticipated to have any long-term impacts on soundscapes.

The Muir Woods Road Rehabilitation Project will have short-term adverse impacts on soundscapes during construction and is not anticipated to have any long-term impacts.

The Muir Woods Water/Wastewater Line Replacement work will have short-term adverse impacts on soundscapes during construction and is not anticipated to have any long-term impacts.

The Muir Woods Sustainable Access Project would have short-term adverse impacts on soundscapes during construction and long-term minor beneficial impacts on soundscapes in the Plaza Area by improving operational efficiency and vehicular circulation and shifting vehicular traffic slightly farther away from the entrance. The No Action Alternative may involve in-kind bridge replacement at some future time. This would have an additional short-term adverse impact on soundscapes during construction.

Taken together, with the exception of the Muir Woods Reservation System Project, the projects would combine to create minor to moderate adverse short-term noise impacts as each project is being constructed. This would particularly be the case if project construction overlaps. The Proposed Action is most likely to overlap with the Water/Wastewater Line Replacement which would increase cumulative impacts to soundscapes in the area.

Over the long term, noise impacts would be generally unaffected, with the exception of beneficial impacts related to the reservation system.

Overall Impacts

Completing all of the actions described in the alternatives would have moderate, temporary adverse impacts on soundscapes throughout MWNM. After work is completed, these projects are not anticipated to have any major long-term impact on soundscapes.

4.13 Air Quality and Greenhouse Gas Emissions

Methodology and Assumptions

The air quality and GHG analysis focuses on impacts to air quality and GHG emissions arising from use of trucks, passenger vehicles, and power equipment. Some vehicles and equipment may be powered by gasoline (such as construction worker vehicles), while others may be powered by diesel, bio-diesel, or vegetable oil. Activities that would result in such emissions include construction worker commutes, delivery of supplies and materials, construction and restoration activities requiring powered equipment, and hauling of waste material such as riprap, bridge materials, and asphalt out of the monument to storage and disposal locations. This would result in emissions of criteria pollutants and toxic air contaminants such as carbon monoxide, particulate matter, hydrocarbons, sulfur oxides, and NOx.

Biodiesel will be required for equipment operating in the stream channel; however, trucks transporting material out of MWNM may use standard diesel fuel. In addition to being less toxic to Coho salmon and other aquatic organisms (Khan et al. 2007), biodiesel emissions are often cleaner than traditional diesel in terms of PM, hydrocarbons, smoke, and carbon monoxide, though emissions of carbon dioxide and NOx can be higher (Anderson 2012).

Impact severity descriptions took into consideration that visitors to MWNM are typically exposed to, and expecting, relatively “fresh” clean air.

Impacts of the No Action Alternative

Analysis

Under the No Action Alternative, no work would be conducted, though some bridges may be replaced in-kind at some point in the future. Bridge replacement would require vehicles and heavy equipment that would result in air pollutant emissions.

Conclusion

The No Action Alternative would have no impact on air quality in the short-term. Any in-kind bridge replacement work would have short-term air quality impacts during construction.

Creek Restoration Alternatives

Impacts of Actions Common to all Creek Restoration Alternatives

Analysis

All creek restoration alternatives include revegetation of any impacted creek banks or areas of forest floor and the installation of grade control in a tributary near Bridge 3. Air quality impacts from revegetation and grade control installation would be minimal since work will be performed using hand equipment. Beneficial impacts on air quality and climate change from these activities may result from improved long-term carbon dioxide uptake and carbon sequestration associated with planted vegetation and enhanced forest health resulting from improved groundwater elevations.

Conclusion

The actions common to all creek restoration alternatives would have little or no short-term impacts on air quality and may have minor long-term beneficial impacts on air quality and climate change due to higher rates of carbon dioxide uptake and carbon sequestration compared to the No Action Alternative.

Impacts of Creek Restoration Alternative 1:

Analysis

Creek Restoration Alternative 1 involves the use of various types of heavy equipment and vehicles to deliver materials, move and place LWD, and remove and haul riprap. While underway, these activities, along with worker trips, would impact air quality in and around the monument. Operating equipment during the construction period would result in increased vehicle exhaust and emissions of air pollutants and GHGs. Overall, there would be a slight and temporary degradation of local air quality due to emissions from construction equipment. These effects would last only as long as construction occurred. BMPs for reducing air pollutant and GHG emissions would be implemented, such as minimizing idling time of equipment when not in use and using low emission producing equipment when feasible (BMP-15) and maintaining construction equipment in proper working condition (BMP-4). Overall, this alternative would not measurably contribute greenhouse gases affecting global climate change.

Conclusion

Creek Restoration Alternative 1 would have short-term adverse impacts on air quality and GHG emissions in and around the MWNM as a result of heavy equipment use, vehicles, and worker trips. Once work is complete, the alternative would have no long-term adverse impact on air quality and climate change. Benefits to local ecosystem health and climate resilience may lead to greater carbon dioxide uptake and sequestration, a beneficial impact.

Impacts of Creek Restoration Alternative 2:

Analysis

Creek Restoration Alternative 2 involves the removal of additional riprap and asphalt trail compared to Creek Restoration Alternative 1. These activities would increase short-term emissions proportionally. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Creek Restoration Alternative 1. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Creek Restoration Alternative 2 would have temporary, moderate, adverse impacts on air quality and GHG emissions throughout the monument that would be larger than those of Creek Restoration Alternative 1 in proportion to the additional amount of work being proposed. Once work is complete, it would have no long-term adverse impact on air quality. Benefits to local ecosystem health and climate resilience may lead to greater carbon dioxide uptake and sequestration.

<u>Impacts of Creek Restoration Alternative 3:</u>

Analysis

Creek Restoration Alternative 3 would involve the same activities as Creek Restoration Alternative 2, with the addition of engineered log jam installation and bank terracing near the Entry Plaza. The additional heavy equipment use and travel in the entry plaza area would increase impacts on air quality compared to Creek Restoration Alternative 2. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Creek Restoration Alternative 1. Overall, this alternative would not measurably contribute greenhouse gases affecting global climate change.

Conclusion

Creek Restoration Alternative 3 would have short-term adverse impacts on air quality in the Plaza Area, lasting longer than those described for Creek Restoration Alternative 2 due to the additional work involved.

<u>Impacts of Creek Restoration Alternative 4:</u>

Analysis

Creek Restoration Alternative 4 involves the removal of additional riprap and asphalt trail and includes engineered log jam installation compared to Creek Restoration Alternative 2. These activities would increase short-term emissions proportionally. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Creek Restoration Alternative 1. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Creek Restoration Alternative 4 would have temporary, moderate, adverse impacts on air quality throughout the monument that would be larger than those of Creek Restoration Alternative 2 in proportion to the additional amount of work being proposed. Once work is complete, the alternative would have no long-term adverse impact on air quality. Benefits to local ecosystem health and climate resilience may lead to greater carbon dioxide uptake and sequestration, a beneficial impact.

Impacts of Creek Restoration Alternative 5:

Analysis

In addition to the activities discussed for Creek Restoration Alternative 4, Creek Restoration Alternative 5 involves terracing the right bank in the Entry Plaza Area. These activities would increase short-term emissions proportionally. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Creek Restoration Alternative 1. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Creek Restoration Alternative 5 would have temporary, moderate, adverse impacts on air quality throughout the monument that would be larger than those of Creek Restoration Alternative 4 in proportion to the additional amount of work being proposed. Once work is complete, the alternative would have no long-term adverse impact on air quality. GHG emissions would be minor during construction, and the restoration would have a long-term beneficial effect related to climate change.

Pedestrian Bridge Replacement Alternatives

Impacts of Actions Common to all Pedestrian Bridge Replacement Alternatives

Analysis

All bridge alternatives include replacing Bridges 1 and 4. The material from these bridges would be hauled out and transported to a landfill and material for new bridge construction would be imported. Powered equipment would be used to dismantle and haul away the existing bridges and to construct the new bridges. Operating equipment during the construction period would result in increased vehicle exhaust and emissions of air pollutants and GHGs. Overall, there would be a slight and temporary degradation of local air quality due to emissions from construction equipment. These effects would last only as long as construction occurred. BMPs for reducing air pollutant and GHG emissions would be implemented, such as minimizing idling time of equipment when not in use and using low emission producing equipment when feasible (BMP-15) and maintaining construction equipment in proper working condition (BMP-4). Overall, this these actions would not measurably contribute GHGs affecting global climate change.

Conclusion

The actions common to all bridge alternatives would result in short-term adverse impacts to air quality and emissions of GHGs at the bridge sites and along the haul away routes. No long-term impact to air quality or climate change is anticipated from this work.

Impacts of Pedestrian Bridge Replacement Alternative A

Analysis

Pedestrian Bridge Replacement Alternative A includes the removal and replacement of Bridges 2 and 3 and some nearby asphalt. This material would be hauled out and transported to a landfill, and material for replacement bridges would be imported. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Actions Common to all

Pedestrian Bridge Replacement Alternatives. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Pedestrian Bridge Replacement Alternative A would result in short-term adverse impacts to air quality and GHG emissions at the bridge sites and along the haul routes. No long-term impact to air quality or climate change is anticipated from this work.

<u>Impacts of Pedestrian Bridge Replacement Alternative B:</u>

Analysis

Pedestrian Bridge Replacement Alternative B is similar to Pedestrian Bridge Replacement Alternative A, but would require the removal of additional asphalt. This material would be hauled out and transported to a landfill. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Actions Common to all Pedestrian Bridge Replacement Alternatives. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Pedestrian Bridge Replacement Alternative B would result in temporary adverse impacts to air quality and have GHG emissions at the bridge sites and along the haul away routes which would be somewhat greater than Pedestrian Bridge Replacement Alternative A. No long-term impact to air quality or climate change is anticipated from this work.

<u>Impacts of Pedestrian Bridge Replacement Alternative C:</u>

Analysis

Pedestrian Bridge Replacement Alternative C would require the removal of additional asphalt than Alternative B but would remove less than Alternative B. This material would be hauled out and transported to a landfill. BMPs for reducing air pollutant and GHG emissions would be implemented as described in Actions Common to all Pedestrian Bridge Replacement Alternatives. Overall, this alternative would not measurably contribute GHGs affecting global climate change.

Conclusion

Pedestrian Bridge Replacement Alternative C would result in temporary adverse impacts to air quality and have GHG emissions at the bridge sites and along the haul away routes which would be somewhat greater than Pedestrian Bridge Replacement Alternative A, but less than Alternative B. No long-term impact to air quality or climate change is anticipated from this work.

Cumulative Impacts

This discussion first focuses on the cumulative impacts of other projects, and then considers these impacts in combination with impacts of the Proposed Action.

The Muir Woods Reservation System will reduce traffic to, and congestion around, MWNM and is likely to have a long-term minor beneficial impact on air quality in the area, as well as reducing GHG emissions.

The Muir Woods Road Bridge Replacement Project and the Muir Woods Road Rehabilitation Project will result in temporary adverse impacts to air quality and emit GHGs during construction; the projects are not anticipated to have any long-term air quality or climate change impacts. These projects are scheduled for 2019 and may overlap.

The Muir Woods Water/Wastewater Line Replacement will result in temporary adverse impacts to air quality and emit GHGs while work is underway and is not anticipated to have any long-term impacts on air quality or climate change.

The Muir Woods Sustainable Access Project would have temporary adverse impacts on air quality and emit GHGs during implementation and would likely have minor long-term beneficial impacts due to improved shuttle and bus circulation.

Any in-kind bridge replacement work would take place at some point in the future and would not be anticipated to meaningfully contribute to any construction-related or operational cumulative impacts.

To the extent that construction of these various projects would overlap, they would combine to create cumulative air quality impacts, and would have combined GHG emissions.

The Proposed Action and the Muir Woods Reservation System will have cumulative long-term beneficial impacts on air quality and climate change in terms of reduced vehicular emissions and greater carbon sequestration.

Overall Impacts

Completing all of the actions described in the alternatives would have moderate short-term impacts on air quality and result in GHG emissions at and around MWNM due to construction activity, worker trips, and hauling trips. Once complete, this work would not have any long-term adverse impacts on air quality. The improvements to the local redwood forest ecosystem's health and climate resilience in addition to new areas of vegetation would have beneficial long-term impacts on air quality and climate change in the form of enhanced carbon dioxide uptake and sequestration.

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Chapter 5
CONSULTATION AND COORDINATION

5.1 Compliance with Agency Consultation Requirements

The following sections describe relevant federal and state consultation requirements and the consultation that has either already been or would be completed for the lead agencies to be in compliance with applicable laws and regulations. **Table 5-1** summarizes the regulatory permits, approvals, and consultations that apply to the alternatives being considered as part of the Proposed Action.

Federal Requirements

Clean Water Act

The Clean Water Act (CWA) is the primary federal legislation governing the protection of surface water. NPS will need to comply with CWA Sections 401 and 404 for both creek restoration and bridge replacement actions.

The authority to implement and oversee most of the programs authorized under the CWA rests with USACE and the SWRCB (through the RWQCBs). USACE, through its regulatory program, administers and enforces CWA Section 404. Under Section 404, a permit is required for the discharge of dredged or fill materials into waters of the U.S., including wetlands. CWA Section 401 requires that an applicant applying for a federal permit to conduct an activity that might result in the discharge of a pollutant to a water of the U.S. obtain a water quality certification (or waiver) verifying that the discharge would not violate state water quality standards. Water quality certifications are issued by RWQCBs in California, with the exception of activities on federal land, in which case the certifications are issued by the USEPA. The Proposed Action would be located within the jurisdiction of the San Francisco RWQCB.

NPS or its designee would prepare applications for permits under CWA Section 404 and water quality certifications under CWA Section 401 from USEPA and/or the San Francisco RWQCB for any actions that require them.

Clean Air Act Section 309

Under CAA Section 309, USEPA may review and provide comments on the environmental impacts of major federal actions, such as those that are described in EAs. In the event that USEPA determines the action is "environmentally unsatisfactory," CAA Section 309 requires USEPA to refer such matters to CEQ (USEPA 2017).

Consistent with CAA Section 309, NPS would appropriately notify USEPA during the public review process.

Federal Endangered Species Act

ESA provides a program for the conservation of threatened and endangered plants and animals and the habitat in which they live. In accordance with the ESA, USFWS and NMFS have authority over projects that might result in the "take" of a species listed as threatened or endangered. If a project is likely to result in the take of a federally listed species, either an incidental take permit under ESA Section 10(a) or a federal interagency consultation under ESA Section 7 is required.

A list of threatened and endangered species known to occur in the vicinity of the Proposed Action are presented in Section 3.3, Threatened or Endangered Species. NPS, as a federal agency, would initiate consultation under Section 7 (either formally or informally) with the appropriate departments within USFWS and NMFS by submitting one or more biological assessments (BAs) (if needed) and a copy of this EA to both agencies. These agencies would review these documents and may make a determination of concurrence with NPS findings and issue a Biological Opinion if a formal consultation is conducted.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) ensures that fish and wildlife receive equal consideration with water resources development during planning and construction of federal water projects by requiring that the federal agencies consult with USFWS, NMFS, and the state wildlife resources agency before the waters of any stream or other waterbody are impounded, diverted, deepened, or otherwise controlled or modified. FWCA requires that the views of USFWS and the state agency be considered when evaluating the impacts and determining mitigation needs. NEPA regulations further require that an EA meet the consultation requirements of FWCA (40 CFR 1502.25[a]).

For the Proposed Action, compliance with FWCA requires that NPS coordinate with NMFS, CDFW, and SWRCB. FWCA consultation requirements are being satisfied through the EA process.

National Historic Preservation Act

Section 106 of the NHPA 1966 (as amended in 1922) requires federal agencies to evaluate the effects of federal undertakings on historic, archaeological, and cultural resources. Before federal funds can be approved for a particular project and the issuance of any license, any of these effects would be evaluated.

NPS serves as the lead agency for compliance with NHPA for the Proposed Action. To comply with NHPA, NPS must "take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register." A copy of this Draft EA will be sent to the State Historic Preservation Officer requesting review and soliciting input on the Proposed Action. NPS will conduct further

Table 5-1. Regulatory Permits, Approvals, and Consultations Relevant to the Proposed Action

Regulatory Agency	Law/Regulation	Purpose	Relevant Activities	Permit/Authorization Type
Federal				
USACE–San Francisco District	CWA Section 404	Regulates placement of dredge and fill materials into waters of the U.S., including wetlands	Removal of riprap, placement of LWD, bank grading and revegetation, terracing, bridge replacement.	Individual or nationwide permits
USEPA	CWA Section 309	Requires USEPA to review and publicly comment on the environmental impacts of major federal actions	Creek restoration and bridge replacement actions.	No permit/authorization issued (only public comments)
USFWS/NMFS	ESA	Consultation with USFWS and NMFS if threatened or endangered species might be affected by the project.	Creek restoration and bridge replacement actions.	ESA Section 7 Consultation.
State				
Regional Water Quality Control Board	CWA Section 401	Water quality certification for placement of dredge and fill materials into waters of the U.S., including wetlands	Removal of riprap, placement of LWD, terracing, bridge replacement.	401 Water Quality Certification is required for federal permits, such as CWA Section 404 Permits
	CWA Section 402	NPDES program, which regulates discharges of pollutants	Creek restoration and bridge replacement actions.	NPDES General Construction Permit

Regulatory Agency	Law/Regulation	Purpose	Relevant Activities	Permit/Authorization Type
	Porter–Cologne Water Quality Control Act	Regulates discharges of materials to land and protection of beneficial uses of waters of the state	Creek restoration and bridge replacement actions.	Waste Discharge Requirements (WDRs)
CDFW	F&G Code Section 1602	Applies to activities that will substantially modify a river, stream, or lake; includes reasonable conditions necessary to protect those resources	Creek restoration and bridge replacement actions.	Streambed Alteration Agreement, if required
	CESA (F&G Code Sections 2080.3, 2080.4, and 2081)	Applies to activities that could result in take of a state-listed threatened or endangered species	Project activities with potential for take of listed species	Incidental Take Permit, if needed
	F&G Code Sections 3503, 3513, 3800, and other sections and subsections	Protection of birds	Project activities with potential for effects on birds	Reflected in other permits (e.g., Streambed Alteration Agreement)
State Historic Preservation Officer	NHPA Section 106	Consultation with State Historic Preservation Officer if historic properties or prehistoric archaeological sites might be affected by the project	Riprap removal and bridge replacement and trail modifications	Consultation will be conducted by NPS

Regulatory Agency	Law/Regulation	Purpose	Relevant Activities	Permit/Authorization Type
Local				
County of Marin	Marin County Code Chapter 11.08 and Ordinance #2025 of the Marin County Flood Control and Water Conservation District	Applies to construction of structures within, upon, over or under a watercourse.	Bridge replacement	Creek Permit.

CY = cubic yard(s)
CDFW = California Department of Fish and Wildlife
CESA = California Endangered Species Act
CWA = Clean Water Act
ESA = Endangered Species Act
LWD = large woody debris
NHPA = National Historic Preservation Act
NMFS = National Marine Fisheries Service
NPS = National Park Services
SJVAPCD = San Joaquin Valley Air Pollution District
USACE = U. S. Army Corps of Engineers
USEPA = U. S. Environmental Protection Agency
USFWS= U.S. Fish and Wildlife Service

consultation with the State Historic Preservation Officer as needed. NPS will enter into an MOA, under the terms of 36 CFR 800.6.

Native American Consultation

The regulations for NHPA Section 106 require federal agencies to consult with Native American tribes that attach cultural or religious significance to cultural resources subject to management during the NHPA Section 106 process (36 CFR 800.2). Each federal agency performing an action that constitutes an undertaking as defined in the Section 106 regulations will consult with relevant Native American tribes regarding that undertaking (36 CFR 800.16[y]).

Other Legal Considerations

Below is a summary of state laws requiring agency consultation.

Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act (Porter-Cologne) established the SWRCB and nine RWQCBs, and gave them authority to regulate the water quality of state waters. Compliance with Porter-Cologne is normally accomplished within the framework of CWA Section 401 compliance.

California Endangered Species Act

The California Endangered Species Act (CESA) (California Fish and Game Code Section 2050 et. seq.) prohibits the take of listed and candidate (petitioned to be listed) species. For projects that would affect a species that is federally and state listed, compliance with the ESA satisfies CESA if CDFW determines that the federal incidental take authorization is consistent with CESA (California Fish and Game Code Section 2080.1). For projects that would result in take of a state-only listed species, the project proponent must apply for a take permit under California Fish and Game Code Section 2081(b).

5.2 Internal Scoping

A Choosing by Advantages (CBA) meeting was held on January 19, 2017, to discuss the Proposed Actions and choose preferred alternatives. Stakeholders and subject matter experts within NPS and the Golden Gate National Parks Conservancy evaluated the advantages of each alternative and chose the preferred alternatives. A secondary CBA meeting was held on February 13, 2017, to confirm the details of the preferred Pedestrian Bridge Replacement Alternative.

5.3 External Scoping

Public Meetings

A public meeting was conducted on September 20, 2016, at the Mill Valley Library.

Local, State, and Federal Agencies

As described in Section 1.5, several agencies participated in site visits and provided scoping input, including NMFS, RWCQB, CDFW, California State Parks, and USACE.

<u>Local, State, and Federal Interest Groups</u>

As described in Section 1.5, several citizen groups and nonprofits provided scoping input including Federated Indians of Graton Rancheria, People for a Golden Gate National Recreation Area, Sierra Club, Marin Conservation League, Save our Seashore, Watershed Alliance of Marin, National Parks Conservation Association, Environmental Action Committee of West Marin, Mount Tam Task Force, and Save the Redwoods League.

Chapter 6
List of Preparers

Name	Title	Role
National Park Service		
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Amy Hoke	Historical Landscape Architect	
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Alison Forrestel	Supervisory Vegetation Ecologist	
Bill Merkle	Wildlife Ecologist	
Parks Conservancy		
Tania Pollak	Environmental Planner	Project Manager
Horizon Water and Environment		
Michael Stevenson	Principal	Project Manager, QA/QC
Ken Schwarz	Principal	Technical Reviewer
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Janis Offermann	Cultural Resources Practice Leader	Cultural Resources
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Debra Lilly	Senior Associate	Editor
Linda Littleton	Editor	Editor
Paul Glendening	GIS Analyst	GIS
Lorrie Jo Williams	Graphic Designer/Editor	Graphic Designer and Editor

Chapter 7
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Chapter 6: List of Preparers

None.