Old Samoa Parcel
Conceptual Mitigation Plan

On State Route 255, at Pacheco and Old Samoa Roads

Just West of the City of Arcata, Humboldt County

November, 2007

Table of Contents

PURPOSE OF CONCEPTUAL MITIGATION PLAN 2

MITIGATION PLAN OVERVIEW 3

SITE FEASIBILITY 4

MITIGATION DESIGN 5

IMPLEMENTATION, TIME SCHEDULE 7

LONG-TERM MANAGEMENT 7

Exhibits

Exhibit 1 – Old Samoa (Demello) Parcel Location Map……..…9

Exhibit 2 – Resource Properties Map ……10

Exhibit 3 – 1941 Aerial Photo of Parcel ……11

Exhibit 4 – Aerial Photo Plan View (2005) ……...……12

Exhibit 5 – Site Sketch ……...……13

Exhibit 6 – Riparian Cross-Section ……...……14

SITE PHOTOS ……..……15

APPENDIX A. Mad River Bridges Mitigation Needs ……18

PURPOSE OF CONCEPTUAL MITIGATION PLAN

The California Department of Transportation (Caltrans) proposes to use wetland mitigation credits developed at an off-site location, to accomplish the coastal wetland mitigation that is necessary to fulfill the permit conditions for the Mad River Bridges Replacement project. Approximately 5.4 acres of off-site coastal wetland credits are anticipated to be necessary[1]. See Appendix A – Mad River Bridges Mitigation Needs.

Caltrans has acquired a 38.29-acre parcel (hereinafter referred to as the Old Samoa parcel), located between State Route 255 and Old Samoa Road, just west of the city of Arcata, in Humboldt County. This parcel is within the coastal zone, in close proximity to north Humboldt Bay. See Exhibit 1, page 9.

Caltrans proposes to utilize the Old Samoa parcel as a multiple-project mitigation site. This conceptual plan demonstrates the ability of the parcel to provide mitigation opportunity; laying out general strategies for wetland restoration at the site, based upon design input from the California Department of Fish and Game (Karen Kovacs, e-mail and pers. comm., May 2007).

Upon agency approval of the Old Samoa parcel as a mitigation site for the Mad River Bridges project, a final wetland mitigation (restoration) plan will be developed. The final mitigation plan, along with permit applications for construction of the multiple-project mitigation site will then be submitted to agencies.

Consultation with Coastal Commission staff (John Dixon, Staff Ecologist 4/06/07), the California Department of Fish and Game (Karen Kovacs, Senior Environmental Scientist) and the City of Arcata (Mark Andre, Deputy Director Environmental Services) have resulted in favorable conversations regarding the ability of the parcel to satisfy necessary mitigation for the Mad River Bridges Replacement project. The Old Samoa parcel is approximately four miles south of the Mad River Bridges project site (see map, page 21).

[1] Of the anticipated 5.4 acres of coastal wetland mitigation needed, 0.24 acre is proposed as a 4:1 mitigation for the combined permanent and temporary impacts to approximately 0.06 acre of less-than-three parameter wetland that cannot be mitigated on-site. The remaining 5.16 acres of off-site mitigation (in combination with the 1.72 acres of riparian restoration to be accomplished on-site at Mad River bridges) will facilitate a 4:1 mitigation ratio for the combined total permanent and temporary impacts to riparian vegetation of 1.72 acres.

MITIGATION PLAN OVERVIEW

The Old Samoa parcel currently functions as an agricultural parcel with haying and cattle grazing being the primary land use. A wetland delineation at the parcel was performed by the URS Corporation in the fall of 2006. A final wetland report was submitted to agencies for concurrence on February 16, 2007. While the United States Corps of Engineers (USACE) has yet to verify the jurisdictional determination, the majority of the parcel appears to meet the definition of a three-parameter wetland, and therefore the parcel also meets the definition of a coastal wetland. This agricultural wetland consists of grazed/hayed palustrine emergent wetland (Cowardin et al). See site photos pages 15 -17.

If Caltrans makes use of the parcel to accomplish mitigation through wetland restoration activities, the California Department of Fish and Game (CDFG) is in support of taking on long-term responsibility for the parcel; adding the parcel to its adjacent holdings within the Mad River Slough Wildlife Area. CDFG is interested in managing the Old Samoa parcel to support Aleutian cackling geese[2] foraging habitat. This management strategy involves maintaining short-grass habitat, requisite for goose foraging, through the use of continued agricultural practices (either seasonal cattle grazing or haying). Providing a refuge for the Aleutian goose will alleviate grazing pressures (browse competition) on private agricultural lands in the area, enhancing private agricultural endeavors.

Caltrans, in consultation with the CDFG, proposes to establish riparian plantings on approximately 1/3 of the property, predominantly at the parcel's northern boundary. Establishing riparian vegetation at this location will diversify and enhance existing wetland habitat functions and values at the site, as well serve as a compliment to surrounding resource properties.

Caltrans and the CDFG also propose a de-leveling of the parcel's artificially flattened and drained topography. This would entail grading or excavation on approximately 1/3 of the parcel. Modifying the parcel's topography would allow more water to remain on site over a longer period of time, thereby enhancing existing seasonal wetlands.

Caltrans and the CDFG also propose prescribed agricultural practices (seasonal grazing or haying) on the parcel, outside the area of proposed riparian plantings, to maintain short-grass habitat for the Aleutian goose. Lastly, ownership of the parcel would be transferred from Caltrans to the CDFG to be added to their Mad River Slough Wildlife Area (and preserved in perpetuity). The Mad River Slough

[2] The Aleutian goose, a former Federal threatened/endangered species, was successfully de-listed in March 2001.

Wildlife Area is managed to protect, restore and enhance coastal wetlands. See Exhibit 2, Resource Properties Map.

If utilized for mitigation, the existing billboard on the parcel would be dismantled and removed from the site. See page 13 for site sketch.

Because of the adjacency of the proposed mitigation site to the Mad River Slough Wildlife Area (502 acres) and the City of Arcata Marsh and Wildlife Sanctuary (307 acres), wetland restoration and preservation of the 38.29-acre Old Samoa parcel will further serve to strengthen habitat connectivity goals in north Humboldt Bay. See Resource Properties Map, page 10.

SITE FEASIBILITY

Historic aerial photos from the 1940's reveals a faint signature of the dendritic pattern of an estuary slough channel on the Old Samoa parcel (see Exhibit 3). However, this parcel has been actively managed for agricultural use for many years. Current hydrologic sources are fresh water; there is no existing connectivity for saltwater influence.

Current land use management practices of the Old Samoa parcel were discussed with the owner (Cliff Demello, June 6, 2006). The parcel owner stated that the site is hayed in early summer and then yearling cows are allowed to graze the site throughout winter. (The landowner noted that wet soil conditions preclude the grazing of larger animals.) Vegetation is then allowed to recover through spring, without grazing, in preparation for the annual hay harvest.

The site appears to be land-planed, to promote site drainage from the north end of the parcel to a drainage ditch located at the south end of the parcel, adjacent to Old Samoa Road. Across the parcel, approximately every 100', south draining swales have been cut perpendicular to the slope to aid in site drainage. Topography is relatively flat with an engineered gradual slope running towards the southeast corner. Precipitation and a high water table provide hydrology at the site. (URS, Jurisdictional Delineation of the Mad River Bridges Mitigation Study Area, February 2007).

On April 6, 2006, a drive-by assessment of the parcel revealed some standing water along its western and southern edges. Waterfowl were noted to be utilizing the parcel. URS (Jurisdictional Delineation, February 2007) utilized *A Manual of California Vegetation* and noted that the parcel is dominated by a mix of Introduced perennial grassland series and California annual grassland series (consisting primarily of European rye grass [*Lolium mutiflorum*]), with the Spikerush series being present in swales.

As previously mentioned, a portion of the Old Samoa parcel contains what was once salt marsh habitat. Bayfront levees, tidegates, dikes, Old Samoa Road and filled former slough channels are current impediments to tidal influence at the site. In its natural state the area would likely have been vegetated by native salt-tolerant species such as pickleweed (*Salicornia virginica*), saltgrass (*Distichlis spicata*), jaumea (*Jaumea carnosa)* and Humboldt Bay owl's clover (*Castilleja ambigua* ssp. *humboldtiensis*).

MITIGATION DESIGN

The Old Samoa parcel is proposed as a mitigation site utilizing a freshwater wetland restoration approach. The area is currently managed for agricultural production; introduced pasture grasses dominate vegetative cover. The proposed mitigation approach would achieve habitat type (and strata) diversification through the establishment of extensive riparian plantings. This approach would also manage the parcel such that existing seasonal wetlands could retain more water over a longer period of time.

Establish Riparian Habitat

Approximately 13 acres of riparian habitat is proposed to be established with the majority of this along the parcels' north boundary adjacent to State Route (SR) 255. A stringer of riparian along the west boundary is also proposed to be planted; connecting to planned riparian plantings on CDFG's newly acquired Moranda parcel, as well as previously established riparian habitat further west, within the Mad River Slough Wildlife Area. Within the riparian establishment area, modifications to topography (at random depths of 6"- 18") would be utilized to ensure adequate water supply. See exhibits 2, 5 and 6.

Creating riparian habitat at this location will provide the following new conditions at the site: tree canopy and understory habitat - providing cover for birds and mammals; neo-tropical bird nesting habitat; perch sites for raptors, and a visual barrier for the CDFG refuge property. Tall grass habitat within this brushy area will provide habitat for small mammals (i.e. raptor prey species). Further, the establishment of riparian habitat between the highway (SR 255) and the adjacent existing wetlands will serve as a buffer, filtering roadside runoff and thereby increasing water quality. Riparian habitat at this location will also increase the habitat functions and values for adjacent wetlands.

Species to be utilized in the planting plan are likely to include willow (*Salix* sp.), alder (*Alnus rubra*), Sitka spruce (*Picea sitchensis*), cascara (*Rhamnus purshiana*), as well as other native shrubs. Riparian plantings will be fenced to exclude cattle.

Re-establish Topography

The parcel has been flattened and drained to increase agricultural production. It is proposed to utilize excavation and grading to restore a more natural hydrologic regime to the seasonal wetlands. Existing low spots can be enlarged and shallow pools can also be excavated to hold more water over a longer period of time. Caltrans and the CDFG would like to monitor the parcel through the next rainy reason (07/08) and based upon observed conditions, develop a final grading plan for the site. It is anticipated that as much as 1/3 of the parcel (approximately 13 acres) would potentially be de-leveled.

Retaining hydrology on site through de-leveling, thus creating wetter habitat, is likely to preclude the presence of introduced pasture grasses; thereby restoring a predominance of hydrophytic native plants. Functions and values to be enhanced include groundwater recharge and discharge (water will be retained on land longer prior to outlet in bay), increased flood flow attenuation, increased sediment/toxicant retention and nutrient removal/transformation, and increased wildlife diversity and abundance.

Mitigation Design Conclusions

The existing grazed seasonal wetland will be significantly enhanced through the establishment of riparian plantings, and by modifying the artificially flattened topography to hold more water over a longer time period. Use of the Old Samoa parcel for mitigation purposes will be a positive contribution to current habitat preservation and connectivity goals in north Humboldt Bay. (See page 10.)

The CDFG (Karen Kovacs, pers. comm. 5/22/2007) believes the best use of the Old Samoa parcel is to provide habitat that is complimentary to the surrounding resource properties. CDFG believes this can best be achieved through the establishment of riparian habitat (providing vertical structure) as well as the proposed de-leveling (holding more water over a longer period).

Retaining the parcel within the public domain will offer long-term protection in perpetuity, achieving resource conservation and stewardship, while protecting water quality and wildlife resource values from the potential and unknown pressures of private management and/or zoning changes. Retaining the parcel in public domain may also provide for increased recreational opportunities within the coastal zone.

It is estimated that the cost to produce the proposed mitigation would be roughly $800,000 (not including endowment or monitoring costs). This dollar amount includes parcel acquisition and costs associated with the proposed de-leveling and plant establishment.

In lieu of an endowment, the CDFG has requested that Caltrans provide funding to the joint-proposed CDFG/City of Arcata - McDaniel Slough Restoration project, to fund the cost of additional work in construction of a flood levee that would allow expanded saltwater restoration onto the newly acquired Moranda parcel. An initial cost estimate on this additional construction work is $175,000 (Mark Andre, pers. comm. 4/25/07).

Funding for the mitigation project would be incorporated into project funding for the Mad River Bridges Replacement, as well as other applicable Caltrans' projects that make use of mitigation credits at the site. Mitigation at the Old Samoa parcel could be constructed as early as the fall of 2008, however it is more likely in summer 2009. If the parcel is developed as a mitigation site, obligatory monitoring reports to resource agencies will be necessary.

IMPLEMENTATION, TIME SCHEDULE

Studies to determine the de-leveling design are anticipated to be complete prior to May 2008. Caltrans in consultation with the CDFG will create a final mitigation design. A final mitigation and monitoring plan, along with permit applications for the mitigation construction itself, is anticipated to be submitted to agencies by December 2008 (it may be possible to submit by mid-summer 2008). Caltrans and/or an agency partner will direct the mitigation construction. It is likely that the mitigation project could be implemented in the summer of 2009 (however it is possible that it may occur as early as fall of 2008).

LONG-TERM MANAGEMENT

Caltrans will be responsible for monitoring and maintaining the riparian habitat until successful establishment has been achieved. To address long-term management responsibilities, Caltrans will develop an agreement with the CDFG to transfer fee title of the mitigation site, as well as all management in perpetuity responsibilities.

References

Andre, Mark. City of Arcata, Deputy Director Environmental Services. E-mail, April 25, 2007.

City of Arcata and the California Department of Fish and Game. March 2006. McDaniel Slough Wetland Enhancement Project. Draft EIR.

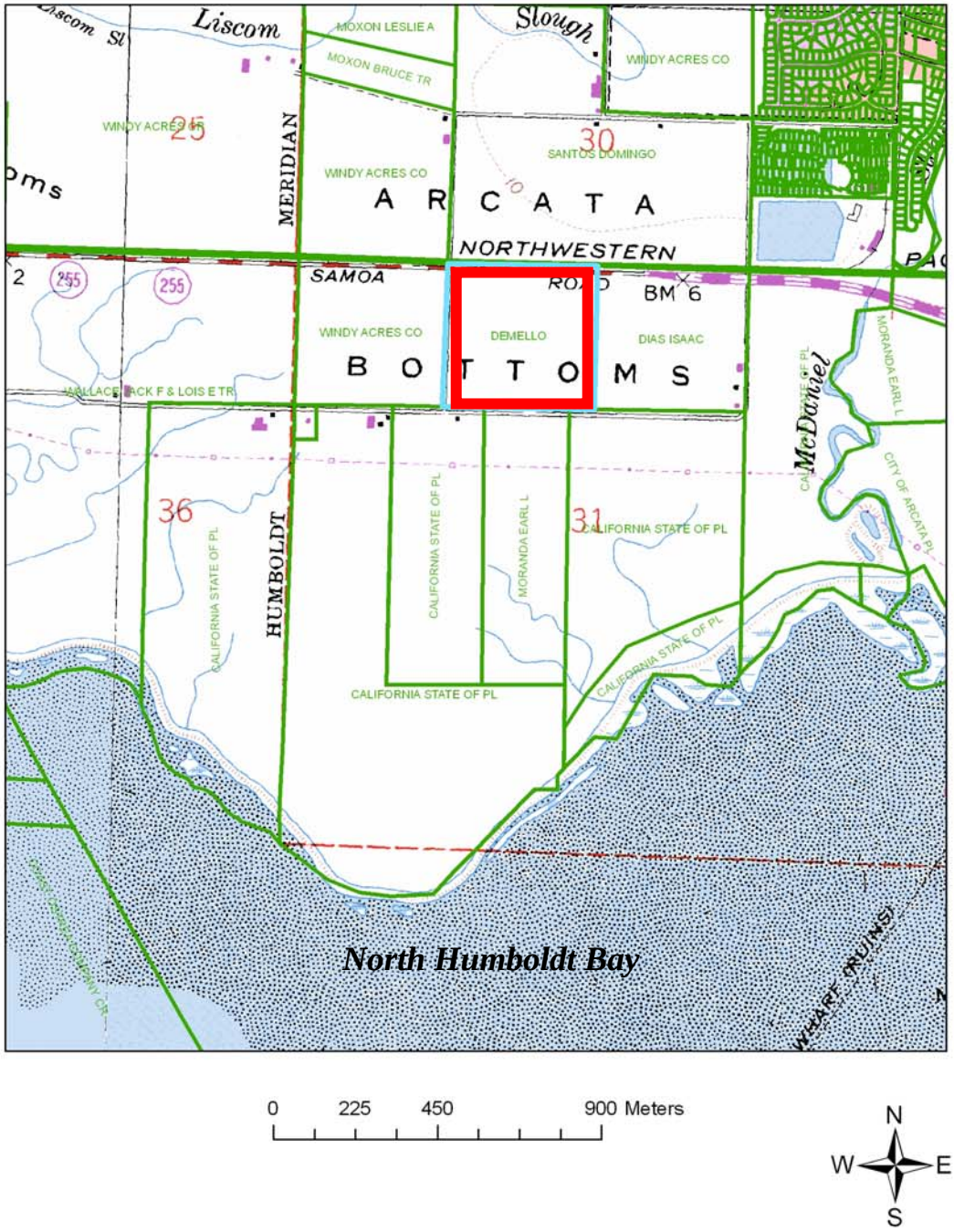
Cowardin L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deep Water Habitats of the United States. United States Fish and Wildlife Service. (FWS/OBS-79/31). 103pp.

Kovacs, Karen. California Department of Fish and Game, Senior Environmental Scientist Supervisor. Eureka Office, Eureka, California. E-mail May 18, 2007.

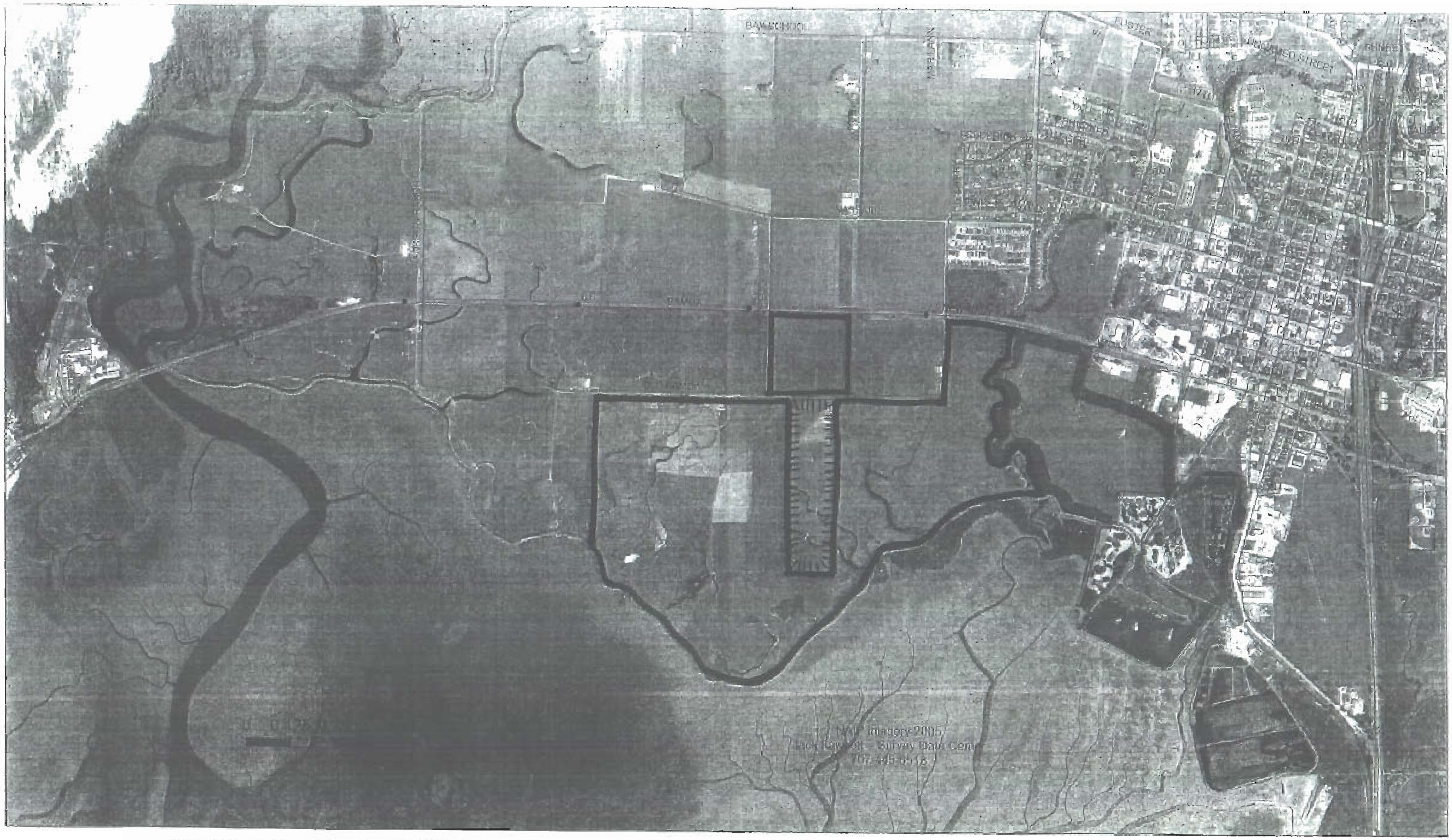
Kovacs, Karen. California Department of Fish and Game, Senior Environmental Scientist Supervisor. Eureka Office, Eureka, California. Personal Communication, May 22, 2007.

URS Corporation. February 2007. Jurisdictional Delineation of the Mad River Bridges Mitigation Study Area. Prepared for Caltrans.

Exhibit 1 – OLD SAMOA (DEMELLO) PARCEL LOCATION MAP



On State Route 255, at Pacheco and Old Samoa Roads, Humboldt County. (Portion of the Arcata South quadsheet.)



CDFG Mad River Slough Wildlife Area

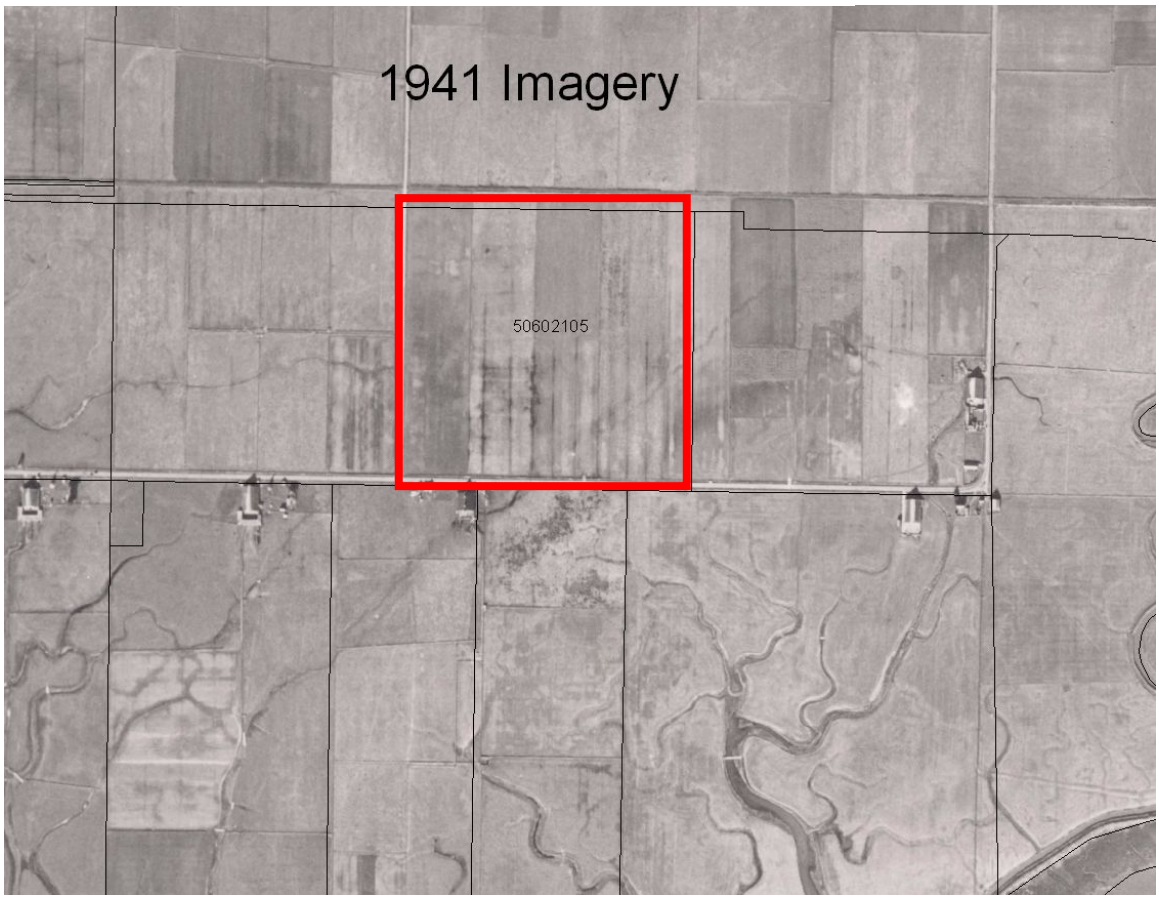
Old Samoa Parcel

CDFG New Parcel (Moranda)

City of Arcata Marsh and Wildlife Sanctuary

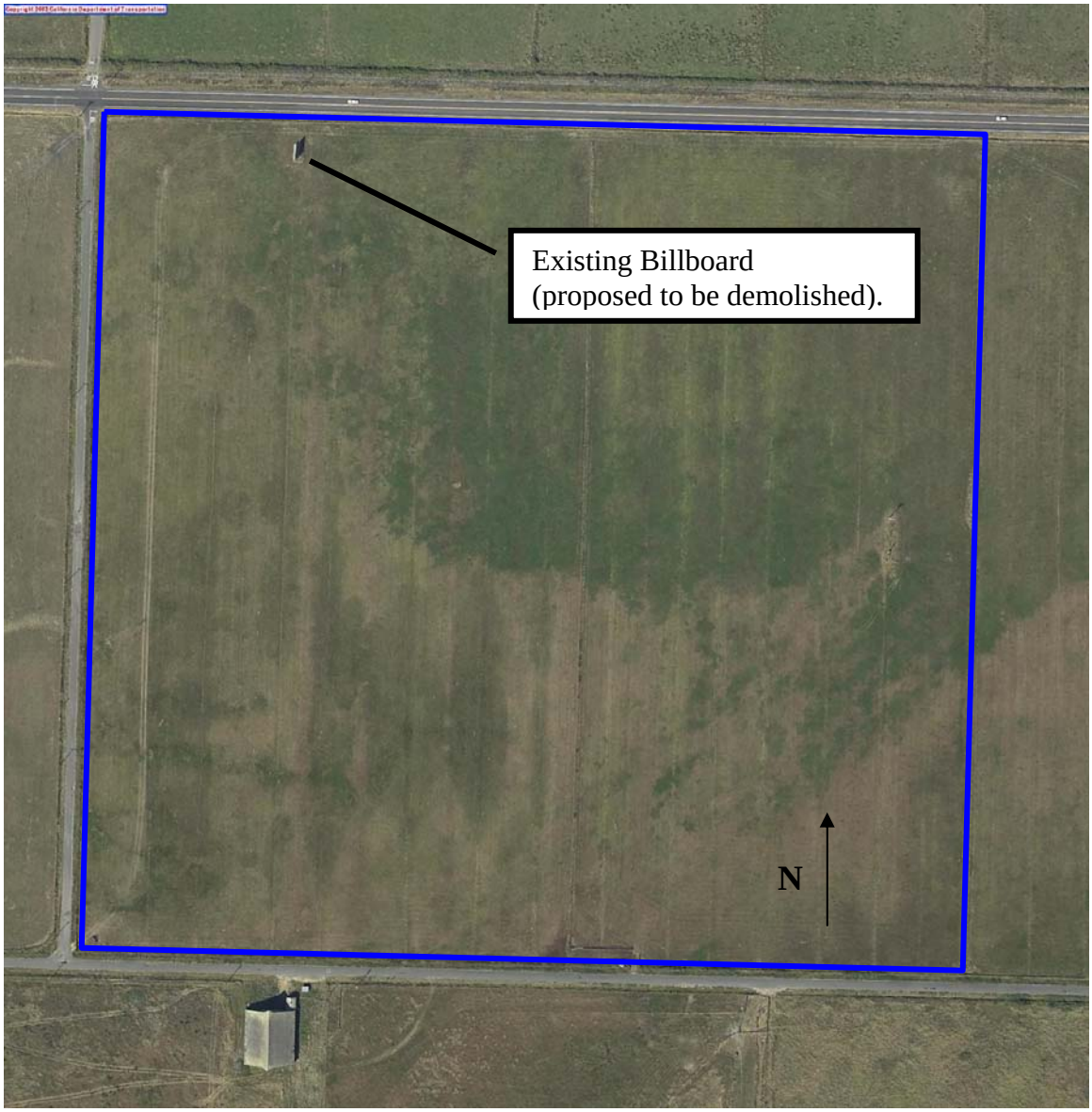
FIGURE 2. Resource Properties Map

Exhibit 3 – 1941 AERIAL PHOTO OF PARCEL



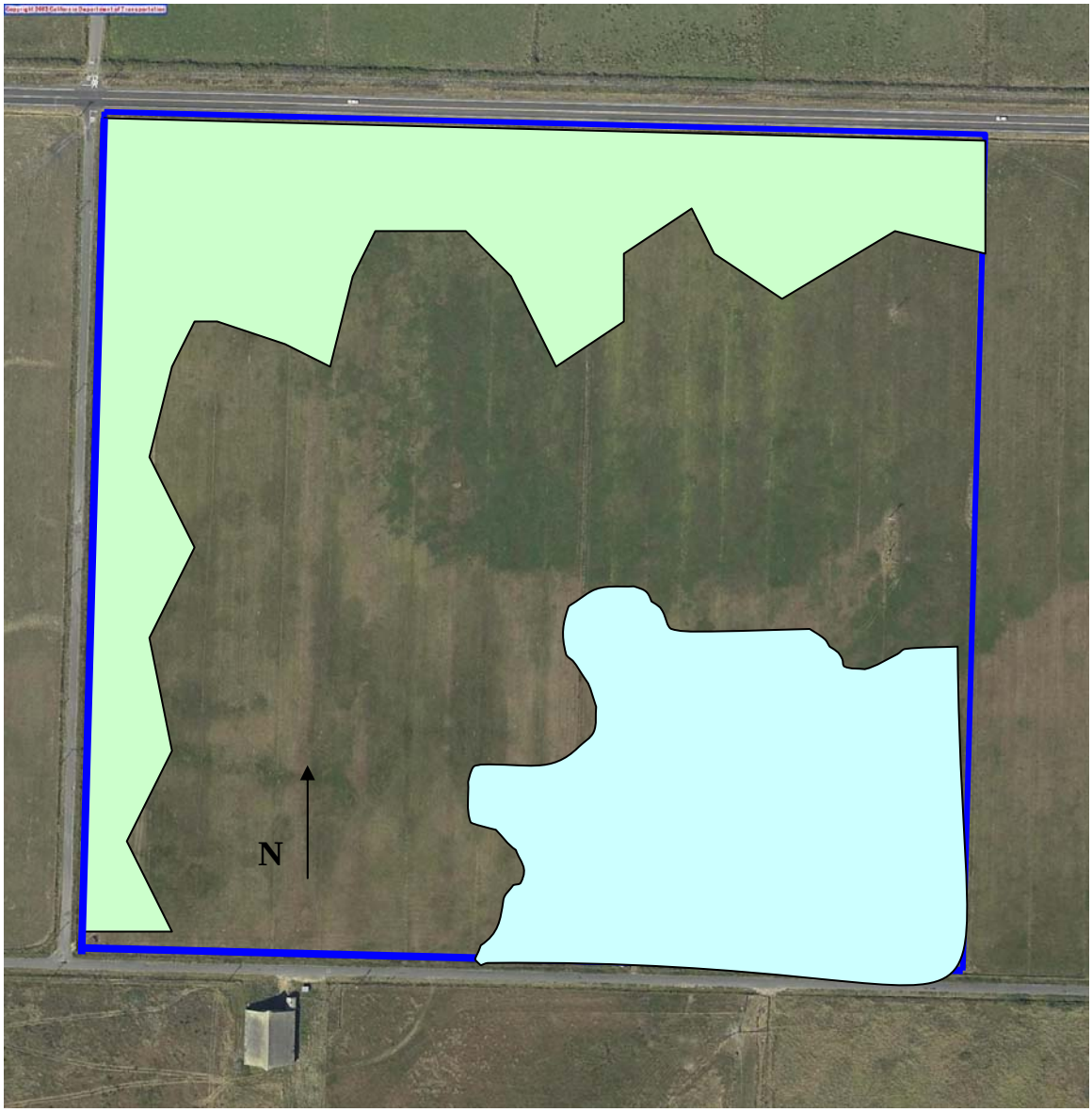
Old Samoa Parcel (50602105). On State Route 255, at Pacheco and Old Samoa Roads, Humboldt County.

Exhibit 4 – AERIAL PHOTO PLAN VIEW (2005)



Old Samoa Parcel boundary, and existing fenceline (approximate).

Exhibit 5 – SITE SKETCH

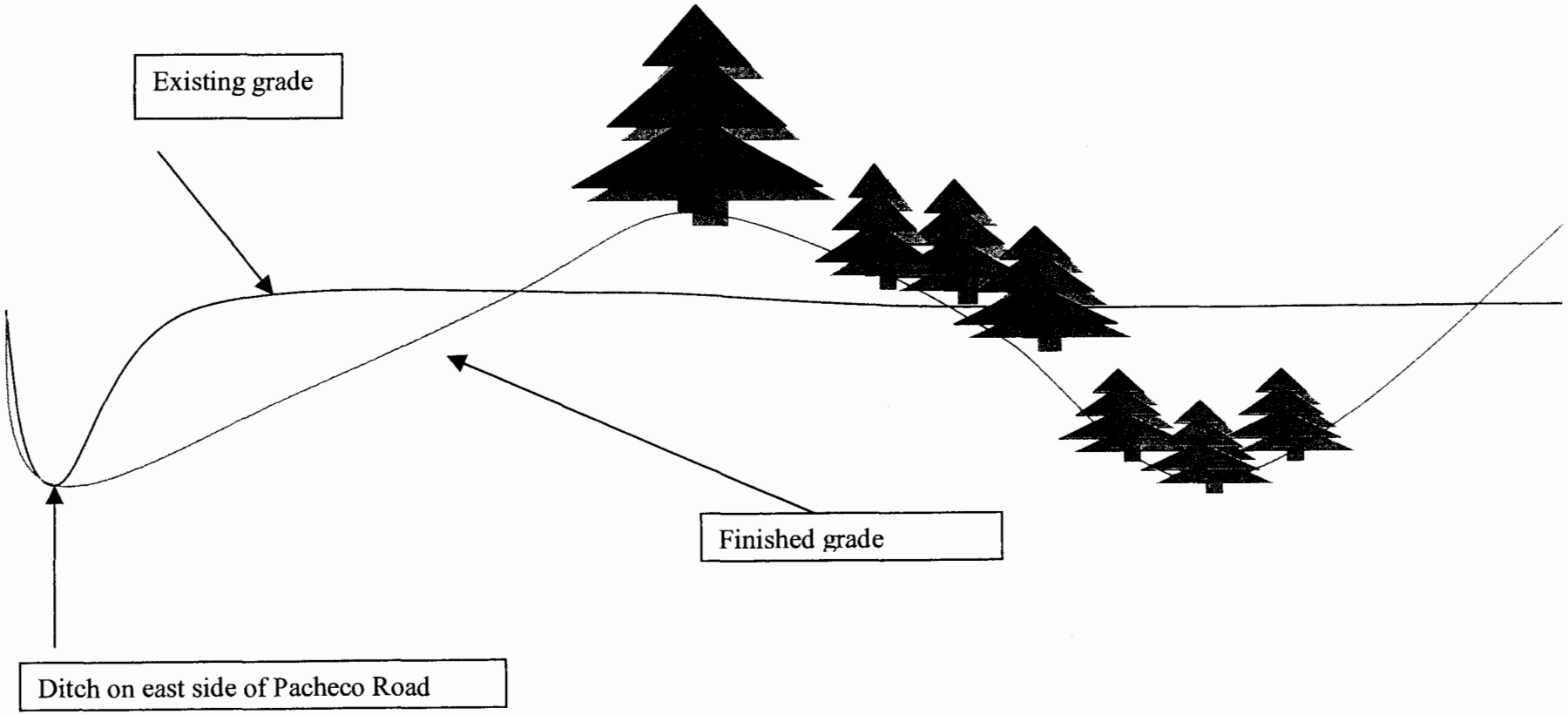


Old Samoa Parcel boundary, and existing fenceline (approximate).

Proposed riparian habitat (approximate).

Proposed de-leveling (approximate).

Exhibit 6 – RIPARIAN CROSS-SECTION (For planning purposes only.)



Planting mix of Sitka spruce and cascara on "higher "ground, red alder and taller *Salix* species in middle, shrub willow at bottom. Exterior fencing (5 strand) and interior (single strand electric fencing) to protect against livestock grazing and provide site security. Hold back monies for 1-2 water troughs, water line (plastic pipe) from well to trough(s) and one water control structure (concrete flashboard riser)

Geese in April 2006 (view from south looking north).

Freshly Hayed - Late June 2006 (view from N/W corner looking S/E).

Freshly Hayed - June 2006 (view from south looking north).

Grazed after Haying – late October 2006 (view from south to north).

Cows in late October 2006 (view from south to north).

Appendix A

Mad River Bridges Mitigation Needs (EA 296101)

The Federal Highway Administration (FHWA) and the California Department of Transportation (Caltrans) are proposing replacement of the Mad River Bridges on State Route 101 in Humboldt County. The bridge project is located between the towns of Arcata and McKinleyville on State Route (SR) 101, between post miles (PM) 89.1/90.4 (see Exhibit 1, page 3). Construction of the bridge project is likely to begin in 2008 and require a four-year construction scenario.

Proposed construction of the Mad River bridges is anticipated to result in temporary and permanent impacts to both United States Army Corps of Engineers (USACE) and California Coastal Commission jurisdictional wetlands. The project will require compensatory wetland mitigation. Because of the project's anticipated four-year construction scenario, impacts have been tabulated by year of construction impact, in an effort to articulate the temporal impacts to jurisdictional resources due to project construction (see tables 1 and 2, pages 19 and 20).

While all USACE wetland mitigation can be accomplished on site, off-site mitigation of an additional 5.4 acres of other coastal wetland is likely to be required. (An on-site mitigation plan has been prepared separately [*Mad River Bridges Replacement On-Site Mitigation and Monitoring Plan*, updated November 2007]).

Of the anticipated 5.4 acres of coastal wetland mitigation needed, 0.24 acre is proposed as a 4:1 mitigation for the combined permanent and temporary impacts to approximately 0.06 acre of less-than-three parameter wetland that cannot be mitigated on-site. The remaining 5.16 acres of off-site mitigation (in combination with the 1.72 acres of riparian restoration to be accomplished on-site at Mad River bridges) will facilitate a 4:1 mitigation ratio for the combined total permanent and temporary impacts to riparian vegetation of 1.72 acres.

5.4 acres of coastal wetland credit at the Old Samoa parcel are proposed to be utilized as compensatory mitigation to satisfy Coastal Development permit conditions for the Mad River Bridges Replacement project. The Old Samoa parcel is approximately four miles south of the Mad River Bridges project site (see map, page 21).

Table 1.) Years One to Three: Mad River Bridges Project Construction
Adverse Impacts to Jurisdictional Wetlands/Waters and Proposed Mitigation
(Units given in acres).

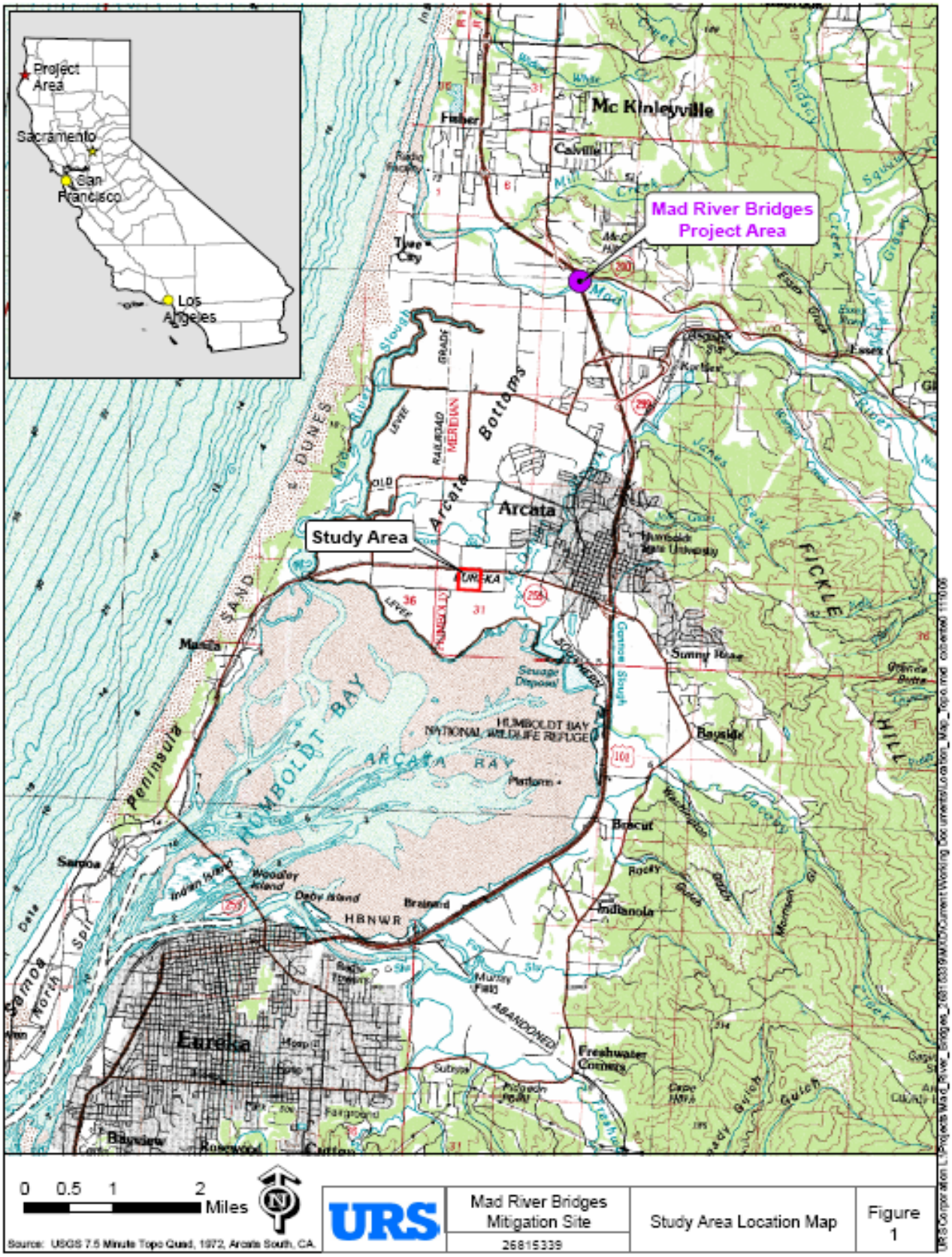
Identifier (See attached Impact Mapping and Surface Water Flow Diversion)	**Temporary Impact**	**Permanent Impact**	**Proposed Mitigation**
USACE Jurisdictional Wetlands and other Waters of the US			
Water C (scour pool at existing pier footing)		0.02	New scour feature will be constructed downstream of existing.
Various Impacts to River Channel in Every Year	2.1		None.
Total	**2.1**	**0.0**[3]	**Construct new scour feature**[4]**.**
Additional Coastal (<3 parameter) Wetlands			
Polygon 1, 21 and 24 (riparian)		0.35	Restoration on-site 1:1 post impact, and mitigate off-site 3:1.
Polygon 2 (<3 parameter wetland)		0.01	Mitigate off-site at 4:1.
Polygon 34, 35 and 16 (<3 parameter wetland)	0.05[5]		"
Polygon 17, 18, 22, 23, 27, 36, 37 and 38 (riparian)	0.55		Restoration on-site 1:1 post impact, and mitigate off-site 3:1.
Polygon 19 and 26 (non-woody riparian)	0.22		"
Polygon 20 and 25 (non-woody riparian)		0.11	"
Polygon 28, 29, 30, 31, 32 and 33 (riparian)		0.43	"
Total	**0.82**	**0.90**	**<Three parameter wetland mitigation OFF-SITE = 0.24 acre**; **Riparian restoration ON-SITE = 1.72 acres**, and **Riparian mitigation OFF-SITE = 5.16 acres**.

[3] The proposed new bridge structures will result in a decrease of permanent fill within the river of 0.06 acre (versus the existing structures). Therefore, the project will result in no permanent loss to waters of the US.
[4] No mitigation is proposed for temporary impacts to Waters of the US, or for 0.01 acres permanent impact to Waters of the US.
[5] Coastal Commission staff has stated that temporary impacts lasting greater than one year should be mitigated at the same rate as permanent impacts (a 4:1 ratio).

<u>Table 2.) Year Four</u>: Mad River Bridges Project Construction, Adverse Impacts to Jurisdictional Wetlands/Waters and Proposed Mitigation (Units given in acres).

Identifier (See Supplemental Coastal Wetland Report Impact Mapping)	**Temporary Impact**	**Permanent Impact**	**Proposed Mitigation**
USACE Jurisdictional Wetlands and other Waters			
Polygon 4 (emergent persistent)		0.04	On-site USACE wetland creation at 1:1, and on-site less-than-three-parameter wetland creation at 3:1.[6]
Polygon 3 and 7 (emergent persistent)	0.02		Restore on-site 1:1 (one season impact; area will immediately re-establish).
Various Impacts to River Channel in Every Year	2.1		None.[7]
Total	**2.12**	**0.04**	**USACE On-site wetland creation = 0.04 acre** And <three parameter wetland creation = 0.12 acre.
Additional Coastal (<3 parameter) Wetlands			
Polygon 5 and 6		0.03	On-site wetland creation at 4:1 (see footnote 6).
Polygon 8 (riparian)	0.01		Restore on-site 1:1 (one season impact; area will immediately re-establish).
Polygon 9 and 11 (non-woody riparian)	0.05		"
Polygon 10 (non-woody riparian)		0.01	Restoration on-site 1:1 post impact, and mitigate off-site 3:1.
Total	**0.06**	**0.04**	**Additional Coastal On-site wetland creation = 0.16 acre.**

[6] Wetland impacts associated with Year Four construction could be fully mitigated on-site at a 1:1 ratio (USACE has approved this), however Caltrans anticipates a total 4:1 ratio will be required per Coastal Commission staff review.
[7] No mitigation is proposed for temporary impacts to Waters of the US.


Project Area
Sacramento
San Francisco
Los Angeles
Mad River Bridges Project Area
Study Area
Mc Kinleyville
Arcata
Eureka
Samoa
Bayside
Indianola
Freshwater
HUMBOLDT BAY
ARCATA BAY
HUMBOLDT BAY NATIONAL WILDLIFE REFUGE
HBNWR
0 0.5 1 2 Miles
Source: USGS 7.5 Minute Topo Quad, 1972, Arcata South, CA.
URS
Mad River Bridges Mitigation Site
26815339
Study Area Location Map
Figure 1

Jones & Stokes

Transmittal Memorandum

Date: November 6, 2007

To: Kelley Garrett, Caltrans

From: Rick Oestman, Jones & Stokes

Subject: **Analysis of Pile Driving Noise Associated with the Mad River Bridge Replacement Project**

Enclosed are three reports that were prepared under Task Order 12 for the Mad River Bridge Replacement Project.

***Analysis of Pile Driving Noise Impacts to Listed Salmonids for the Mad River Bridge Replacement Project*: August 23, 2007 (Revised November 5, 2007)**
This report analyzes anticipated underwater sound that would be expected to be generated from impact pile-driving of 7-foot-diameter piles at the Mad River project, assuming that one pile section would be driven in a day. It includes an appendix that provides the basis for the source sound levels and underwater sound transmittance used in the analysis. Very minor changes were made during this revision, including 10-meter predictions for Pier 3. Ten-meter predictions for underwater noise are not valid for Piers 2 and 4 because they are located more than 10 meters from the water (also noted in the revised document). Tables 5 and 6 were updated.

***Supplemental Pile-Driving Noise Analysis for the Mad River Bridge Replacement Project—DRAFT*: November 2, 2007**
This memorandum analyzes anticipated underwater sound that would be expected to be generated from impact pile-driving of 7-foot-diameter piles at the Mad River project, assuming two pile sections would be driven in a day. It relies on the August 23 report and appendix to support the analysis.

***Mad River Bridge Replacement Project: Evaluation of Underwater Noise Generated by Use of Smaller Piles (30-Inch-Diameter)—DRAFT*: November 6, 2007**
This report analyzes anticipated underwater sound that would be expected to be generated from impact pile-driving of 30-inch-diameter piles at the Mad River project, assuming 10 to 15 pile sections would be driven in a day. This report addresses the California Coastal Commission's request to evaluate whether potential impacts of pile-driving noise would be lessened if the replacement bridges were built with smaller piles. It also contains an appendix that provides the basis for the source sound levels and underwater sound transmittance used in the analysis.

We understand that a preliminary draft of the first report, dated July 24, was circulated to certain regulatory staff. It appeared from the questions that it generated that the draft being reviewed

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was not a complete package. Specifically, the National Marine Fisheries Service (NMFS) reviewer appeared not to have access to the tables used to predict sound levels or the appendix that provided the basis of the estimated source sound levels. We firmly believe that it would be inappropriate to use data collected in open, deep water as the basis of the estimated source sound level in this analysis. The Mad River project involves piles driven on land, within dewatered cofferdams or cofferdams with bubble curtains, and adjacent to very shallow water—all factors that affect the transmittance of sound and the expected level of sound in water. The source levels we use in the analysis are based on measured empirical data collected in similar conditions to those that occur at the Mad River Bridge.

Please also note that in the prediction tables, there are several distances that have N/A rather than a predicted sound level. This occurs when that distance from the pile is outside the wetted channel (in the upland).

The results of the analyses reported here indicate that the project as designed (with thirteen 7-foot piles) would not exceed single strike interim criteria for peak sound or single event level (SEL). Using the NMFS accumulation method, accumulated SEL in excess of 187 $dB_{SEL(Accumulated)}$ for a day of pile driving would extend to between 45 and 90 meters from the piles if one pile section is driven in a day, and from 65 to 170 meters from a pile if two or three pile sections were driven in a day (depending on which section[s] are being driven).

When comparing these results to the use of 30-inch piles, the analyses indicate that the distance at which accumulated SEL would extend based on a day of pile driving would be much larger (25 to 300 meters, depending on which sections is being driven) than experienced driving one, two, or even three 7-foot-diameter pile sections in a day. Further, because more piles would need to be driven, the number of days that the surrounding water would be exposed to elevated sound levels would also be greater.

We hope that the enclosed set of reports will provide the agencies with the additional information they need to draw conclusions regarding the expected source sound levels and underwater transmittance for the Mad River Bridge Replacement Project. We recommend that we meet with interested agency staff personally to address any additional concerns to make this process as expedient as possible.

Analysis of Pile Driving Noise Impacts to Listed Salmonids for the Mad River Bridge Replacement Project

EA 01-296101

Contract 03A1317 Task Order 12

August 23, 2007

Revised: November 5, 2007

Table of Contents

Introduction 1
Pile Driving Activities Generating Noise 1
General Habitat Conditions and Fish Presence 4
Noise Assessment 6
Potential Effects 8
Comparison of Estimated Sound Generation to Interim Criteria 8
Avoidance and Minimization Measures. 12
Timing of Pile Driving 12
Other Avoidance and Minimization Measures 13
References 14
List of Preparers 15

Appendix I. Caltrans Highway 101 Bridge Replacement Mad River Field Survey

Appendix II. Analysis of Underwater Sound Levels—Mad River Bridge Replacement Project at U.S. Highway 101 in Humboldt County

List of Tables and Figures

Page

Table 1 Current Status of Listing and Critical Habitat for Listed Salmonid ESUs Occurring in the Mad River 1
Table 2 Number and Size of Piles to be Driven at the Mad River Bridge 1
Table 3 Distance between Abutments / Piers and the Typical Summertime and Wintertime Wetted Channel of the River 2
Table 4 Anticipated Pile-Driving Activity for the Mad River Bridge Replacement 3
Table 5 Year 1 Noise Impact Assessment—Southbound Bridge Piers and Abutments ..... follows 6
Table 6 Year 2 & 3 Impact Assessment—Northbound Bridge Piers and Abutments ..... follows 6
Table 7 Distance to 187 dB SEL accumulated for Pier 3 and Pier 4 Piles Assuming Four Sections Per Pile 11

Follows Page

Figure 1 Existing Habitat Features in the Vicinity of the Mad River Bridge 1

List of Abbreviated Terms

Caltrans	California Department of Transportation
CISS	cast in steel shell
dB	decibels
ESUs	evolutionarily significant units
I&R	Illingworth and Rodkin, Inc.
NMFS	National Marine Fisheries Service
OG	Original Ground
peak	Peak Sound Pressure
RMS	root mean square
RSP	rock slope protection
SEL	Sound Exposure Level

Introduction

This report evaluates the potential effects of sound generated from pile driving activities during the Mad River Bridge Replacement Project on listed salmonid evolutionarily significant units (ESUs). The listed ESUs include California Coastal Chinook salmon, Southern Oregon/Northern California Coast Coho salmon, and Northern California Steelhead (both summer and winter run). General information regarding the distribution and biology of these ESUs has been previously provided in the original Biological Assessment and Biological Opinion regarding this action and will not be repeated here. However, changes to the status and critical habitat designations have occurred since the February 2005 Biological Opinion and are reported in Table 1.

Table 1. Current Status of Listing and Critical Habitat for Listed Salmonid ESUs Occurring in the Mad River

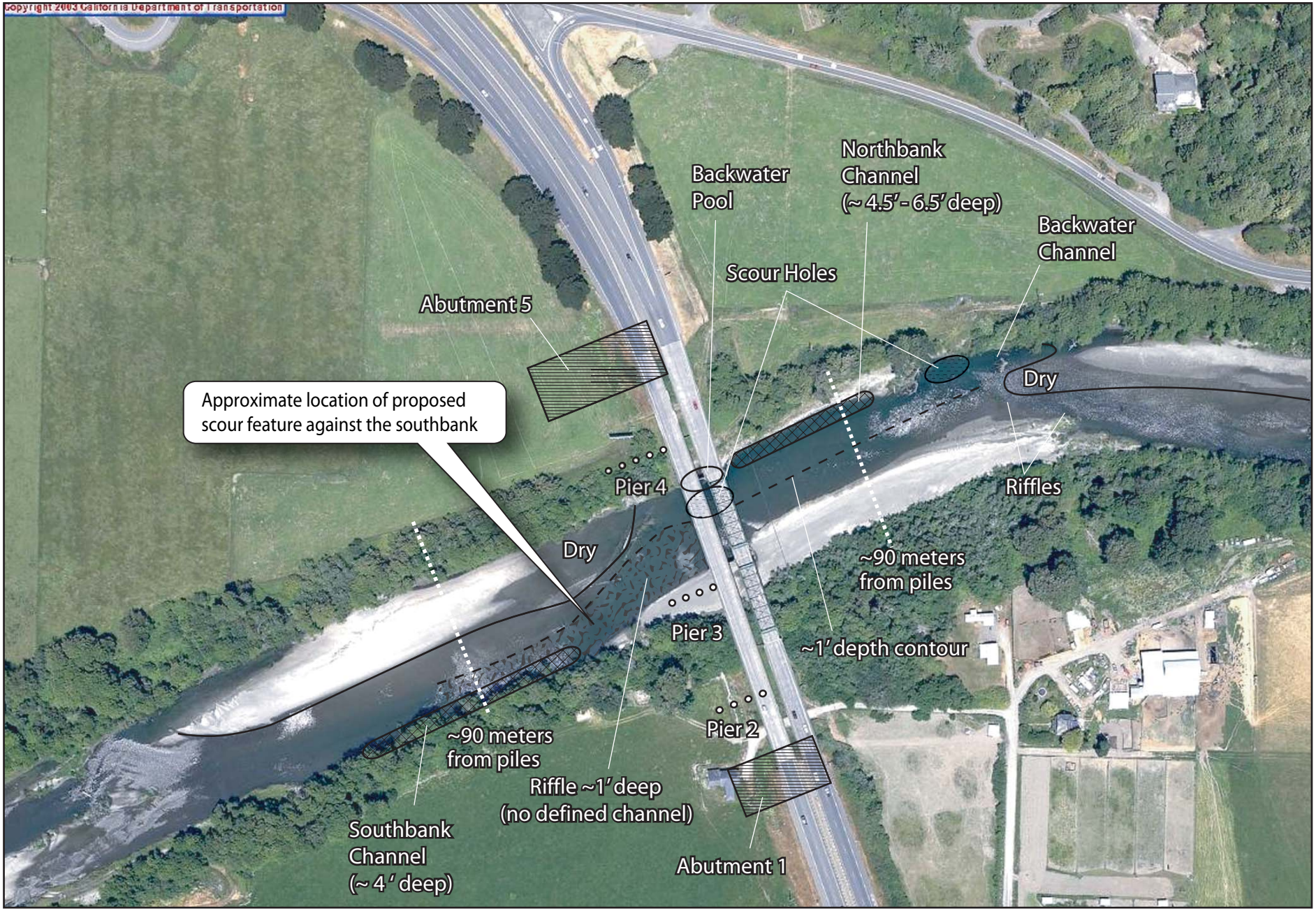
ESU	California Coastal Chinook salmon	Southern Oregon/ Northern California Coast Coho salmon	Northern California Steelhead
Listing Status reaffirmed	Threatened 70 FR 37160 June 28, 2005	Threatened 70 FR 37160 June 28, 2005	Threatened 71 FR 834 January 5, 2006
Critical Habitat Designation	70 FR 52488 September 2, 2005	64 FR 24049 May 5, 1999	70 FR 52488 September 2, 2005

Pile Driving Activities Generating Noise

This analysis addresses noise from pile driving only. As part of the replacement of the U.S. 101 bridge over the Mad River, the California Department of Transportation (Caltrans) will replace both the northbound and southbound bridges. The new bridges will include impact pile driving of 13 2.2-meter (7-foot) diameter cast in steel shell (CISS) steel piles, four 1.2-meter (4-foot) diameter CISS steel piles (at Pier 2), and 79 0.36-meter (14-inch) wide H-type piles (Table 2). Figure 1 shows the location of the new piles.

Table 2. Number and Size of Piles to be Driven at the Mad River Bridge

Pier / Bridge	Southbound Lanes	Northbound Lanes
Abutment 1 (at south end of bridge)	H-type piles (13 0.36-meter)	H-type piles (14 0.36-meter)
Pier 2	2 (2.2-meter diameter CISS piles) 4 (1.2-meter diameter CISS piles)	2 (2.2-meter diameter CISS piles)
Pier 3	2 (2.2-meter diameter CISS piles)	2 (2.2-meter diameter CISS piles)
Pier 4	2 (2.2-meter diameter CISS piles)	3 (2.2-meter diameter CISS piles)
Abutment 5 (at north end of bridge)	H-type piles (20 0.36-meter)	H-type piles (32 0.36-meter)



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Jones & Stokes

Figure 1
Existing Habitat Features in the Vicinity of the Mad River Bridge

Table 3 shows the approximate distance between the piles to be driven and the typical summertime and wintertime wetted channel of the Mad River. No piles will be impact driven within the wetted channel of the river.

Table 3. Distance between Abutments / Piers and the Typical Summertime and Wintertime Wetted Channel of the River

Pier / Bridge	Southbound Lanes	Northbound Lanes
Abutment 1 (south)	90 meters or greater (approximately 78 meters or greater in winter)	90 meters or greater (approximately 78 meters or greater in winter)
Pier 2	65 meters (approximately 43 meters in winter)	65 meters (approximately 43 meters in winter)
Pier 3*	3 meters (winter N/A)	5 meters (winter N/A)
Pier 4	15 meters (winter N/A)	15 meters (winter N/A)
Abutment 5 (north)	70 meters (approximately 65 meters in winter)	70 meters (approximately 65 meters in winter)

* Distance without extension of the gravel bar

Prior to driving the piles at both the southbound and northbound Piers 2, 3, and 4, cofferdams would be constructed to isolate the areas. The cofferdams would be constructed by installing sheet pile with a vibratory hammer. The area inside the cofferdams would be excavated 3 to 7 meters (10 to 23 feet) below Original Ground (OG) to the column/pile interface. When excavated, water will likely seep into the cofferdams. The cofferdams would be dewatered down to the column/pile interface to allow installation of the columns and foundations. During pile driving, the cofferdams would either be dewatered to the column/pile interface or the piles would be driven with a bubble curtain around the pile in the cofferdam.

A vibratory hammer would also be used to construct cofferdams around the existing piers to isolate those areas during their demolition. With the exception of the cofferdam around the north shore bridge piers to be removed, these cofferdams would be driven on land. Note that the cofferdams installed for the construction of the new Piers 2, 3, and 4 are also constructed on land, not in water.

Table 4 outlines the anticipated sequence of pile-driving events during the four-year construction schedule.

Table 4. Anticipated Pile-Driving Activity for the Mad River Bridge Replacement

Year	Anytime of Year	During In-Water Work Window (June 15–October 15)	During In-Water Pile-Driving Window (July 1–September 1)
1	Drive H-type piles and construct southbound bridge abutments. Construct cofferdams around new southbound bridge Pier 2. Drive two CISS piles for southbound bridge at Pier 2. Drive four 1.2-meter diameter piles for load test.	Construct cofferdams around new Pier 3 and 4 locations for southbound bridge (no in-water sheet piles).	Drive four CISS piles for southbound bridge at Piers 3 and 4 (two each).
2		Construct cofferdam around existing southbank, southbound bridge piers for demolition (no in-water sheet piles).	Construct cofferdam around existing northbank, southbound bridge piers for demolition (in-water sections).
3	Drive H-type piles and construct northbound bridge abutments. Construct cofferdams around new northbound Pier 2. Drive two CISS piles for northbound bridge Pier 2.	Construct cofferdams around new Pier 3 and 4 locations for northbound bridge (no in-water sheet piles).	Drive five CISS piles for northbound bridge Piers 3 (two) and 4 (three).
4		Construct cofferdams around existing southbank northbound bridge piers for demolition.	Construct cofferdams around existing northbank northbound bridge piers for demolition.

The H-type piles for the abutments will be installed with an impact pile driver and would each take about 10–15 minutes to drive.

Cofferdams will be constructed with sheet pile using a vibratory hammer. It typically takes 10–15 minutes to vibrate in each sheet pile, then about 10 minutes between vibratory drives to pick, stab, and adjust each succeeding sheet pile. Each cofferdam will likely take two to three days to install.

Although specific installation methods have not yet been identified (typically left to the contractor), it is likely that each CISS pile will have to be installed in three to four sections (because of the driven depth required and the length of pile that can be transported to the site [40–60 foot lengths]). In such cases, it is typical to drive the first (bottom) section, weld the second section in place, drive the second section, then weld the third section, and so on. Based on experience with other projects, it typically takes about 15 minutes of pile driving over the course of one hour to drive the bottom section. Welding sections of 2.2-meter diameter CISS pile (and the associated inspections for each weld) can take three to five days. After welding each section, it typically takes a

half hour of pile driving over the course of one hour to drive the pile deep enough to add the next section. Thus, the total drive time for one 2.2-meter diameter CISS pile would be approximately one hour and forty-five minutes (assuming four sections to a pile) over an approximate 9- to 15-day period.

Based on the above, which is considered a reasonable worst case scenario for the 2.2-meter diameter CISS piles at all three piers, it is anticipated that there would be 24 days during which these piles would be driven during Year 1 (15 minutes on 6 days and a half hour on 18 days), and there would be 28 days during which these piles would be driven during Year 3 (15 minutes on 7 days and a half hour on 21 days). No impact pile driving would occur during Year 2 or Year 4.

In addition to the 2.2-meter diameter piles, four 1.2-meter diameter piles would be driven at the southbound Pier 2. These piles are necessary to secure a template for the pile load test. These piles would also likely be conveyed to the site in three to four sections, which would be welded together and would be driven within the cofferdam built for the southbound Pier 2 pile installation. The duration and spacing of the pile driving is assumed to be approximately the same as the 2.2-meter diameter CISS piles.

General Habitat Conditions and Fish Presence

The following is based on field visits conducted on June 21 and July 17, 2007. The project lies about in the middle of an S-meander of the lower Mad River. The water around the upstream meander flows over an approximately 0.6-meter (2-foot) deep riffle, which shallows and broadens to a riffle approximately 0.15-meter (0.5-foot) deep (Figure 1). As flow approaches the right (north) bank, a thalweg has formed along the bank to the bridge (channel is about 80 meters [260 feet] long). This thalweg ranges from 2 to 1.4 meters (6.5 to 4.5 feet) deep and is about an average of 2 meters (6.5 feet) wide. There is also an 11-meter (36-foot) long, 2-meter (6.5-foot) deep blind backwater channel extending from the shallow riffle area eastward.

The rest of the channel upstream of the bridge is shallow (over half of the wetted channel was less than a 0.3 meters [1 foot] deep) or dry in the summer. The flow has scoured a deeper hole in the front of northern pier of the northbound bridge. The bridge scour hole is approximately 3 meters (10 feet) deep and 3 meters (10 feet) wide and 4 meters (13 feet) long. Downstream of the bridge, the depth shallows to a broad 0.3-meter (1-foot) deep riffle as the main flow crosses the channel to the south bank. Through this riffle section there is no defined channel. As the flow contacts the south bank, beginning about 70 meters (230 feet) from the existing bridge, the flow has scoured an approximately 1.4-meter (4.5-feet) deep channel along the bank under the overhanging vegetation.

Detailed notes from the snorkel surveys conducted on July 17, 2007 are provided in Appendix 1. During the snorkel surveys, the biologist entered the river upstream of the 0.6-meter (2-foot) deep riffles, located upstream and just outside of the area presented in Figure 1. In this riffle, the biologist encountered relatively high densities of coho salmon parr. Up to about two parr per meter square were holding territories and feeding on the

drift. Occasional steelhead parr were also observed in this area. As the biologist continued into the shallower 0.15-meter (0.5-foot) deep riffle, utilization of the riffle decreased markedly. One 8–10 centimeter long flatfish (unknown species) was also observed in the shallow riffle. Downstream of the shallow riffle, the biologist entered a scour hole associated with a conglomeration of large woody debris and the adjacent backwater channel. Eight coho salmon parr were observed in the backwater channel. Approximately 12–16 suckers ranging in size from 15 to 30 centimeters (unknown species) were also holding under the large woody debris. The biologist then worked his way down the northbank thalweg. Only six coho salmon parr were observed in the thalweg, but there were likely many more fish in this area hiding in the rock slope protection (RSP). Thirty to 40 fish (likely mostly coho salmon parr and a few steelhead) were observed just north of the northern edge of the existing northbank pier in June, which also indicates relatively high density along this bank (at least near the bridge where backwater and shade conditions exist). One age 2+ rainbow trout was also observed by the snorkeling biologist in this area.

Within the scour hole created by the northbank pier, the biologist observed one adult steelhead. Three coho salmon parr and several sculpins were also observed in this area. During an opportunistic snorkel by Caltrans biologist Kelley Garrett on July 12th, she observed 3 adult salmonids holding in this scour hole but could not determine the species. There is also a shallow backwater pool north of the northbank piers, between the pier and the bank (approximately 1.4 meters [4.5 feet] deep, 4.5 meters [15 feet] long, and 1.5 meters [5 feet] wide). This area was isolated except through the break between the northbank piers. Three coho salmon parr were observed in the pool.

As the Jones & Stokes biologist continued downriver of the bridge, he encountered a broad (spanning the wetted channel), shallow (0.15- to 0.3-meters [0.5- to 1-foot] deep) riffle. Very few parr were observed in this area (estimated at one coho salmon parr per 9 meters square). The biologist then entered the thalweg along the southbank of the river. This channel was overhung by as much as 3 meters (10 feet) of dogwood and alder branches that provide excellent cover. Within this 1.4-meter (4.5-foot) deep channel, the biologist observed five adult steelhead holding in a large woody debris pile in the channel about 30 meters (100 feet) below the proposed scour hole or approximately 70 meters (230 feet) downstream from the where the piles will be installed for the southbound Pier 3. The steelhead had been in freshwater long enough for their spots to darken and their backs to have become brown. Their size was estimated to be approximately 0.6 meters (2 feet). Other fish observed in the southbank channel included several coho salmon parr and steelhead parr (because of the vegetation and large woody debris, estimates of numbers was not possible), an age 2+ steelhead (or rainbow trout), an additional 35 to 50 suckers ranging in size from 20 to 35 centimeters (of the same species encountered in the north bank channel), and an American shad.

No Chinook salmon were observed by the biologist during the survey, and it is believed that the juveniles utilize an ‘Ocean-type’ life history strategy migrating to the ocean as newly emerged fry in the spring rather than rearing in-stream as coho and steelhead do.

Noise Assessment

The construction of the Mad River Bridge would not include any in-water impact pile driving, but some vibratory pile driving (for cofferdam construction around the existing northbank piers) will be required. The construction does include the installation of 13 2.2-meter diameter CISS piles located from 65 meters (215 feet) from the anticipated wetted channel for Pier 2 piles, to 15 meters (50 feet) from the Pier 4 piles, to a minimum of 3 meters (10 feet) from the estimated edge of the summertime wetted channel for Pier 3 piles (without extending the gravel bar into the river at Pier 3) (see Table 3). Pier 3 piles (both northbound and southbound bridge piers) would be installed below the ordinary high water mark, but would be installed on the gravel bar. The analysis assumes that the cofferdams will be dry when piles are driven, or if they contain water deeper than 1 meter (3.3 feet), a bubble curtain would be operated within the cofferdam during pile driving. Both scenarios (dry cofferdam or bubble curtain in the cofferdam) provide about 5 decibels (dB) of attenuation.

It has been typical to evaluate sound propagation through water using open-water sound attenuation models such as the Nedwell linear model or the practical spreading loss model. However, these types of open water models are not appropriate to estimate transmission loss through groundwater to surface water. There are currently no models that can be used for this purpose.

We do, however, have the results of noise monitoring of numerous pile-driving projects in a variety of environments, and of piles driven on land and in water. It is appropriate for this analysis to use existing best available data to estimate underwater sound levels that would be expected for construction techniques used and conditions that exist at the Mad River Bridge.

Jones & Stokes retained the services of Illingworth and Rodkin, Inc. (I&R) to estimate underwater sound levels that would be expected for the Mad River Bridge Replacement project. I&R has conducted underwater noise monitoring for numerous projects involving impact and vibratory pile driving in and near water. Appendix 2 provides I&R's detailed analysis based on measured empirical data. The data tables from that report are provided here as Tables 5 and 6. The following is a summary of their findings. Throughout, sound-level metrics are referenced as follows (unless otherwise indicated):

- Peak Sound Pressure (peak), dB re 1 µPa, and
- Sound Exposure Level (SEL), dB re 1 μPa^2 sec for one strike.

Cofferdam Construction with Vibrated Sheet Piles. Based on underwater noise data collected at a similar construction site (Ten Mile River), the sound generated from vibratory sheet-pile installation is quite low. For sheet pile driven on land about 25 meters (82 feet) from the water, sound levels measured in shallow water (1 meter [3.3 feet] deep) approximately 30 to 45 meters (100 to 470 feet) from the pile were 160 dB $_{Peak}$ and 140 dB $_{SEL}$ (Tables 5 and 6). Farther from the sheet pile (100 meters [330 feet] from the sheet pile) in deeper water (1 to 1.5 meters [3.3 to 5 feet] deep), sound levels

Mad River Bridge Replacement

Table 5. Year 1 Noise Impact Assessment- Southbound Bridge Piers and Abutments

Activity Description	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground															
Vibratory Sheet Installation on land	10	600 sec.	160	<160	<160	<160	140	140	140	135	168	168	168	163	--
Vibratory Sheet Installation in very shallow wat	10	600 sec.	160	<160	<160	<160	145	145	145	140	173	173	173	168	--
Vibratory Sheet Installation in deeper water	10	600 sec.	170	165	<160	<160	155	150	145	140	183	178	173	168	--
Pier 2 SB Bridge															
Bottom Section P1	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
Bottom Section P2	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
2nd Section P1	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
2nd Section P2	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
3rd Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
3rd Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Pier 3 SB Bridge															
Bottom Section P1	15	450 strike	190	190	190	180	165	165	160	155	192	192	187	182	45 meters
Bottom Section P2	15	450 strike	190	190	190	80	165	165	160	155	192	192	187	182	45 meters
2nd Section P1	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
2nd Section P2	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
3rd Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
3rd Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Pier 4 SB Bridge															
Bottom Section P1	15	450 strike	NA	190	190	180	NA	165	160	155	NA	192	187	182	45 meters
Bottom Section P2	15	450 strike	NA	190	190	80	NA	165	160	155	NA	192	187	182	45 meters
2nd Section P1	30	900 strike	NA	200	190	180	NA	170	165	157	NA	200	195	187	75 meters
2nd Section P2	30	900 strike	NA	200	190	180	NA	170	165	157	NA	200	195	187	75 meters
3rd Section P1	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
3rd Section P2	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
Top Section P1	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
Top Section P2	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
SB Bridge Abutments															
H-Type Pile	15	600 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	168	163	--

NA = Not applicable - the specified distance is on land, not in water

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Mad River Bridge Replacement

Table 6. Year 2 & 3 Impact Assessment- Northbound Bridge Piers and Abutments

Activity Description	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground															
Vibratory Sheet Installation on land	10	600 sec.	160	<160	<160	<160	140	140	140	135	168	168	168	163	--
Vibratory Sheet Installation in very shallow water	10	600 sec.	160	<160	<160	<160	145	145	145	140	173	173	173	168	--
Vibratory Sheet Installation in deeper water	10	600 sec.	170	165	<160	<160	155	150	145	140	183	178	173	168	--
Pier 2 NB Bridge															
Bottom Section P1	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
Bottom Section P2	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
2nd Section P1	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
2nd Section P2	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
3rd Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
3rd Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Pier 3 NB Bridge															
Bottom Section P1	15	450 strike	190	190	190	180	165	165	160	155	192	192	187	182	45 meters
Bottom Section P2	15	450 strike	190	190	190	80	165	165	160	155	192	192	187	182	45 meters
2nd Section P1	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
2nd Section P2	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
3rd Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
3rd Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Pier 4 NB Bridge															
Bottom Section P1	15	450 strike	NA	190	190	180	165	165	160	155	NA	192	187	182	45 meters
Bottom Section P2	15	450 strike	NA	190	190	80	165	165	160	155	NA	192	187	182	45 meters
Bottom Section P3	15	450 strike	NA	190	190	80	165	165	160	155	NA	192	187	182	45 meters
2nd Section P1	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
2nd Section P2	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
2nd Section P3	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
3rd Section P1	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
3rd Section P2	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
3rd Section P3	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P1	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P2	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P3	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
NB Bridge Abutment															
H-Type Pile	15	600 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	168	163	--

NA = Not applicable - the specified distance is on land, not in water

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

were slightly greater at 170 dB $_{Peak}$ and 140 dB $_{SEL}$. This finding is likely due to the very shallow water closer to the sheet pile. Noise does not propagate efficiently through shallow water.

For sheet pile driven in water, measured sound levels were greater than those driven on land with values in the range of 180–185 dB $_{Peak}$ and 165 dB $_{SEL}$ measured at 10 meters (33 feet) in 15-meter (50-foot) deep water. However, noise generated from sheet piles vibrated in-water produce higher frequency sound that would not propagate effectively in shallow water. Thus, I&R estimates that SEL from sheet pile driven in the shallow waters surrounding the existing piers on the north bank would be about 155 dB $_{SEL}$ at 10 meters (33 feet) from the sheet pile.

H-type Pile Installation. H-type pile installation for Abutment 1 and Abutment 5 would occur approximately 90 meters (295 feet) and 70 meters (230 feet) (respectively) from the estimated summertime wetted channel. In the winter, when the wetted channel is wider, the distance would be reduced to approximately 78 meters (256 feet) and perhaps 65 meters (213 feet) for Abutment 1 and 5 respectively.

Based on measures collected at two sites by I&R, they estimated that, if the wetted edge of the channel were at 45 meters (150 feet) from the pile installation, underwater noise levels would be approximately 160 dB $_{Peak}$ and 140 dB $_{SEL}$ or less (Tables 5 and 6). The location of the H-pile installations in relation to the wetted channel at Mad River would be a minimum of about 65 meters (213 feet) (during the winter); thus, sound levels would be less than the levels cited above for the 45-meter (150-foot) separation.

CISS Pile Installation. CISS piles will be installed at northbound and southbound Piers 2, 3, and 4. Tables 5 and 6 provide best professional estimates of Peak and SEL sound pressure levels expected at various distances from the CISS piles.

Installation of the Pier 2 pilings is proposed to occur anytime of year. Pier 2 is located approximately 65 meters (213 feet) from the wetted channel under summertime flow conditions and a minimum of approximately 43 meters (141 feet) from the wetted channel under higher flow conditions. I&R estimated that the underwater sound levels at 45 meters (150 feet) from the pile to be 180 dB $_{Peak}$ at a maximum, with an SEL of 150 dB. Thus, even with wintertime flow levels, underwater sound levels from Pier 2 piles are estimated to be low.

Installation of the piles for Pier 3 and Pier 4 would occur during the period of time preferred by Dan Free (the National Marine Fisheries Service [NMFS] biologist assigned to this project, as communicated by him during a phone call with Kelley Garrett [Caltrans]). This “in-channel pile driving window” (July 1 to September 1) occurs during low flow conditions. During the summer, Pier 3 pilings would be a minimum of 3 to 5 meters (10 to 16 feet) from the wetted channel if the gravel bar were not extended into the river to afford additional dry areas for construction. If the bar were extended, the estimated distance to the wetted channel would be approximately 20 to 30 meters (66 to 100 feet). I&R estimated that the underwater sound levels generated by this size pile would be 190 dB $_{Peak}$ and 165 dB $_{SEL}$ at a distance of 10 meters (33 feet) from the pile for

the first (bottom) sections installed. For driving subsequent (top) sections, I&R estimated 205 dB $_{Peak}$ and 170 dB $_{SEL}$ at 10 meters (33 feet) from the pile. At 45 meters (147 feet) from these piles, noise levels were estimated to drop to 195 dB $_{Peak}$ and 167 dB $_{SEL}$.

Pier 4 is located approximately 15 meters (50 feet) from the wetted channel of the river during summertime conditions. Estimated underwater noise produced during the installation of Pier 4 piles would be the same as that described for Pier 3 piles, except that because Pier 4 is located 15 meters (50 feet) from the wetted channel, there is no prediction for underwater sound level at 10 meters (33 feet).

Potential Effects

Comparison of Estimated Sound Generation to Interim Criteria.

Dr. Arthur Popper (University of Maryland) and Dr. Mardi Hastings (Pennsylvania State University), leading experts in the field of fish bioacoustics, reviewed and synthesized currently available information and recommended guidelines for assessing and mitigating effects of pile driving sound on fish. Their work is reported in the document entitled "The Effects of Sound on Fish" (Hastings and Popper 2005). Dr. Popper and several other experts (Popper et al. 2006) expanded upon this report and provided recommendations for specific interim threshold criteria to evaluate potential injury to fish from pile driving. The recommended interim threshold criteria pile driving are an SEL of 187 dB re: 1 μ-Pa^{2}s•sec and a peak sound pressure of 208 dB re: 1 μ-Pa $_{Peak}$ in any single strike. For the purposes of impact assessment, this threshold is applied at 10 meters (33 feet) from a pile. The thresholds described above are commonly referred to as the "dual criteria" and are used as one method in this assessment.

The I&R estimate of sound propagation from piles to be driven as part of the Mad River Bridge replacement are below the interim criteria proposed by Popper et. al. (2006). In no cases were the estimated peak or single strike SEL values in the wetted channel predicted to exceed 208 dB $_{Peak}$ or 187 dB $_{SEL}$, respectively (Tables 5 and 6).

NMFS appears to have accepted the 208 dB $_{Peak}$ interim criterion (as part of the interim dual criterion) as it has appeared at least in draft biological opinions (the draft Biological Opinion for Ten Mile River). In no cases are in-water noise levels estimated to exceed 208 dB $_{Peak}$ (see Tables 5 and 6).

NMFS's interpretation of the SEL criterion proposed in the Popper et al. (2006) white paper states that energy from all strikes that a fish may be exposed to should be summed and then compared to the 187 dB $_{SEL}$ criterion. A simple example is where a fish would be exposed to 500 pile strikes. The accumulated SEL value (referred to here as $SEL_{[accumulated]}$) would be 27 dB greater than the single strike SEL value (27 dB is calculated by taking 10 times the logarithm of 500). According to NMFS's interpretation, the $SEL_{(accumulated)}$ value should then be compared to the 187 dB $_{SEL}$ criterion.

Application of NMFS's approach for SEL criterion would indicate the potential for injury to salmon within 90 meters (295 feet) of pile-driving activities from cumulative exposure to pile driving of the duration estimated for the top sections of Pier 3 and Pier 4 piles and within 45 to 75 meters (147 to 246 feet) for driving the bottom sections of the Pier 3 and Pier 4 piles (accumulated SELs are estimated to exceed 187 dB at these distances from Pier 3 and Pier 4).

Tables 5 and 6 estimate the SEL per strike and the accumulated SEL based on the NMFS's approach to the calculation of SEL. These tables show that in no case was the single strike SEL estimated to exceed 187 dB $_{SEL}$. The highest single strike SEL is estimated to be 170 dB at 10 meters (33 feet) from the pile while driving the top sections of the CISS piles at Pier 3 and Pier 4. For Pier 2, the greatest single strike SEL is estimated to be 150 dB $_{SEL}$ at 45 meters (147 feet) from the Pier 2 piles (for all pile sections). Under wintertime flows (when the distance between the wetted channel and the Pier 2 piles would be the least), this noise level would be estimated to occur at approximately 2 meters (6.6 feet) offshore.

When using the NMFS's method of SEL accumulation, the SEL interim criterion would not be exceeded during the driving of any of the Pier 2 piles because of the distance between these piles and the water (even under winter flow conditions). The highest SELs calculated for the Pier 2 piles using the NMFS's method would be 180 dB $_{SEL}$ at a distance of 45 meters from the piles (the approximate distance to the wetted channel in the winter). The SELs drop to 175 dB by 75 meters from the Pier 2 piles.

Using the NMFS's method for calculation of SEL for the bottom sections of Pier 3 and 4 piles, the estimated $SEL_{(accumulated)}$ values would be 192 dB $_{SEL}$ at 10 meters from the piles, and would drop to 187 dB $_{SEL}$ at 45 meters (147 feet) from the piles (the bottom sections of these piles require about 15 minutes of actual drive time). The top sections of the Pier 3 and 4 piles would take about 30 minutes of actual drive time each. So, accumulating the energy generated from driving these top sections (900 pile strikes—30 minutes of one day) using the NMFS's method results in SELs above 187 dB $_{SEL}$; the highest $SEL_{(accumulated)}$ value at 10 meters (33 feet) from the piles is estimated to be 200 dB $_{SEL}$.

Tables 5 and 6 also calculated the attenuation distance to 187 dB $_{SEL}$. The calculations, using the NMFS's method, show that the $SEL_{(accumulated)}$ values would attenuate to below 187 dB SEL within 45 meters (147 feet) of the Pier 3 and Pier 4 piles while driving the bottom sections and within 90 meters (295 feet) of the piles while driving the top sections.

NMFS typically assumes that exposure of a fish to underwater noise levels above a threshold of 150 dB root mean square (RMS) would result in behavioral effects to fish. Although not specifically estimated by I&R (Appendix 2), it is expected that, in an open water system, noise levels above 150 dB RMS might occur out to or beyond 120 meters (393 feet) from a large pile. However, this is likely very conservative at the Mad River site because of the presence of shallow water, gravel bars, and turns in the river.

Estimated Exposure of Fish to Sound Levels Exceeding Interim Thresholds. Based on the estimates by I&R (Tables 5 and 6), no fish would be expected to be exposed to underwater sound exceeding 208 dB $_{Peak}$ during pile driving associated with the Mad River Bridge replacement. The highest expected underwater peak sound levels are estimated to be 205 dB, which extend out to approximately 20 meters (66 feet) from the Pier 3 and Pier 4 piles when driving the top two pile sections of each pile (the bottom two pile sections area estimated to produce underwater noise up to a maximum of 200 dB $_{Peak}$ and 190 dB $_{Peak}$ out to 20 meters [66 feet] from the pile). Depending on river conditions and the construction method used (extension of the southbank gravel bar and actual location of wetted channel during pile driving), it is difficult to determine the area that would be exposed to underwater sound above 200 dB $_{Peak}$. At a maximum, this area would encompass an area up to about 5 meters (16 feet) from northbank (which will likely be either dry or consist of a very shallow riffle) and out to about 15 meters (50 feet) from the southbank in the vicinity of the Pier 3 piles (an area that will be either very shallow [0 to less than 1 meter] or dry because of the extension of the southbank gravel bar).

Fish in the river would not be exposed to single strike SELs which exceeded 187 dB SEL. The greatest single strike SEL estimated by I&R at 10 meters (33 feet) is 170 dB SEL.

If NMFS's method of accumulating sound energy is used, $SEL_{(accumulated)}$ values above 187 dB would not occur in the river as a result of impact driving the 2.2-meter or 1.2-meter diameter piles for Pier 2, or from the H-type piles at the two abutments, or from vibratory installation of the sheet pile for the cofferdams driven on land.

For piles driven at Pier 3 and Pier 4, the distance to 187 dB $_{SEL\ (accumulated)}$ is estimated to be 45 meters (147 feet) for driving the bottom sections of piles at Pier 3 and Pier 4, 75 meters (246 feet) for driving the second section of piles at Pier 3 and Pier 4, and 90 meters (295 feet) for driving the third and fourth sections of piles at Pier 3 and Pier 4. A distance of 90 meters (295 feet) from the most upriver and most downriver piles has been marked on Figure 1.

$SEL_{(accumulated)}$ values above 187dB $_{SEL\ (accumulated)}$ would only be experienced on the days during which Pier 3 and Pier 4 piles are driven during Year 1 and Year 3. Table 7 illustrates the duration and distances that SELs exceeding 187 dB (using the NMFS's method) would be experienced in the river.

Table 7. Distance to 187 dB $_{SEL\ accumulated}$ for Pier 3 and Pier 4 Piles Assuming Four Sections Per Pile

Year	Duration of Drive per Section	Maximum Number of Days (all piles)	Distance to 187 dB $_{SEL\ accumulated}$
1	Southbound Bridge Bottom—15 minutes Section 2—30 minutes Section 3—30 minutes Section 4—30 minutes	 4 days 4 days 4 days 4 days	 45 meters 75 meters 90 meters 90 meters
2	None	0	N/A
3	Northbound Bridge Bottom—15 minutes Section 2—30 minutes Section 3—30 minutes Section 4—30 minutes	 5 days 5 days 5 days 5 days	 45 meters 75 meters 90 meters 90 meters
4	None	0	N/A

Downriver of the location of the Pier 3 and Pier 4 piles, the proposed scour pool lies about 45 meters (147 feet) from the western-most piles; beyond that lies the southbank channel. Using the NMFS's accumulation method, the area of the proposed scour pool and about 45 meters (147 feet) of the southbank channel would be exposed to accumulated SEL above 187 dB for days during which the third and fourth sections are driven for each pile. On days that the first and second sections are driven, the downstream extent of accumulated sound about 187 dB SEL would be less (see Table 7). Other areas downriver of the bridge experiencing accumulated SELs above 187 dB would include the shallow riffle areas below the bridge.

Upriver of the Pier 3 and Pier 4 piles (under existing conditions), areas under and upriver of the bridge (the scour and backwater pool near the existing northbank pier) and approximately a 40-meter (131-foot) segment of the northbank channel would be exposed to accumulated SELs of 187 dB. Shallow riffle area to the 90-meter (295-foot) distance would also be exposed to 187 dB SEL while the third and fourth sections of these piles are driven. As noted above, distances would be less when the first and second sections of the piles are driven (see Table 7).

It is very important to note that accumulated SELs above 187 dB would not extend to the upper scour pool, backwater channel, or the riffles upriver where the higher densities of coho parr were observed.

Injury to adult salmon and steelhead is not expected because of their mobility and size; however, the sound generated during pile driving would cause a temporary harassment leading to the adults perhaps moving to less suitable habitats during the 15- to 30-minute periods (during a day) that pile driving would occur.

It is very difficult to determine the area of the various stream habitats that may be exposed to accumulated SELs above 187 dB because flow conditions (and thus areas of exposed gravel bars and riffles) are variable, and it is currently unknown if the southbank gravel bar will be extended into the river. The maximum total area exposed during a

pile-driving event (driving one section of one pile) would be calculated as the average width of the wetted channel times 180 meters (590 feet) (90 meters [295 feet] upstream and 90 meters [295 feet] downstream of the pile). Given conditions in June and July 2007, the rough average river width was estimated to be about 20 to 25 meters (66 to 83 feet), which would result in a 30 minute exposure of 3,600 to 4,500 square meters (38,750 to 43,056 square feet) of river to accumulated SELs exceeding 187 dB when the top two section of each pile are driven—about 3,000 square meters (32,000 square feet) being riffle habitat and the remainder consisting of the deeper habitats (the northbank and southbank channels). The amount of habitat experiencing this level would be less for the bottom two sections of each pile and if the gravel bar is extended to constrict the channel or water bladders are used to isolate habitats.

It should be noted that it is possible that a contractor may choose to drive two pile sections on some days (one section each of the paired piles at each bridge pier). If this were to occur, the number of days during which pile driving would occur would be reduced, but the extent of accumulated SELs calculated using the NMFS's method would extend farther from the piles. Using the NMFS's calculation, fish might be exposed to $SEL_{(accumulated)}$ values above 187 dB within 120 to 140 meters (394 to 460 feet) if they were to remain in that area throughout the entire day's pile driving and if two pile sections are driven in a single day.

Avoidance and Minimization Measures.

Timing of Pile Driving

- Because the driving of piles at Abutment 1, Abutment 5, and Pier 2 would not result in underwater noise in the river that would exceed thresholds, no timing restrictions are proposed for the driving of those piles.
- Because vibrating sheet piles on land for cofferdams would not result in underwater noise above thresholds, no timing restrictions are proposed for the construction of cofferdams on land.
- Driving of CISS piles at Piers 3 and 4 is estimated to elevate underwater accumulated $SEL_{(accumulated)}$ to levels above the 187 dB threshold over approximately 180 meters (590 feet) of river. Consequently, these piles will be driven during the NMFS-recommended window of July 1 to September 1, when the least number of fish would be exposed.
- Driving of sheet pile in the water to form a portion of the cofferdam that will be used to isolate the existing northshore bridge pier is estimated to elevate underwater SEL (accumulated) to levels above the 187 dB threshold for a maximum distance of 20 meters (66 feet) if the water is greater than 1 meter deep (noise from vibratory pile installation does not propagate effectively through shallow water, and SEL accumulated from a full day of installation of sheet piles in water would only extend through the deep area around the pier face). To be protective, portions of the cofferdam for the demolition of the northbank bridge pier that require in-water

installation of sheet pile will be installed during the NMFS-recommended window of July 1 to September 1, when the least number of fish would be exposed.

Other Avoidance and Minimization Measures

Additional avoidance and minimization measures are categorized below by the various habitat features occurring within 90 meters (295 feet) of the proposed CISS piles.

Northbank Channel—During the time of year that the Pier 3 and Pier 4 pile driving is expected to occur (between July 1 and September 1 during Year 1 and Year 3), coho salmon parr are expected to congregate in the northbank channel, steelhead parr and age 1+ and 2+ would be expected in small numbers, and one to a few adults could occur. The attractions to this area by these fish are the deeper, shadier conditions and the presence of a rough bank that provides localized eddies and refuge (within the RSP). To minimize the presence of fish in this area, it is proposed that the attractiveness of this habitat be temporarily masked by placing an "icing" of small (less than or equal to one inch) clean, washed gravel over the RSP out to about 100 meters (328 feet) from the new piles. The clean gravel would first be laid by hand, then, as fish vacate the area of activity, a backhoe would be used to deliver the gravel slowly. The gravel would act to "smooth" the surface of the bank, minimizing localized eddying and refuge. It is expected that this icing would occur twice, once in Year 1 and again in Year 3, preceding that year's pile driving. It is expected that the gravel would wash out, exposing the RSP during winter flows each year.

Above Bridge Riffles—No specific avoidance or minimization measures are proposed for the riffle areas because those methods would likely be more harmful to fish than the pile driving or would be very difficult to implement. Fish removal and isolation of the riffle areas would be very problematic due to the area, varied depth and width of the river, and the probability of debris. When pile drivers of the size used to drive 2.2-meter diameter piles start operating, there is usually a period during which the sound generated from driving the pile is lower (the pile is hit with less force) before maximum force is realized. This period of lower hammer energy would be expected, to some unknown degree, to startle fish within the range of higher noise levels, and they would be expected to vacate the area where noise irritates them physically.

Scour Hole at the Existing Northbank Pier—The scour hole adjacent to the existing northbank pier is an important habitat feature, particularly for returning adult Chinook salmon (and other adults) in the fall. In order to maintain its function in the fall for as long as possible (until the, northbound bridge pier on the north bank is demolished in Year 4), we are not proposing any modification to this habitat feature. During the time of year that the Pier 3 and Pier 4 piles will be driven, it would be likely that just a few (1–5) adult summer steelhead, and perhaps a few juvenile fish, would occupy this pool. It is expected that when pile driving occurs, these fish would retreat from areas where sound levels are irritating, likely to areas of lower sound levels in the southbank channel.

Backwater Pool at the Existing Northbank Pier—This small backwater pool area provides limited habitat, but is accessible to fish. It is proposed that this pool, which lies

between the existing northbank piers and the north bank, be cleared of fish and filled with larger cobbles and gravel to a depth that prevents fish entry. By using larger material with a smaller material to fill the interstitial areas, it would be expected that this area would only need to be cleared of fish and filled with rock and gravel once prior to pile driving in Year 1. Conversely, this area could be seined or electrofished and isolated before each pile driving event, but the potential for take during the clearing of fish would be higher than if clearing and filling were performed just once.

Below Bridge Riffles—Performing avoidance and minimization measures in the riffles below the existing bridges would be problematic for the same reason as cited for the riffles above the bridge, and no measures are proposed. The riffles within 90 meters of the piles have a low utilization by fish, and fish within the range of higher noise levels would be expected to vacate the area where noise irritates them physically.

Southbank Channel—It would be very difficult to isolate southbank area, or to clear the southbank channel of fish, due to the extensive riparian canopy. This area appears to be a very important habitat feature to both adult and juvenile fish. Any method used to remove or exclude fish from the area would result in habitat degradation, which would likely be more harmful to fish over the long-term. It is expected that fish would retreat downstream from the upriver end of the channel to avoid irritating noise levels during the short duration of pile driving.

Proposed Scour Feature—Because construction of a new scour feature within 90 meters (295 feet) might attract fish to an area of elevated noise levels during pile driving, it is proposed that this feature not be constructed until pile driving is completed in Year 3. Because no modification to the scour hole below the bridge would occur, that habitat would continue to function as adult refuge during the upstream migration period until the northbound bridge pier on the north bank is demolished in Year 4. Thus, if the proposed scour feature were constructed in Year 3, it would be in place in time to replace the existing scour pool (which would be degraded or eliminated in summer of Year 4) in the fall of Year 3.

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Appendix I Caltrans Highway 101 Bridge Replacement Mad River Field Survey

CalTrans Hwy 101 Bridge Replacement
Mad River Field Survey

07/17/07

Grant Novak
Fisheries Biologist

On 07/17/07 a Jones and Stokes Associates biologist conducted a site visit and in-water fish survey of the reaches immediately up and downstream of the hwy 101 bridge crossing the Mad River near Arcata, CA. The biologist entered the water ~700' upstream of the bridge and, using a mask and snorkel, performed a visual surveys to determine fish species present (particularly ESA listed salmonids) and their apparent utilization of the aquatic reaches immediately up and downstream of the proposed Mad River/Hwy 101 bridge replacement.

Two in-water surveys were conducted between 10:25am and 1:00pm. The first survey began at 10:25am ending at 11:00am and the second survey began at 12:00pm and ended at 1:00pm. The task of the first survey was primarily to note and characterize the aquatic environment and it's utilization by fish while the purpose of the second survey was to attempt to take pictures and measure depths using a 25' stadia rod. Water temperature at 10:25am was 21°C when measured at point A (see Fig. 1. Field Map attached) in an ~2.5' deep riffle where it was assumed that mixing was likely consistent and a representative temperature could be measured. Weather was overcast and a light sprinkling rain occurred intermittently throughout the survey. Water clarity was good and visibility was ~15' in the water. Water velocities were not measured during this survey but a relative scale of velocities in the surveyed reaches will be described as high or low with riffles generally being higher velocity and deeper channels and pools having a lower velocity.

Coho salmon (O*ncorhynchus kisutch)* and Steelhead/Rainbow trout (*Oncorhynchus mykiss*) parr were differentiated based on the presence of spots on the caudal and dorsal fins (Steelhead/Rainbow trout) or lack of spots on caudal and dorsal fins (Coho). While presence of Chinook salmon (*Oncorhynchus tschawytscha*) has been noted in available literature none were noted in this survey and it is assumed that they are of an ocean-type life-history strategy migrating to the ocean as fry during their first Spring. Coho and Chinook parr are differentiated based on relative size and position of parr marks with Coho exhibiting parr marks that are compressed laterally with spacing between being larger than the width of the parr mark and Chinook exhibiting parr marks that are wider than those found on Coho with spacing between being less than the width of the parr marks. When possible, an attempt was made to observe the anal fin as the three anterior rays of a Coho's anal fin are longer than the posterior rays. Many parr were easily observable at a close distance and it appeared that all parr without spots on the caudal and dorsal fins had anal fins indicative of Coho.

The entry point for the initial survey (see Fig 1, position A) was a shallow, ~2.5' deep pool between two riffles that was being utilized by Coho parr and Steelhead parr primarily as feeding ground during the time of the surveys. Upon entering the water the presence of Coho salmon parr and Steelhead parr was immediately evident. The biologist attempted to move in a slow, non-threatening manner in order to observe any fishes present in as unaffected a state as possible. Coho parr were spread throughout the riffle at the entry site in densities of 1-2 parr/m^2 or greater and the areas between the depths of 1' and 2.5' could be described as fully utilized by feeding parr. Parr had taken individual territories and were feeding steadily on drifting debris. The main species observed at position A were Coho parr with an occasional Steelhead parr (~15:1 Coho to Steelhead). It is unclear exactly how many individual parr were observed as they continually moved about while feeding but there were at least 7-9 parr in the field of vision at any given moment. Some of the parr showed aggressive behavior in the form of charges and fin nips directed at other parr.

The survey continued downstream where the depth shallowed to an ~.5' deep riffle. Utilization by salmonids decreased markedly in the shallow, higher velocity riffle (see Fig 1, position C). One 3"-4" flatfish of unidentified species was noted hiding in the sand of the riffle. Immediately downstream of the riffle was an ~7' deep scour hole around a conglomeration of large woody debris (LWD). The fine, silty substrate in the scour hole differed from the small gravel substrate of the riffle. An ~6.5' deep blind, backwater channel stretched ~35' along the North bank to the East beginning at the scour hole around the LWD (see Fig 1, position B). 8 Coho parr were noted in the backwater channel and a school of ~12-16 sucker-fish (*spp?*) were seen holding beneath the LWD at the entrance to the backwater channel. The suckers ranged in size from 6''-12'' and were grey-brown in color with large, distinct scales.

Downstream of the scour hole the channel traveled along the North bank to ~15' upstream of the hwy 101 bridge (see Fig 1, position E). The channel along this stretch was 6.5' deep at the upstream portion with the middle and downstream portion reducing in depth to 4.5'. RSP had been placed on this shoreline to slow erosion along the outside of the southward turning bend. The channel substrate was the same fine silt over small gravel found in the backwater channel and the velocity was rated low. ~6 Coho parr were noted along the RSP but it is believed that, because the RSP offers structure in-which the parr can hide, that there were likely more fish present than were observed. One 2+ year old rainbow trout was noted along this stretch at the downstream margin immediately upstream of the scour hole formed by the hwy 101 bridge piling. It isn't known whether this was a resident rainbow or an anadromous steelhead. The fish was heavily and darkly spotted and a pink stripe down its side was clear, leading to the presumption that the fish was the resident form of *O. mykiss* rather than the anadromous form which is generally more silver in coloration.

Lots of large woody debris had collected on the upstream edge of the hwy 101 bridge support column causing a deflection in flow which, in turn, created a deep scour hole around the base of the column. The LWD was composed of many 6"-8" trunks intertwined with various debris that extended from ~6' above the surface of the water

down to the deepest portion of the scour hole at 10'. One adult steelhead was seen holding beneath the LWD along the upstream edge of the column but, due to the depth, lack of light, and obstructed view it was impossible to estimate its size beyond a range of 20"-30". Several 3"-4" sculpin were seen settled on the silty substrate beneath the bridge and 3 coho parr were seen holding in the current break resulting from the collection of LWD. A backwater pool can be accessed through a slot separating the northbound lane and southbound lane support columns. The pool was formed by deflection of water by the support column during high flow events but, at the time of the survey, it was only accessible through the slot betweent he columns. The pool was 4.5' deep, ~15' long, and ~5' wide. Three Coho parr were noted in the pool.

Another riffle was located immediately downstream of the bridge. The riffle was from .5'-1' deep and contained very few parr. It was estimated at the time that there was ~1 Coho parr per $9m^2$. This riffle begins a northward bend in the river and a channel has formed along the South bank beginning immediately downstream of the bridge. The channel is 4' deep at the location of the proposed scour feature. The bank is very steep here with overhanging alder and dogwood suspended above the water as far as 10' from the bank. LWD has collected along this outside bend and 5 adult steelhead were observed holding beneath a particularly dense pile of LWD located ~100' downstream of the proposed scour feature. The steelhead had been in the freshwater long enough for their spots to darken and their backs to have become brown rather than blue or silver. Each adult was of a similar size estimated at ~25" and ~8lbs. Immediately downstream of the holding steelhead an American shad (*spp?*) was seen swimming swiftly upstream. The shad was estimated to be ~22" long. A 2+ year old, 12"-14" *O. mykiss* was seen holding beneath overhanging vegetation and several coho and steelhead parr were seen holding in the LWD and overhanging vegetation but exact numbers were impossible to record due to the low light levels, LWD, and tree limbs falling into the water. A school of 50-75 sucker fish had collected beneath some LWD ~150' downstream of the proposed scour feature location. They ranged in size from 8"-14" and were a dark brown in color.

Appendix II Analysis of Underwater Sound Levels—Mad River Bridge Replacement Project at U.S. Highway 101 in Humboldt County

ANALYSIS OF UNDERWATER SOUND LEVELS— MAD RIVER BRIDGE REPLACEMENT PROJECT AT U.S. HIGHWAY 101 IN HUMBOLDT COUNTY

01-Hum-101 KP144.4, Bridge No. 04-0025L

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Table of Contents

Introduction 2
Fundamentals of Underwater Noise 2
Underwater Sound Generating Activities 4
Discussion of Underwater Noise Levels from Construction 6
Cofferdam Sheet Piles 6
Abutment H-type Piles Driven on Land 7
Permanent CISS Piles 8
San Francisco-Oakland Bay Bridge East Span Replacement 8
Benicia-Martinez Bridge 10
Geyserville Russian River Replacement Bridge 11
Underwater Sound Thresholds 12
FHWA Adopted Thresholds 13
NOAA Thresholds 14
Noise from Pile Installation 14
Peak Sound Pressures 15
Single and Multiple Pile Strikes—FHWA 15
Multiple Piles Strikes—NOAA 15
Accumulated SEL for H-Type Piles 15
Accumulated SEL for Cofferdam Sheet Piles 16
Accumulated SEL for CISS Piles 16

List of Tables and Figures

		Page
Table 1	Definitions of Underwater acoustical terms	4
Table 2.	Russian River, Geyserville Measured Sound Levels—Bent 4	12

		Follows Page
Figure 1	Characteristics of a Pile-Driving Pulse	4
Figure 2	SFOBB Pile Driving in dewatered cofferdam at Pier E15W using Menck 1700MHU	9
Figure 3	Benicia-Martinez Bridge Pile Driving in cofferdam with shallow water at Pier 6 using Menck 500MHU	10
Figure 4	Geyserville Russian River Bridge construction looking at piles for Bents 2 and 3 with mark for Bent 4 near river edge	11
Figure 5	Geyserville Russian River Bridge construction looking from river at piles for Bent 4	12

List of Abbreviated Terms

CISS	cast in steel shell
FHWA	Federal Highway Administration
NOAA	National Oceanic and Atmospheric Administration
SEL	sound exposure level
FHWG	Fisheries Hydroacoustic Workgroup
NCHRP	National Cooperative Highway Research Program

Introduction

This study assesses potential underwater sound levels generated by planned construction activities involved with the replacement of the U.S. Highway 101 bridge across the Mad River. U.S. 101, a freeway, crosses the Mad River in Humboldt County just north of Arcata and south of Mc Kinleyville in California. Replacement of the bridge would require installation of large diameter cast in steel shell (CISS) piles as part of piers to support the new bridge. In addition, cofferdams would be constructed around the existing and new piers. These cofferdams would require the installation of sheet piles. Steel-H-type piles would be installed at the bridge abutments, which are set back from the river. This report includes the prediction of underwater sound levels predicted based on results of measurements for similar projects. Predicted sound levels are compared against interim thresholds adopted the Federal Highway Administration (FHWA) and also against interim thresholds proposed by the National Oceanic and Atmospheric Administration (NOAA). These thresholds are discussed in the report.

Pile driving would produce noise in the river. Piles are not planned to be driven in the wetted channel of the river during construction of new structures; however, some of the piers and associated piles would be close to the river. In addition it is anticipated that cofferdam construction in and near the water would be required to remove the existing in-water bridge piers that are near the main thalwag. This would require the installation of sheet piles in the river. There is no way to reasonably predict underwater sound levels from these activities, other than to rely on data from previous measurements. Available underwater sound data for projects involving the installation of similar piles were reviewed. The levels for various activities were estimated using these data combined with an understanding of how and where these activities would occur. These predictions are essentially a best estimate based on empirical data and engineering judgment, but by their very nature have a certain degree of uncertainty associated with them. Also predicted were the duration that pile driving would occur for installation of each pile. The number of pile strikes that might have occurred were estimated from these predicted pile-driving/installation times. Again, these are based on available data from similar projects. The availability of data for this type of work at sites with conditions similar to the Mad River site (i.e., pile driving near shallow water) is highly limited.

Fundamentals of Underwater Noise

When a pile-driving hammer strikes a pile, a pressure pulse is created which propagates through the pile and radiates sound into the water and the ground substrate as well as the air. A plot of a sound pressure pulse as a function of time is referred to as the *waveform.* NOAA's National Marine Fisheries Service has requested that Caltrans provide them with the peak pressure and the root-mean-squared (RMS) or average pressure over the pulse duration. The *peak pressure* is the highest absolute value of the measured waveform, and can be a negative or positive pressure peak. The RMS level is determined by analyzing the waveform and computing the average of the squared pressures over the time that encompases that portion of the waveform containing 90

percent of the sound energy.[1] This RMS term is described as $RMS_{90\%}$ in this report. This has been approximated in the field for pile-driving sounds by measuring the signal with a precision sound-level meter set to the "impulse" RMS setting ($RMS_{impulse}$). Another measure of the pressure waveform that can be used to describe the pulse is the sound energy itself. The total sound energy in the pulse is referred to in many ways, such as the "total energy flux"[2]. The "total energy flux" is equivalent to the un-weighted sound exposure level (SEL) for a plane wave propagating in a free field, a common unit of sound energy used in airborne acoustics to describe short-duration events. The unit is dB re: 1μPa^2-sec. In this report, peak pressures and RMS sound pressure levels are expressed in decibels re 1 μPa; however, in other literature they can take other forms such as a Pascal or pounds per square inch. The total sound energy in an impulse accumulates over the duration of that impulse. How rapidly the energy accumulates may be significant in assessing the potential effects of impulses on fish. The figure 1 illustrates the descriptors used to describe the acoustical characteristics of an underwater pile-driving pulse. Table 1 includes the definitions of terms commonly used to describe underwater sounds.

Researchers have indicated that high peak pressures along with the rate of change (i.e., rise time) are important considerations in assessing potential biological impacts (i.e., injury or mortality)[3]. Descriptors such as the peak pressure, $RMS_{90\%}$, and SEL are useful descriptors in describing the magnitude of these impulses. None of these descriptors adequately account for the effect of rise time for pile-driving impulses. The peak pressure only refers to the magnitude of maximum pressure fluctuation, which may be only one factor causing damage. The RMS averaged over 90% of the impulse includes averaging over a relatively long period of the impulse where the pressure fluctuation is much lower. For instance, about 50% of the energy from a typical pile-driving impulse accumulates in less than a quarter of the time that 90% of the energy accumulates. The SEL or "total energy flux" is basically normalized to one second and, therefore, is not as useful for discerning differences in impulses where the majority of the energy occurs within 1/10th of a second. However, SEL is useful to researchers in assessing impacts to animals. The pressure waveforms show the individual characteristics of these strikes; and yet it is difficult to identify any meaningful differences in the impulses. Studying the waveforms can provide an indication of rise time, though rise time differences are not clearly apparent due to the numerous rapid fluctuations that are characteristic to this type of impulse. A plot showing the accumulated sound energy over the duration of the impulse (or at least the portion where much of the energy accumulates) appears to be the best available tool for illustrating the differences in source strength and rise time. An example of the characteristics of a typical pile-driving pulse is shown in Figure 1.

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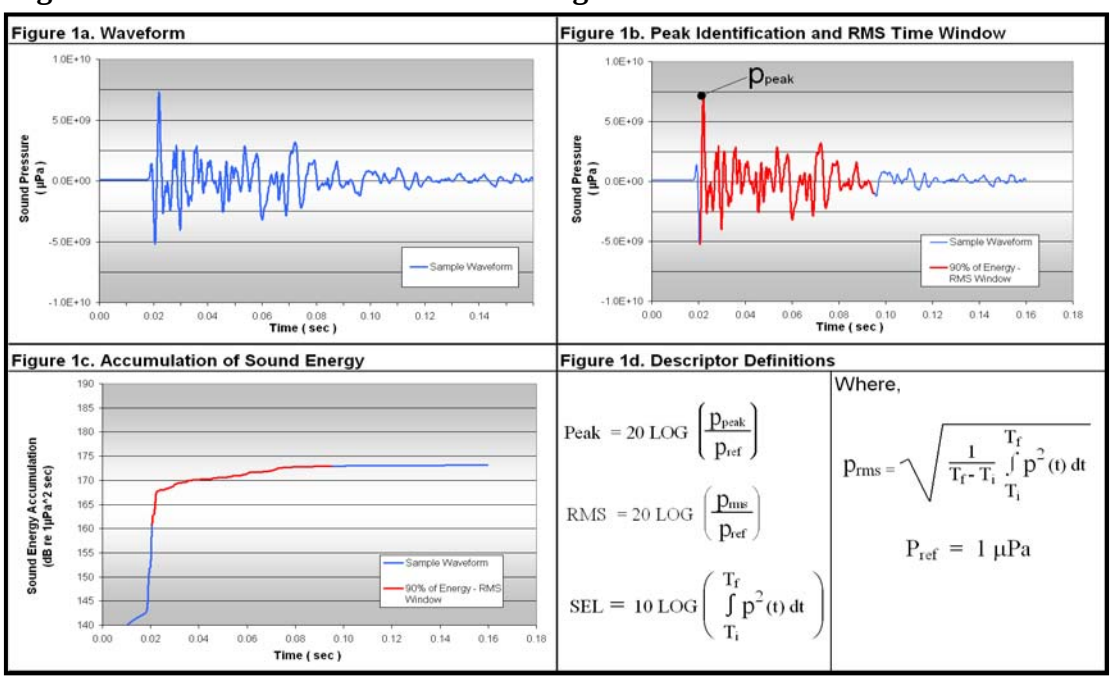
[1] Richardson, Greene, Malone & Thomson, *Marine Mammals and Noise*, Academic Press, 1995, and Greene, personal communication.
[2] Finerran, et. al., Temporary Shift in Masked Hearing Thresholds in Odontocetes after Exposure to Single Underwater Impulses from a Seismic Watergun, *Journal of the Acoustical Society of America*, June 2002.
[3] Wardle, et.al. *Effects of Seismic Air Guns on Marine Fish.* Continental Shelf Research 21 (2001) 1005-1027. Pergamon. June 21, 2000.

Table 1. Definitions of Underwater Acoustical Terms

TERM	DEFINITIONS
Peak Sound Pressure, unweighted (dB)	Peak sound pressure level based on the largest absolute value of the instantaneous sound pressure. This pressure is expressed in this report as a decibel (referenced to a pressure of 1 µPa) but can also be expressed in units of pressure, such as µPa or PSI.
RMS Sound Pressure Level, (NMFS Criterion) dB re 1 µPa	The average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy for one pile-driving impulse[4].
Sound Exposure Level (SEL), dB re 1 μPa^2 sec	Proportionally equivalent to the time integral of the pressure squared and is described in this report in terms of μPa^2 sec over the duration of the impulse. Similar to the unweighted SEL standardized in airborne acoustics to study noise from single events.
Waveforms, µPa over time	A graphical plot illustrating the time history of positive and negative sound pressure of individual pile strikes shown as a plot of µPa over time (i.e., seconds)
Frequency Spectra, dB over frequency range	A graphical plot illustrating the distribution of sound pressure vs. frequency for a waveform, dimension in rms pressure and defined frequency bandwidth

Figure 1. Characteristics of a Pile-Driving Pulse



Underwater Sound Generating Activities

[4] The underwater sound measurement results obtained during the Pile Installation Demonstration Project indicated that most pile driving impulses occurred over a 50 to 100 millisecond (msec) period. Most of the energy was contained in the first 30 to 50 msec. Analysis of that underwater acoustic data for various pile strikes at various distances demonstrated that the acoustic signal measured using the standard "impulse exponential-time-weighting" (35-msec rise time) correlated to the RMS (impulse) level measured over the duration of the impulse.

The primary sources of underwater noise would be the driving of large CISS piles, driving of sheet piles to construct cofferdams, driving of steel H-type piles for the abutment, and demolition of the existing bridge piers that are in water. Most of these activities would be conducted outside of the water, but close enough to generate noise in the river.

- Cofferdam construction would require the installation of steel sheet piles. These piles mostly would be installed on land or immediately adjacent to the river. Sheet piles would be installed with a vibratory driver/extractor. Each steel sheet pile requires about 5 to 10 minutes to install and about 10 minutes between driving periods for picking, stabbing, and adjustments. Large cofferdams can require several days to construct (i.e., driving sheet piles). The sizes of these cofferdams have not yet been determined. It is anticipated that cofferdam construction in the water would be required to remove the existing in-water bridge piers that are near the main thalwag. This would require the installation of sheet piles in the river.

- Steel H-type piles of about 0.4 meters (14-inches) in width would be required to place the abutments. The abutments are setback 70 to 90 meters from the river high-water mark, especially on the south side. H-type piles would be driven using an impact hammer.

- Large CISS piles of 2.2-meter (7-foot) diameter and about 30 to 45 meters (100 to 150 feet) in length would be driven for each new bridge pier. Preliminary indications are that a hydraulic hammer with a rating of about 500 to 700 kiloJoules would be required to drive the piles. The driving periods would not be continuous. It is likely that the pile would be driven in two to four sections. One to five days between sections would be necessary to splice the top half of the pile before driving could resume. It is possible that center-relief drilling would be required for the last portion of the piles. In this case, it may take many different days to drive a pile. This assessment assumes that at least four separate days would be required to drive each pile and that the total drive time per day would be 15 to 30 minutes.

- Demolition of the existing bridge piers near the north shore would likely involve the use of a hoe ram. It is anticipated that this work would be contained within cofferdams; and therefore, would not result in underwater noise that approaches any of the injury thresholds.

Pile driving near the water causes sound energy to radiate indirectly into the water as a result of ground-borne vibration at the bottom, beneath the river. The low-frequency ground-borne vibration can cause localized sound pressures in the water that are radiated from the bottom of the river. Piles driven through saturated soils adjacent to the river can cause higher sound levels when sound transmits directly off the pile into the surrounding saturated soils and then into the adjacent river. In these cases, the pile is driven into land that is at or above the surface level of the river. Driving the pile in a cofferdam that is excavated below the river bottom can eliminate this sound path. Airborne sound makes an unsubstantial contribution to underwater sound levels because of the attenuation at the air/water interface. A minimum water depth is required to allow sound to propagate. This depth is frequency dependent. For frequencies normally associated with pile-driving sounds, the minimum depth is 1 to 2 meters (3 to 6 feet).

Discussion of Underwater Noise Levels from Construction

Cofferdam Sheet Piles

Sheet piles would be installed on land near the river to construct a cofferdam around the piers for the new bridge. The cofferdams for Piers 3 and 4 near the river would be excavated to an elevation below the river bottom. A vibratory driver/extractor would be used to install these sheet piles. The distance from these operations to the river would vary for each pier and each sheet pile within a cofferdam. Exact construction plans are not available, but it appears the Contractor may keep a 15-meter (50-foot) cross section of river open. Therefore, the distance from sheet piles to the river would range from close to the river (about 5 meters) to 50 meters with Pier 3 of both bridges. Pier 4 is about 15 meters from the river. Construction of Pier 2 for both bridges may occur at various times of the year, so distances would vary due to variations in river flow. They would usually be installed at least 65 meters from the river.

Underwater noise from the vibratory installation of sheet piles in water has not been a concern to the resource agencies in the past. Accordingly, there is not a lot of data for sheet piles driven on land near water. Recently, measurements have been made at the Ten Mile River bridge construction project[5,6]. Cofferdams were constructed near and in the river. The closest land-based cofferdam was Bent 5, where sheet piles were driven on land within about 20 meters of the river. Ten Mile River at this construction site is quite shallow, where the deepest part of the channel is usually 1 to 1.5 meters near the project. Most measurements were made at about 100 meters from the piles, which was the closest portion of the channel to the construction. These levels were quite low, about 140 dB RMS, which would correspond to about 140 dB SEL measured over one second. Peak pressures were typically about 160 dB, with the maximum levels around 170 dB. Measurements of about 1 meter deep were made in the shallower water near shore, within 30 to 40 meters of the sheet piles. These levels were even lower, with RMS/SEL(1-sec) levels of about 120 to 130 dB (maximum of 146 dB) and peak sound pressures of 160 dB. One reason for the low levels closer to the activity was probably the very shallow water conditions where the measurements were made. Sound does not propagate efficiently through shallow water.

At the Ten Mile River bridge Pier 7, sheet piles were installed in very shallow water and measured at 10 meters, and at distant positions. Data collected at these positions indicate low sound levels, similar to those for the land-based installation. At 10 meters from the piles, peak sound pressures were generally 155 to 165 dB, and RMS/SEL(1-sec) levels were 140 to 145 dB. Other pile-driving activities interfered with levels measured at the more distant positions; however, there is no reason to believe that the relatively high frequency sounds from these vibratory activities would propagate effectively in that environment.

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[5] Memo from K. Pommerenck (Illingworth & Rodkin, Inc.) to Lisa Embree of Caltrans, dated 4/25/2007, transmitting the underwater noise measurement results for sheet piles at Bent 5 of the Ten Mile River.

[6] K. Pommerenck (Illingworth & Rodkin, Inc.): Summary of underwater noise measurements for the week of July 16-18, 2007. Submitted to Lisa Embree of Caltrans. This report summarized results of measurements for sheet piles installed at Pier 7, which was in shallow water.

Sheet piles vibrated in deeper water make more noise. The vibratory installation of sheet piles was measured at the Port of Oakland on two occasions as part of construction of an underwater sea wall[7,8]. Water depth was about 15 meters. Peak sound pressures were generally 170 to 175 dB, although the beginning portion of some piles had peak pressures of 180 to 185 dB. RMS and SEL (1-sec) levels were generally 155 to 165 dB. Noise from sheet piles includes substantial high-frequency sound content and would not be expected to propagate much in the shallow water conditions in the Mad River. Accordingly, any sheet piles driven in the Mad River are expected to make less noise than the Port of Oakland piles due to the shallow water conditions. The SEL values for sheet piles are therefore estimated to be 140 dB at 10 meters for sheet piles on land, 145 dB at 10 meters for sheet piles installed in the gravel riverbed near water, and 150 dB at 10 meters for sheet piles in water.

Abutment H-type Piles Driven on Land

H-type piles of this size that are driven in water typically produce under water sound levels of 190 dB peak and 175 dB RMS at 10 meters from the pile. SEL levels have not been reported for these piles, but are estimated to be about 160-165 dB. The steel H-type piles for the bridge abutments would be driven on land. The south abutments would be about 90 meters or further from the river. The north abutments would be about 70 meters from the river. Therefore, the ground would substantially attenuate all sounds from this activity. H-type piles driven on land near water have been measured for several projects.

H-type piles used to construct a bridge across the Platte River in Nebraska were measured[9]. These piles were driven in a cofferdam that was excavated and dewatered to a level about 3 meters below the adjacent river bottom. The depth of the river was very shallow, about 2 meters or less. Sound pressure levels were slightly higher at 20–25 meters than at 10 meters from the pile. This was likely the result of shielding from the cofferdam that extended well below the river bottom. At 25 meters from the piles, peak sound pressures were 177 dB, RMS sound pressure levels were 164 dB, and SEL levels were 148 dB.

Temporary H-type piles were driven on shore adjacent to the water and in water for the construction of the new Noyo River Bridge. Peak pressures for piles driven on land next to the water ranged from 174 dB at 23 meters to 157 dB at 94 meters. RMS levels for these distances ranged from 159 dB to 145 dB. SEL levels were not measured, but were probably less than 140 dB at 94 meters.

Noise from H-type piles driven using an impact hammer on land near at the Ten Mile River bridge have recently been measured and found to result in considerably low noise levels[10]. RMS sound pressure levels were typically below 150 dB for piles driven on land about 43 meters from

[7] Illingworth & Rodkin, Inc. 2006. *Port of Oakland Berth 30, Underwater Sound Measurements for the installation of Steel Sheet Piles with a Hydraulic Vibratory Hammer*. Prepared for the Port of Oakland. May 8.
[8] Illingworth & Rodkin, Inc. 2007. *Port of Oakland Berth 35/37, Underwater Sound Measurements for the Installation of Steel Sheet Piles with a Hydraulic Vibratory Hammer*. Prepared for the Port of Oakland. January 23.
[9] Illingworth & Rodkin, Inc. 2006. *Results of Underwater Sound Measurements for the Driving of "H" Piles – Interstate 80 Platte River Bridges*. Prepared for the Nebraska Department of Roads. March 24.
[10] Memo from K. Pommerenck (Illingworth & Rodkin, Inc.) to Lisa Embree of Caltrans, dated 4/25/2007, transmitting underwater noise measurement results for piles at Bent 5 of the Ten Mile River.

the main river channel (20 meters from the edge of water). Peak pressures at this same location were similarly quite low, about 170 dB or less.

Based on these data, the driving of H-type piles for the Mad River abutments (70 to 90 meters from the river) would be expected to result in underwater noise levels of about 170 dB peak and 150 dB RMS or lower. The estimated SEL would be 140 dB or less.

Permanent CISS Piles

The northbound and southbound bridges would be supported by three piers (Piers 2, 3, and 4) and two abutments (Abutment 1 at the south end of the bridges and Abutment 5 at the north end of the bridges). The piers would be constructed with at total of 13 2.2-meter (7-foot) diameter CISS piles. Pier 2 (the furthest south) would be constructed on land about 65 meters from the nearest wetted portion of the river (summer conditions). Pier 2 would consist of four CISS piles (two for each bridge). Pier 3, which would also be constructed with four CISS piles (two for each bridge), is located on the south bank, in a position that is currently 5 to 10 meters from the wetted channel. Pier 4 will be constructed with five CISS piles (two for the southbound bridge and three for the north bound bridge) and will be located on the north bank, approximately 15 meters from the wetted channel of the river. None of the piles would be driven in water.

Under existing conditions, Pier 3 of both bridges would be about 5 to 10 meters from the wetted channel. However, construction techniques will likely divert more of the river to the north (deeper) side so a cofferdam could be constructed. Pier 3 piles would be driven in the excavated cofferdam that would either be dewatered or include an air bubble curtain system if the remaining water inside exceeds a depth of 1 meter. Under this situation, the distance from the pile to the wetted portions of the river would be about 10 to 20 meters. Pier 4 and Pier 2 piles would also be driven within dewatered cofferdams (or mostly dewatered).

Sounds from large diameter CISS piles have been measured in water for several bridge projects. Most notably are the San Francisco-Oakland Bay Bridge and the Benicia-Martinez Bridge. These underwater sound measurements for these bridge projects were made mostly in open water. The Geyserville Russian River bridge replacement project included 1.2-meter diameter piles driven on land near the river. Although these piles were smaller, the environment was similar to that of the Mad River. Data from these projects are described below.

San Francisco-Oakland Bay Bridge East Span Replacement

One-hundred-meter-long, 2.4-meter diameter piles were driven into the bottom of the San Francisco Bay using 500 kiloJoule and 1700 kiloJoule hydraulic hammers. These piles were much longer and slightly larger in diameter than those planned for the Mad River. However, data collected for the first half of driving (the first 50 meters of pile length) of some piles has relevance. Several of the piles were driven in dewatered cofferdams. Only a few of these conditions were measured for the bottom half of the pile when the Menck MHU500T hydraulic hammer was used. Underwater sound data from the entire project is available from the project website: *www.biomitigation.org*. Sound data was published by Illingworth & Rodkin, Inc. for all of the Skyway work, which included most of the large diameter CISS pies driven for the

project[11]. In addition, sound pressure level measurements for the driving of large diameter CIDH casings near Yerba Buena Island (T1) and the large-diameter CISS piles for the Self-Anchored Suspension foundation (Pier E2) was published as part of the marine mammal monitoring requirements[12].

Pier E16E included piles driven in a dewatered cofferdam in shallow water, with depths of mostly about 3 to 4 meters. The Menke MHU500T, providing about 550 kiloJoules of energy, was used to drive the top half of this pile. About 200 feet of pile had been driven into the ground before these measurements were made. Sound pressures measured between 25 and 65 meters from the pile were mostly less than 180 dB peak, 170 dB RMS, and 160 dB SEL. One position that was 95 meters west had much higher sound levels. At this position, sound pressures reached 196 dB peak, 184 dB RMS, and 172 dB SEL. This was an isolated area around the pile, where sound levels were lower at all other positions. More extensive monitoring was conducted at Pier E15W near Pier E16E to investigate these higher sound levels (see Figure 2). Again, a small area of substantially higher sound levels was found, while all other areas around the pile had much lower levels. In general, measurements made from 35 meters to 300 meters from the pile had sound pressure levels under 190 dB peak and 180 dB RMS. One isolated area at 70 to 77 meters southwest of the pile had levels 202 dB peak and 189 dB RMS near the end of the drive, when almost 100 meters of pile was driven into the ground. Measurements under similar conditions for Pier E12W found higher sound levels in fairly isolated areas. The area of elevated sound pressures was larger in area and had higher levels. While most levels around the pile were 20 dB lower, the area about 100 to 150 meters from the piles in the west through south positions had sound pressures up to 205 dB peak and 194 dB RMS. These levels were measured during the final driving stages (deepest driving) when the MHU1700T hammer was used that is rated at 1,750 kiloJoules. This activity produced higher sound levels than those expected at Mad River because the pile was driven much farther into the ground and the surrounding water was much more vast and deeper. The highest levels occurred when the larger hammer (MHU1700T) and deepest driving at this project was encountered.

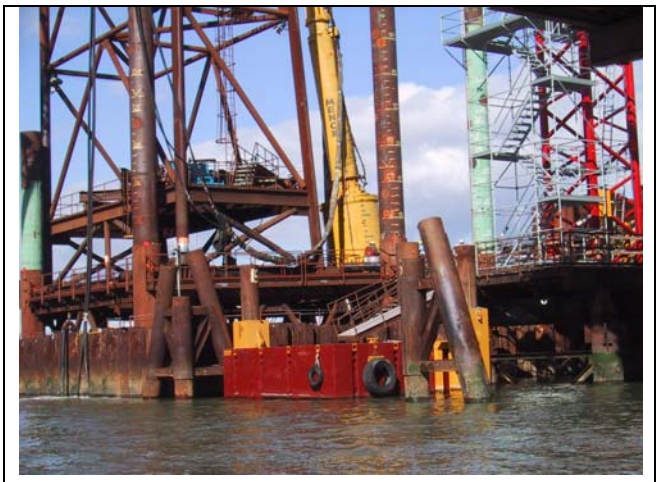


Figure 2. SFOBB Pile Driving in dewatered cofferdam at Pier E15W using Menck 1700MHU

Measurements were made at Pier E11W when the bottom pile sections (i.e., first 50 meters of pile) were driven using the MHU500T hammer. In this case, most sound pressure levels were below 185 dB peak and 175 dB RMS, with the exception of the south through southeast directions. In these directions, sound pressures were elevated to about 190–195 dB peak, 180–

[11] Illingworth & Rodkin, Inc. 2005. *Hydroacoustic Monitoring Repor— San Francisco-Oakland Bay Bridge East Span Seismic Safety project.* Prepared for the State of California Department of Transportation, under contract to Parsons Brinckerhoff. May.

[12] Illingworth & Rodkin, Inc. 2006. *Hydroacoustic Measurements at T1 and E2—San Francisco-Oakland Bay Bridge East Span Seismic Safety Project*. Prepared for the State of California Department of Transportation, under contract to Parsons Brinckerhoff. August.

183 dB RMS, and 170–173 dB SEL. The highest levels occurred between 90 and 120 meters from the pile during the last 5 minutes of pile driving. Levels were lower both closer and farther from the pile. Water depth was about 5 meters. This was the first 50-meter section of pile that would be similar to the pile lengths planned at Mad River, but the water was deeper.

Extensive measurements were made for other piers with dewatered cofferdams, though in deeper water when only the top pile sections were driven with the MHU1700T hammer. Typically levels east, north, and west were much lower than those measured in southerly directions. There was much attention focused on these elevated levels from the piles, but they only occurred in isolated areas, specific directions and distances. Drop off rates were plotted for these driving conditions. For the most part, sound pressures were below 190 dB peak and 180 dB RMS in all directions except the louder isolated cases that typically occurred in the southerly direction. The loudest levels were found at 100 meters from these long piles. In the louder directions, highest sound levels were also found at 100 meters from the pile, where sound pressures were 190–205 dB peak and 180–190 dB RMS. SEL levels analyzed for individual strikes showed roughly a –10-dB relationship to RMS levels.

Benicia-Martinez Bridge

Most piles driven for the new Benicia-Martinez Bridge were driven in open water. At Pier 6, underwater sound measurements were made when piles were driven in a cofferdam with water surrounded by very shallow water (see Figure 3). Water depth inside the cofferdam was about 2 meters, with 1- to 2-meter-deep water surrounding the cofferdam. The piles 2.4 meters in diameter were driven with a MHU500T hammer. These data were never reported, but were included in the files of Illingworth & Rodkin, Inc. At the time of the measurements, pile resistance was great and little progress in driving the piles with the hammer at 550 kiloJoules was being made. That is, the blow count per meter was very high. A cofferdam with water is not expected to have an effect in attenuating sound levels. Since water depth inside and outside of the cofferdam varied considerably, it was not possible to reliably measure this effect.

Figure 3. Benicia-Martinez Bridge Pile Driving in cofferdam with shallow water at Pier 6 using Menck 500MHU

Measurements outside the cofferdam ranged from 206 dB peak and 193 dB RMS at 12 meters to 179 dB peak and 162 dB RMS at 54 meters. Measurements at 36 meters from the cofferdam were 190 dB peak and 170 dB RMS. SEL levels were not analyzed from these recordings. Pile driving from these activities would probably be louder than the Mad River, because the pile was being driven when it had reached resistance and water was deeper (about 2 meters deep) throughout the area.

Geyserville Russian River Replacement Bridge

Permanent 0.6-meter diameter piles about 40 meters in length were driven on land and in the Russian River to support the new bridge. The bridge was supported on bents instead of piers. Each bent consisted of two of these piles. Underwater sound measurements were made for the driving of several piles both on land and in the water[13]. Bents 2 and 3 were constructed in the dry portion of the riverbed, while Bent 4 was immediately adjacent to the river. Bent 5 was in 1.5-meter deep water, where the wetted channel was about 15 to 20 meters wide and 2 meters deep. The piles were typically driven in two sections: a bottom section that was vibrated and driven and the top section that was driven. The piles were driven with a Del Mag D100-13 hammer that has a maximum obtainable energy of about 340 kiloJoules (300,000 ft-lbs). Top sections required about 5 to 7 minutes of continuous driving over a 45- to 60-minute period. The piles were spliced and the top sections were driven on a separate day. About 45 to 60 minutes of continuous driving over a 90- to 120-minute period was needed to drive the top sections.

The piles driven for Bents 2 and 3 at Russian River are the most typical for the setting that would occur for Piers 2 of each bridge at Mad River (see Figure 4). However, the piles were smaller in diameter and required less energy to drive. Bent 2 was about 60 meters from the main channel, where underwater sound levels were about 165 dB peak and 155 dB RMS during the driving of the bottom section. Measurements for the top section were not made, but thought to be 3 to 5 dB higher. Bent 3 was 33 meters from the main channel, where sound pressures were 180 dB peak, 168 dB RMS, and 157 dB SEL for the loudest portion of the bottom-section pile driving. The top section was not measured, but also thought to be about 3 to 5 dB higher.

Figure 4. Geyserville Russian River Bridge construction looking at piles for Bents 2 and 3 with mark for Bent 4 near river edge

Bent 4 was immediately adjacent to the river channel (see Figure 5). The bottom section of the piles was first vibrated into the dry riverbed. Measurements were made at 20 meters from the pile, but levels consistently above the background could not be measured. Peak pressures were estimated at below 150 dB. Sound pressures for the bottom section at 20 meters were 192 dB peak, 180 dB RMS, and 165 dB SEL. The underwater sound levels for a top section of a Bent 4 pile was measured at three different positions in the main channel (all downstream). Sound levels varied considerably with time during the driving of this pile section at all positions, especially the closest positions. During the first part of pile driving, sound pressure levels at 10 and 20 meters were about 198 dB peak, 185 dB RMS, and 174 dB SEL. The highest levels were 202 dB peak, 189 dB RMS, and 175 dB SEL. During the second part of the drive, sound pressures were much lower at 10 and 20 meters.

[13] Illingworth & Rodkin, Inc. 2006. *Russian River Replacement Bridge at Geyserville—Underwater Sound Measurement Data for Driving Permanent 48-inch CISS Piles*. Prepared for the State of California Department of Transportation, District 4, under contract to CC Meyers. August.

Peak pressures were about 190 dB, RMS levels were about 180 dB, and SEL levels were about 167 dB. At 50 meters, sound pressure levels were lowest during the first part of the drive and highest about 2/3rds of the way through the drive. Overall variation was less than at 10 and 20 meters from the pile. Sound pressures for the first part were 188 dB peak, 174 dB RMS, and 162 dB SEL. For the second part, sound pressures were 190 dB peak, 177 dB RMS, and 164 dB SEL. Peak pressures reached a maximum of 195 dB. Overall, the average sound pressures for the driving of one Bent 4 are summarized in Table 2.

Figure 5. Geyserville Russian River Bridge construction looking from river at piles for Bent 4

Table 2. Russian River, Geyserville Measured Sound Levels—Bent 4

Distance	Sound Pressure Level in dB		
	Peak (re 1µPa)	**RMS** (re 1µPa)	**SEL** (re 1µPa^{2}sec)
Russian River Bent 4 Bottom Section			
20 meters	192	180	165
Russian River Bent 4 Top Section			
10 meters	192	181	170
20 meters	195	182	170
45 meters	190	177	164

Measurements were also made for the Bent 5 piles that were driven in the Russian River. These piles naturally produced higher sound levels, but only for the first part of the driving period of the top sections. These measurements included an additional location farther away, which showed a dramatic drop off in sound levels at a distance beyond 40–50 meters. The measurements at 75 meters were about 15 dB lower than the 45-meter measurements. A spot measurement at 65 meters showed levels almost 10 dB lower than those at 45 meters. The SELs for Bent 5 piles at Russian River were estimated to be 160 dB at 65 meters and 155–157 dB at 75 meters.

The Geyserville data for Bents 2, 3, and 4 probably provide the best indication of noise levels that could be expected from the large CISS piles planned at the Mad River. The Geyserville piles were smaller; so 3 dB could be added to adjust noise levels for the difference in pile size and driving energy. However, the Mad River piles would be driven starting at an elevation at or below the river bottom, which would provide some shielding from the highest sounds. Therefore, we do not propose such a correction. Furthermore, the Geyserville data are comparable for the most relevant piles measured at the San Francisco-Oakland Bay Bridge(Pier E11W) and the Benicia-Martinez Bridge. Based on a review of these data, sound level predictions for the Mad River piles are provided in the *Attachment*.

Underwater Sound Thresholds

A Fisheries Hydroacoustic Workgroup (FHWG) that consisted of transportation officials, resources agencies, the marine construction industry (including Ports), and bioacoustics experts was formed in 2003 to address the underwater sound issues associated with marine construction.

The first order of business was to document all that was clearly known about the effects of sound on fish. The result of this effort was a report prepared by Dr. Mardi Hastings and Dr. Arthur Popper, titled "Effects of Sound on Fish[14]." This report provided recommended preliminary guidance to protect fish. A graph showing the relationship between the SEL from a single pile strike and injurious effects to fish based on size (i.e., mass) was presented. Fish with a mass of about 0.03 grams were expected to have no injury for a received SEL of a pile strike below 194 dB and suffer 50% mortality at about 197 dB. The report also described possible effects to the auditory system (i.e., auditory tissue damage and hearing loss), based on a received dose of sound. The recommendations were frequency dependent, based on the hearing thresholds of fish or most sensitive auditory bandwidths. Presentations to the FHWG found that, for salmonids, hearing effects would be expected at or near the thresholds for injury based on the single strike SEL. Research to further investigate the effects of pile-driving sounds on fish was also recommended in this report. Some of these were taken up in an ongoing National Cooperative Highway Research Program (NCHRP 25-28). This NCHRP study is intended to develop guidelines for the prediction and mitigation of the impacts on fish from underwater sound pressure and particle motion caused by pile driving. The current projected completion date is late 2008.

To provide additional explanation of the injury criteria recommended in the "The Effects of Sound on Fish" and to provide a practical means to apply the criteria, Caltrans commissioned Dr. Popper and other leading experts to prepare a subsequent report. This report is entitled "Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper" (*White Paper*)[15]. The *White Paper* recommends a dual criteria for evaluating the potential for injury to fish from pile-driving operations. The dual criteria approach considered that a single pile strike with high enough amplitude, as measured by zero to peak (either negative or positive pressure), could cause injury. A peak pressure threshold for a single strike was recommended at 208 dB. The White Paper suggested a value between 205 and 215 dB and found through other studies that the 208 dB level was adequate.

To account for the energy in a single strike, the SEL metric proposed by Hastings and Popper[14] was included as the second part of the duel criteria. The proposed threshold is 187 dB SEL that would be applied to only the highest pile strike. Thus, the dual criteria of 208 dB Peak or 187 dB SEL for any pile strike were recommended for the interim until further research has been conducted.

FHWA Adopted Thresholds

The FHWA has adopted the dual criteria as recommended under the White Paper described above. The current adopted thresholds by FHWA are for single piles strikes that result in underwater sound levels of 208 dB peak or 187 dB SEL or greater.

[14] Hastings, M and A. Popper. 2005. Effects of Sound on Fish. Prepared for the California Department of Transportation. January 28 (revised August 23).

[15] Popper, A., Carlson, T. , Hawkins, A., Southall, B., and Gentry, R. 2006. Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper. May 15.

NOAA Thresholds

Although NOAA participated in the FHWG, the agency does not completely agree with the dual criteria approach recommended in the White Paper and adopted by FHWA. Basically, NOAA does not believe the criteria are fully protective for the effect of cumulative piles strikes. NOAA does agree with the 208 dB peak threshold for a single strike. To account for the accumulation of strikes, NOAA suggests accumulating SEL for successive pile strikes. This accumulated SEL is then compared to the White Paper SEL threshold. This approach results in an extremely conservative interpretation of the White Paper SEL criterion. Under this approach, the NOAA proposed method accumulates SEL from pile strikes that could be orders of magnitude below the threshold for injury. In theory, a pile strike that a fish may not even detect could accumulate to a level that NOAA considers to cause injury. There is no lower boundary or cutoff in the proposed NOAA threshold. Under the proposed NOAA threshold, the accumulated SEL is based on the number of strikes and the SEL level per strike. An "equal energy hypothesis" is assumed where all received strikes have the same SEL. Implicit is that this is a received level, but difficult to assess if one cannot account for the position of the fish receiving the sound through an event. To account for the NOAA SEL threshold, the SEL per strike for various distances are predicted. Then the number of strikes that would be required to drive a pile is predicted. The impact area is then considered as the portion of the fish habitat where the accumulated SEL is at or above 187 dB. This is calculated by adding the SEL at a certain position or distance to 10 times the base 10 Logarithm of the number of pile strikes:

$$\textit{Accumulated SEL} = \textit{Received SEL}_{\textit{per strike}} + 10 * \textit{Log}_{10}(\textit{no. of pile strikes})$$

Again, this assessment assumes that all pile strikes are of the same SEL. If a fish remains within an area that accumulates to 187 dB SEL for the entire event, it would be considered harmed under the NOAA threshold. The effect to a fish moving through the area during the pile-driving event would be unknown, since the received SEL levels would vary with each strike as the fish's position changes relative to the pile being driven.

Noise from Pile Installation

Installation of sheet piles using vibratory driver/extractors would make noise in the river that will be relatively low but detectable. H-type piles driven for the abutments would be set back considerably from the river, and the piles would be driven through ground that is well above the surface level of the river. Sound levels in the river will also be low for these H-type piles, but possibly detectable.

The driving of the CISS piles for Piers 2, 3, and 4 of both bridges are expected to result in elevated noise levels in the river. The levels of noise will be dependent on a number of factors that include substrate conditions, distance from the pile, and water depth. Very high sound levels are not expected to occur in areas of very shallow water because shallow water does not support the propagation of pile driving sound. Pile-driving noise measurements have shown that these sounds drop off considerably with decreasing depth between the surface and 2 meters. At the water-air interface, sound pressure drops to zero. Therefore, noise impacts can only be identified through measurements for areas of the river where the depth exceeds 1 meter. However, the

effect of extremely shallow waters (i.e., less than 1 meter deep) on the resulting in low sound levels was not considered in this assessment.

Peak Sound Pressures

Impact pile driving of Pier 2 piles, abutment H-type piles, and cofferdam vibratory sheet piles are predicted to result in peak sound pressures of less than 200 dB at any position on the river. Maximum peak sound pressures for pile driving are predicted to be 205 dB within about 10 to 20 meters of Pier 3 and Pier 4 piles. This would occur for the top pile portions of these piers only. Sound levels above the single strike peak pressure threshold of 208 dB adopted by NOAA and FHWA are not predicted to occur.

Single and Multiple Pile Strikes—FHWA

The White Paper suggested that a single strike threshold of 187 dB SEL would be protective for multiple piles strikes. So, if the highest pile strike during a pile-driving event is less than 187 dB SEL, there is no adverse cumulative impact from multiple strikes. FHWA has adopted this threshold. The maximum predicted SEL from any single pile strike associated with the project would be about 175 dB. Accordingly, single strike SEL criterion of 187 dB is not predicted to be exceeded.

Multiple Piles Strikes—NOAA

NOAA's approach to assessing impacts from multiple strikes is to calculate the received SEL for all pile strikes from a pile-driving event. In this approach, NOAA has adopted the 187 dB SEL level for a single strike and applied it to the accumulation of SEL for multiple strikes. This approach does not account for the periods when recovery could occur in the 1- to 1.5-second periods between the sound events that last for about 0.1 to 0.2 seconds. In addition, the approach assumes that relatively low sound levels that would be unlikely to result in injurious effects could accumulate with a large number of pile strikes to a level that could exceed 187 dB SEL.

Under the NOAA threshold, the accumulated sound energy would be dependent on the number of impact pile strikes received or the time that a vibratory installation occurs as well as the SEL associated with a pile strike. The number of piles strikes is calculated based on the predicted pile-driving times and using the estimated frequency of pile strikes for a particular hammer. Accumulated SEL levels for pile driving were calculated based on the predicted sound levels and predicted drive times. These calculations are attached.

The SEL sound levels at different distances were predicted based on measurements for similar piles in similar environments. The driving times were also based on experience measuring similar piles.

Accumulated SEL for H-Type Piles

H-type piles driven away from the river, at 50 meters or farther, would result in SEL levels of 140 dB or less per strike at the closest position in the river. Experience indicates that these piles take about 5 to 15 minutes to drive continuously. As a result, accumulated SELs in the river would be 168 dB or less. This is a conservative assessment because the two abutments where the H-type piles are to be driven are 70 to 90 meters from the wetted channel.

Accumulated SEL for Cofferdam Sheet Piles

Most cofferdam sheet piles would be installed on land using a vibratory driver/extractor. Some sheet piles would be installed in the dry riverbed very close to water, and some in the water near the existing bridge. SELs for sheet pile installation on land near water and in shallow water were predicted based on previous measurement data. Sheet piles usually require about 3 to 6 minutes of driving to install, but some can take about 10 minutes or longer, depending on the substrates. Actual driving time is about 4 to 6 minutes. A continuous driving time of 10 minutes was used for the accumulated SEL calculations. Predicted accumulated SELs for each sheet pile would be less than 187 dB for any sheet pile driven on land or in the shallow water. Many sheet piles would likely be driven in one day. These piles are usually less than 1 meter wide and interlock with others. The cumulative impact would have to be considered by predicting the accumulated SEL for a time period in which fish would be continuously present. Past experience has shown that about 10 sheet piles can be driven in one day. In some cases more can be driven, but they may be farther away. In any case, the driving of multiple sheet piles on land or in very shallow water would result in accumulated SELs of less than 187 dB at 10 meters. Driving of multiple sheet piles in the deeper water (e.g., at the thelwag near the existing north piers) would result in accumulated SELs exceeding 187 dB. The area experiencing this impact would be confined to the deeper water of the thelwag within about 20 meters.

Accumulated SEL for CISS Piles

The length of the CISS piles will likely prevent transport of the piles to the project site in a single piece. Accordingly, the large CISS piles would likely be driven in several sections. In addition, center relief drilling may be required. This assessment assumes that each CISS pile would be driven in four sections. The first section would be stabbed then driven with an impact hammer for about 15 minutes. The 2nd, 3rd, and 4th sections would be driven on separate days using an impact hammer. These sections were assumed to require 30 minutes of continuous driving time each. This would naturally vary depending on driving conditions. Preliminary indications are that a large hydraulic hammer would be required to drive these piles. These hammers usually strike the pile at a rate of one strike every two seconds. Strikes with considerably less energy can occur more frequently, but result in lower noise levels per strike. Conversely, the strikes with the most energy per strike occur a little less frequently. For this assessment, a pile strike was assumed every two seconds of pile driving.

These driving times and predicted SELs at various distances from the pile were combined with each CISS pile-driving scenario to predict the accumulated SEL. Accumulation of SEL is expected to reach or exceed the 187 dB SEL accumulated threshold for all Pier 3 and 4 pile-driving events. Because Pier 2 is setback from the river, accumulated SELs are not predicted to reach the NOAA threshold for any of those pile-driving events. It should be noted that four smaller diameter steel-pipe piles would be required at the southbound Pier 2 as part of a load test for the foundation piles. Since these piles would be smaller, they would result in less noise than the Pier 2 CISS piles.

The bottom section of the piles (the first sections to be driven) would result in lower noise levels because of less expected resistance and the drive times would be relatively short. The predicted accumulated SEL is expected to reach 187 dB out to 45 meters from the piles at Pier 3 and Pier 4, assuming the pile is driven for 15 minutes (600 strikes).

The subsequent upper sections of these CISS piles would require about 30 minutes each of pile driving time (900 pile strikes), where each strike would generate higher sound levels. The combination of more pile strikes and higher sound levels per strike would result in higher accumulated SEL levels for the top sections. These piles are predicted to have accumulated SEL levels of 187 dB or higher, as far as 75 to 90 meters from the pile for each driving event.

The predictions of accumulated SEL for CISS piles described above assume only one pile section would be driven. However, it is possible that two piles could be driven in one day. If this were to occur, 3 dB would have to be added to the accumulated SEL predicted for a single pile-driving event. Sound propagation beyond 75 meters has not been extensively measured in shallow conditions similar to the Mad River, so as a conservative estimate a rate of 5 dB per doubling of distance should be used. This rate is lower than the rate measured for Noyo River and Russian River (Geyserville) pile-driving activities. If two piles were driven at Pier 2, accumulated SELs in the water are still expected to remain below 187 dB. If two piles are driven in a single day at Piers 3 and 4 the areas where SELs would exceed 187 dB are predicted to be 65 meters for bottom sections, 120 meters for middle sections, and 140 meters for top sections.

Mad River Bridge Replacement
Year 1 Noise Impact Assessment- Southbound Bridge Piers and Abutments

Activity Description	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground															
Vibratory Sheet Installation on land	10	600 sec.	160	<160	<160	<160	140	140	140	135	168	168	168	163	--
Vibratory Sheet Installation in very shallow wat	10	600 sec.	160	<160	<160	<160	145	145	145	140	173	173	173	168	--
Vibratory Sheet Installation in deeper water	10	600 sec.	170	165	<160	<160	155	150	145	140	183	178	173	168	--
Pier 2 SB Bridge															
Bottom Section P1	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
Bottom Section P2	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
2nd Section P1	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
2nd Section P2	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
3rd Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
3rd Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Pier 3 SB Bridge															
Bottom Section P1	15	450 strike	190	190	190	180	165	165	160	155	192	192	187	182	45 meters
Bottom Section P2	15	450 strike	190	190	190	80	165	165	160	155	192	192	187	182	45 meters
2nd Section P1	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
2nd Section P2	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
3rd Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
3rd Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Pier 4 SB Bridge															
Bottom Section P1	15	450 strike	NA	190	190	180	NA	165	160	155	NA	192	187	182	45 meters
Bottom Section P2	15	450 strike	NA	190	190	80	NA	165	160	155	NA	192	187	182	45 meters
2nd Section P1	30	900 strike	NA	200	190	180	NA	170	165	157	NA	200	195	187	75 meters
2nd Section P2	30	900 strike	NA	200	190	180	NA	170	165	157	NA	200	195	187	75 meters
3rd Section P1	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
3rd Section P2	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
Top Section P1	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
Top Section P2	30	900 strike	NA	205	195	185	NA	170	167	159	NA	200	197	189	90 meters
SB Bridge Abutments															
H-Type Pile	15	600 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	168	163	--

NA = Not applicable - the specified distance is on land, not in water

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Mad River Bridge Replacement
Year 2 & 3 Impact Assessment- Northbound Bridge Piers and Abutments

Activity Description	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground															
Vibratory Sheet Installation on land	10	600 sec.	160	<160	<160	<160	140	140	140	135	168	168	168	163	--
Vibratory Sheet Installation in very shallow water	10	600 sec.	160	<160	<160	<160	145	145	145	140	173	173	173	168	--
Vibratory Sheet Installation in deeper water	10	600 sec.	170	165	<160	<160	155	150	145	140	183	178	173	168	--
Pier 2 NB Bridge															
Bottom Section P1	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
Bottom Section P2	15	450 strike	NA	NA	170	170	NA	NA	150	145	NA	NA	177	172	--
2nd Section P1	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
2nd Section P2	30	900 strike	NA	NA	175	175	NA	NA	150	145	NA	NA	180	175	--
3rd Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
3rd Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P1	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Top Section P2	30	900 strike	NA	NA	180	180	NA	NA	150	145	NA	NA	180	175	--
Pier 3 NB Bridge															
Bottom Section P1	15	450 strike	190	190	190	180	165	165	160	155	192	192	187	182	45 meters
Bottom Section P2	15	450 strike	190	190	190	80	165	165	160	155	192	192	187	182	45 meters
2nd Section P1	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
2nd Section P2	30	900 strike	200	200	190	180	170	170	165	157	200	200	195	187	75 meters
3rd Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
3rd Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P1	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Top Section P2	30	900 strike	205	205	195	185	170	170	167	159	200	200	197	189	90 meters
Pier 4 NB Bridge															
Bottom Section P1	15	450 strike	NA	190	190	180	165	165	160	155	NA	192	187	182	45 meters
Bottom Section P2	15	450 strike	NA	190	190	80	165	165	160	155	NA	192	187	182	45 meters
Bottom Section P3	15	450 strike	NA	190	190	80	165	165	160	155	NA	192	187	182	45 meters
2nd Section P1	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
2nd Section P2	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
2nd Section P3	30	900 strike	NA	200	190	180	170	170	165	157	NA	200	195	187	75 meters
3rd Section P1	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
3rd Section P2	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
3rd Section P3	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P1	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P2	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
Top Section P3	30	900 strike	NA	205	195	185	170	170	167	159	NA	200	197	189	90 meters
NB Bridge Abutment															
H-Type Pile	15	600 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	168	163	--

NA = Not applicable - the specified distance is on land, not in water

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Mad River Bridge Replacement Project

Evaluation of Underwater Noise Generated by Use of Smaller Piles (30-Inch-Diameter)—DRAFT

Contract 03A1317, Task Order 12

03-1A8420

November 6, 2007

Table of Contents

Page

Introduction....1
Pile-Driving Activities Generating Noise....2
Noise Assessment....5
Cofferdam Construction with Vibrated Sheet Piles....6
H-Type Pile Installation....6
CISS Pile Installation....7
Pier 2....7
Piers 3 and 4....7
Comparison of Estimated Sound Generation to Interim Criteria....7
Differences in Sound Levels Produced by Proposed Piles and Use of Smaller Piles....10
Differences in Estimated Exposure of Fish to Sound Levels Exceeding Interim Thresholds....11
References Cited....12
List of Preparers....12
Caltrans....12
Jones & Stokes....12
Illingworth & Rodkin....12

Appendix A. Illingworth & Rodkin 30-Inch Pile Analysis

List of Tables and Figures

		Page
Table 1	Current Listing Status and Critical Habitat for Federally Listed Salmon and Steelhead Species Occurring in Mad River	1
Table 2	Number and Size of Piles That Would Need to Be Driven if 30-Inch Piles Are Used	2
Table 3	Distance between Abutments/Piers and Typical Summer and Winter Wetted Channel of the River	3
Table 4	Anticipated Pile Driving Activity if 30-Inch Piles Are Used	4
Table 5	Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-Inch Piles	follows 6
Table 6	Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-Inch Piles	follows 6
Table 7	Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Southbound Bridge, Year 1)	9
Table 8	Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Northbound Bridge, Year 3)	9
Table 9	Number of Days and Distances at Which 7-Foot and 30-Inch Pile-Driving Scenarios for Piers 3 and 4 Are Estimated to Result in Accumulated Sound Levels Exceeding 187 $dB_{SEL(Accumulated)}$	11

		Follows Page
Figure 1	Existing Habitat Features in the Vicinity of the Mad River Bridge	2

Mad River Bridge Replacement Project: Evaluation of Underwater Noise Generated by Use of Smaller Piles (30-Inch-Diameter)

Introduction

The California Coastal Commission (CCC) has requested that the California Department of Transportation (Caltrans) conduct an analysis of pile-driving noise that would be expected if the Mad River Bridges were reconstructed using 0.76-meter-diameter (30-inch-diameter) cast-in-steel-shell (CISS) piles rather than the 2.2-meter-diameter (7-foot-diameter) CISS piles in the current design. Caltrans project engineers have estimated the number and location of the 30-inch piles that would be necessary for this alternative (an engineering design has not been prepared for 30-inch piles). This alternative analysis uses the same methods as the analysis of the current project design (California Department of Transportation 2007a).

This report evaluates the potential effects of sound generated from pile-driving activities during the Mad River Bridge Replacement Project on salmonids listed as threatened or endangered under the federal Endangered Species Act if 30-inch-diameter piles were used rather than the 7-foot-diameter CISS piles in the current design. The federally listed species in the project area include the California coastal chinook salmon evolutionarily significant unit (ESU), southern Oregon/northern California coast coho salmon ESU, and northern California steelhead (both summer and winter run) distinct population segment (DPS). General information regarding the distribution and biology of these species has been provided in the original biological assessment and biological opinion regarding this action; this information will not be repeated here. However, changes to the status and critical habitat designations have occurred since the February 2005 biological opinion, as reported in Table 1.

Table 1. Current Listing Status and Critical Habitat for Federally Listed Salmon and Steelhead Species Occurring in Mad River

Species	Listing Status Reaffirmed	Critical Habitat Designation
California coastal chinook salmon ESU	Threatened—70 FR 37160, June 28, 2005	70 FR 52488, September 2, 2005
Southern Oregon/northern California coast coho salmon ESU	Threatened—70 FR 37160, June 28, 2005	64 FR 24049, May 5, 1999
Northern California steelhead DPS	Threatened—71 FR 834, January 5, 2006	70 FR 52488, September 2, 2005

Note: FR = Federal Register

The CCC also requested that Caltrans evaluate the potential effects of noise generated during pile-driving on coastal cutthroat trout, a species that is listed as threatened under the California Endangered Species Act.

Pile-Driving Activities Generating Noise

This analysis addresses noise from pile-driving only. Caltrans is proposing to replace both the northbound and southbound bridges of U.S. Highway 101 that cross the Mad River just south of McKinleyville, California. The current design for the new bridges includes impact pile-driving of thirteen 7-foot-diameter CISS steel piles, four 1.2-meter-diameter (4-foot-diameter) CISS steel piles (at Pier 2), and seventy-nine 0.36-meter-wide (14-inch-wide) H-type piles. Figure 1 shows the location of the new piles. See Caltrans 2007a for project details.

The CCC requested that Caltrans conduct an analysis of the underwater noise that would be expected if 30-inch-diameter piles were used rather than the proposed 7-foot-diameter piles. The Caltrans project manager estimated that a total of two-hundred sixty 30-inch-diameter, 1-inch-thick steel shell piles would be required to replace the thirteen 7-foot-diameter piles (Mullen pers. comm.). The 30-inch-diameter piles would be located at the same proposed pier locations as the 7-foot-diameter piles (Figure 1). Four 16- to 24-inch template piles would be also be impact-driven at southbound Pier 2 to secure a template for the pile load test, which would replace the 1.2-meter template piles described in Caltrans 2007a.

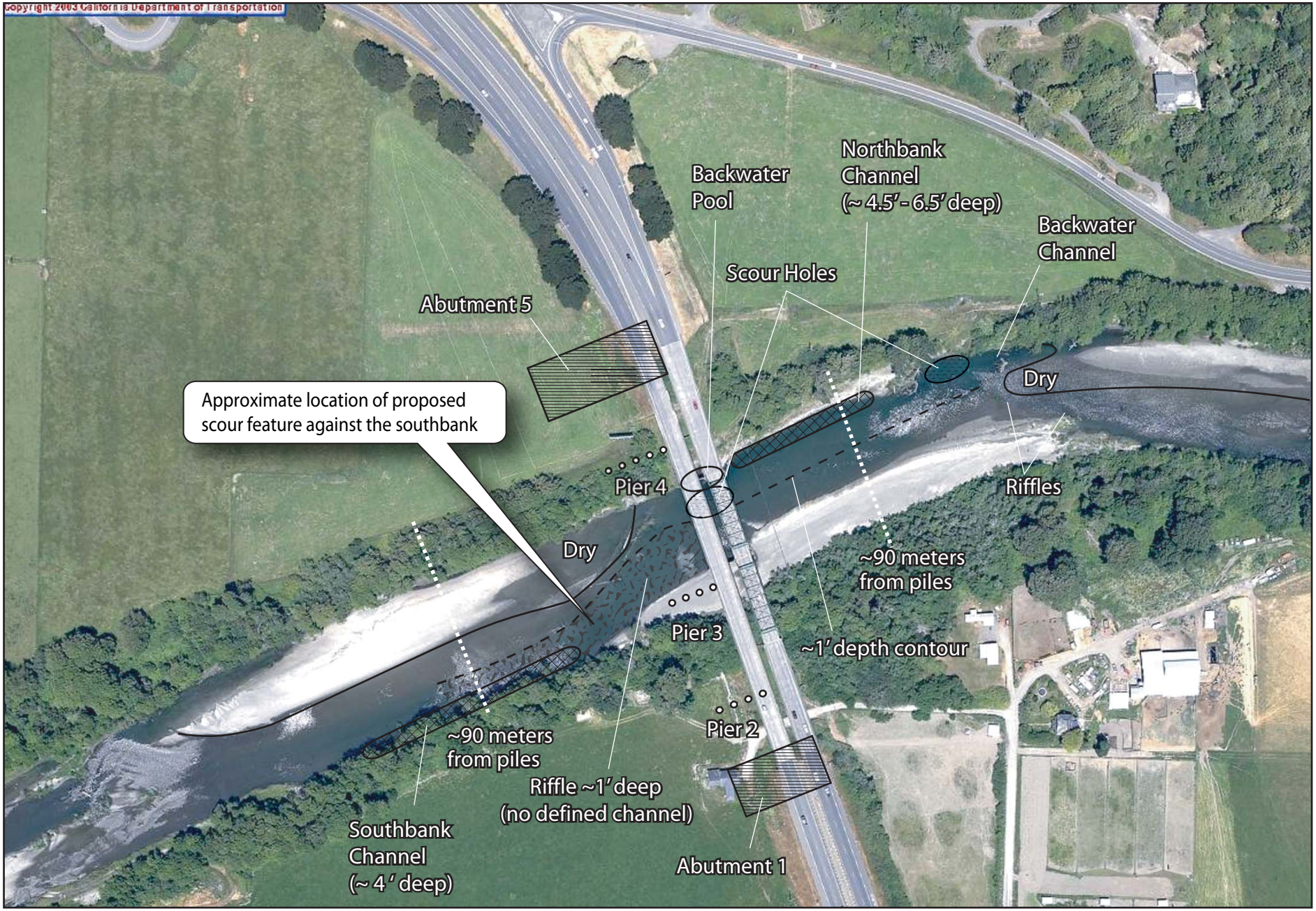
Table 2 summarizes the number, size, and location of piles that would be driven under this alternative analysis.

Table 2. Number and Size of Piles That Would Need to Be Driven if 30-Inch Piles Are Used

Pier/Bridge	Number of Piles (Size)	
	Southbound Lanes	Northbound Lanes
Abutment 1 (south end of bridge)	13 (14-inch H-type piles)	14 (14-inch H-type piles)
Pier 2	40 (30-inch-diameter CISS piles) 4 (0.4- to 0.6-meter-diameter [16- to 24-inch-diameter] CISS piles)	40 (30-inch-diameter CISS piles)
Pier 3	40 (30-inch-diameter CISS piles)	40 (30-inch-diameter CISS piles)
Pier 4	40 (30-inch-diameter CISS piles)	60 (30-inch-diameter CISS piles)
Abutment 5 (north end of bridge)	20 (14-inch H-type piles)	32 (14-inch H-type piles)

A bridge design utilizing 30-inch-diameter piles would also require footings. The proposed and alternative bridge designs would both include impact-driven pile installation for H-type piles for the two abutments, as well as installation of temporary sheet piles (to be vibrated in) for cofferdams for pile-driving and demolition areas.

Table 3 shows the approximate distance between the piles to be driven and the typical summer and winter wetted channel of the Mad River. No piles will be impact-driven within the wetted channel of the river, as in the proposed design.



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Jones & Stokes

Figure 1
Existing Habitat Features in the Vicinity of the Mad River Bridge

Table 3. Distance between Abutments/Piers and Typical Summer and Winter Wetted Channel of the River

Pier/Bridge	Distance between Abutments/Piers the Summer/Winter Wetted Channel	
	Southbound Lanes	**Northbound Lanes**
Abutment 1 (south)	**Summer:** 90 meters (295 feet) or greater **Winter:** ~7 meters (256 feet) or greater	**Summer:** 90- meters (295 feet) or greater **Winter:** ~78 meters (256 feet) or greater
Pier 2	**Summer:** 65 meters (213 feet) **Winter:** ~43 meters (141 feet)	**Summer:** 65 meters (213 feet) **Winter:** ~43 meters (141 feet)
Pier 3*	**Summer:** 0 meters (0 feet) **Winter:** N/A	**Summer:** 0 meters (0 feet) **Winter:** N/A
Pier 4	**Summer:** 15 meters (49 feet) **Winter:** N/A	**Summer:** 15 meters (49 feet) **Winter:** N/A
Abutment 5 (north)	**Summer:** 70 meters (230 feet) **Winter:** ~65 meters (213 feet)	**Summer:** 70 meters (230 feet) **Winter:** ~65 meters (213 feet)

* Distance without extension of the gravel bar. The footprint of 20 piles would be approximately 4.6 by 6.1 meters (15 by 20 feet). This could extend the footprint within the wetted channel. All pile-driving would occur within a dry cofferdam or cofferdam with bubble curtain.

For both the proposed and alternative pile sizes, cofferdams would be constructed to isolate the pier area before driving the piles at both the southbound and northbound Piers 2, 3, and 4. Construction of the cofferdams would be conducted in the same manner as the proposed design. The cofferdams would be constructed by installing sheet pile with a vibratory hammer. The area inside the cofferdams would be excavated 11 meters (36 feet) below original ground at the column/pile interface. When excavated, water will likely seep into the cofferdams. The cofferdams would be dewatered down to the column/pile interface to allow installation of the footings, columns, and foundations. During CISS pile-driving, the cofferdams would be dewatered to the column/pile interface or the piles would be driven with a bubble curtain around the pile in the cofferdam. This is the same as the proposed design, but with the 30-inch piles, each group of piles would also require a footing.

For both the proposed and smaller pile alternative, a vibratory hammer would be used to construct cofferdams around the existing piers to isolate those areas during their demolition. Except for the cofferdam around the north shore bridge piers to be removed and the north side of the cofferdams for installation of Pier 3, these cofferdams would be driven on land. Note that the cofferdams installed for the construction of the new Piers 2 and 4 are constructed completely on land, not in water.

Table 4 outlines the anticipated sequence of pile driving events during the 4-year construction schedule if 30-inch piles were to be used. This is identical to the schedule for the proposed design, except for the number and size of piles for the piers and constructing the in-water portion of the cofferdams for Pier 3 between July 1 and September 1.

Table 4. Anticipated Pile Driving Activity if 30-Inch Piles Are Used

Year	Any Time of Year	During In-Water Work Window (June 15–October 15)	During In-Water Pile-Driving Window (July 1–September 1)
1	Drive H-type piles and construct southbound bridge abutments. Construct cofferdams around new southbound bridge Pier 2. Drive 40 CISS piles for southbound bridge at Pier 2. Drive four template piles at Pier 2 for load test.	Construct portions of cofferdams on land around new Pier 3 and 4 locations for southbound bridge (no in-water sheet piles).	Complete construction of cofferdams around new Pier 3 and 4 locations (in-water portions) Drive 80 CISS piles for southbound bridge at Piers 3 and 4 (40 each).
2	–	Construct cofferdam around existing south bank, southbound bridge piers for demolition (no in-water sheet piles).	Construct cofferdam around existing north bank, southbound bridge piers for demolition (in-water sections).
3	Drive H-type piles and construct northbound bridge abutments. Construct cofferdams around new northbound Pier 2. Drive 40 CISS piles for northbound bridge Pier 2.	Construct cofferdams around new Pier 3 and 4 locations for northbound bridge (no in-water sheet piles).	Drive 100 CISS piles for northbound bridge Piers 3 (40) and 4 (60).
4	–	Construct cofferdams around existing south bank northbound bridge piers for demolition.	Construct cofferdams around existing north bank northbound bridge piers for demolition.

For both the proposed and smaller pile alternative, the H-type piles for the abutments will be installed with an impact pile-driver and would each take about 10 to 15 minutes to drive. For both the proposed and smaller pile alternative, the cofferdams would be constructed with sheet pile using a vibratory hammer. It typically takes 10 to 15 minutes to vibrate in each sheet pile, then about 10 minutes between vibratory drives to pick, stab, and adjust each succeeding sheet pile. Each cofferdam will likely take 2 to 3 days to install.

In addition to the numbers of piles required, the process for the installation of 30-inch-diameter piles would likely be different than described in Caltrans 2007a for the 7-foot-diameter piles. Although specific installation methods have not yet been identified (typically left to the contractor), it is likely that each 30-inch CISS pile would be installed using methods similar to those currently being used for the installation of the 0.6-meter (24-inch) steel piles at the Ten Mile River Bridge. Current construction activities for the Ten Mile River Bridge Replacement Project are used to describe the possible construction scenario for this analysis. (See Appendix A.)

The permanent 24-inch piles for the Ten Mile River Bridge were 37 to 56 meters (120 to 185 feet) long. Each pile was initially installed as 24- to 32-meter (80- to 105-foot) sections (pre-welded), and then two 12.2-meter (40-foot) sections were attached to each pile and driven in sequence. Each pier for the Ten Mile River Bridge had 32 piles. The following describes the activities that typically occurred for the installation of each pier:

- The first sections of each pile (120- to 185-foot sections) were initially vibrated in using a vibratory hammer, which took about 5 minutes each over a 2.5-day period for each pier.
- The first sections of each pile were then driven using an impact hammer, which took about 20 minutes each over 2 to 2.5 days for each pier.
- The second 40-foot section of each pile was then welded into place and driven using an impact hammer. The driving process took about 25 minutes per pile over 2 to 2.5 days for each pier.
- The third, and final, 40-foot section of each pile was welded into place and driven with an impact hammer. The driving process took about 25 minutes per pile over 2 to 2.5 days for each pier.

Based on this experience with 24-inch-diameter piles at Ten Mile River Bridge, a likely construction scenario for Mad River Bridge using 30-inch-diameter piles was developed. The following scenario was used by Illingworth and Rodkin (I&R) to estimate noise expected to be generated for the alternative Mad River Bridge replacement using 30-inch-diameter piles. (See Appendix A.)

The analysis assumes that ten to fifteen 30-inch-diameter pile sections can be driven each day. For the southbound Piers 2, 3, and 4 and northbound Piers 2 and 3 (40 piles each), the analysis assumes 10 bottom sections are vibrated in, then impact-driven; the second section is added to each in the group, then impact-driven; and the third section is added to each in the group, then impact-driven. Then, two additional groupings of 15 piles each are installed in the same manner for each pier, for a total of 40 piles driven during 12 days (3 days of vibrating and 9 days of impact pile-driving for each pier). The installation of the northbound Pier 4 would be similar, but there would be four groupings of 15 piles each (60 piles total), resulting in 4 days of vibratory installation and 12 days of impact installation for that pier.

In addition to the 30-inch-diameter piles, four 16- or 24-inch-diameter piles would be driven at the southbound Pier 2. These piles are necessary to secure a template for the pile load test. These piles would also likely be conveyed to the site in three to four sections, which would be welded together and driven within the cofferdam built for the southbound Pier 2 pile installation.

Noise Assessment

The construction of the Mad River Bridge with 7-foot or 30-inch-diameter piles would not include any in-water impact pile-driving, but some in-water vibratory pile-driving, for cofferdam construction around the existing piers, would be required.

The alternative construction with the smaller piles would include the installation of two-hundred sixty 30-inch-diameter CISS piles located 65 meters (215 feet) from the anticipated wetted channel for Pier 2 piles and located 15 meters (50 feet) from the Pier 4 piles (Table 3). Because of the larger footprint of 20 piles compared to one 7-foot-diameter pile, some of the Pier 3 piles could encroach into the wetted channel, depending on river height and gravel bar configuration at the time of construction. All areas where pier piles are impact-driven would be contained in a

cofferdam during impact-driving. The analysis assumes that the cofferdams would be dry when piles are driven, or if they contain water deeper than 1 meter (3.3 feet), a bubble curtain would be installed within the cofferdam. Both scenarios (dry cofferdam or bubble curtain in the cofferdam) provide about 5 decibels (dB) of attenuation.

It has been typical to evaluate sound propagation through water using open water sound attenuation models such as the Nedwell linear model or the practical spreading loss model. However, as with the initial assessment for the 7-foot-diameter piles, these types of open water models are not appropriate to estimate transmission loss through groundwater to surface water. There are currently no models that can be used for this purpose.

I&R, a consulting firm that has been retained to conduct hydroacoustic monitoring for numerous pile-driving projects, does not have measured sound data for 30-inch CISS piles. I&R does, however, have the results of noise monitoring of numerous pile-driving projects using 0.61- and 0.91-meter (24- and 36-inch) CISS piles in a variety of environments, as well as piles driven on land and in water. It is appropriate for this analysis to use the best available data to estimate underwater sound levels that would be expected for construction materials and techniques used and conditions that exist at the Mad River Bridge.

Jones & Stokes retained the services of I&R to estimate underwater sound levels that would be expected if 30-inch piles were used for this project. Appendix A provides I&R's detailed analysis based on measured empirical data I&R has collected from similar projects. The process used to estimate the expected noise from driving the alternative 30-inch-diameter piles is the same as that used in the assessment of driving the 7-foot-diameter piles, as reported in Caltrans 2007a. Because data for 30-inch-diameter piles is not available, I&R used data from 24- and 36-inch CISS piles to estimate anticipated sound levels. The data tables from that report are reproduced here as Tables 5 and 6. Following is a summary of I&R's findings. Throughout, sound level metrics are referenced as follows, unless otherwise indicated:

- **Peak:** Peak Sound Pressure, dB re: 1 micropascal (µPa)
- **SEL:** Sound Exposure Level, dB re: 1 μPa^2 sec for one strike

Cofferdam Construction with Vibrated Sheet Piles

The methods for construction of the cofferdams would not change if pile size was changed from 7-foot to 30-inch piles. In the previous analysis (Caltrans 2007a) I&R estimated that the maximum peak sound values from vibratory sheet pile installation would be 160 to 170 dB_{Peak} at 10 meters (33 feet) from the pile, depending on water depth (the louder peak in deeper water). I&R estimated the SEL from sheet pile-driven in the shallow waters (0 to 0.46-meter [0 to 1.5 feet]) surrounding the new Pier 3 and the existing piers on the north bank would be about 155 dB_{SEL} at 10 meters (33 feet) from the sheet pile.

H-Type Pile Installation

Neither the installation methods for the H-type piles for the abutments nor the sound they would generate would differ from that described in Caltrans 2007a. I&R estimated that noise at the

Table 5. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 1 - Southbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land 10 section	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in very shallow wa	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m
Pier 2 SB Bridge (40 Piles)																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Pier 3 SB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Pier 4 SB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
SB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--
	Pile Driving Time with impacts:			5800 min													

NA = Not applicable because distance specified not in water or SEL <150 dB

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for intial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Table 6. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 3 - Northbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in very shallow wate	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m
Pier 2 NB Bridge (40 Piles)																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--
Pier 3 NB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Pier 4 NB Bridge																	
Vibrate 10 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Vibrate 20 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--
Impact 10 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 20 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 20 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 20 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
NB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--
	Pile Driving Time with impacts:			6825 min													

NA = Not applicable because distance specified not in water or SEL <150 dB

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for intial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

wetted edge of the channel would 160 dB_{Peak} and 140 dB_{SEL} or less during the impact-driving of the H-piles.

CISS Pile Installation

The alternate analysis assumes that 30-inch-diameter CISS piles would be installed at northbound and southbound Piers 2, 3, and 4. Tables 5 and 6 provide best professional estimates of Peak and SEL sound pressure levels expected at various distances from these CISS piles.

Pier 2

Installation of the Pier 2 pilings is proposed to occur during any time of year. Pier 2 is located approximately 65 meters (213 feet) from the wetted channel under summer flow conditions and a minimum of approximately 43 meters (141 feet) from the wetted channel under higher-flow conditions. I&R estimated the underwater sound levels at 45 meters (150 feet) from the impact-driven 30-inch piles to be 175 dB_{Peak} at a maximum, with an SEL of 150 dB. Therefore, even with winter flow levels, underwater sound levels from Pier 2 piles are estimated to be low.

Piers 3 and 4

Installation of the 30-inch piles for Piers 3 and 4 would occur during the period preferred by Dan Free, the National Marine Fisheries Service (NMFS) biologist assigned to this project (Free pers. comm.). This "in-channel" pile-driving window (July 1 to September 1) occurs during low flow conditions. During summer, the Pier 3 pilings would be in a cofferdam and could extend into the wetted channel. The cofferdam could extend into the wetted channel approximately 3 meters (10 feet) if the gravel bar is not extended into the river to afford additional dry areas for construction. If the bar is extended, the estimated distance to the wetted channel would be approximately 20 to 30 meters (66 to 100 feet). I&R estimated that the underwater sound levels generated by 30-inch piles would be 165 dB_{Peak} and 160 dB_{SEL} at a distance of 10 meters (33 feet) from the piles for the first (vibrated) sections installed. For the subsequent impact-driven sections, I&R estimated maximum sound levels of 200 dB_{Peak} and 167 dB_{SEL} at 10 meters (33 feet) from the pile. At 45 meters (147 feet) from these piles, the maximum sound levels from impact pile-driving were estimated to drop to 185 dB_{Peak} and 160 dB_{SEL}.

Pier 4 is located approximately 15 meters (50 feet) from the wetted channel of the river during summer conditions. Estimated underwater noise produced during the installation of the 30-inch Pier 4 piles are conservatively estimated to be the same as described for Pier 3 piles, except that Pier 4 is located 15 meters (50 feet) from the wetted channel, and there is no estimate for underwater sound at 10 meters (not in water).

Comparison of Estimated Sound Generation to Interim Criteria

Dr. Art Popper (University of Maryland) and Dr. Mardi Hastings (Pennsylvania State University), leading experts in the field of fish bioacoustics, reviewed and synthesized currently available information and recommended guidelines for assessing and mitigating effects of pile-driving sound on fish. Their work is reported in the document entitled *The Effects of Sound on Fish* (Hastings and Popper 2005). Dr. Popper and several other experts expanded on this report

and provided recommendations for specific interim threshold criteria to evaluate potential injury to fish from pile-driving (Popper et al. 2006). The recommended interim threshold criteria for pile-driving are an SEL of 187 dB re: 1 $\mu Pa^2 s \bullet sec$ and a peak sound pressure of 208 dB re: 1 μPa_{Peak} in any single strike. For the purposes of impact assessment, this threshold is applied at 10 meters (33 feet) from a pile. The thresholds described above are commonly referred to as the interim "dual criteria" and are used as one method in this assessment.

The estimated sound levels from 30-inch piles, if they were to be driven as part of this project, are below the interim criteria proposed in Popper et al. 2006. In no cases were the estimated peak or single strike SEL values in the wetted channel predicted to exceed 208 dB_{Peak} or 187 $dB_{SEL,}$ respectively.

NMFS' interpretation of the SEL criterion proposed in Popper et al. 2006 states that energy from all strikes to which a fish may be exposed should be summed, then compared to the 187-dB_{SEL} criterion. A simple example is where a fish would be exposed to 500 pile strikes. The accumulated SEL value (referred to here as $SEL_{Accumulated}$) would be 27 dB more than the single strike SEL value (27 dB is calculated by taking 10 times the logarithm of 500). According to NMFS' interpretation, the $SEL_{Accumulated}$ value should then be compared to the interim 187-dB_{SEL} criterion.

Tables 5 and 6 estimate the SEL per strike and accumulated SEL for the 30-inch pile alternative based on NMFS' approach to the calculation of $SEL_{Accumulated}$. These tables show that in no cases is the single strike SEL estimated to exceed 187 dB_{SEL}. The highest single strike SEL is estimated to be 167 dB at 10 meters (33 feet) from the pile while impact-driving the topmost sections of the CISS piles at Piers 3 and 4. For Pier 2, the greatest single strike SEL is estimated to be 150 dB_{SEL} at 45 meters (147 feet) from the piles, which is the distance to the water's edge for all impact-driven pile sections. Under winter flows, when the distance between the wetted channel and Pier 2 piles would be the least, this noise level (150 dB_{SEL}) is estimated to occur approximately 2 meters (6.6 feet) offshore.

When using the NMFS method of SEL accumulation, the SEL interim criterion would not be exceeded during the driving of any of the Pier 2 piles because of the distance between these piles and the water, even under winter flow conditions.

The estimated $SEL_{Accumulated}$ values for 30-inch piles per event (one day of pile-driving) at Piers 3 and 4 are shown in Tables 5 and 6. Using the NMFS method, SEL for 30-inch piles at Piers 3 and 4 would range from 195 dB (first vibrated section) to 209 dB (top impact-driven sections) at 10 meters (33 feet) from the piles. Depending on the section of the pile being impact-driven and the pier, the $SEL_{Accumulated}$ values for the impact-driven piles would drop to 187 $dB_{SEL(Accumulated)}$ at a distance of 200 to 300 meters (656 to 984 feet) from the piles. (Note: Dropoff rates were based on measured data out to about 75 meters (246 feet). Beyond 75 meters, dropoff was conservatively estimated using 15log[distance], which is roughly 5 dB per doubling of distance. See Appendix A for details.)

Tables 7 and 8 break down the pile-driving activities for Piers 3 and 4, including the drive times and the distance to 187 $dB_{SEL(Accumulated)}$ for each day piles would be driven. The distance to 187 $dB_{SEL(Accumulated)}$ should be considered very conservative because it does not take in to account

the bends in the river channel, presence of gravel bars in the river, or shallow depth of the river, all of which would attenuate sound propagation up or down the river. In addition, the accumulation method used by NMFS likely overestimates accumulation for larger numbers of pile strikes.

Table 7. Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Southbound Bridge, Year 1)

Pier	Section	Installation Method	Drive Time per Pile	Drive Time per Day	Number of Days Driving Occurs	Distance to 187 $dB_{SEL(Accumulated)}$
3	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	20 meters 20 meters
3	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
3	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
3	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	N/A N/A
4	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
4	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters

Table 8. Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Northbound Bridge, Year 3)

Pier	Section	Installation Method	Drive Time per Pile	Drive Time per Day	Number of Days Driving Occurs	Distance to 187 $dB_{SEL(Accumulated)}$
3	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	20 meters 20 meters
3	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
3	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
3	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	1st (bottom)	Vibrate	5	15 piles—75 min	4	N/A
4	2nd	Impact	20	15 piles—300 min	4	275 meters
4	3rd	Impact	25	15 piles—375 min	4	300 meters
4	4th (top)	Impact	25	15 piles—375 min	4	300 meters

NMFS typically assumes that exposure of a fish to underwater noise levels above a threshold of 150 dB root mean square (RMS) would result in behavioral effects to fish. Although not specifically estimated by I&R (Appendix A), it is expected that, in an open water system, noise levels above 150 dB RMS might occur out to or beyond 300 to 400 meters (984 to 1,312 feet)

from a 30-inch-diameter pile. However, this is likely very conservative at the Mad River site because of the presence of shallow water, gravel bars, and turns in the river channel.

Differences in Sound Levels Produced by Proposed Piles and Use of Smaller Piles

The objective of this analysis is to determine whether the peak and accumulated noise generated by impact pile-driving could be lessened by the use of smaller piles to replace the Mad River Bridge. To use smaller piles, many more piles would have to be driven to meet the load requirements of the bridges. In this case, two-hundred sixty 30-inch CISS piles would be required to replace the thirteen 7-foot-diameter CISS piles in the current design. The summary below compares the use of 30-inch piles to a case where only one 7-foot-diameter pile section is driven in a day (as described in Caltrans 2007a), and to a case where multiple (two or three) 7-foot-diameter pile sections are driven in a day (as described in Caltrans 2007b):

- The maximum Peak sound pressure at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be less (up to 200 dB) than for 7-foot-diameter CISS piles (up to 205 dB). For both types of piles, the maximum peak values are below the interim criteria of 208 dB_{Peak}.
- The maximum SEL per strike at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be less (up to 167 dB) than for impact-driving 7-foot-diameter CISS piles (up to 170 dB). For both types of piles, the maximum SEL single strike values are below 187 $dB_{SEL.}$
- The maximum $SEL_{Accumulated}$ at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be more (up to 209 dB) than for impact-driving one 7-foot-diameter pile section (up to 200 dB) or multiple sections (up to 203 dB). For both types of piles, the maximum $SEL_{Accumulated}$ exceeds 187 $dB_{SEL(Accumulated)}$ at 10 meters (33 feet), which is the NMFS interpretation of the SEL interim threshold value.
- The maximum impact pile-driving time per day would be more for impact-driving up to 15 sections of 30-inch CISS piles (200 to 375 minutes over the course of a day) than for impact-driving one, two, or three sections of 7-foot-diameter CISS piles (30, 60, or 90 minutes a day, respectively).
- The maximum distance at which the $SEL_{Accumulated}$ would be attenuated to 187 $dB_{SEL(Accumulated)}$ using the NMFS method is more from impact-driving of 30-inch CISS piles (up to 300 meters) than for impact-driving one or more 7-foot-diameter CISS pile sections during one day (65 to 170 meters [213 to 558 feet], respectively).
- The number of pile-driving events (days on which pile-driving occurs at Piers 2, 3 and 4) would be more for impact-driving two-hundred sixty 30-inch CISS piles (27 days in Year 1 and 30 days in Year 3) than for impact-driving one 7-foot-diameter CISS pile section in a day (24 days in Year 1 and 28 days in Year 3) or two 7-foot-diameter CISS pile sections in a day (12 days in Year 1 and 12 days in Year 3).

Differences in Estimated Exposure of Fish to Sound Levels Exceeding Interim Thresholds

There would be no difference in fish exposure to sound generated from installation of H-type piles at the abutments, Pier 2 piles, or cofferdam installation for the proposed or alternative pile size. None of these activities would be expected to generate underwater sound levels exceeding Peak or SEL interim criteria for either scenario.

Based on this analysis, the use of 30-inch CISS piles to replace the 7-foot-diameter CISS piles would expose a larger area to accumulated sound levels above 187 $dB_{SEL(Accumulated)}$ for more days during the installation of Piers 3 and 4 during Years 1 and 3 of construction (Table 9). Please note that this table is not the total days of pile driving, but only the days during which 187 $dB_{SEL(Accumulated)}$ is estimated to be exceeded.

Table 9. Number of Days and Distances at Which 7-Foot and 30-Inch Pile-Driving Scenarios for Piers 3 and 4 Are Estimated to Result in Accumulated Sound Levels Exceeding 187 $dB_{SEL(Accumulated)}$

Distance (Meters) from Pile to Attenuation to 187 $dB_{SEL(Accumulated)}$	Number of Days (Year 1/Year 3)		
	7-Foot-Diameter Piles—One Section Driven/Day	7-Foot-Diameter Piles—Multiple Sections Driven/Day	30-Inch Diameter Piles—10–15 Sections Driven/Day
20	–	–	3/3
45	4/5	–	–
65	–	2/2	–
75	4/5	–	–
90	8/10	–	–
110	–	2/1	–
130	–	0/1	–
150	–	4/2	–
170	–	0/2	–
200	–	–	2/2
250	–	–	4/4
275	–	–	4/4
300	–	–	8/11

It is concluded that the replacement of the 7-foot-diameter CISS piles with 30-inch CISS piles for the Mad River Bridge Replacement Project does not appear to lessen the potential exposure of fish to accumulated sound levels at or above 187 $dB_{SEL(Accumulated)}$. To the contrary, because more of the smaller piles would be required, more piles would be driven during any given day and pile-driving would need to occur on more days, it is likely that more fish habitat would be exposed to accumulated sound levels above 187 $dB_{SEL(Accumulated)}$ more frequently.

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Appendix A Illingworth & Rodkin 30-Inch Pile Analysis

ALTERNATIVE ANALYSIS OF UNDERWATER SOUND LEVELS USING 30 INCH PILES – MAD RIVER BRIDGE REPLACEMENT PROJECT AT U.S. HIGHWAY 101 IN HUMBOLDT COUNTY DRAFT

01-Hum-101 KP144.4, Bridge No. 04-0025L

November 1, 2007

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Introduction

The report evaluates underwater noise levels associated with an alternative conceptual design to use smaller piles on the Mad River Bridge project. The alternative conceptual bridge design would consist of 0.8-meter (30-inch) diameter CISS piles instead of the planned 7-foot-diameter CISS piles. This alternative design would be comprised of a total of 260 CISS piles for the project that are 30-inch diameter, 1-inch thick steel shell piles, to be located at the same proposed pier locations as for the 7-foot-diameter pile design. The southbound bridge would utilize 40 of these piles at planned Pier 2; 40 piles at planned Pier 3, and 40 piles at proposed Pier 4. The northbound bridge would utilize 40 piles at Pier 2; 40 piles at Pier 3, and 60 piles at the wider Pier 4. (A bridge design utilizing 30-inch-diameter piles would also require use of a footing.) The alternative bridge design also includes H-piles for abutments, as well as temporary sheet piles (to be vibrated in) for cofferdams within the river channel. The H-type and sheet pile installation would be similar to the planned project evaluated with the 7-foot diameter piles. The primary difference in underwater sound generation would be the differences between installing the 30-inch diameter piles versus the 7-foot diameter piles. The pier locations would be the same as analyzed above and cofferdam designs are assumed to be similar.

A construction plan to install these piles has not been developed. Current construction activities for the Ten Mile Bridge Replacement project were used to describe a possible construction scenario. The permanent 24-inch CISS piles were 120 to 185 feet long. These piles were initially installed as 80 to 105 foot sections (pre-welded) and then two 40-foot sections were attached. Each pier had 32 piles. The piles were initially vibrated, which took about 2 and one half days. The piles were then driven using an impact hammer, which also took about 2 to 2 ½ days. The welded sections were also driven using an impact hammer. Each pile took about 5 minutes to install using a vibratory hammer. Impact driving of the initial section following the vibratory installation took about 20 minutes of continuous driving. The 40-foot sections took about 25 minutes each to drive continuously with the impact hammer. A similar scenario is used to evaluate Mad River construction driving times to calculate sound exposure.

Source Data

Sound levels that would be generated from these piles were estimated by evaluating projects similar where measurements were made. Sounds from similar size CISS piles have been measured in water for several projects. The most representative projects are those that have involved the driving of piles on land close to river bodies. Three projects involved this type of pile driving and are described below. Table 1 provides a summary of the source data.

Stockton Wastewater Treatment Plant Pipe Line, San Joaquin River

Construction of a wastewater treatment pipeline across the San Joaquin River involved the driving of 20-inch and 36-inch steel shell piles on land (edge of levee) adjacent to the river. The 20-inch piles were constructed to support a temporary construction trestle. The 36-inch piles were constructed to permanently support a wastewater treatment pipeline that crosses the river. Driving of a temporary pile is shown in Figure 1.

Table 1. Data Sources from Projects with Underwater Sound Measurements

Pile Size	Project/Location	Pile Position	Hammer Type	Position	Typical Measured Sound Levels Peak	SEL
20in	Stockton WWTP/San Joaquin River	Land adjacent to river	Impact	10m	198	171
				20m	188	163
36in	Stockton WWTP/San Joaquin River	Land adjacent to river	Impact	10m	201	173
				20m	198	170
			Vibrate	10m	165	160
				20m	160	150
24in	Geyserville Bridge/Russian River	Saturated Land adjacent to river	Impact	15m	197	173
				35m	187	163
				70m	172	--
24in	Geyserville Bridge/Russian River	On shore adjacent to river	Impact	15m	190	160
				90m	180	155
48in	Geyserville Bridge/Russian River	Immediately adjacent to shore	Impact	10m	200	175
				20m	200	172
				50m	190	165
24in	Ten Mile River/Pier 6	Cofferdam at shoreline	Vibrate	10m	175	~150
				100m	<165	<150
24in	Ten Mile River/Pier 6	Cofferdam at shoreline	Impact	10m	185	~165
				100m	170	~150

Figure 1 Stockton Wastewater Treatment Plant pipeline construction looking at 20-inch trestle piles driven near river edge

Both the 20-inch and 36-inch piles were first vibrated and then driven to there final depth using a diesel impact hammer. Measurements were made for both piles. A Delmag D19-42 impact hammer that provided about 71 kilojoules of energy was used to drive the 20-inch piles. Vibrated levels were not measured for the 20-inch piles. Underwater sound levels produced by the driving of those piles were 198 dB peak (201 dB max.) and 171 dB SEL at 10 meters. At 20 meters, peak pressures were typically 188 dB and SELs were 163 dB.

Measurements were made when the 36-inch piles were vibrated and impact driven with a Delmag D46-42 diesel impact hammer providing up to 180 kilojoules. For vibrated levels, peak pressures were typically 165 dB, but reached 173 dB at 10 meters. The 1-second SEL at 10 meters estimated from the RMS levels was typically 155 dB, but reached 165 dB. At 20 meters peak pressures were 160 dB (max. 165 dB) and SELs were typically 150 dB, but reached 155 dB. Impact driving resulted in peak pressures of 201 dB peak at 10 meters (max. 204 dB) and an SEL of 173 dB. At 20 meters, peak pressures were 198 dB (max. 200 dB) and the SEL was 170 dB. Each of the 36-inch piles took about 5 minutes to drive with the impact hammer. These piles were driven very close to the water, where there was a steep edge created by the river levee. This condition would likely cause higher sound levels than for the Mad River, because sound from the pile can propagate horizontally through the levee into the river.

Geyserville Russian River Bridge Replacement

The installation of 24-inch steel pipe piles used to support a temporary construction trestle were measured. Most of these piles measured were driven in saturated soils adjacent to the river channel. Measurements were made in swift waters about 15 to 90 meters from the piles. Piles were driven on land, about 10 meters from shore and then on land right at the shore. Piles were stabbed using a vibratory driver/extractor. Figure 2 shows the installation of these land-based piles.

Figure 2a. Impact driving of east side trestle piles, photo taken from closest measurement position on existing bridge

Figure 2b. Impact driving of 24-inch steel trestle pile being driven at river bank

Sound levels associated with vibratory installation of the piles at 35 meters could not be measured and were not audible. The swift river resulted in high background noise of about 160 dB RMS. The first set of measurements were made when the 24-inch piles were about 10 meters from the shore (although the soils were saturated due to the high river levels) and measurements were made at 35 and 90 meters from the pile in water that was at least 2 meters deep. At 35 meters, typical sound levels started off at about 175 dB peak and steadily increased to 190 dB peak, 175 dB RMS and about 160 dB SEL. At 90 meters, sound levels reached 178 dB peak and 165 dB RMS. SEL was not measured, but estimated to be about 155 dB. Had these piles been driven for Mad River, we would have expected lower levels because the soils conditions would not have been as saturated and the piles would be driven in cofferdams excavated below the river level. However, the alternative Mad River design calls for larger diameter and longer piles.

Measurements were also made for the Russian River temporary trestle piles when they were driven in shallow water during late spring when river levels dropped substantially. Sound levels were lower than those measured for land-based piles and the reason is thought to be the water depth. Shallow water does not support the propagation of underwater sound. In addition, measurements made in water that is less than 2 meters deep usually results in lower pressures, because the hydrophone is so close to the water/air interface, which is also known as the pressure release zone. Sound pressures near the air/water surface theoretically approach 0 dB. In slightly less than 1-meter deep water at 18 meters, sound pressures were a maximum of 184 dB peak and 160 dB SEL. At 10 meters, levels were slightly higher, about 187 dB peak, and 162 dB SEL.

Ten Mile River Replacement Bridge

Recent measurement data from the Ten Mile River Bridge Replacement project have been obtained. 24-inch diameter CISS piles support the piers for this bridge. These piles are driven through a dewatered cofferdam. Some water was present in the cofferdams, so an air bubble curtain had to be used where peak pressures approached 190 dB. Pier 5 is located on land with the closest portion about18 meters from the edge of the estuary (see Figures 3a and 3b). Pier 6 is located in very shallow water near the edge. Ten Mile River resembles more of a tidal estuary than a flowing river at the project site. Water depth is very shallow, less than 1 meter through out much of the river except the deepest parts where water depth can reach almost 2 meters

during high tides. Underwater noise measurements during pile installation were made in waters that were 1 meter or deeper.

Figure 3a. Permanent CISS piles at Ten Mile River Bridge Pier 5, photo taken from closest measurement position in water.

Figure 3b. Close-up picture of Pier 5 piles

Pier 5 measurements for impact driving are only data that are currently available. At the closest in water position (1 meter or deeper), which was 38 meters from the pile, sound levels were 172 dB peak and 163 dB RMS. SEL levels were not yet measured, but are estimated to be about 150 dB. Levels at 100 meters were below 165 dB peak.

Sound pressure levels were measured for Pier 6, which was at the shoreline (partially in water). Sound levels during vibratory installation were 175 dB peak and 160 dB RMS at 10 meters. The SEL for 1 second of driving would be similar to the RMS. Levels at 100 meters were below the reported detection limit of 165 dB peak (SEL would be less than 150 dB). Subsequent impact driving resulted in sound levels at 10 meters of 185 dB peak (max. 190 dB) and 175 dB RMS. SEL was not measured, but estimated at 165 dB. At 100 meters, levels were about 172 dB peak, and less than 165 dB RMS. The SEL was estimated at less than 150 dB. At the time of this writing, the two 40-foot sections that are to be added have not been driven.

Estimate of 30-inch Diameter CISS Pile Source Levels

The measured sound data described previously indicate a considerable range in sound levels that could be expected from the driving of land-based 30-inch diameter CISS piles. It appears from all of the data that vibratory installation of the piles would generate peak sound pressures of less than 170 dB and SELs of about 160 dB at 10 meters and 150 dB or lower at 20 meters or further away. Impact driving levels would vary considerably.

We do know that in water and unattenuated, 30-inch steel pipe or CISS piles produce sound levels of about 210 dB peak, 190 dB RMS and 180 dB SEL at 10 meters and these levels would drop off at a rate of at least *15 Log (Distance)*. When these piles are driven on land, they produce lower noise levels, but have a lower distance attenuation rate near the pile. As

previously discussed, the piles for the Mad River Bridge will be driven in excavated land-based dewatered cofferdams, where the pile will be driven below the bottom of the river. If necessary, an air bubble curtain would be used to lower sound pressures.

The data collected at Stockton for 36-inch piles is expected to be higher than what would be expected at Mad River, because the piles were driven in a levee next the shore. If about 5 dB of sound reduction were applied, levels would be about 195 dB peak and 165 dB SEL at 10 and 20 meters. The 48-inch piles driven for the Russian River Bridge would be higher than those expected at Mad River for 30-inch piles; because they are larger piles and were driven at a level slightly above the river. These piles were also immediately adjacent to the river. About 5 dB could be reduced from the predicted levels for the 7-foot diameter piles to estimate that for the smaller 30-inch piles. This puts the source levels at about 195 to 200 dB peak and 165 dB SEL at 10 to 20 meters. The levels measured for the 24-inch trestle piles driven on saturated land near the river are somewhat consistent with these levels. However, one has to keep in mind that those smaller trestle piles were driven in saturated soils, which probably transmitted sound fairly efficiently into the adjacent river channel. Lower sound pressures were measured at Ten Mile River, when permanent 24-inch CISS piles were driven. Use of the Ten Mile River Bridge data would indicate sound levels of about 185 dB peak and 165 dB SEL at 10 to 20 meters. Ten Mile River does not have any pools deeper than 2 meters, and most of the measurements made there were in water closer to 1 meter deep. The Ten Mile River data may be similar to what would be expected in the shallower waters at Mad River. At the deeper pools, higher levels should be anticipated.

Estimated Peak and SEL Sound Generated by Driving 30-inch Piles at Mad River

Tables 2 and 3 provide estimates of maximum peak, single strike SEL and accumulated SEL for each event (day of pile driving) based on the source levels identified above. To estimate distance to 187dB $SEL_{Accumulated}$,15 Log (distance) was used for the transmission loss. The $SEL_{Accumulated}$ assumes that 10 or 15 pile sections are driven in a day and that the piles are installed in four sections.

Table 2. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 1 - Southbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 150 dB SEL for a Single Strike	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																		
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--	--
Vibratory Sheet Installation in very shallow wat	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m	20m
Pier 2 SB Bridge (40 Piles)																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Pier 3 SB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Pier 4 SB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
SB Bridge Abutments																		
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--	--
NA = Not applicable	Pile Driving Time with impacts:			5800 min														

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for intial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Table 3. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 3 - Northbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 150 dB SEL for a Single Strike	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																		
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--	--
Vibratory Sheet Installation in very shallow wat	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m	20m
Pier 2 NB Bridge (40 Piles)																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	--	--
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	--	--
Pier 3 NB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Pier 4 NB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Vibrate 20 Sections	5	20	100	6000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	--	--
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 20 Sections	20	20	400	16000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 20 1st ADD-ON Sections	25	20	500	20000 strike	NA	195	185	180	NA	165	160	155	NA	208	203	198	150m	350m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 20 2nd ADD-ON Sections	25	20	500	20000 strike	NA	200	185	180	NA	167	160	155	NA	210	203	198	175m	350m
NB Bridge Abutments																		
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--	--
NA = Not applicable	Pile Driving Time with impacts:			6700 min														

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for intial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Jones & Stokes

Memorandum

Date: November 6, 2007

To: Kelley Garrett, California Department of Transportation

From: Rick Oestman and Dave Buehler

Subject: **Supplemental Pile-Driving Noise Analysis for the Mad River Bridge Replacement Project—DRAFT**

This memorandum provides an analysis of pile-driving noise associated with the Mad River Bridge Replacement Project that supplements information provided in the report entitled *Analysis of Pile Driving Noise Impacts to Listed Salmonids for the Mad River Bridge Replacement Project*, dated August 23, 2007, as revised on November 5, 2007 (California Department of Transportation 2007).

As stated in the August 23, 2007 report, Dr. Art Popper has recommended interim criteria to evaluate potential fish injury of 208 dB_{PEAK} (peak sound pressure, dB re 1 µPa) and 187 dB_{SEL} (sound exposure level, dB re 1 μPa^2 sec) for any single strike. The National Marine Fisheries Service (NMFS), however, is of the opinion that the accumulated energy to which a fish could be exposed should be compared to the 187-dB_{SEL} criteria. The August 23, 2007 report evaluated accumulated noise associated with the installation of a single 7-foot-diameter pile section, a single H pile, and a single sheet pile as a first-order estimate of source sound levels, transmittance of this sound through the ground to water, and transmittance of the sound through water.

As requested by the California Department of Transportation, this supplemental analysis provides an evaluation of accumulated noise associated with anticipated daily pile-driving operations under the assumption that a fish could be exposed to a day's worth of noise from pile-driving. The maximum peak sound levels for a single strike and the maximum single strike SEL would be the same for either scenario, as reported in the August 23, 2007 report. However, accumulated SEL values are higher because it is assumed in this analysis that fish would be exposed to noise from more than one pile-driving event in a day.

Analysis

Based on information provided by the project engineers, it is assumed in this supplemental analysis that the following number of piles would be driven per day. It is further assumed that only one type of pile would be driven on a given day:

- Sheet piles—up to 10 per day.

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Table 1A. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 7-foot Piles

Year 1 - Southbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in very shallow wa	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	188	NA	NA	25m
Pier 2 SB Bridge																	
Impact 2 Bottom Sections	15	2	30	900 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	175	175	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	180	180	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	180	180	NA	NA	150	<150	NA	NA	NA	NA	--
Pier 3 SB Bridge																	
Impact 2 Bottom Sections	15	2	30	900 strike	190	190	190	180	165	165	160	155	195	195	190	185	65 meters
Impact 2 Pile Sections	30	2	60	1800 strike	200	200	190	180	170	170	165	157	203	203	198	190	110 meters
Impact 2 Pile Sections	30	2	60	1800 strike	205	205	195	185	170	170	167	159	203	203	200	192	150 meters
Impact 2 Pile Sections	30	2	60	1800 strike	205	205	195	185	170	170	167	159	203	203	200	192	150 meters
Pier 4 SB Bridge																	
Impact 2 Bottom Sections	15	2	30	900 strike	NA	190	190	180	NA	165	160	155	NA	195	190	185	65 meters
Impact 2 Pile Sections	30	2	60	1800 strike	NA	200	190	180	NA	170	165	157	NA	203	198	190	110 meters
Impact 2 Pile Sections	30	2	60	1800 strike	NA	205	195	185	NA	170	167	159	NA	203	200	192	150 meters
Impact 2 Pile Sections	30	2	60	1800 strike	NA	205	195	185	NA	170	167	159	NA	203	200	192	150 meters
SB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--
NA = Not applicable	Pile Driving Time with impacts:			420 min													

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Table 1B. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 7-foot Piles

Year 3 - Northbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	DriveTime in min.[1]	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in very shallow wa	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	--
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	188	NA	NA	25m
Pier 2 NB Bridge																	
Impact 2 Bottom Sections	15	2	30	900 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	175	175	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	180	180	NA	NA	150	<150	NA	NA	NA	NA	--
Impact 2 Pile Sections	30	2	60	1800 strike	NA	NA	180	180	NA	NA	150	<150	NA	NA	NA	NA	--
Pier 3 NB Bridge																	
Impact 2 Bottom Sections	15	2	30	900 strike	190	190	190	180	165	165	160	155	195	195	190	185	65 meters
Impact 2 Pile Sections	30	2	60	1800 strike	200	200	190	180	170	170	165	157	203	203	198	190	110 meters
Impact 2 Pile Sections	30	2	60	1800 strike	205	205	195	185	170	170	167	159	203	203	200	192	150 meters
Impact 2 Pile Sections	30	2	60	1800 strike	205	205	195	185	170	170	167	159	203	203	200	192	150 meters
Pier 4 NB Bridge																	
Impact 3 Bottom Sections	15	3	45	1350 strike	NA	190	190	180	NA	165	160	155	NA	196	191	186	65 meters
Impact 3 Pile Sections	30	3	90	2700 strike	NA	200	190	180	NA	170	165	157	NA	204	199	191	130 meters
Impact 3 Pile Sections	30	3	90	2700 strike	NA	205	195	185	NA	170	167	159	NA	204	201	193	170 meters
Impact 3 Pile Sections	30	3	90	2700 strike	NA	205	195	185	NA	170	167	159	NA	204	201	193	170 meters
NB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	140	135	NA	NA	175	170	--

NA = Not applicable Pile Driving Time with impacts: 525 min

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially.

2 Assume large hydrualic hammer for CISS piles, striking about once every 2 seconds, except for intial, quieter blows. H piles assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

- 7-foot-diameter piles—up to two per day in Year 1 (Piers 3 and 4) and Year 3 (Pier 3 only), and up to three per day at Pier 4 (only) in Year 3.

- H-type piles—up to five per day.

This analysis focuses on the piles driven at Piers 3 and 4 because they are the only locations close enough to the river to effectively transmit the sounds from pile-driving to the river at levels that could be of concern, based on this analysis and the previous analysis. Table 1 summaries the noise analysis based on these assumptions. Table 2 compares the results presented in the August 23, 2007 report to the analysis based on the operational assumptions described above.

Table 2. Comparison of Analyses

	Distance to 187 dB_{SEL} Level	
7-Foot-Diameter Piles	August 23, 2007 Report (1 Pile Segment/Day)	Supplemental Analysis (Multiple Pile Segments/Day)
Year 1, Pier 3 SB Bottom Section	45 meters	65 meters (2 segments per day)
Year 1, Pier 3 SB 2nd Section	75 meters	110 meters (2 segments per day)
Year 1, Pier 3 SB 3rd Section	90 meters	150 meters (2 segments per day)
Year 1, Pier 3 SB Top Section	90 meters	150 meters (2 segments per day)
Year 1, Pier 4 SB Bottom Section	45 meters	65 meters (2 segments per day)
Year 1, Pier 4 SB 2nd Section	75 meters	110 meters (2 segments per day)
Year 1, Pier 4 SB 3rd Section	90 meters	150 meters (2 segments per day)
Year 1, Pier 4 SB Top Section	90 meters	150 meters (2 segments per day)
Year 3, Pier 3 NB Bottom Section	45 meters	65 meters (2 segments per day)
Year 3, Pier 3 NB 2nd Section	75 meters	110 meters (2 segments per day)
Year 3,Pier 3 NB 3rd Section	90 meters	150 meters (2 segments per day)
Year 3,Pier 3 NB Top Section	90 meters	150 meters (2 segments per day)
Year 3, Pier 4 NB Bottom Section	45 meters	65 meters (3 segments per day)
Year 3, Pier 4 NB 2nd Section	75 meters	130 meters (3 segments per day)
Year 3,Pier 4 NB 3rd Section	90 meters	170 meters (3 segments per day)
Year 3,Pier 4 NB Top Section	90 meters	170 meters (3 segments per day)

Notes: NB = northbound SB = southbound

Assuming exposure to vibratory pile-driving of 10 sheet piles per day, the 187-dB_{SEL} level is predicted to be reached at 25 meters. Assuming exposure to noise from one sheet pile, the 187-dB_{SEL} level is not predicted to extend into the water.

Assuming exposure to impact pile-driving of either one or five H-Type piles per day, the 187-dB_{SEL} level is not predicted to extend into the water.

For Pier 2, the 187-dB SEL levels are not predicted to extend into the water.

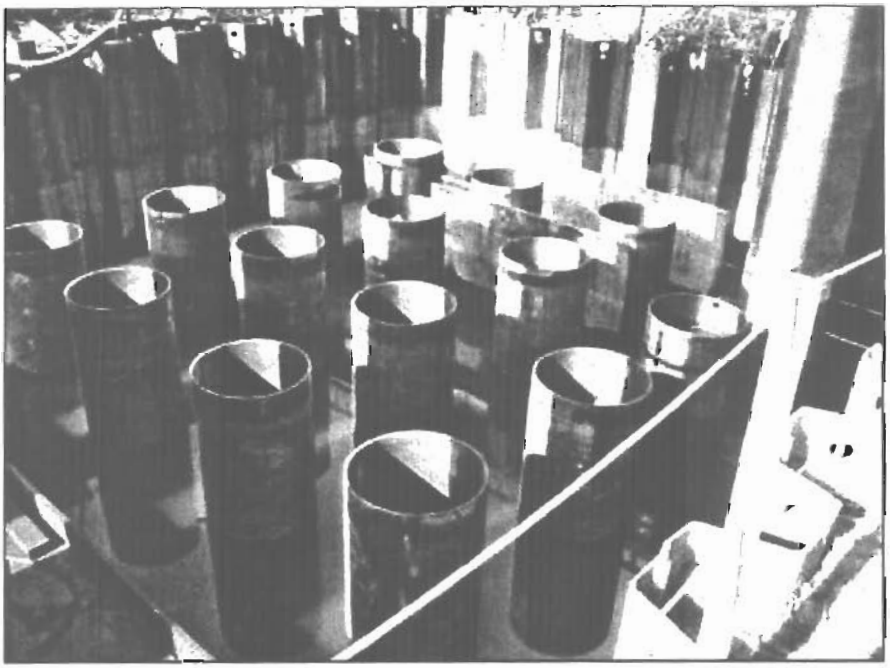
Conclusions

As with the previous analysis, there are no situations where the single strike criteria of 208 dB_{Peak} or 187 dB_{SEL} recommended by Dr. Popper are predicted to be exceeded. Based on these criteria, no adverse effects to fish would be anticipated by project-related pile-driving. However, using NMFS' SEL accumulation method, the analysis presented in the August 23, 2007 report and this analysis indicate that fish could be exposed to accumulated noise exceeding 187 dB_{SEL}. If it is assumed that fish would be exposed to noise from multiple pile-driving events throughout that day, the distance within which the accumulated noise level would exceed 187 dB_{SEL} would be in the range of 40% to 90% greater than if it is assumed that the fish would only be exposed to noise from one pile-driving event per day.

References Cited

California Department of Transportation (Caltrans). 2007. *Analysis of Pile Driving Noise Impacts to Listed Salmonids for the Mad River Bridge Replacement Project*. (EA 01-296101, Contract 03A1717, Task Order 12.) District 1. Prepared by Jones & Stokes and Illingworth & Rodkin. August 23 (Revised November 5).

Mad River Bridge Replacement Project



Evaluation of Underwater Noise Generated by Use of Smaller Piles (30-Inch-Diameter)—DRAFT

Contract 03A1317, Task Order 12

03-1A8420

November 6, 2007

Exhibit G

Table of Contents

Page

Introduction....1
Pile-Driving Activities Generating Noise....2
Noise Assessment....5
Cofferdam Construction with Vibrated Sheet Piles....6
H-Type Pile Installation....6
CISS Pile Installation....7
Pier 2....7
Piers 3 and 4....7
Comparison of Estimated Sound Generation to Interim Criteria....7
Differences in Sound Levels Produced by Proposed Piles and Use of Smaller Piles....10
Differences in Estimated Exposure of Fish to Sound Levels Exceeding Interim Thresholds....11
References Cited....12
List of Preparers....12
Caltrans....12
Jones & Stokes....12
Illingworth & Rodkin....12

Appendix A. Illingworth & Rodkin 30-Inch Pile Analysis

List of Tables and Figures

		Page
Table 1	Current Listing Status and Critical Habitat for Federally Listed Salmon and Steelhead Species Occurring in Mad River	1
Table 2	Number and Size of Piles That Would Need to Be Driven if 30-Inch Piles Are Used	2
Table 3	Distance between Abutments/Piers and Typical Summer and Winter Wetted Channel of the River	3
Table 4	Anticipated Pile Driving Activity if 30-Inch Piles Are Used	4
Table 5	Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-Inch Piles	follows 6
Table 6	Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-Inch Piles	follows 6
Table 7	Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Southbound Bridge, Year 1)	9
Table 8	Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Northbound Bridge, Year 3)	9
Table 9	Number of Days and Distances at Which 7-Foot and 30-Inch Pile-Driving Scenarios for Piers 3 and 4 Are Estimated to Result in Accumulated Sound Levels Exceeding 187 $dB_{SEL(Accumulated)}$	11
		Follows Page
Figure 1	Existing Habitat Features in the Vicinity of the Mad River Bridge	2

Mad River Bridge Replacement Project: Evaluation of Underwater Noise Generated by Use of Smaller Piles (30-Inch-Diameter)

Introduction

The California Coastal Commission (CCC) has requested that the California Department of Transportation (Caltrans) conduct an analysis of pile-driving noise that would be expected if the Mad River Bridges were reconstructed using 0.76-meter-diameter (30-inch-diameter) cast-in-steel-shell (CISS) piles rather than the 2.2-meter-diameter (7-foot-diameter) CISS piles in the current design. Caltrans project engineers have estimated the number and location of the 30-inch piles that would be necessary for this alternative (an engineering design has not been prepared for 30-inch piles). This alternative analysis uses the same methods as the analysis of the current project design (California Department of Transportation 2007a).

This report evaluates the potential effects of sound generated from pile-driving activities during the Mad River Bridge Replacement Project on salmonids listed as threatened or endangered under the federal Endangered Species Act if 30-inch-diameter piles were used rather than the 7-foot-diameter CISS piles in the current design. The federally listed species in the project area include the California coastal chinook salmon evolutionarily significant unit (ESU), southern Oregon/northern California coast coho salmon ESU, and northern California steelhead (both summer and winter run) distinct population segment (DPS). General information regarding the distribution and biology of these species has been provided in the original biological assessment and biological opinion regarding this action; this information will not be repeated here. However, changes to the status and critical habitat designations have occurred since the February 2005 biological opinion, as reported in Table 1.

Table 1. Current Listing Status and Critical Habitat for Federally Listed Salmon and Steelhead Species Occurring in Mad River

Species	Listing Status Reaffirmed	Critical Habitat Designation
California coastal chinook salmon ESU	Threatened—70 FR 37160, June 28, 2005	70 FR 52488, September 2, 2005
Southern Oregon/northern California coast coho salmon ESU	Threatened—70 FR 37160, June 28, 2005	64 FR 24049, May 5, 1999
Northern California steelhead DPS	Threatened—71 FR 834, January 5, 2006	70 FR 52488, September 2, 2005

Note: FR = Federal Register

The CCC also requested that Caltrans evaluate the potential effects of noise generated during pile-driving on coastal cutthroat trout, a species that is listed as threatened under the California Endangered Species Act.

Pile-Driving Activities Generating Noise

This analysis addresses noise from pile-driving only. Caltrans is proposing to replace both the northbound and southbound bridges of U.S. Highway 101 that cross the Mad River just south of McKinleyville, California. The current design for the new bridges includes impact pile-driving of thirteen 7-foot-diameter CISS steel piles, four 1.2-meter-diameter (4-foot-diameter) CISS steel piles (at Pier 2), and seventy-nine 0.36-meter-wide (14-inch-wide) H-type piles. Figure 1 shows the location of the new piles. See Caltrans 2007a for project details.

The CCC requested that Caltrans conduct an analysis of the underwater noise that would be expected if 30-inch-diameter piles were used rather than the proposed 7-foot-diameter piles. The Caltrans project manager estimated that a total of two-hundred sixty 30-inch-diameter, 1-inch-thick steel shell piles would be required to replace the thirteen 7-foot-diameter piles (Mullen pers. comm.). The 30-inch-diameter piles would be located at the same proposed pier locations as the 7-foot-diameter piles (Figure 1). Four 16- to 24-inch template piles would be also be impact-driven at southbound Pier 2 to secure a template for the pile load test, which would replace the 1.2-meter template piles described in Caltrans 2007a.

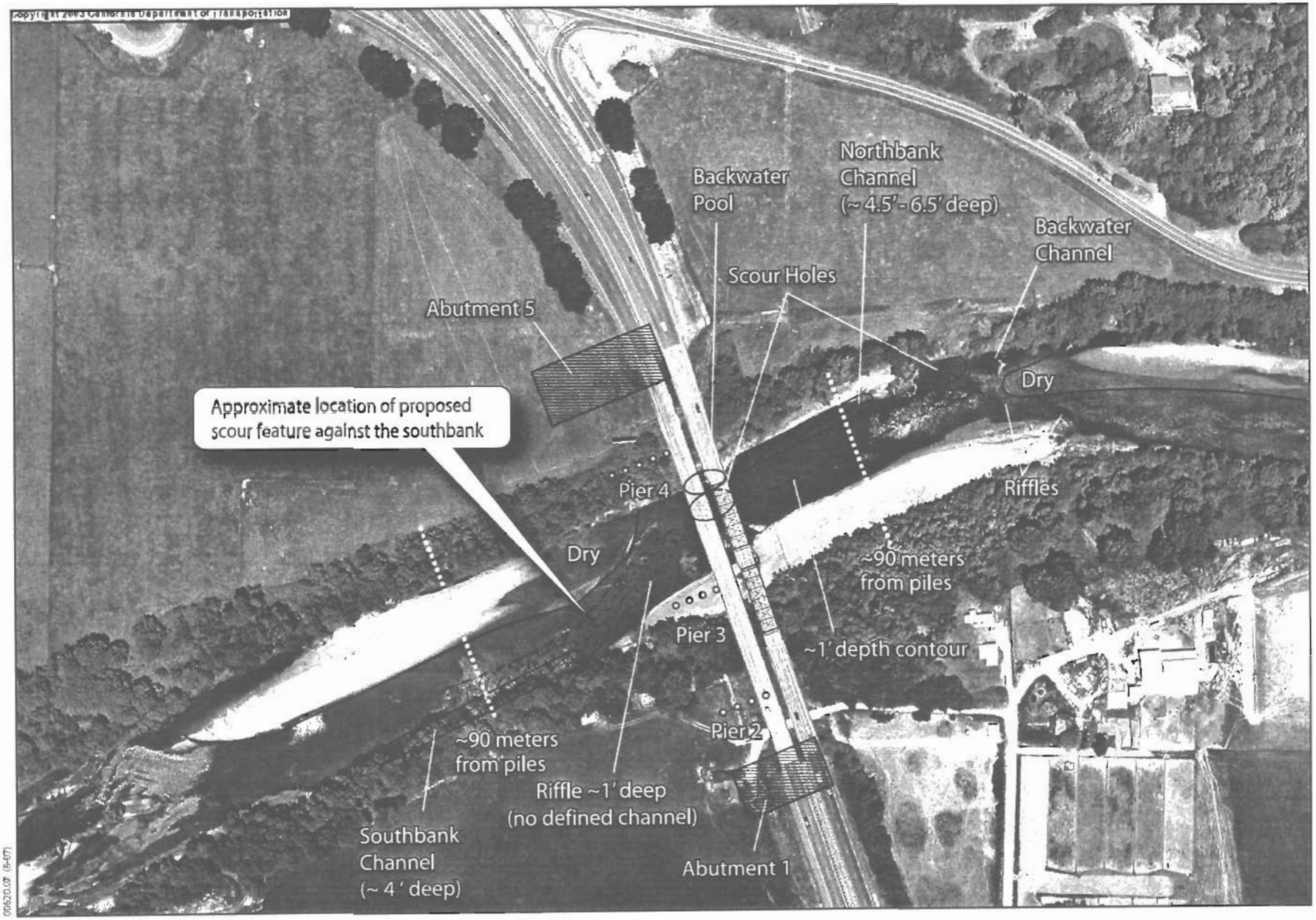
Table 2 summarizes the number, size, and location of piles that would be driven under this alternative analysis.

Table 2. Number and Size of Piles That Would Need to Be Driven if 30-Inch Piles Are Used

Pier/Bridge	Number of Piles (Size)	
	Southbound Lanes	Northbound Lanes
Abutment 1 (south end of bridge)	13 (14-inch H-type piles)	14 (14-inch H-type piles)
Pier 2	40 (30-inch-diameter CISS piles) 4 (0.4- to 0.6-meter-diameter [16- to 24-inch-diameter] CISS piles)	40 (30-inch-diameter CISS piles)
Pier 3	40 (30-inch-diameter CISS piles)	40 (30-inch-diameter CISS piles)
Pier 4	40 (30-inch-diameter CISS piles)	60 (30-inch-diameter CISS piles)
Abutment 5 (north end of bridge)	20 (14-inch H-type piles)	32 (14-inch H-type piles)

A bridge design utilizing 30-inch-diameter piles would also require footings. The proposed and alternative bridge designs would both include impact-driven pile installation for H-type piles for the two abutments, as well as installation of temporary sheet piles (to be vibrated in) for cofferdams for pile-driving and demolition areas.

Table 3 shows the approximate distance between the piles to be driven and the typical summer and winter wetted channel of the Mad River. No piles will be impact-driven within the wetted channel of the river, as in the proposed design.



Jones & Stokes

Figure 1
Existing Habitat Features in the Vicinity of the Mad River Bridge

Table 3. Distance between Abutments/Piers and Typical Summer and Winter Wetted Channel of the River

Pier/Bridge	Distance between Abutments/Piers the Summer/Winter Wetted Channel	
	Southbound Lanes	Northbound Lanes
Abutment 1 (south)	**Summer:** 90 meters (295 feet) or greater **Winter:** ~7 meters (256 feet) or greater	**Summer:** 90- meters (295 feet) or greater **Winter:** ~78 meters (256 feet) or greater
Pier 2	**Summer:** 65 meters (213 feet) **Winter:** ~43 meters (141 feet)	**Summer:** 65 meters (213 feet) **Winter:** ~43 meters (141 feet)
Pier 3*	**Summer:** 0 meters (0 feet) **Winter:** N/A	**Summer:** 0 meters (0 feet) **Winter:** N/A
Pier 4	**Summer:** 15 meters (49 feet) **Winter:** N/A	**Summer:** 15 meters (49 feet) **Winter:** N/A
Abutment 5 (north)	**Summer:** 70 meters (230 feet) **Winter:** ~65 meters (213 feet)	**Summer:** 70 meters (230 feet) **Winter:** ~65 meters (213 feet)

* Distance without extension of the gravel bar. The footprint of 20 piles would be approximately 4.6 by 6.1 meters (15 by 20 feet). This could extend the footprint within the wetted channel. All pile-driving would occur within a dry cofferdam or cofferdam with bubble curtain.

For both the proposed and alternative pile sizes, cofferdams would be constructed to isolate the pier area before driving the piles at both the southbound and northbound Piers 2, 3, and 4. Construction of the cofferdams would be conducted in the same manner as the proposed design. The cofferdams would be constructed by installing sheet pile with a vibratory hammer. The area inside the cofferdams would be excavated 11 meters (36 feet) below original ground at the column/pile interface. When excavated, water will likely seep into the cofferdams. The cofferdams would be dewatered down to the column/pile interface to allow installation of the footings, columns, and foundations. During CISS pile-driving, the cofferdams would be dewatered to the column/pile interface or the piles would be driven with a bubble curtain around the pile in the cofferdam. This is the same as the proposed design, but with the 30-inch piles, each group of piles would also require a footing.

For both the proposed and smaller pile alternative, a vibratory hammer would be used to construct cofferdams around the existing piers to isolate those areas during their demolition. Except for the cofferdam around the north shore bridge piers to be removed and the north side of the cofferdams for installation of Pier 3, these cofferdams would be driven on land. Note that the cofferdams installed for the construction of the new Piers 2 and 4 are constructed completely on land, not in water.

Table 4 outlines the anticipated sequence of pile driving events during the 4-year construction schedule if 30-inch piles were to be used. This is identical to the schedule for the proposed design, except for the number and size of piles for the piers and constructing the in-water portion of the cofferdams for Pier 3 between July 1 and September 1.

Table 4. Anticipated Pile Driving Activity if 30-Inch Piles Are Used

Year	Any Time of Year	During In-Water Work Window (June 15–October 15)	During In-Water Pile-Driving Window (July 1–September 1)
1	Drive H-type piles and construct southbound bridge abutments. Construct cofferdams around new southbound bridge Pier 2. Drive 40 CISS piles for southbound bridge at Pier 2. Drive four template piles at Pier 2 for load test.	Construct portions of cofferdams on land around new Pier 3 and 4 locations for southbound bridge (no in-water sheet piles).	Complete construction of cofferdams around new Pier 3 and 4 locations (in-water portions) Drive 80 CISS piles for southbound bridge at Piers 3 and 4 (40 each).
2	–	Construct cofferdam around existing south bank, southbound bridge piers for demolition (no in-water sheet piles).	Construct cofferdam around existing north bank, southbound bridge piers for demolition (in-water sections).
3	Drive H-type piles and construct northbound bridge abutments. Construct cofferdams around new northbound Pier 2. Drive 40 CISS piles for northbound bridge Pier 2.	Construct cofferdams around new Pier 3 and 4 locations for northbound bridge (no in-water sheet piles).	Drive 100 CISS piles for northbound bridge Piers 3 (40) and 4 (60).
4	–	Construct cofferdams around existing south bank northbound bridge piers for demolition.	Construct cofferdams around existing north bank northbound bridge piers for demolition.

For both the proposed and smaller pile alternative, the H-type piles for the abutments will be installed with an impact pile-driver and would each take about 10 to 15 minutes to drive. For both the proposed and smaller pile alternative, the cofferdams would be constructed with sheet pile using a vibratory hammer. It typically takes 10 to 15 minutes to vibrate in each sheet pile, then about 10 minutes between vibratory drives to pick, stab, and adjust each succeeding sheet pile. Each cofferdam will likely take 2 to 3 days to install.

In addition to the numbers of piles required, the process for the installation of 30-inch-diameter piles would likely be different than described in Caltrans 2007a for the 7-foot-diameter piles. Although specific installation methods have not yet been identified (typically left to the contractor), it is likely that each 30-inch CISS pile would be installed using methods similar to those currently being used for the installation of the 0.6-meter (24-inch) steel piles at the Ten Mile River Bridge. Current construction activities for the Ten Mile River Bridge Replacement Project are used to describe the possible construction scenario for this analysis. (See Appendix A.)

The permanent 24-inch piles for the Ten Mile River Bridge were 37 to 56 meters (120 to 185 feet) long. Each pile was initially installed as 24- to 32-meter (80- to 105-foot) sections (pre-welded), and then two 12.2-meter (40-foot) sections were attached to each pile and driven in sequence. Each pier for the Ten Mile River Bridge had 32 piles. The following describes the activities that typically occurred for the installation of each pier:

- The first sections of each pile (120- to 185-foot sections) were initially vibrated in using a vibratory hammer, which took about 5 minutes each over a 2.5-day period for each pier.
- The first sections of each pile were then driven using an impact hammer, which took about 20 minutes each over 2 to 2.5 days for each pier.
- The second 40-foot section of each pile was then welded into place and driven using an impact hammer. The driving process took about 25 minutes per pile over 2 to 2.5 days for each pier.
- The third, and final, 40-foot section of each pile was welded into place and driven with an impact hammer. The driving process took about 25 minutes per pile over 2 to 2.5 days for each pier.

Based on this experience with 24-inch-diameter piles at Ten Mile River Bridge, a likely construction scenario for Mad River Bridge using 30-inch-diameter piles was developed. The following scenario was used by Illingworth and Rodkin (I&R) to estimate noise expected to be generated for the alternative Mad River Bridge replacement using 30-inch-diameter piles. (See Appendix A.)

The analysis assumes that ten to fifteen 30-inch-diameter pile sections can be driven each day. For the southbound Piers 2, 3, and 4 and northbound Piers 2 and 3 (40 piles each), the analysis assumes 10 bottom sections are vibrated in, then impact-driven; the second section is added to each in the group, then impact-driven; and the third section is added to each in the group, then impact-driven. Then, two additional groupings of 15 piles each are installed in the same manner for each pier, for a total of 40 piles driven during 12 days (3 days of vibrating and 9 days of impact pile-driving for each pier). The installation of the northbound Pier 4 would be similar, but there would be four groupings of 15 piles each (60 piles total), resulting in 4 days of vibratory installation and 12 days of impact installation for that pier.

In addition to the 30-inch-diameter piles, four 16- or 24-inch-diameter piles would be driven at the southbound Pier 2. These piles are necessary to secure a template for the pile load test. These piles would also likely be conveyed to the site in three to four sections, which would be welded together and driven within the cofferdam built for the southbound Pier 2 pile installation.

Noise Assessment

The construction of the Mad River Bridge with 7-foot or 30-inch-diameter piles would not include any in-water impact pile-driving, but some in-water vibratory pile-driving, for cofferdam construction around the existing piers, would be required.

The alternative construction with the smaller piles would include the installation of two-hundred sixty 30-inch-diameter CISS piles located 65 meters (215 feet) from the anticipated wetted channel for Pier 2 piles and located 15 meters (50 feet) from the Pier 4 piles (Table 3). Because of the larger footprint of 20 piles compared to one 7-foot-diameter pile, some of the Pier 3 piles could encroach into the wetted channel, depending on river height and gravel bar configuration at the time of construction. All areas where pier piles are impact-driven would be contained in a

cofferdam during impact-driving. The analysis assumes that the cofferdams would be dry when piles are driven, or if they contain water deeper than 1 meter (3.3 feet), a bubble curtain would be installed within the cofferdam. Both scenarios (dry cofferdam or bubble curtain in the cofferdam) provide about 5 decibels (dB) of attenuation.

It has been typical to evaluate sound propagation through water using open water sound attenuation models such as the Nedwell linear model or the practical spreading loss model. However, as with the initial assessment for the 7-foot-diameter piles, these types of open water models are not appropriate to estimate transmission loss through groundwater to surface water. There are currently no models that can be used for this purpose.

I&R, a consulting firm that has been retained to conduct hydroacoustic monitoring for numerous pile-driving projects, does not have measured sound data for 30-inch CISS piles. I&R does, however, have the results of noise monitoring of numerous pile-driving projects using 0.61- and 0.91-meter (24- and 36-inch) CISS piles in a variety of environments, as well as piles driven on land and in water. It is appropriate for this analysis to use the best available data to estimate underwater sound levels that would be expected for construction materials and techniques used and conditions that exist at the Mad River Bridge.

Jones & Stokes retained the services of I&R to estimate underwater sound levels that would be expected if 30-inch piles were used for this project. Appendix A provides I&R's detailed analysis based on measured empirical data I&R has collected from similar projects. The process used to estimate the expected noise from driving the alternative 30-inch-diameter piles is the same as that used in the assessment of driving the 7-foot-diameter piles, as reported in Caltrans 2007a. Because data for 30-inch-diameter piles is not available, I&R used data from 24- and 36-inch CISS piles to estimate anticipated sound levels. The data tables from that report are reproduced here as Tables 5 and 6. Following is a summary of I&R's findings. Throughout, sound level metrics are referenced as follows, unless otherwise indicated:

- **Peak:** Peak Sound Pressure, dB re: 1 micropascal (μPa)
- **SEL:** Sound Exposure Level, dB re: 1 μPa^2 sec for one strike

Cofferdam Construction with Vibrated Sheet Piles

The methods for construction of the cofferdams would not change if pile size was changed from 7-foot to 30-inch piles. In the previous analysis (Caltrans 2007a) I&R estimated that the maximum peak sound values from vibratory sheet pile installation would be 160 to 170 dB $_{Peak}$ at 10 meters (33 feet) from the pile, depending on water depth (the louder peak in deeper water). I&R estimated the SEL from sheet pile-driven in the shallow waters (0 to 0.46-meter [0 to 1.5 feet]) surrounding the new Pier 3 and the existing piers on the north bank would be about 155 dB $_{SEL}$ at 10 meters (33 feet) from the sheet pile.

H-Type Pile Installation

Neither the installation methods for the H-type piles for the abutments nor the sound they would generate would differ from that described in Caltrans 2007a. I&R estimated that noise at the

Table 5. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 1 - Southbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[1]	Maximum Peak at 10m	at 20m	at 45m	at 75m	Estimated SEL per Strike[3] at 10m	at 20m	at 45m	at 75m	Accumulated SEL[4] at 10m	at 20m	at 45m	at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land 10 section	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–
Vibratory Sheet Installation in very shallow wa	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m
Pier 2 SB Bridge (40 Piles)																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Pier 3 SB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Pier 4 SB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
SB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<150	NA	NA	140	135	NA	NA	175	170	–
	Pile Driving Time with impacts			5800 min													

NA = Not applicable because distance specified not in water or SEL <150 dB

Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for initial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event = 10^{*} Log_{10}(No. of events)

Table 6. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-inch Piles

Year 3 - Northbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	at 20m	at 45m	at 75m	Estimated SEL per Strike[3] at 10m	at 20m	at 45m	at 75m	Accumulated SEL[4] at 10m	at 20m	at 45m	at 75m	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																	
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–
Vibratory Sheet Installation in very shallow water	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	193	190	<150	<150	193	NA	NA	NA	20m
Pier 2 NB Bridge (40 Piles)																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–
Pier 3 NB Bridge																	
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	300m
Pier 4 NB Bridge																	
Vibrate 10 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Vibrate 20 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–
Impact 10 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 20 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	275m
Impact 10 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 20 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	300m
Impact 10 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
Impact 20 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	300m
NB Bridge Abutments																	
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	145	135	NA	NA	175	170	–
	Pile Driving Time with impacts			6625 total													

NA = Not applicable because distance specified not in water or SEL <150 dB

Notes:

1. Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of setbacks per day
2. Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for initial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.
3. Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.
4. SEL per event = 10* Log $_{10}$(No. of events)

wetted edge of the channel would 160 dB_{Peak} and 140 dB_{SEL} or less during the impact-driving of the H-piles.

CISS Pile Installation

The alternate analysis assumes that 30-inch-diameter CISS piles would be installed at northbound and southbound Piers 2, 3, and 4. Tables 5 and 6 provide best professional estimates of Peak and SEL sound pressure levels expected at various distances from these CISS piles.

Pier 2

Installation of the Pier 2 pilings is proposed to occur during any time of year. Pier 2 is located approximately 65 meters (213 feet) from the wetted channel under summer flow conditions and a minimum of approximately 43 meters (141 feet) from the wetted channel under higher-flow conditions. I&R estimated the underwater sound levels at 45 meters (150 feet) from the impact-driven 30-inch piles to be 175 dB_{Peak} at a maximum, with an SEL of 150 dB. Therefore, even with winter flow levels, underwater sound levels from Pier 2 piles are estimated to be low.

Piers 3 and 4

Installation of the 30-inch piles for Piers 3 and 4 would occur during the period preferred by Dan Free, the National Marine Fisheries Service (NMFS) biologist assigned to this project (Free pers. comm.). This "in-channel" pile-driving window (July 1 to September 1) occurs during low flow conditions. During summer, the Pier 3 pilings would be in a cofferdam and could extend into the wetted channel. The cofferdam could extend into the wetted channel approximately 3 meters (10 feet) if the gravel bar is not extended into the river to afford additional dry areas for construction. If the bar is extended, the estimated distance to the wetted channel would be approximately 20 to 30 meters (66 to 100 feet). I&R estimated that the underwater sound levels generated by 30-inch piles would be 165 dB_{Peak} and 160 dB_{SEL} at a distance of 10 meters (33 feet) from the piles for the first (vibrated) sections installed. For the subsequent impact-driven sections, I&R estimated maximum sound levels of 200 dB_{Peak} and 167 dB_{SEL} at 10 meters (33 feet) from the pile. At 45 meters (147 feet) from these piles, the maximum sound levels from impact pile-driving were estimated to drop to 185 dB_{Peak} and 160 dB_{SEL}.

Pier 4 is located approximately 15 meters (50 feet) from the wetted channel of the river during summer conditions. Estimated underwater noise produced during the installation of the 30-inch Pier 4 piles are conservatively estimated to be the same as described for Pier 3 piles, except that Pier 4 is located 15 meters (50 feet) from the wetted channel, and there is no estimate for underwater sound at 10 meters (not in water).

Comparison of Estimated Sound Generation to Interim Criteria

Dr. Art Popper (University of Maryland) and Dr. Mardi Hastings (Pennsylvania State University), leading experts in the field of fish bioacoustics, reviewed and synthesized currently available information and recommended guidelines for assessing and mitigating effects of pile-driving sound on fish. Their work is reported in the document entitled *The Effects of Sound on Fish* (Hastings and Popper 2005). Dr. Popper and several other experts expanded on this report

and provided recommendations for specific interim threshold criteria to evaluate potential injury to fish from pile-driving (Popper et al. 2006). The recommended interim threshold criteria for pile-driving are an SEL of 187 dB re: 1 $\mu Pa^2 s \cdot sec$ and a peak sound pressure of 208 dB re: 1 μPa_{Peak} in any single strike. For the purposes of impact assessment, this threshold is applied at 10 meters (33 feet) from a pile. The thresholds described above are commonly referred to as the interim "dual criteria" and are used as one method in this assessment.

The estimated sound levels from 30-inch piles, if they were to be driven as part of this project, are below the interim criteria proposed in Popper et al. 2006. In no cases were the estimated peak or single strike SEL values in the wetted channel predicted to exceed 208 dB_{Peak} or 187 dB_{SEL}, respectively.

NMFS' interpretation of the SEL criterion proposed in Popper et al. 2006 states that energy from all strikes to which a fish may be exposed should be summed, then compared to the 187-dB_{SEL} criterion. A simple example is where a fish would be exposed to 500 pile strikes. The accumulated SEL value (referred to here as $SEL_{Accumulated}$) would be 27 dB more than the single strike SEL value (27 dB is calculated by taking 10 times the logarithm of 500). According to NMFS' interpretation, the $SEL_{Accumulated}$ value should then be compared to the interim 187-dB_{SEL} criterion.

Tables 5 and 6 estimate the SEL per strike and accumulated SEL for the 30-inch pile alternative based on NMFS' approach to the calculation of $SEL_{Accumulated}$. These tables show that in no cases is the single strike SEL estimated to exceed 187 dB_{SEL}. The highest single strike SEL is estimated to be 167 dB at 10 meters (33 feet) from the pile while impact-driving the topmost sections of the CISS piles at Piers 3 and 4. For Pier 2, the greatest single strike SEL is estimated to be 150 dB_{SEL} at 45 meters (147 feet) from the piles, which is the distance to the water's edge for all impact-driven pile sections. Under winter flows, when the distance between the wetted channel and Pier 2 piles would be the least, this noise level (150 dB_{SEL}) is estimated to occur approximately 2 meters (6.6 feet) offshore.

When using the NMFS method of SEL accumulation, the SEL interim criterion would not be exceeded during the driving of any of the Pier 2 piles because of the distance between these piles and the water, even under winter flow conditions.

The estimated $SEL_{Accumulated}$ values for 30-inch piles per event (one day of pile-driving) at Piers 3 and 4 are shown in Tables 5 and 6. Using the NMFS method, SEL for 30-inch piles at Piers 3 and 4 would range from 195 dB (first vibrated section) to 209 dB (top impact-driven sections) at 10 meters (33 feet) from the piles. Depending on the section of the pile being impact-driven and the pier, the $SEL_{Accumulated}$ values for the impact-driven piles would drop to 187 $dB_{SEL(Accumulated)}$ at a distance of 200 to 300 meters (656 to 984 feet) from the piles. (Note: Dropoff rates were based on measured data out to about 75 meters (246 feet). Beyond 75 meters, dropoff was conservatively estimated using 15log[distance], which is roughly 5 dB per doubling of distance. See Appendix A for details.)

Tables 7 and 8 break down the pile-driving activities for Piers 3 and 4, including the drive times and the distance to 187 $dB_{SEL(Accumulated)}$ for each day piles would be driven. The distance to 187 $dB_{SEL(Accumulated)}$ should be considered very conservative because it does not take in to account

the bends in the river channel, presence of gravel bars in the river, or shallow depth of the river, all of which would attenuate sound propagation up or down the river. In addition, the accumulation method used by NMFS likely overestimates accumulation for larger numbers of pile strikes.

Table 7. Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Southbound Bridge, Year 1)

Pier	Section	Installation Method	Drive Time per Pile	Drive Time per Day	Number of Days Driving Occurs	Distance to 187 $dB_{SEL(Accumulated)}$
3	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	20 meters 20 meters
3	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
3	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
3	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	N/A N/A
4	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
4	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters

Table 8. Distance to 187 $dB_{SEL(Accumulated)}$ for Pier 3 and Pier 4 Piles, Assuming Four Sections Per Pile (Northbound Bridge, Year 3)

Pier	Section	Installation Method	Drive Time per Pile	Drive Time per Day	Number of Days Driving Occurs	Distance to 187 $dB_{SEL(Accumulated)}$
3	1st (bottom)	Vibrate	5	10 piles—50 min 15 piles—75 min	1 2	20 meters 20 meters
3	2nd	Impact	20	10 piles—200 min 15 piles—300 min	1 2	200 meters 275 meters
3	3rd	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
3	4th (top)	Impact	25	10 piles—250 min 15 piles—375 min	1 2	250 meters 300 meters
4	1st (bottom)	Vibrate	5	15 piles—75 min	4	N/A
4	2nd	Impact	20	15 piles—300 min	4	275 meters
4	3rd	Impact	25	15 piles—375 min	4	300 meters
4	4th (top)	Impact	25	15 piles—375 min	4	300 meters

NMFS typically assumes that exposure of a fish to underwater noise levels above a threshold of 150 dB root mean square (RMS) would result in behavioral effects to fish. Although not specifically estimated by I&R (Appendix A), it is expected that, in an open water system, noise levels above 150 dB RMS might occur out to or beyond 300 to 400 meters (984 to 1,312 feet)

from a 30-inch-diameter pile. However, this is likely very conservative at the Mad River site because of the presence of shallow water, gravel bars, and turns in the river channel.

Differences in Sound Levels Produced by Proposed Piles and Use of Smaller Piles

The objective of this analysis is to determine whether the peak and accumulated noise generated by impact pile-driving could be lessened by the use of smaller piles to replace the Mad River Bridge. To use smaller piles, many more piles would have to be driven to meet the load requirements of the bridges. In this case, two-hundred sixty 30-inch CISS piles would be required to replace the thirteen 7-foot-diameter CISS piles in the current design. The summary below compares the use of 30-inch piles to a case where only one 7-foot-diameter pile section is driven in a day (as described in Caltrans 2007a), and to a case where multiple (two or three) 7-foot-diameter pile sections are driven in a day (as described in Caltrans 2007b):

- The maximum Peak sound pressure at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be less (up to 200 dB) than for 7-foot-diameter CISS piles (up to 205 dB). For both types of piles, the maximum peak values are below the interim criteria of 208 dB_{Peak}.
- The maximum SEL per strike at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be less (up to 167 dB) than for impact-driving 7-foot-diameter CISS piles (up to 170 dB). For both types of piles, the maximum SEL single strike values are below 187 dB_{SEL}.
- The maximum $SEL_{Accumulated}$ at 10 meters (33 feet) from impact-driving of 30-inch CISS piles would be more (up to 209 dB) than for impact-driving one 7-foot-diameter pile section (up to 200 dB) or multiple sections (up to 203 dB). For both types of piles, the maximum $SEL_{Accumulated}$ exceeds 187 $dB_{SEL(Accumulated)}$ at 10 meters (33 feet), which is the NMFS interpretation of the SEL interim threshold value.
- The maximum impact pile-driving time per day would be more for impact-driving up to 15 sections of 30-inch CISS piles (200 to 375 minutes over the course of a day) than for impact-driving one, two, or three sections of 7-foot-diameter CISS piles (30, 60, or 90 minutes a day, respectively).
- The maximum distance at which the $SEL_{Accumulated}$ would be attenuated to 187 $dB_{SEL(Accumulated)}$ using the NMFS method is more from impact-driving of 30-inch CISS piles (up to 300 meters) than for impact-driving one or more 7-foot-diameter CISS pile sections during one day (65 to 170 meters [213 to 558 feet], respectively).
- The number of pile-driving events (days on which pile-driving occurs at Piers 2, 3 and 4) would be more for impact-driving two-hundred sixty 30-inch CISS piles (27 days in Year 1 and 30 days in Year 3) than for impact-driving one 7-foot-diameter CISS pile section in a day (24 days in Year 1 and 28 days in Year 3) or two 7-foot-diameter CISS pile sections in a day (12 days in Year 1 and 12 days in Year 3).

Differences in Estimated Exposure of Fish to Sound Levels Exceeding Interim Thresholds

There would be no difference in fish exposure to sound generated from installation of H-type piles at the abutments, Pier 2 piles, or cofferdam installation for the proposed or alternative pile size. None of these activities would be expected to generate underwater sound levels exceeding Peak or SEL interim criteria for either scenario.

Based on this analysis, the use of 30-inch CISS piles to replace the 7-foot-diameter CISS piles would expose a larger area to accumulated sound levels above 187 $dB_{SEL(Accumulated)}$ for more days during the installation of Piers 3 and 4 during Years 1 and 3 of construction (Table 9). Please note that this table is not the total days of pile driving, but only the days during which 187 $dB_{SEL(Accumulated)}$ is estimated to be exceeded.

Table 9. Number of Days and Distances at Which 7-Foot and 30-Inch Pile-Driving Scenarios for Piers 3 and 4 Are Estimated to Result in Accumulated Sound Levels Exceeding 187 $dB_{SEL(Accumulated)}$

Distance (Meters) from Pile to Attenuation to 187 $dB_{SEL(Accumulated)}$	Number of Days (Year 1/Year 3)		
	7-Foot-Diameter Piles—One Section Driven/Day	7-Foot-Diameter Piles—Multiple Sections Driven/Day	30-Inch Diameter Piles—10–15 Sections Driven/Day
20	–	–	3/3
45	4/5	–	–
65	–	2/2	–
75	4/5	–	–
90	8/10	–	–
110	–	2/1	–
130	–	0/1	–
150	–	4/2	–
170	–	0/2	–
200	–	–	2/2
250	–	–	4/4
275	–	–	4/4
300	–	–	8/11

It is concluded that the replacement of the 7-foot-diameter CISS piles with 30-inch CISS piles for the Mad River Bridge Replacement Project does not appear to lessen the potential exposure of fish to accumulated sound levels at or above 187 $dB_{SEL(Accumulated)}$. To the contrary, because more of the smaller piles would be required, more piles would be driven during any given day and pile-driving would need to occur on more days, it is likely that more fish habitat would be exposed to accumulated sound levels above 187 $dB_{SEL(Accumulated)}$ more frequently.

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Appendix A Illingworth & Rodkin 30-Inch Pile Analysis

ALTERNATIVE ANALYSIS OF UNDERWATER SOUND LEVELS USING 30 INCH PILES – MAD RIVER BRIDGE REPLACEMENT PROJECT AT U.S. HIGHWAY 101 IN HUMBOLDT COUNTY DRAFT

01-Hum-101 KP144.4, Bridge No. 04-0025L

November 1, 2007

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Introduction

The report evaluates underwater noise levels associated with an alternative conceptual design to use smaller piles on the Mad River Bridge project. The alternative conceptual bridge design would consist of 0.8-meter (30-inch) diameter CISS piles instead of the planned 7-foot-diameter CISS piles. This alternative design would be comprised of a total of 260 CISS piles for the project that are 30-inch diameter, 1-inch thick steel shell piles, to be located at the same proposed pier locations as for the 7-foot-diameter pile design. The southbound bridge would utilize 40 of these piles at planned Pier 2; 40 piles at planned Pier 3, and 40 piles at proposed Pier 4. The northbound bridge would utilize 40 piles at Pier 2; 40 piles at Pier 3, and 60 piles at the wider Pier 4. (A bridge design utilizing 30-inch-diameter piles would also require use of a footing.) The alternative bridge design also includes H-piles for abutments, as well as temporary sheet piles (to be vibrated in) for cofferdams within the river channel. The H-type and sheet pile installation would be similar to the planned project evaluated with the 7-foot diameter piles. The primary difference in underwater sound generation would be the differences between installing the 30-inch diameter piles versus the 7-foot diameter piles. The pier locations would be the same as analyzed above and cofferdam designs are assumed to be similar.

A construction plan to install these piles has not been developed. Current construction activities for the Ten Mile Bridge Replacement project were used to describe a possible construction scenario. The permanent 24-inch CISS piles were 120 to 185 feet long. These piles were initially installed as 80 to 105 foot sections (pre-welded) and then two 40-foot sections were attached. Each pier had 32 piles. The piles were initially vibrated, which took about 2 and one half days. The piles were then driven using an impact hammer, which also took about 2 to 2 ½ days. The welded sections were also driven using an impact hammer. Each pile took about 5 minutes to install using a vibratory hammer. Impact driving of the initial section following the vibratory installation took about 20 minutes of continuous driving. The 40-foot sections took about 25 minutes each to drive continuously with the impact hammer. A similar scenario is used to evaluate Mad River construction driving times to calculate sound exposure.

Source Data

Sound levels that would be generated from these piles were estimated by evaluating projects similar where measurements were made. Sounds from similar size CISS piles have been measured in water for several projects. The most representative projects are those that have involved the driving of piles on land close to river bodies. Three projects involved this type of pile driving and are described below. Table 1 provides a summary of the source data.

Stockton Wastewater Treatment Plant Pipe Line, San Joaquin River

Construction of a wastewater treatment pipeline across the San Joaquin River involved the driving of 20-inch and 36-inch steel shell piles on land (edge of levee) adjacent to the river. The 20-inch piles were constructed to support a temporary construction trestle. The 36-inch piles were constructed to permanently support a wastewater treatment pipeline that crosses the river. Driving of a temporary pile is shown in Figure 1.

Table 1. Data Sources from Projects with Underwater Sound Measurements

Pile Size	Project/Location	Pile Position	Hammer Type	Position	Typical Measured Sound Levels: Peak	Typical Measured Sound Levels: SEL
20in	Stockton WWTP/San Joaquin River	Land adjacent to river	Impact	10m	198	171
				20m	188	163
36in	Stockton WWTP/San Joaquin River	Land adjacent to river	Impact	10m	201	173
				20m	198	170
			Vibrate	10m	165	160
				20m	160	150
24in	Geyserville Bridge/Russian River	Saturated Land adjacent to river	Impact	15m	197	173
				35m	187	163
				70m	172	--
24in	Geyserville Bridge/Russian River	On shore adjacent to river	Impact	15m	190	160
				90m	180	155
48in	Geyserville Bridge/Russian River	Immediately adjacent to shore	Impact	10m	200	175
				20m	200	172
				50m	190	165
24in	Ten Mile River/Pier 6	Cofferdam at shoreline	Vibrate	10m	175	~150
				100m	<165	<150
24in	Ten Mile River/Pier 6	Cofferdam at shoreline	Impact	10m	185	~165
				100m	170	~150

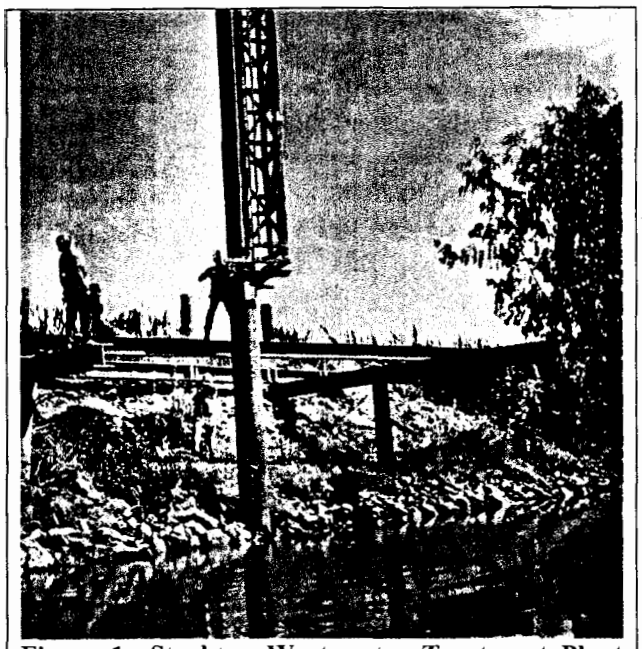


Figure 1 Stockton Wastewater Treatment Plant pipeline construction looking at 20-inch trestle piles driven near river edge

Both the 20-inch and 36-inch piles were first vibrated and then driven to there final depth using a diesel impact hammer. Measurements were made for both piles. A Delmag D19-42 impact hammer that provided about 71 kilojoules of energy was used to drive the 20-inch piles. Vibrated levels were not measured for the 20-inch piles. Underwater sound levels produced by the driving of those piles were 198 dB peak (201 dB max.) and 171 dB SEL at 10 meters. At 20 meters, peak pressures were typically 188 dB and SELs were 163 dB.

Measurements were made when the 36-inch piles were vibrated and impact driven with a Delmag D46-42 diesel impact hammer providing up to 180 kilojoules. For vibrated levels, peak pressures were typically 165 dB, but reached 173 dB at 10 meters. The 1-second SEL at 10 meters estimated from the RMS levels was typically 155 dB, but reached 165 dB. At 20 meters peak pressures were 160 dB (max. 165 dB) and SELs were typically 150 dB, but reached 155 dB. Impact driving resulted in peak pressures of 201 dB peak at 10 meters (max. 204 dB) and an SEL of 173 dB. At 20 meters, peak pressures were 198 dB (max. 200 dB) and the SEL was 170 dB. Each of the 36-inch piles took about 5 minutes to drive with the impact hammer. These piles were driven very close to the water, where there was a steep edge created by the river levee. This condition would likely cause higher sound levels than for the Mad River, because sound from the pile can propagate horizontally through the levee into the river.

Geyserville Russian River Bridge Replacement

The installation of 24-inch steel pipe piles used to support a temporary construction trestle were measured. Most of these piles measured were driven in saturated soils adjacent to the river channel. Measurements were made in swift waters about 15 to 90 meters from the piles. Piles were driven on land, about 10 meters from shore and then on land right at the shore. Piles were stabbed using a vibratory driver/extractor. Figure 2 shows the installation of these land-based piles.

Figure 2a. Impact driving of east side trestle piles, photo taken from closest measurement position on existing bridge

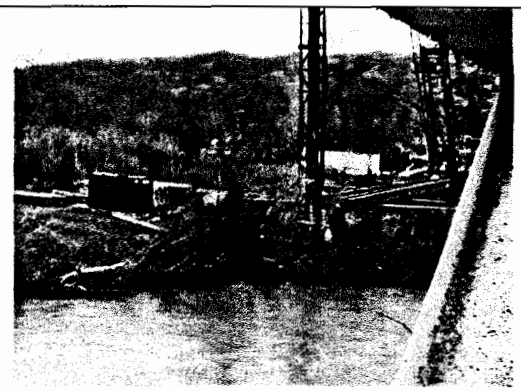


Figure 2b. Impact driving of 24-inch steel trestle pile being driven at river bank

Sound levels associated with vibratory installation of the piles at 35 meters could not be measured and were not audible. The swift river resulted in high background noise of about 160 dB RMS. The first set of measurements were made when the 24-inch piles were about 10 meters from the shore (although the soils were saturated due to the high river levels) and measurements were made at 35 and 90 meters from the pile in water that was at least 2 meters deep. At 35 meters, typical sound levels started off at about 175 dB peak and steadily increased to 190 dB peak, 175 dB RMS and about 160 dB SEL. At 90 meters, sound levels reached 178 dB peak and 165 dB RMS. SEL was not measured, but estimated to be about 155 dB. Had these piles been driven for Mad River, we would have expected lower levels because the soils conditions would not have been as saturated and the piles would be driven in cofferdams excavated below the river level. However, the alternative Mad River design calls for larger diameter and longer piles.

Measurements were also made for the Russian River temporary trestle piles when they were driven in shallow water during late spring when river levels dropped substantially. Sound levels were lower than those measured for land-based piles and the reason is thought to be the water depth. Shallow water does not support the propagation of underwater sound. In addition, measurements made in water that is less than 2 meters deep usually results in lower pressures, because the hydrophone is so close to the water/air interface, which is also known as the pressure release zone. Sound pressures near the air/water surface theoretically approach 0 dB. In slightly less than 1-meter deep water at 18 meters, sound pressures were a maximum of 184 dB peak and 160 dB SEL. At 10 meters, levels were slightly higher, about 187 dB peak, and 162 dB SEL.

Ten Mile River Replacement Bridge

Recent measurement data from the Ten Mile River Bridge Replacement project have been obtained. 24-inch diameter CISS piles support the piers for this bridge. These piles are driven through a dewatered cofferdam. Some water was present in the cofferdams, so an air bubble curtain had to be used where peak pressures approached 190 dB. Pier 5 is located on land with the closest portion about18 meters from the edge of the estuary (see Figures 3a and 3b). Pier 6 is located in very shallow water near the edge. Ten Mile River resembles more of a tidal estuary than a flowing river at the project site. Water depth is very shallow, less than 1 meter through out much of the river except the deepest parts where water depth can reach almost 2 meters

during high tides. Underwater noise measurements during pile installation were made in waters that were 1 meter or deeper.

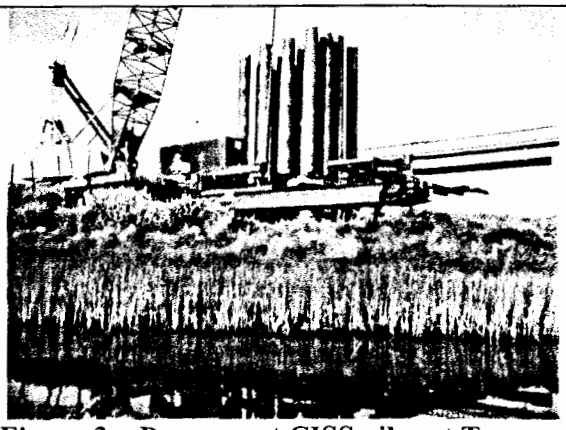


Figure 3a. Permanent CISS piles at Ten Mile River Bridge Pier 5, photo taken from closest measurement position in water.

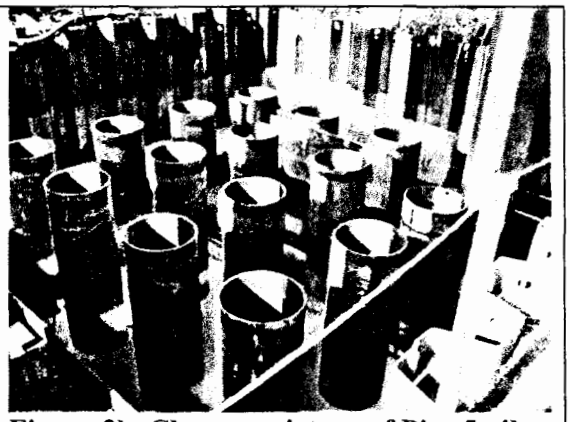


Figure 3b. Close-up picture of Pier 5 piles

Pier 5 measurements for impact driving are only data that are currently available. At the closest in water position (1 meter or deeper), which was 38 meters from the pile, sound levels were 172 dB peak and 163 dB RMS. SEL levels were not yet measured, but are estimated to be about 150 dB. Levels at 100 meters were below 165 dB peak.

Sound pressure levels were measured for Pier 6, which was at the shoreline (partially in water). Sound levels during vibratory installation were 175 dB peak and 160 dB RMS at 10 meters. The SEL for 1 second of driving would be similar to the RMS. Levels at 100 meters were below the reported detection limit of 165 dB peak (SEL would be less than 150 dB). Subsequent impact driving resulted in sound levels at 10 meters of 185 dB peak (max. 190 dB) and 175 dB RMS. SEL was not measured, but estimated at 165 dB. At 100 meters, levels were about 172 dB peak, and less than 165 dB RMS. The SEL was estimated at less than 150 dB. At the time of this writing, the two 40-foot sections that are to be added have not been driven.

Estimate of 30-inch Diameter CISS Pile Source Levels

The measured sound data described previously indicate a considerable range in sound levels that could be expected from the driving of land-based 30-inch diameter CISS piles. It appears from all of the data that vibratory installation of the piles would generate peak sound pressures of less than 170 dB and SELs of about 160 dB at 10 meters and 150 dB or lower at 20 meters or further away. Impact driving levels would vary considerably.

We do know that in water and unattenuated, 30-inch steel pipe or CISS piles produce sound levels of about 210 dB peak, 190 dB RMS and 180 dB SEL at 10 meters and these levels would drop off at a rate of at least *15 Log (Distance)*. When these piles are driven on land, they produce lower noise levels, but have a lower distance attenuation rate near the pile. As

previously discussed, the piles for the Mad River Bridge will be driven in excavated land-based dewatered cofferdams, where the pile will be driven below the bottom of the river. If necessary, an air bubble curtain would be used to lower sound pressures.

The data collected at Stockton for 36-inch piles is expected to be higher than what would be expected at Mad River, because the piles were driven in a levee next the shore. If about 5 dB of sound reduction were applied, levels would be about 195 dB peak and 165 dB SEL at 10 and 20 meters. The 48-inch piles driven for the Russian River Bridge would be higher than those expected at Mad River for 30-inch piles; because they are larger piles and were driven at a level slightly above the river. These piles were also immediately adjacent to the river. About 5 dB could be reduced from the predicted levels for the 7-foot diameter piles to estimate that for the smaller 30-inch piles. This puts the source levels at about 195 to 200 dB peak and 165 dB SEL at 10 to 20 meters. The levels measured for the 24-inch trestle piles driven on saturated land near the river are somewhat consistent with these levels. However, one has to keep in mind that those smaller trestle piles were driven in saturated soils, which probably transmitted sound fairly efficiently into the adjacent river channel. Lower sound pressures were measured at Ten Mile River, when permanent 24-inch CISS piles were driven. Use of the Ten Mile River Bridge data would indicate sound levels of about 185 dB peak and 165 dB SEL at 10 to 20 meters. Ten Mile River does not have any pools deeper than 2 meters, and most of the measurements made there were in water closer to 1 meter deep. The Ten Mile River data may be similar to what would be expected in the shallower waters at Mad River. At the deeper pools, higher levels should be anticipated.

Estimated Peak and SEL Sound Generated by Driving 30-inch Piles at Mad River

Tables 2 and 3 provide estimates of maximum peak, single strike SEL and accumulated SEL for each event (day of pile driving) based on the source levels identified above. To estimate distance to 187dB $SEL_{Accumulated}$,15 Log (distance) was used for the transmission loss. The $SEL_{Accumulated}$ assumes that 10 or 15 pile sections are driven in a day and that the piles are installed in four sections.

Table 2. Mad River Bridge Replacement - **Prediction of Daily Underwater Sound Levels for 30-Inch Piles**

Year 1 - Southbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total Drive Time in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 45m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 45m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 45m	Accumulated SEL[4] at 75m	Estimated Distance to 150 dB SEL for a Single Strike	Estimated Distance to 187 dB Accumulated SEL
Goffersdam Sheet Piles (A Group)																		
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–	–
Vibratory Sheet Installation in very shallow wat	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–	–
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	193	NA	NA	NA	20m	20m
Pier 2 SB Bridge (49 Piles)																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	150	<150	NA	NA	NA	NA	–	–
Pier 3 SB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	160	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Pier 4 SB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
SB Bridge Abutments																		
H-Type Pile	15	5	75	3000 strike	NA	NA	180	170	NA	NA	140	135	NA	NA	175	170	–	–
NA = Not applicable	Pile Driving Time with Impacts			5800 min														

Notes

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds except for initial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 seconds.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event + 10* Log_{10}(no. of events)

Table 3. Mad River Bridge Replacement - Prediction of Daily Underwater Sound Levels for 30-Inch Piles

Year 3 - Northbound Bridge Piers and Abutments

Activity Description	Drive Time per Pile (min)[1]	Piles per Day	Total DriveTime in min.	Events[2]	Maximum Peak at 10m	Maximum Peak at 20m	Maximum Peak at 40m	Maximum Peak at 75m	Estimated SEL per Strike[3] at 10m	Estimated SEL per Strike[3] at 20m	Estimated SEL per Strike[3] at 40m	Estimated SEL per Strike[3] at 75m	Accumulated SEL[4] at 10m	Accumulated SEL[4] at 20m	Accumulated SEL[4] at 40m	Accumulated SEL[4] at 75m	Estimated Distance to 150 dB SEL for a Single Strike	Estimated Distance to 187 dB Accumulated SEL
Cofferdam Sheet Piles in Ground																		
Vibratory Sheet Installation on land 10 sections	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–	–
Vibratory Sheet Installation in very shallow wat	10	10	100	6000 sec.	160	<160	<160	<160	<150	<150	<150	<150	NA	NA	NA	NA	–	–
Vibratory Sheet Installation in deeper water	10	10	100	6000 sec.	170	165	<160	<160	155	150	<150	<150	195	NA	NA	NA	20m	20m
Pier 2 NB Bridge (40 Piles)																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	NA	<165	<165	NA	NA	<150	<150	NA	NA	NA	NA	–	–
Impact 10 Sections	20	10	200	8000 strike	NA	NA	170	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 Sections	20	15	300	12000 strike	NA	NA	170	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Impact 15 2ND ADD-ON Sections	25	15	375	15000 strike	NA	NA	175	170	NA	NA	160	<150	NA	NA	NA	NA	–	–
Pier 3 NB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	160	150	<150	<150	195	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Vibrate 15 Sections	5	15	75	4500 sec.	165	165	<165	<165	160	150	<150	<150	197	NA	NA	NA	20m	20m
Impact 10 Sections	20	10	200	8000 strike	195	195	185	180	165	165	160	155	204	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	195	195	185	180	165	165	160	155	206	206	201	196	150m	275m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	195	195	185	180	165	165	160	155	205	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	195	195	185	180	165	165	160	155	207	207	202	197	150m	300m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	200	200	185	180	167	167	160	155	207	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	200	200	185	180	167	167	160	155	209	209	202	197	175m	300m
Pier 4 NB Bridge																		
Vibrate 10 Sections	5	10	50	3000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Vibrate 15 Sections	5	15	75	4500 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Vibrate 20 Sections	5	20	100	6000 sec.	NA	165	<165	<165	NA	150	<150	<150	NA	NA	NA	NA	–	–
Impact 10 Sections	20	10	200	8000 strike	NA	195	185	180	NA	165	160	155	NA	204	199	194	150m	200m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 15 Sections	20	15	300	12000 strike	NA	195	185	180	NA	165	160	155	NA	206	201	196	150m	275m
Impact 20 Sections	20	20	400	16000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 10 1st ADD-ON Sections	25	10	250	10000 strike	NA	195	185	180	NA	165	160	155	NA	205	200	195	150m	250m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 15 1st ADD-ON Sections	25	15	375	15000 strike	NA	195	185	180	NA	165	160	155	NA	207	202	197	150m	300m
Impact 20 1st ADD-ON Sections	25	20	500	20000 strike	NA	195	185	180	NA	165	160	155	NA	208	203	198	150m	350m
Impact 10 2nd ADD-ON Sections	25	10	250	10000 strike	NA	200	185	180	NA	167	160	155	NA	207	200	195	175m	250m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 15 2nd ADD-ON Sections	25	15	375	15000 strike	NA	200	185	180	NA	167	160	155	NA	209	202	197	175m	300m
Impact 20 2nd ADD-ON Sections	25	20	500	20000 strike	NA	200	185	180	NA	167	160	155	NA	210	203	198	175m	350m
NB Bridge Abutments																		
H-Type Pile	15	5	75	3000 strike	NA	NA	160	<160	NA	NA	149	139	NA	NA	175	170	–	–
NA = Not applicable	*Pile Driving Time with Impacts*			6700 min														

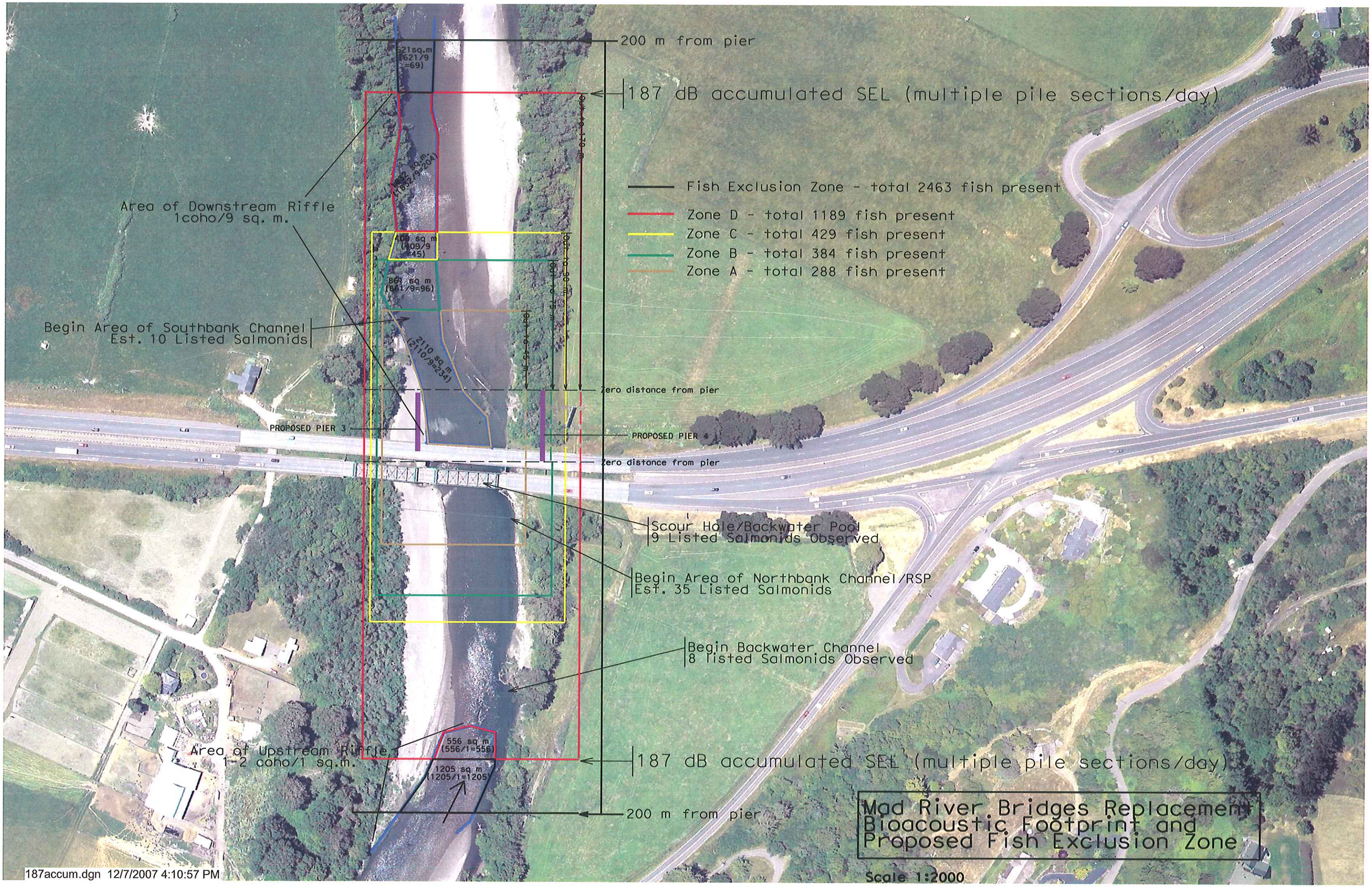
Notes:

1 Based on best estimate of drive times from previous studies. Drive times may vary substantially. Assume 5 minutes per pile times the number of sections per day

2 Assume diesel impact hammer for CISS piles, striking about once every 1.5 seconds, except for initial, quieter blows. H piles also assume to be driven with diesel impact hammer at rate of one blow per 1.5 second.

3 Based on average SEL per strike for impact driving from past measurement data for similar projects. Vibratory installation SELs are for 1 second.

4 SEL per event = $10 * \log_{10}$(no. of events)


200 m from pier
187 dB accumulated SEL (multiple pile sections/day)
621sq.m (621/9 =69)
1632 sq.m. (1632/9=204)
409 sq m (409/9 =45)
861 sq m (861/9=96)
2110 sq m (2110/9=234)
Fish Exclusion Zone - total 2463 fish present
Zone D - total 1189 fish present
Zone C - total 429 fish present
Zone B - total 384 fish present
Zone A - total 288 fish present
Area of Downstream Riffle
1coho/9 sq. m.
Begin Area of Southbank Channel
Est. 10 Listed Salmonids
Zero distance from pier
PROPOSED PIER 3
PROPOSED PIER 4
Zero distance from pier
Scour Hole/Backwater Pool
9 Listed Salmonids Observed
Begin Area of Northbank Channel/RSP
Est. 35 Listed Salmonids
Begin Backwater Channel
8 listed Salmonids Observed
Area of Upstream Riffle
1-2 coho/1 sq.m.
556 sq m (556/1=556)
1205 sq m (1205/1=1205)
187 dB accumulated SEL (multiple pile sections/day)
200 m from pier
Mad River Bridges Replacement
Bioacoustic Footprint and
Proposed Fish Exclusion Zone
Scale 1:2000
187accum.dgn 12/7/2007 4:10:57 PM

Fish Exclusion to Avoid and Minimize Bioacoustic Impacts to Salmonids from Pile Driving During the Construction of Mad River Bridges

Prepared by
Samantha J. Hadden, Fisheries Biologist, M.S.
Jones& Stokes
And
Kelley Garrett, Associate Environmental Planner, Caltrans

December 6, 2007

Exhibit I

1.0 Project Description

Caltrans, in consultation with National Marine Fisheries Service (NMFS) and California Department of Fish and Game (CDFG) propose to exclude, to the extent feasible all federally and state listed juvenile and adult salmonids from the areas potentially impacted by acoustic noise from pile driving activities during construction of the replacement of the Mad River Bridges. The area of potential disturbance from acoustic noise (187 dB $SEL_{accumulated}$) is currently projected to occur within the project area both upstream and downstream of pile driving activities. Fish exclusion will commence prior to the pile driving work window, which begins July 1 during the construction of Pier 3 and Pier 4. The fish exclusion project described here is being undertaken in direct consultation with NMFS and CDFG in order to avoid and minimize potential harm to listed salmonids and other aquatic life forms, and was determined to be the most prudent to reduce potential sublethal and lethal impacts during pile driving activities.

The results from a supplemental analysis to the *Pile-Driving Noise Analysis for the Mad River Bridge Replacement Project* (November 2007) conducted by Jones & Stokes and Illingworth & Rodkin estimated that potential underwater noise impacts associated with driving 7 ft diameter piles at pier 3 and pier 4 will not exceed the NMFS single strike 208 dB. The 187 dB $SEL_{accumulated}$ threshold, used to assess the onset of potential harm, would occur at a distance of 90 m (upstream and downstream) if one pile segment per day were driven, and at 170 m (upstream and downstream) if up to three pile segments were driven per day. Based on these anticipated hydroacoustic footprints, two potential exclusion scenarios will be evaluated in this document. The first scenario will assess the potential fish take associated with excluding fish from a total of 180 m (90 m upstream and downstream of the impact hammer). The second scenario will assess the potential fish take associated with excluding fish from a total of approximately 400 m (i.e., 200 m upstream and downstream of the impact hammer), which would protect fish from the predicted area of bioacoustic disturbance (i.e., 170 m upstream and downstream)[1].

Under both scenarios, fish movement into the area of potential bioacoustic disturbance would be restricted via a fish weir structure that will be placed upstream and downstream of pile driving activities to establish a fish exclusion

[1] A distance of 200 m was chosen due to physical site conditions. There is a deep channel scour pool on the right bank (river right) 170 m upstream of the Mad River Bridges, which could complicate the placement of the fish net weir.

zone (FEZ). In addition to the weir structure at each end of the FEZ, a migration channel will be constructed to allow fish passage when it is determined by Caltrans and the construction contractor that there will be a sufficient hiatus (approximately 1-2 weeks) in pile driving to allow fish access to habitats located upstream and downstream of the FEZ. Once the fish weir and migration channel are in place, fish and other aquatic organisms (e.g., amphibians) will be removed from the FEZ using techniques approved by professional fisheries biologists in consultation with NMFS and CDFG. The net-weir will be continuously monitored both above and below the water surface to ensure its integrity and clear any debris that may be present while it is in place. Fish exclusion structures and fish removal operations will begin with sufficient time each season prior to pile driving to ensure the that the maximum number of fish and other aquatic organisms are safely re-located to suitable habitats outside of the FEZ.

Several temporary stream habitat alterations will be necessary to assist in the removal of fish from the FEZ and also to augment stream habitat downstream of the FEZ. There is a deep scour hole located near the southbound bridge within the FEZ(s) that was identified as too complex to facilitate the efficient removal of fishes. As a consequence, it was determined in consultation with NMFS and CDFG that the deep scour hole be filled with a water bladder each year prior to fish removal. In an effort to mitigate for temporary habitat losses within the FEZ, stream habitat downstream will be augmented with structures in accordance with an approved *Mad River Bridge Replacement Project Fish Exclusion and Monitoring Plan*. This plan will include provisions for an adaptive management process to allow flexibility in order to ensure efficient construction of all structures that will provide a maximum level of protection to sensitive species as well as a contingency plan in the event of structural failure. Currently, it is anticipated that a complete description and analysis of all components of the fish exclusion project will be required per a CDFG Lake and Streambed Alteration Permit term and condition. Work associated with this element of the project will begin on approximately June 15, 2009-when the in-water work window for the first year of project construction on the Mad River Bridges Replacement Project commences.

1.0 Fish Exclusion Methodology

The potential fish take associated with a) excluding fish from the FEZ and b) not excluding fish from the potential area of disturbance will be estimated using the preliminary data collected by Caltrans consultants on July 17, 2007. However, it must be noted that a single diver collected the data on juvenile salmonid densities on one occasion. There were no efforts made to calibrate the visual observation count with other fish population estimation techniques (e.g., electro-fishing). The number of salmonids estimated from these data will be used to compare the

different project alternatives associated with potential bioacoustics impacts associated with pile driving.

Prior to the implementation of any *Mad River Bridge Replacement Project Fish Exclusion and Monitoring Plan* a comprehensive habitat and fish abundance survey will be completed. This will be necessary to determine unknown factors associated with all elements of fish exclusion including:

- The location and of enumeration of fishes throughout the FEZ
- The quantity and quality of underwater habitats within the FEZ
- Depth profile along the FEZ for migration corridor placement

Professional fisheries biologists retained by Caltrans contractors in consultation with NMFS and CDFG will conduct these surveys during the year(s) prior to year one of pile driving, and again prior to construction of the fish weir and migration corridor as well as once pile driving has ceased each year. These surveys will also assist Caltrans and the resource agencies in determining the appropriate level of mitigation for the temporary loss of habitats and the take potential of listed salmonids during the course of the project.

The first phase of the fish exclusion project will begin with clearing the scour hole under the southbound Mad River Bridge of small woody material prior to fish removal. This area is likely to have high densities of fish associated with it, and is too complex to use traditional fish removal techniques (i.e., electro-fishing, seining). After as much organic material as possible has been removed fish will be flushed out manually by fish biologists. A water bladder will then be temporarily placed within the scour hole to prevent fishes from taking refuge there during fish removal. This will prevent fish from seeking refuge in the hole during fish removal efforts. The water bladder will remain for the duration of pile driving activities. Potential fish take numbers associated with his effort cannot be known at this time. (However, we are providing an estimate based on a one-time a survey data). The overall loss of in fish production (lethal take) would likely be greater if no reduction in habitat complexity at the site were implemented.

Fish-Weir and Migration Channel

This migration channel would consist of a series of adjacent weir panels composed of square wood frame with plastic or metal mesh stapled to the frame. These panels would then be affixed to T-bar fence posts pounded into the substrate to a sufficient depth to support the weight of the weir panels in combination with the force of river flows. These panels will be placed opposite to one another along the

river approximately 1 m (~ 3.1 ft) apart to create the fish migration corridor. The height of the panels will be sufficient to prevent both adult and juvenile salmonids from leaping into the main channel of the river. The minimum distance between the surface of the water and the top of the net should not be less than three feet in order to prevent adult salmonids from leaping over the net and entering the FEZ (the maximum 90 degree vertical leap of most adult salmonids does not exceed three feet under optimal leaping conditions).

The benefit of this method will be two-fold; 1) fish removal would be conducted over the entire exclusion zone only one time per construction season; and 2) steelhead adults and smolts would be allowed to migrate unimpeded through the exclusion zone during those periods (approximately 1-2 weeks) when there would be no pile driving. The contractor will notify the permit inspector at least 2-3 days prior to commencing pile driving in order to allow fisheries biologists to flush/remove fish out of the weir channel, as well as ensure its structural integrity.

The maximum feasible length of the fish-weir and migration channel is a total of length of 1,000 m (~3,100 ft). However, based on the anticipated hydroacoustic footprint the FEZ itself as well as the migration corridor within it would span an approximate 400 m of river length. This equates to approximately 400 m^2 of river channel that will comprise the migration corridor. The area of the river channel within the 400 m FEZ would be approximately 6,450 m^2, assuming an average wetted channel width of 16 m. Therefore; the migration corridor would occupy approximately 6 percent of the channel within a 400 m FEZ. However, the total length of the structure is, and will continue to be a function of the estimated acoustic footprint from pile driving.

If the integrity of the net-weirs located upstream or downstream should fail at any time all pile driving activities will cease and the permitting agencies will be notified. Pile driving will be allowed to start again once the fish-weir is back in place and efforts have been made to remove any fish that entered the FEZ. Any potential impacts from the failure of the FEZ will be included in the final project mitigation plan.

Fish weir and migration corridor structures will be removed after each pile driving season ends (approximately September 1). Impacts to fish habitat from the placement of these structures is anticipated to be minimal and temporary. The primary impacts would be disturbance of the substrate within the FEZ. Since, the placement of the structures is limited to approximately 3 months in pile driving construction years during low flow periods it is unlikely that channel features in the vicinity of the FEZ would be impacted by unnatural scour patterns produced by the structures.

Migration Corridor Management

The fish migration corridor will be operated based on an adaptive management strategy to facilitate the movement of fishes through the FEZ during pile driving construction years in which there would be a hiatus of at least four days in pile driving activities from July 1 through September 1. Under these conditions, the contractor would notify the permit inspector who would then direct the fisheries biologists retained for the project to open the migration corridor and then subsequently notify CDFG and NMFS. Fish and other aquatic organisms would then be allowed to freely move through the corridor while no pile driving is occurring.

The contractor will then notify the permit inspector of their intent to reinitiate pile-driving activities at least 2 days prior to pile driving. The permit inspector will then direct the fisheries biologist to begin to flush fish (and other organisms) out of the migration channel. The method used to flush fish out of the migration corridor would likely be seining. After each seining event the entire length of the migration corridor would be snorkeled to ensure that the maximum number of organisms are removed from the channel as feasibly possible. Given the narrow width and shallow depths along much of the river in this area, it is likely that all of the fish can be removed from the migration corridor efficiently within one day.

Fish Removal

Techniques for removal of fish from the potential bioacoustic area of disturbance (See attached map) will include a potential combination of (1) seining; (2) baited minnow traps; and (3) electro-fishing. The preferred method for fish removal would be seining, however given the complexity of substrates and the presence of aquatic vegetation and large woody material (LWM) within the exclusion area, it may be necessary to employ the use of more invasive fish removal techniques. For example, the area located approximately 45 meters downstream of the southbound Mad River Bridge on the right bank (north) channel has a substantial mass of LWM. These types of complex channel habitats generally have high densities of juvenile salmonids associated with them and are not conducive to seining. An alternative technique would be to isolate the area with block nets, and then utilize baited minnow traps (Figure 1) over a 24-hour period to capture and remove as many salmonids as possible. This technique is considered to be effective at capturing juvenile salmonids without harm.

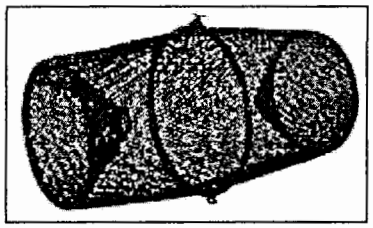


Figure 1. Minnow trap

A backpack electrofishing unit could then potentially be used to remove additional juvenile salmonids from the area. Ultimately, the exact fish removal method will need to be determined onsite (after results from a comprehensive habitat and fish snorkel survey) by professional fisheries biologists retained for the project with experience in the use, risk, and limitations of each technique in consultation with local NMFS and CDFG biologists.

It is unlikely that these efforts will result in the complete removal of fishes from the FEZ. Conservative estimates of fish removal efficiencies generally range from 20 to 60 percent depending on factors such as type of removal method used, fish size, fish species, habitat complexity, and the experience level of the biologists employed to operating the equipment used (Johnson et al., 2007, Peterson et al, 2004). In addition, a fish mortality rate of 10 percent potentially may occur among those fish captured during removal due to direct mortality (physical damage) and indirect factors from handling (stress).

It is assumed that other aquatic species such as amphibians would be exposed to the same potential handling mortalities as the target fish species. In most instances amphibians (e.g., salamanders) and frogs respond to seining and electrofishing in the same manner as fish. On July 6, 2007 western toad tadpoles were seen to be plentiful in warm shallow waters within the project area. On July 17, 2007 juvenile western toads were found to be plentiful upon the banks of the gravel bars within the project area. Additionally a single Northern red-legged frog, California species of special concern)was observed (Pers. Comm., Kelley Garrett). At this time it is not anticipated that biologists will encounter a large number special-status amphibians (red-legged frogs) during fish removal efforts. However, snorkel surveys conducted pre- and post-fish removal snorkel surveys will refine these estimates.

Fish and other organisms removed from the area of disturbance will be placed into suitable habitat areas upstream and/or downstream of the FEZ. If it is determined during initial fish and habitat surveys that the density of fish to be removed from the FEZ exceeds the capacity of available habitats outside the FEZ, temporary habitat augmentation structures will be placed downstream of the FEZ in order to decrease potential inter and/or intra- specific competition for stream microhabitats

among fishes, as well as provide additional cover to decrease any potential increases in predation due to temporary habitat losses from exclusion. These structures will likely be comprised of tree trunks and limbs bundled together from shrub and small tree removal within the Mad River Bridge replacement construction zone. The bundles will be anchored to the substrate during each pile driving construction year. The limbs will be un-bundled and distributed along the banks of the Mad River at the end of the project per an original term and condition in the original Biological Opinion issued by NMFS.

2.0 Potential Incidental Take Associated with Fish Exclusion

The total number of salmonids within the potential FEZ's was estimated based on observations made during the July 17, 2007 snorkel survey. During that survey it was determined that in some areas the density of juvenile salmonids was approximately one-to-two fishes per one square meters and in other areas one fish per nine square meters; fish counts within more discrete habitat areas were also developed during the survey. In the absence of a more comprehensive abundance survey, the most conservative approach is to assume that all potential stream habitats are fully occupied. Based on this, the number of salmonids estimated to be present in the proposed FEZ's of 180 m and 400 m is estimated at 429 salmonids and 2463 salmonids respectively.

In order for Caltrans and the resource agencies to determine the best fish exclusion scenario the following analysis is being provided to estimate the potential take associated with creating a FEZ of approximately 180 m and 400 m.. This analysis is meant to provide resource managers and interested parties with estimates on the number of salmonids that can potentially be removed from the anticipated area of bioacoustic disturbance. According to the most recent report entitled *Analysis of Pile Driving Noise Impacts to Listed Salmonids for the Mad River Bridge Replacement Project* (Caltrans, November 2007), the 187 dB $SEL_{accumulated}$ threshold would only extend approximately 90 m upstream and downstream (180 m total) from the impact zone if one pile section was driven per day; and be 170 m (340 m total) if up to three pile sections are driven per day. The impacts associated with these two pile driving scenarios both with and without fish exclusion are as follows:

Scenario 1 (one-pile-section-per-day); under this scenario the potential take of listed salmonids could be **up to 15,444 without fish exclusion**. Due to construction constraints this scenario would likely require three pile driving years thereby extending the project into a 5th year of construction. Fish exclusion alone over three construction years could result in a potential take of 1287 (429 x 3) listed salmonids. Therefore, the creation of a 180 m FEZ (i.e., 90 m upstream and

downstream) would reduce the overall take by potentially 92 % over the anticipated three years of pile driving.

Scenario 2 (multiple-pile-sections-per-day); under this scenario the potential take of listed salmonids could be **up to 39,764 without fish exclusion**. This scenario would require two years of pile driving over four construction years. Fish exclusion alone over two construction years could result in a potential take of 4926 (2463 x 2) listed salmonids. Therefore, the creation of a 400 m FEZ (i.e., 200 m upstream and downstream) would reduce the overall take by potentially 88 % over the anticipated three years of pile driving.

However, estimates of fish numbers as well as the acoustic footprint of pile driving will be further refined after the first year of pile driving by both fisheries and hydroacoustic monitoring efforts. For example, it may be that the hydroacoustic footprint of driving multiple pile sections per day may be less than 170 m upstream and downstream, or the estimated number of listed salmonids within each FEZ may be lower or higher. Both of these parameters will influence the estimated number of listed salmonids that could experience harm (i.e., take). In addition, the complexity of habitats from which fish will be removed will also affect the number the number of fish removed and the number of fish remaining within the FEZ that could be subjected to the 187 dB $SEL_{accumulated}$ threshold of harm.

Based on this analysis the potential take associated with fish exclusion could be up to 92 percent less with fish exclusion over pile driving Scenario 1. However, as previously stated the estimate of potential take numbers is largely based on a single, uncalibrated survey event. The number of fish potentially adversely affected during pile driving cannot be estimated with any statistical level of confidence at this time. However, these estimates can be used as a management tool to evaluate the efficacy of removing fish from the area of potential harm.

It must also be noted that there is a certain amount of danger associated with excluding fish from too large of an area if it is not warranted. For example, with drive scenario two (drive multiple pile sections/day) if the 187 dB $SEL_{accumulated}$ threshold is only predicted to extend 170 m both up and downstream, and an FEZ of 200 m up and downstream is implemented, fish remaining in the zone between 170 m and 200 m (after all feasible removal methods have been utilized), could potentially migrate into the area predicted to cause bioacoustic harm (i.e., Zone D, See attached map).

3.0 Discussion of Potential Impacts

For anadromous salmonids, the lower reaches of the Mad River in the vicinity of the proposed project serves primarily as corridors for juvenile rearing and migration and adult immigration. Any potential impacts to habitats within the FEZ would be temporary. While there could be potential impact to summer steelhead adults if any individuals attempt to migrate upstream while the migration channel is closed (i.e., during pile driving), the majority of adults generally immigrate from April through June and tapers off by July. Since, the majority of summer steelhead will have completed their upstream migration by June, and the migration corridor will allow any later individuals to migrate upstream during periods of pile driving hiatus it is unlikely that the fish exclusion project proposed here would substantially affect the Mad River summer steelhead population. All other adult salmonid populations begin their upstream migration after September 1. Pile driving activities at piers 3 and 4 will cease by September 1, and the migration corridor will again be reopened. The entire FEZ will be removed by September 15 therefore, it is not likely that the project will have an adverse impact to other anadromous adult salmonids.

Any potential impacts to juvenile salmonids could potentially reduce overall Mad River population production. Juvenile coho salmon generally spend one to two years in freshwater prior to emigration. The majority of juvenile coho salmon rearing in the Mad River watershed occurs within its tributaries. These small streams provide refuge from winter flows and microhabitats for both foraging and cover. The overall quality of habitats within the FEZ is considered to be high, but their precise quantities are not currently known. However, in general these lower river reaches are considered to be high in macroinvertebrate prey densities and also provide a substantial number of high quality foraging habitats. Any-potential impacts to these habitats from fish exclusion would be temporary and therefore are not likely to adversely impact the fish population.

Mad River coho salmon production has declined in the past ten years primarily due to reduced adult returns (CDFG 2002). Given that adult coho returns are considered low, any reduction in the overall number of outmigrants could impact the existing Mad River coho salmon population. Caltrans is currently conducting a coho salmon cohort analysis, which will be submitted to NMFS in order to estimate the potential impact on any potential juvenile losses on the coho salmon population. This analysis will be used to help establish a basis of reckoning for project mitigation.

In addition, the utilization of aquatic habitat by both adult and juvenile salmonids will be documented throughout the FEZ both prior to and after exclusion. This will ultimately provide Caltrans and the resources agencies with valuable data that

can also be used as a basis for establishing mitigation ratios once the project is completed. Data are currently not available or are insufficient at this time to establish a final reckoning for potential salmonid and habitat losses. However, data collected during the implementation of a *Mad River Bridge Replacement Project Fish Exclusion and Monitoring Plan* will be reconciled with available data compiled from the resource agencies to provide a final analysis of impacts associated with the project.

Overall, potential impacts to listed salmonids due to pile driving activities could occur with or without the implementation of a fish exclusion project. However, excluding fish from the area of potential harm would avoid and minimize these impacts to the greatest extent possible.

References

CDFG 2002. Coho Salmon Status Review. *California Fish and Game Commission.*

Johnson, D.H., et al. 2007. Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations. *American Fisheries Society.*

Peterson, J.T., et al. 2004. An Evaluation of Multipass Electrofishing for Estimating the Abundance of Stream-Dwelling Salmonids. *Transactions of the American Fisheries Society* 133: 462-475.

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November 7, 2007

Local Weirs--Background Information

All the major tributaries to the Klamath River, between the Pacific Ocean and Iron Gate Dam, have a current or had a historic weir program. This includes the Shasta River, Scott River, Salmon River, Trinity River, and New River.

Below is a link to the CA Fish & Game Klamath-Trinity Chinook Monitoring Project Powerpoint Presentation from April 2004. The pictures presented below are from this presentation.

http://www.calmonitor.org/resources/presentations/Tuesday_SCL_compressed/

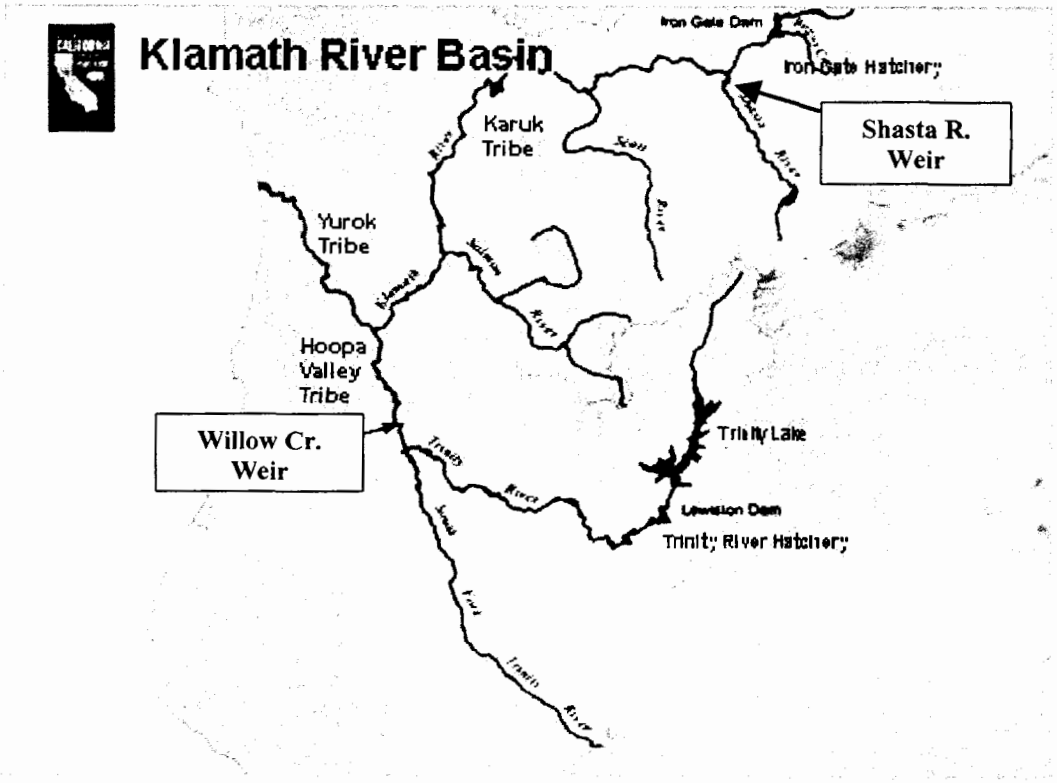
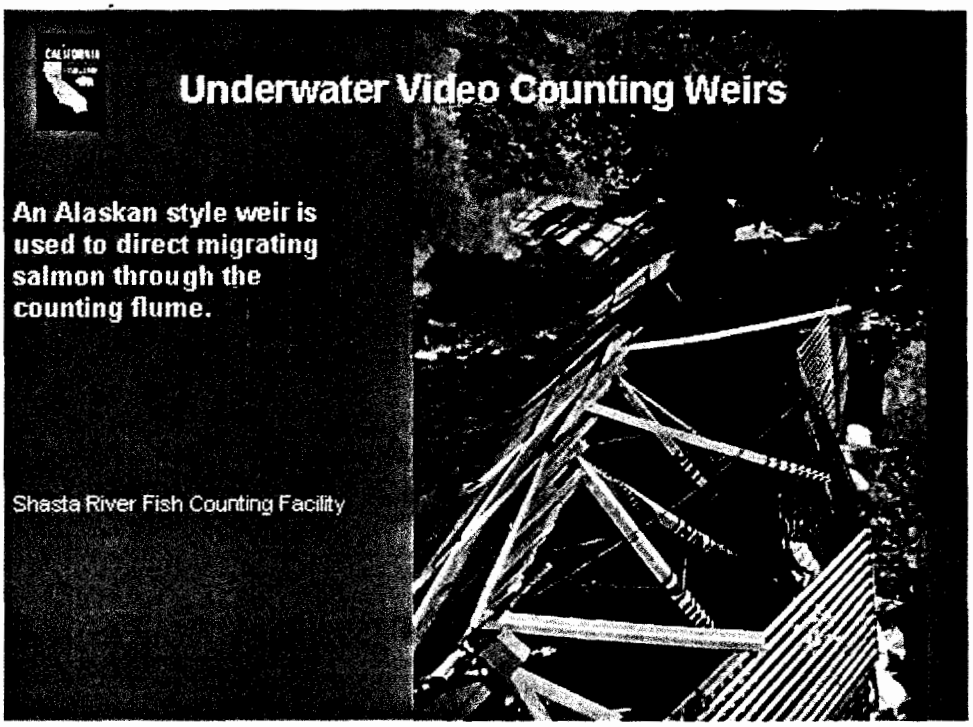
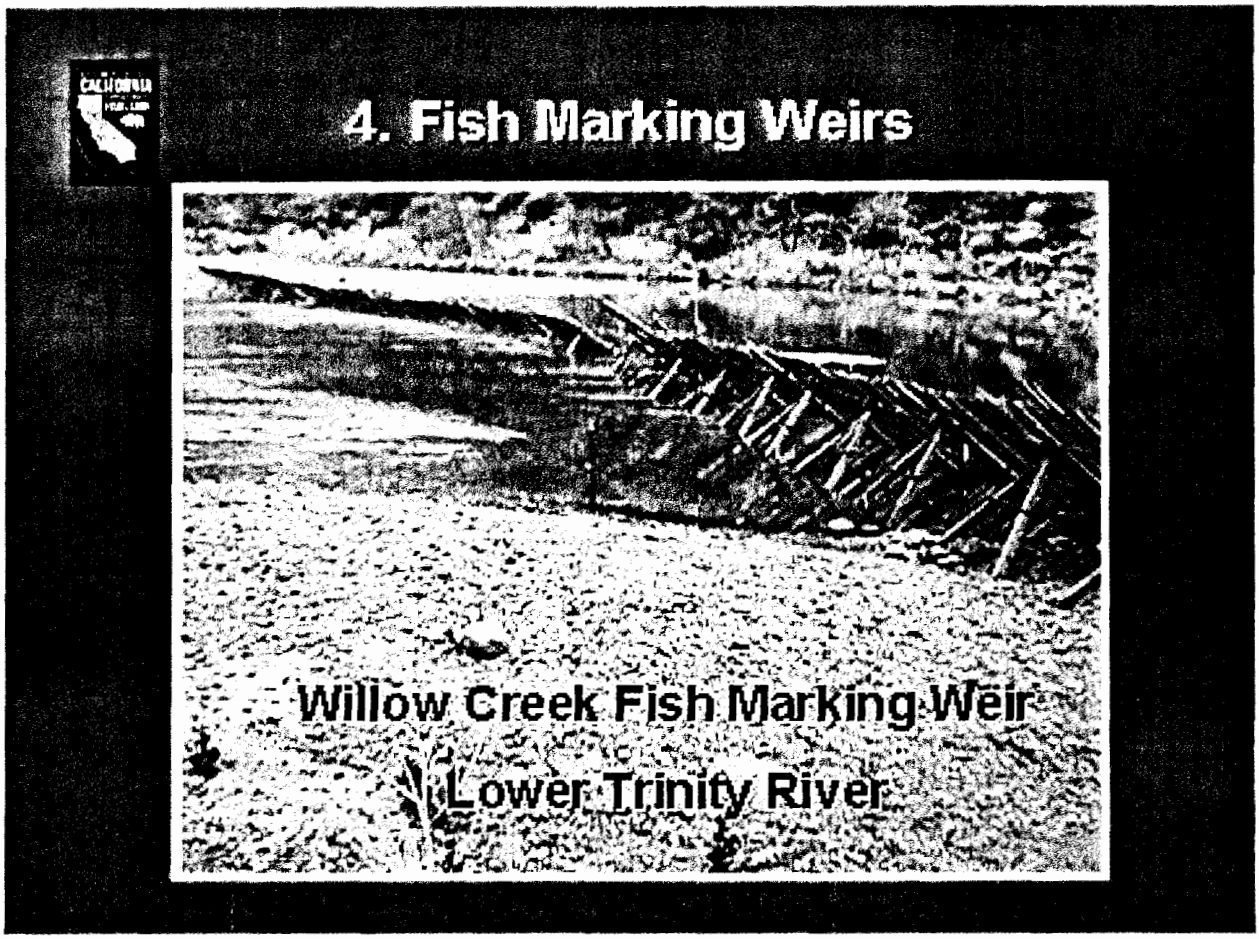


Exhibit J

Two currently utilized weirs in the Klamath River Basin are discussed here (locations indicated above). The weir on the Shasta River has been used as a video count weir, and the Willow Creek location has been used as a fish marking (tagged) weir.



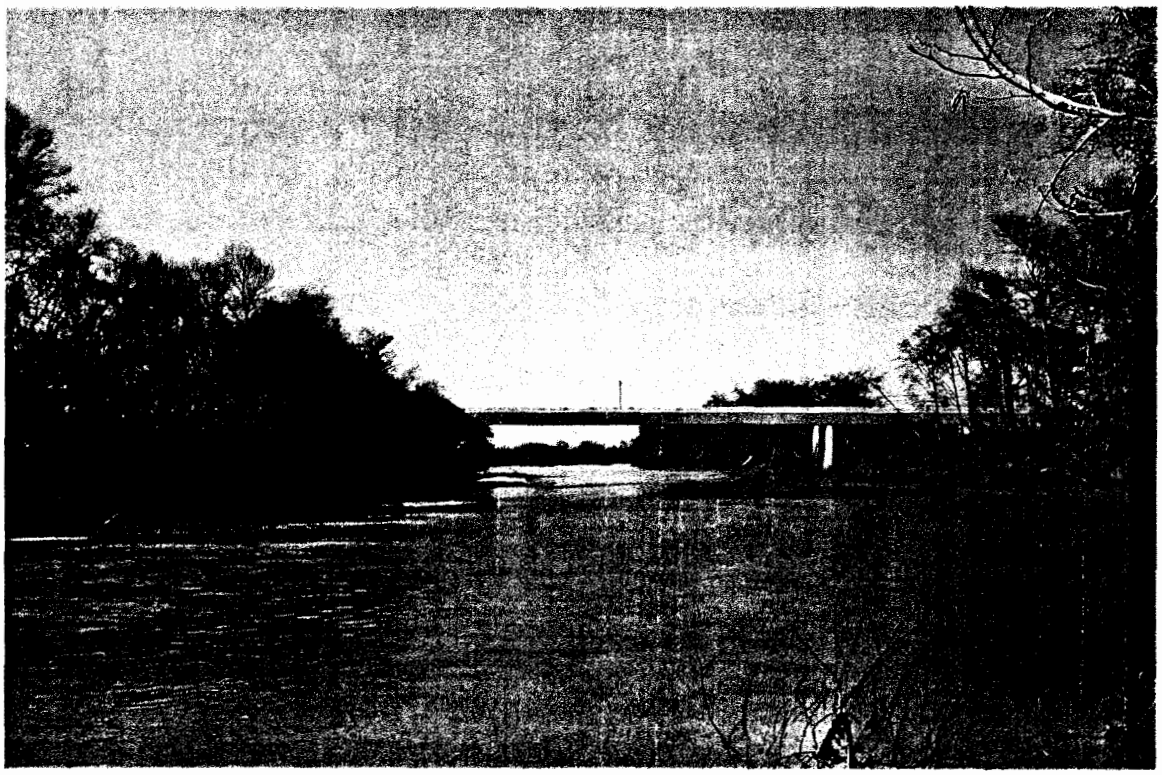


Mad River RSP

I consulted with two of our hydraulic engineers, Lucy Kostrzewa and Glenn Hurlburt, about the RSP at the current (Northbound) Mad River Bridge. The slope was engineered with soil, rock, and willows, in 2000, in order thwart on-going bank erosion that could eventually harm the structure (see photo). The slope has done well since its placement. It is covered by willows and other vegetation, and it is not contributing to damage elsewhere in the channel.

The proposed replacement bridges were modeled with the RSP in place. The design relies upon the premise that the channel is stable at that location. Removing the RSP will create an unstable slope that would threaten the integrity of the proposed bridges. Removing the RSP would also destroy establishing riparian habitat. Fish habitat (this was designed into the original project) would also be destroyed.

Marine Mammal Monitoring Plan for the Mad River Bridge Replacement Project



November 2007

Exhibit K

Project Description

Caltrans proposes to replace the existing bridges over the Mad River in Humboldt County. The bridges cross the river approximately four miles upstream of the river's mouth.

Although both species are infrequent visitors to the river, harbor seals (*Phoca vitulina*) and California sea lion (*Zalophus californianus*) are known to occur in the estuary. Because of potential noise-related dangers to marine mammals during construction, the following monitoring plan has been developed.

Potential Project Related Effects

Pacific harbor seals and California sea lions are protected under the Marine Mammal Protection Act, under which it is illegal to "take" a marine mammal without prior authorization from NOAA Fisheries. Take is defined as harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal. Harassment is defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal in the wild, or has the potential to disturb a marine mammal in the wild by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding, or sheltering.

Based on information from similar projects involving pile driving and on a review of published literature, NOAA Fisheries has determined that impulsive hammering sounds can have a detrimental effect on marine mammals by causing stress, interfering with communications and predator/prey detection, and changing behavior. Impulse sound pressure levels of 160 dB have been shown to cause behavioral changes. More significantly, acoustic overexposure to such loud sounds can lead to temporary or permanent loss of hearing. NOAA Fisheries is in the process of determining safety criteria for marine species exposed to underwater sound, including impulsive sound.

Pile Driving

As indicated in the Hydroacoustic Report, noise levels for the permanent piles driven inside cofferdams dewatered to the existing mudline could reach a peak level of 205 dB at 10 meters from the source with a range of 192 to 200 dB accumulated SEL.

Even though not commonly observed in the project area, pile driving activities have the potential to harass harbor seals and sea lions that may be swimming and/or foraging in the project vicinity. Any short term impacts, while fairly

negligible, may result in a temporary reduction in utilization of the estuary while work is in progress or until animals acclimate to the disturbance. However, it is presumed that individuals will likely avoid the project area once construction in the river begins, thus avoiding direct injury. Since the Mad River estuary is used only intermittently for foraging and does not provide haul-out areas, pile driving should not have any substantial effect on any individuals. The utilization of a monitor during pile driving further reduces the opportunities for any individual seal or sea lion to be anything other than annoyed during pile driving.

Other Potential Effects

Due to the low probability of marine mammals being present during construction and the fact that turbidity will be closely monitored, any increase in turbidity should have minimal effect, if any, on harbor seals or sea lions.

Removal of land based temporary piles used during the construction of the new bridge and the removal of the old bridge will be done using vibratory hammers. There may be some minor vibration directly adjacent to the piles and increased turbidity. Both are expected to be localized and short in duration.

Monitoring Plan

It is the intention of this monitoring plan to ensure the safety of marine mammals by not exposing them to dangerous levels of underwater noise; however, it is also in the best interest of these animals for the project to be completed as quickly as possible to avoid prolonging these dangers. A balance must be struck between protecting the animals and avoiding unnecessary construction delays. This plan assumes a provision of adaptive management that achieves the best balance possible between, on the one hand, allowing timely completion of construction so that the exposure to dangerous noise levels is not prolonged, and on the other hand, avoiding the exposure of animals in the Mad River estuary to dangerous noise levels. Adaptive alteration to this plan will be based on the expert assessment of the marine mammal monitor during initial observations of how pinnipeds react/respond to pile driving, and important alterations will be approved by NOAA Fisheries. All changes will be carefully documented.

In addition to protecting marine mammals from harassment, it is also the intention of this monitoring effort to collect data that will be useful in helping NOAA Fisheries to further understand the effects of certain types of construction noise and activity on marine mammals.

A biologist shall be present during pile driving to observe for marine mammals in the vicinity of the pile driving activity. To avoid harassment, as defined above, a

preliminary safety zone of 500 feet will be established around the pile-driving sites based on data that marine mammals have shown behavioral changes when exposed to impulse sound pressure levels as low as 160 dB.

Noise levels will be monitored during pile driving of permanent piles installed near the river. After each set of noise measurements is completed, the size of the safety zone will be increased or decreased and may change with the type of noise being generated.

Responsibilities of the monitor during construction are to ensure that marine mammals are not exposed to excessive noise levels from pile-driving activities. Pile driving will not be initiated if marine mammals are present within the safety zone. Either the monitor or Caltrans staff (on the days when the monitor is not present) will scan the safety zone upstream and downstream of the bridge for 5 to 10 minutes continuously at the beginning of each day just prior to pile driving to determine whether marine mammals are present.

Pile driving will not begin until the safety zone is clear. If a marine mammal later swims into the safety zone during pile driving, pile driving will continue. Prior to initiating driving of any pile with the full energy of the hammer, the contractor will conduct a "dry start" which consists of the pile being tapped with the hammer several times.

The monitor will then scan the area for the next 30 seconds to 1 minute to determine if an animal is still in the area or if one has moved closer to the work area. If pile driving stops for one minute or more, the monitor will conduct another scan of the area. The monitor will focus on the safety zone but include upstream and downstream areas in the sweep as well. The scan will involve two visual "sweeps" of the area using the naked eye and binoculars, if necessary. Typically, the sweep would be conducted slowly as follows: one sweep going from left to right and the other returning from right to left (or however the monitor wants to do it). The length of time it takes to do the sweep will depends on the amount of area that needs to be covered, weather conditions, other visual impairments (for example, glare on the water) and how long it takes the monitor to thoroughly survey the area.

The monitor will notify the Caltrans Resident Engineer of the results of each required scan and any observation of marine mammal entry into the safety zone. Caltrans staff will then notify the contractor whether and when to start or stop pile driving. A log of dates, times, and results of the 5-minute scans will be kept.

The monitor shall record the date, time, location, distance, direction of travel, species, abundance, approximate age class, and behavior of the marine mammal

sighted. All monitoring data collected during construction will be made available to NOAA Fisheries.

An attempt will be made to answer the following questions:

- How do marine mammals respond to the onset of pile driving?
- How far away from the noise do animals seem to be affected?
- Are certain behaviors associated with distance from the disturbance, i.e., are they more likely to exhibit one behavior when they are near the noise and another when they are farther away?
- If they leave the area during pile driving, how long does it take them to return after pile driving stops? Is it within 45 minutes?
- Are they ever observed swimming into or near the outer edges of the safety zone during pile driving?
- What is the distance at which retreat behavior is observed?
- Does there appear to be any habituation? Do animals seem to be less disturbed later in the season than initially?
- Do these animals appear to be reacting/responding more to pile driving than to other types of construction-related activities? Are they startled by any other particular noises? What types of noises?
- Do changes to the monitoring plan seem to be affecting what is observed in these animals?

Caltrans has incorporated all protective measures recommended and required by the permits and approvals by the U.S. Fish and Wildlife Service, NOAA National Marine Fisheries Service, the California Department of Fish and Game, the Regional Water Quality Control Board, and the Army Corps of Engineers.

Based on information provided by the designated Marine Mammal Monitor, the Construction Liaison will have the authority to require the Resident Engineer to immediately stop any activity that is not in compliance with any agency permit or approval, and to order any reasonable measure to avoid the take of an individual of the Covered Species.

Monthly summary reports will be submitted to NOAA Fisheries. A final report summarizing the construction monitoring and any general trends observed will be submitted within 30 days after monitoring has ended.

References

Caltrans. 2006. Marine Mammal Monitoring Plan for the Ten Mile River Bridge Replacement Project.

Caltrans. 2002. Application for an Incidental Harassment Authorization – Humboldt Bay Bridges Seismic Retrofit.

Caltrans. 1997. Richmond-San Rafael Bridge Seismic Retrofit Project - National Marine Fisheries Service Application for an Incidental Harassment Authorization.

North State Resources, Inc., in association with Ibis Environmental Services, Inc. December 2002. Noyo River Bridge Replacement Project Marine Mammal Monitoring Report. Prepared for California Department of Transportation-Region 3.