Final Report

Los Padres Dam and Reservoir Alternatives and Sediment Management Study

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List of Acronyms and Abbreviations

1D	one-dimensional
2D	two-dimensional
AF	acre-feet
AFY	acre-feet per year
ASR	aquifer storage and recovery
BESMo	University of British Columbia's one-dimensional morphodynamic sediment transport model
BGS	behavioral guidance system
°C	degrees Celsius
Cal-Am	California American Water
CAL FIRE	California Department of Forestry and Fire Protection
CD	product of concentration and duration
CDFG	California Department of Fish and Game (now California Department of Fish and Wildlife)
CDFW	California Department of Fish and Wildlife
CDMG	California Division of Mines and Geology (now California Geological Survey)
CDO	cease-and-desist order
cfs	cubic feet per second
CRBHM	Carmel River Basin Hydrologic Model
CSUMB	California State University, Monterey Bay
CY	cubic yards
DO	dissolved oxygen
DPS	Distinct Population Segment
DSOD	Division of Safety of Dams
ESA	Environmental Science Associates
ESA	Endangered Species Act
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FNU	formazin nephelometric unit
FR	Federal Register
FSC	floating surface collector
FWC	floating weir collector
HDR	HDR Engineering, Inc.
HEC-HMS	Hydraulic Engineering Center Hydrologic Modeling System
HMR	hydrometeorological report
IFIM	Instream Flow Incremental Methodology
LiDAR	Light Detection and Ranging
LP Alternatives Study	Los Padres Dam and Reservoir Alternatives and Sediment Management Study
LPD	Los Padres Dam
LPR	Los Padres Reservoir
mg-hr/L	milligrams per hour per liter
mg/L	milligrams per liter

mm	millimeters
MOA	memorandum of agreement
MPWMD	Monterey Peninsula Water Management District
NAVD88	North American Vertical Datum of 1988
NDEP	Nevada Division of Environmental Protection
NGVD29	National Geodetic Vertical Datum of 1929
NMFS	National Marine Fisheries Service
NMWS	normal maximum water surface
NOAA	National Oceanic and Atmospheric Administration
NSE	Nash-Sutcliffe Efficiency
O&M	operations and maintenance
OPCC	Opinion of Probable Construction Costs
PIT	passive integrated transponder
PMF	probable maximum flood
PMP	probable maximum precipitation
rkm/hr	river kilometer per hour
RM	river mile
S-CCC	South-Central California Coast (steelhead population)
SEV	severity of ill effect
SWRCB	State Water Resources Control Board
TM	technical memorandum
TRC	Technical Review Committee
UAS	unmanned aerial system
UBC	University of British Columbia
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Executive Summary

This report presents the results of the Los Padres Dam and Reservoir Alternatives and Sediment Management Study (LP Alternatives Study). The study, managed by the Monterey Peninsula Water Management District (MPWMD), was initiated to investigate the technical, biological, and economic feasibility of a broad suite of alternatives for Los Padres Dam (LPD) and Los Padres Reservoir (LPR). The alternatives were developed to address a reservoir gradually filling with sediment and the dam and reservoir's effects on an important population of threatened steelhead. The study was carried out by a team of engineering and science consultants led by AECOM, with support from Balance Hydrologics, Stillwater Sciences, and HDR Engineering. The alternatives evaluated in the study included dam removal, improvements to fish passage facilities, the addition of sediment management facilities, and reservoir expansion. The study was partially funded by California American Water (Cal-Am) and was conducted in close coordination with a Technical Review Committee (TRC) that includes technical experts and representatives from the MPWMD, Cal-Am, the National Marine Fisheries Service (NMFS), the California Department of Fish and Wildlife (CDFW), and the United States Fish and Wildlife Service. The LP Alternatives Study incorporates the results of related studies, including analysis of water availability (led by MPWMD), analysis of steelhead habitat availability in relation to instream flow (led by MPWMD's consultant, Normandeau), alternatives analysis of fish passage improvements at LPD (conducted by a consultant team led by HDR Engineering), and studies of Carmel River steelhead at Los Padres Dam and in relation to streamflow (led by NMFS' Southwest Fisheries Science Center).

The LP Alternatives Study was developed using an iterative process during which the TRC and stakeholders were engaged through a series of document review and workshop-style meetings, with input incorporated at multiple points as the work progressed. Prior to developing detailed analysis, the AECOM Team compiled background information on existing conditions and identified preliminary alternatives for TRC and stakeholder review. AECOM and study participants then documented the character of sediment accumulated in LPR, updated and further developed the alternative descriptions, and evaluated how changes in sediment transport or management could affect the Carmel River. Once the alternatives and sediment effects were described, the effects of the alternatives on steelhead were evaluated. Through review of technical memoranda and discussion at meetings, the TRC, stakeholders, and the AECOM Team evaluated, reconfigured, and refined the alternatives to further define five dam, reservoir, and sediment management alternatives for further study. One of the five alternatives, Alternative 4, Recover Storage Capacity with Excavation, was eliminated because it had limited advantages and the highest cost relative to other alternatives.

At completion of the study, two alternatives (Alternative 2 – Dam and Sediment Removal; and Alternative 3 – Storage Expansion and Dredging) are proposed for further consideration for the long-term future of LPD and LPR. CDFW was unique among stakeholders in suggesting that Alternative 2 would have greater benefits for steelhead and other native aquatic species, in part due to a conviction that warming due to climate change will reduce the value of warmer, downstream habitats relative to the cooler stream habitats upstream of LPR. Of the four alternatives carried into the LP Alternatives Study Draft Final Report, two (Alternative 1 – Fish Passage, No Sediment Action; and Alternative 5 – Recover Storage Capacity with Sluice Tunnel) were eliminated from further consideration before publication of this final report, based on evaluations provided in earlier drafts, feedback from the TRC, and decisions formalized at TRC Meeting No. 4. Alternatives 1, 2, 3, and 5, including reasons why Alternatives 1 and 5 were eliminated, are summarized below.

Alternative 1 – Fish Passage, No Sediment Action (Eliminated): This alternative retains LPD in place; includes no action to manage the existing sediment accumulation in the reservoir or future sediment inputs; includes improved or replaced fish passage facilities; and modifies the dam and spillway to accommodate the updated probable maximum flood (PMF). Two upstream and two downstream fish passage options were identified in the Los Padres Fish Passage Study as warranting additional consideration. Upstream fish passage improvements would include either a new fish ladder or replacement of the existing trap-and-transport facility with an upgraded facility designed to current standards. Downstream fish passage would include a new, full-scale floating surface collector with pumped attraction flow or a combination of improved passage through the spillway and modification of the existing floating weir collector to improve attraction to its entrance. The LP Alternatives Study assumes that one of these upstream and downstream fish passage options would be adapted to any alternative that retains LPD.

The current concrete spillway at LPD does not accommodate the PMF, based on current standards. Improvements to the spillway and possibly the dam embankment would be necessary to convey the updated PMF. The current concept, applied to all dam-in alternatives, includes an increase in the dam embankment height to create the head necessary to convey the updated PMF through the existing spillway cross section. The existing spillway walls would also be raised to accommodate the increased flow. The fish passage improvements summarized above may need to be refined to accommodate the embankment raise.

Alternative 1 would result in the continuation of dynamics similar to those now existing for roughly 100 years, until the reservoir is filled with sediment. Although sediment deposition is expected to increase the bed elevation of the lower 35,000 feet of the Carmel River over the next 60 years regardless of any action taken at LPD, Alternative 1 would continue to block coarse sediment transport, resulting in incrementally less deposition in the lower river than other alternatives. This would cause further channel bed degradation downstream of LPD to roughly the old San Clemente Dam location, which would decrease habitat suitability for steelhead, especially between the former San Clemente Dam and LPD, and would have diminishing effects on habitat quality downstream to the ocean. Along with other alternatives that keep the dam in place, Alternative 1 would allow for flow augmentation during the dry season to support rearing habitat for steelhead downstream of LPD. Alternative 1 would continue to block upstream movement of juveniles, thus continuing to prevent access to perennial flow and thermal refugia upstream of LPR. Managed fish passage would continue to cause stress and migration delay for migrating adult steelhead and would force downstream-migrating juveniles to transit through LPR, where a substantial portion are lost to predation or assume a resident or adfluvial life history. A significant uncertainty associated with Alternative 1 is how quickly the remaining reservoir will fill with sediment, thereby impacting existing infrastructure, fish passage, storage capacity, and potential summer releases. A substantial geotechnical investigation and coordination with the California Division of Safety of Dams would be needed to confirm the extent of dam improvements included with this alternative.

Alternative 1 was intended to serve as a no-action alternative for use in relative comparison with other action alternatives; however, no stakeholder wanted to see this alternative considered for implementation due to its high cost and lack of benefits compared to other alternatives. Both NMFS and CDFW explicitly stated in written comment that they do not consider it a feasible alternative. Alternative 1 is presented in this final report at the full level of detail to which it was developed during the study, so that the information is available should it be needed as the basis of comparison in a future environmental document; however, Alternative 1 was eliminated from further consideration for the long-term future of LPD.

Alternative 2 – Dam and Sediment Removal: Under this alternative, most accumulated reservoir sediment would be removed from LPR prior to dam removal using dry excavation techniques. An upstream diversion structure and pipeline would be installed to allow for dewatering of the reservoir during the permitted in-water work window. Approximately 1,680,000 cubic yards (CY) of sediment would be excavated and placed permanently in onsite disposal sites. Approximately 350,000 CY of coarser sediment in the upper reservoir would be left in place for future natural transport downstream. After sediment removal, the full dam would be removed and the associated dam debris would be placed in the permanent disposal sites.

Alternative 2 would significantly increase bedload sediment supply to downstream reaches. It is predicted to cause roughly 20 feet of aggradation just downstream of LPD. Relative to alternatives that do not increase bedload transport, incrementally more aggradation is predicted in the lowest 35,000 feet of the Carmel River, which could result in a similar, incremental, increase in flood risk. Deposition would increase steelhead spawning gravel availability downstream of LPD. Although flood modeling was not conducted as part of the LP Alternatives Study, substantial channel aggradation near the confluence with Cachagua Creek, relative to other alternatives, could also increase flood risk in the community of

Cachagua if not evaluated further and addressed prior to dam removal. Instream habitat complexity would increase, but the loss of summer flow releases from LPR is predicted to result in a substantial decrease in dry season flows, which currently provide rearing habitat for steelhead downstream of LPD. Benefits of dam removal would be maximized with reduced groundwater extraction along the Carmel River during the dry season, in which case flow-dependent steelhead production was predicted to surpass existing. Alternative 2 provides the safest and most efficient steelhead passage, providing fully volitional upstream and downstream passage for all life stages. Downstream migrants would not have to transit LPR, likely increasing smolt production and anadromous life history expression. *O. mykiss* would be provided year-round access to roughly 10,000 feet of restored habitat through the dam and reservoir footprint and to the upper watershed, which currently provides suitable habitat and optimal temperatures for rearing steelhead throughout the year. Dam removal would likely require a change in the legal method and location of diversion to protect the existing water right associated with LPD, but this would require future negotiations with the State Water Resources Control Board. Additional evaluation of flood risk downstream of LPD would also be needed. Alternative 2 is one of two alternatives retained for further consideration at the end of the LP Alternatives Study, along with Alternative 3.

Alternative 3 – Storage Expansion and Dredging: This alternative includes both dredging accumulated sediments to recover lost reservoir storage and increasing the maximum storage at LPR by installing operable gates in the existing spillway. An associated embankment dam raise would be needed to accommodate the updated probable maximum flood. Installing pneumatically actuated gates on the existing spillway crest would add approximately 625 acre-feet (AF) in reservoir storage. Spillway gates could be raised toward the end of the precipitation season, when the risk of large storms has passed but there is sufficient flow to capture water for release later in the year. Wet dredging with barge-mounted equipment would remove accumulated fine sediment for permanent, onsite disposal. A portion of coarse sediment would also be dredged, some of which could be reintroduced to the river via floodplain disposal sites directly downstream of LPD. Dredging would add approximately 1,113 AF in reservoir storage. With new gates in the spillway and reservoir dredging, Alternative 3 could increase storage at LPR by about 1,793 AF. Although MPWMD and NMFS prefer that any alternative that retains LPD maximize the benefits associated with storage and release, Cal-Am may prefer not to include the spillway gates due to structural and operational issues their inclusion could cause. Fish passage improvements described above for Alternative 1 would be adapted to Alternative 3.

Because of the increased reservoir storage, Alternative 3 could potentially provide the highest dry season flows for maintaining steelhead rearing habitat downstream of LPD. Less frequent dry back in the lower 9 miles of the Carmel River is predicted under Alternative 3; especially in normal water years. This is expected to increase flow-dependent steelhead production, relative to existing, although the value of this habitat over time in the face of climate change has been questioned by CDFW. Up to 3,600 feet of stream channel upstream of the reservoir (including 100 feet of Danish Creek) could be affected by dredging or inundation during gate operation. One-time introduction of coarse sediment to floodplain disposal sites downstream of LPD would partially mitigate the disruption in sediment supply caused by LPD; however, over the long term, sediment effects for Alternative 3 are likely to be similar to those described for Alternative 1, with continued incision of the channel downstream of LPD, and corresponding effects on flood risk and steelhead habitat. Fish passage under Alternative 3 would be similar to Alternative 1, with potential to increase stress and migration delay; block access to perennial, cold water refugia; and subject downstream migrants to transit through LPR, likely favoring resident and adfluvial over anadromous life histories. Additional design coordination would be needed between passage improvement designs and the spillway gates and embankment raise. A substantial geotechnical investigation and coordination with the California Division of Safety of Dams would be needed to confirm the extent of dam improvements included with this alternative. Alternative 3 is the second alternative, and only dam-in alternative, retained for further consideration at the end of the LP Alternatives Study.

Alternative 5 – Recover Storage Capacity with Sluice Tunnel (Eliminated): This alternative aimed to restore sediment continuity and recover reservoir storage, while retaining LPD. Because the dam would remain in place, Alternative 5 would include fish passage improvements and dam and spillway improvements to accommodate the updated PMF, as described for Alternative 1. An approximately 14-foot-wide by 900-foot-long sluice tunnel would be installed through the eastern abutment, most likely using drill-and-blast excavation methods. In operation, the tunnel would be used to sluice sediment from the reservoir during wet water years. Limited sediment would be excavated to construct the upstream end of the tunnel in the reservoir. The tunnel excavation spoils would be placed in an onsite disposal site. Sluicing would involve opening a large gate within the sluice tunnel, lowering the reservoir, and allowing storm flows to pass through the reservoir area as run-of-the-river flows that would erode and flush a significant amount of the accumulated sediment downstream. The sluice tunnel could be used as long as LPD is in place to maintain sediment transport and reservoir storage capacity.

Depending on how the sluicing operation is managed, the amount of coarse sediment moving downstream would vary. For the purposes of this report, the sluice tunnel is assumed to transport fine and coarse accumulated sediment as well as annual sediment loads. Fine sediment is expected to have significant short-term effects on aquatic organisms, including steelhead. Although further analysis is needed, initial estimates indicate that peak suspended sediment concentrations of 5,800 mg/L to greater than 49,000 mg/L could occur during initial use of the sluice tunnel. Depending on duration, all life stages of steelhead could experience paralethal and lethal effects at these sediment concentrations. If the sluice tunnel is used aggressively to transport coarse accumulated sediment and annual bedload, Alternative 5 could result in geomorphic changes that would benefit steelhead, over the long term, like the benefits described for dam removal under Alternative 2. The timing and duration of sluicing would be controlled by operation of the sluice gate and could be managed to minimize short-term adverse effects of fine and coarse sediment transport (such as paralethal and lethal effects, and deposition in rearing habitat areas, respectively). Like Alternative 2, the downstream flood risk may also increase at some locations relative to Alternatives 1 and 3.

Water availability under Alternative 5 for dry season flow augmentation would be intermediate to Alternative 1 and Alternative 3, assuming that recovery of a substantial portion of former reservoir storage would be achieved. The suboptimal water temperature regime that occurs seasonally when the reservoir water surface is at or below the spillway associated with other alternatives that retain LPD would persist, as would managed fish passage and effects on migration, effects due to reservoir transit, and lack of access to upstream refugia habitat. Sluicing could result in reversion of a portion of the former reservoir pool that has been filled with sediment and is developing as stream habitat back to reservoir pool. Sluicing would not likely be required every year. When the sluice tunnel is operated, though, it would interfere with fish passage and would entrain fish in LPR, transporting them abruptly to downstream of LPD in turbid storm flow. Substantial uncertainty exists regarding the effectiveness of the sluice tunnel and the resulting effects on geomorphology, steelhead, flood risk, and reservoir storage capacity. Therefore, the outcomes with Alternative 5 are less certain than other alternatives. Design coordination with fish passage options, as described for Alternative 3, would be needed for Alternative 5. In addition, a substantial geotechnical investigation and coordination with the California Division of Safety of Dams would be needed to confirm the extent of dam improvements included with this alternative.

Alternative 5 was eliminated from further consideration for the long-term future of LPD. Due to uncertainty regarding its effectiveness in managing sediment and the frequency and severity of its potential effects on steelhead, it was initially considered lower priority than other alternatives. However, after review of the draft final report, NMFS commented that it would be difficult to mitigate the adverse effects to steelhead anticipated due to sluicing. By the conclusion of the LP Alternatives Study, both NMFS and CDFW clearly stated in their written comments that they do not consider Alternative 5 to be feasible; and all stakeholders agreed that it is not favored and does not warrant the additional analysis that would be required to resolve outstanding uncertainty.

Cost Estimates: Preliminary estimates (including an Opinion of Probable Construction Cost [OPCC] and future operations and maintenance [O&M] costs) were prepared for each alternative included in the draft final report, including Alternatives 1 and 5, which have been eliminated from further consideration for the long-term future of LPD. For all alternatives that retain the dam, including Alternative 1, the LP Alternatives Study used an OPCC for fish passage improvements of $82.1 million. OPCCs for the alternatives are $104.0 million for Alternative 1, $94.7 million for Alternative 2, $183.4 million for Alternative 3, and $163.7 million for Alternative 5. Future annual O&M costs do not differentiate among the dam-in alternatives, with all estimates ranging between $1.1 million and $1.2 million annually. Alternative 2 stands out from all other alternatives as having no O&M costs, because once the dam has been removed and regulatory monitoring requirements met, the site would not require operations or maintenance.

Alternatives Comparison: Key attributes of the two alternatives retained for further consideration (Alternatives 2 and 3) are compared. Alternative 2 was judged to be the most sustainable. It has the lowest construction cost, lowest sediment management cost, and no O&M cost; and its benefits would be maintained by natural processes in perpetuity without the need for ongoing political will, capital, or labor. Alternative 3 is fossil-fuel-intensive and would eventually require another major sediment management action. Geomorphic benefits and increased flood risk are correlated; Alternative 2 would increase bedload transport and would benefit steelhead spawning habitat over the long term but would also have localized increases in flood risk, relative to Alternative 3. Alternative 3 stands out as offering the largest increase in reservoir storage capacity and greatest potential for dry-season releases at LPR, thereby maintaining the greatest amount of dry season rearing habitat downstream of LPD (assuming that climate change does not result in temperatures too warm for steelhead) and providing an opportunity to increase water rights. Conversely, Alternative 2 would eliminate dry season flow augmentation downstream of LPD and would potentially lead to renegotiation of the existing water right associated with LPR.

Benefits for Steelhead: Although Alternative 2 would have multiple benefits for steelhead, the benefits come with the predicted loss of substantial dry season rearing habitat downstream of LPD. It is difficult to predict how the steelhead population would respond to a loss of wetted channel in the lower river, where production is currently highest, combined with the ecosystem restoration that comes with dam removal. Such restoration would include improved spawning habitat downstream of LPD; volitional passage for all life stages without the temperature, predation, and residualization effects of LPR; restoration of roughly 10,000 feet of stream channel through the footprint of LPD, LPR, and accumulated sediment; and access for juveniles to perennial, cold-water refugia in the upper watershed. Alternative 3, by increasing storage and dry-season release, also has strong benefit for steelhead but maintains many of the habitat and passage impacts associated with the existing LPD and LPR. Both Alternative 2, if dry-season infiltration in the lower river is low, and Alternative 3, regardless of the dry-season infiltration rate in the lower river, are predicted to increase steelhead production relative to existing conditions when streamflow is considered as the primary variable representing steelhead habitat. Climate change could affect the quality of summer rearing habitat over time, potentially shifting productivity in response to changing stream temperatures, which could affect the modeled gains in production for Alternatives 2 and 3. Additional study would be needed to quantify the tradeoffs among non-flow habitat parameters that also would be affected by Alternatives 2 and 3.

Uncertainties: Conceptual or planning-level alternatives are uncertain by nature. As LPR continues to fill with sediment, its benefits are diminished but its impacts on the ecosystem and fish passage remain. This report identifies uncertainties that could be resolved through further investigation or analysis with focus on uncertainties considered more likely to influence the selection of a preferred alternative.

Conclusion: Looking toward next steps, if dam removal (Alternative 2) is preferred, the following additional studies and actions are recommended to focus on specific design and permitting questions and to help address areas of uncertainty:

- Engage the State Water Resources Control Board and initiate water rights negotiations
- Investigate geotechnical conditions and cultural resources around sediment disposal sites
- Proceed with flood modeling

If a solution that retains the dam is preferred (Alternative 3), or if stakeholders continue considering both Alternatives 2 and 3, the following investigations should be considered high priority:

- Investigate geotechnical conditions and cultural resources around sediment disposal sites
- Conduct additional design coordination with fish passage improvements
- Confirm dam safety analysis and design requirements with the Division of Safety of Dams
- Further evaluate stream temperatures, considering climate change and effects of the alternatives

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1. Introduction

A team of engineering and science consultants led by AECOM, and including Balance Hydrologics, Stillwater Sciences, and HDR Engineering Inc. (HDR), was retained by the Monterey Peninsula Water Management District (MPWMD) to prepare a study that investigates the technical, biological, and economic feasibility of a broad suite of alternatives for Los Padres Dam (LPD) and Reservoir that include dam removal, retention of the existing reservoir with the addition of fish passage and sediment management, and reservoir expansion. The study is partially funded by California American Water (Cal-Am), and was conducted in close coordination with the Technical Review Committee (TRC), which consists of technical experts and representatives from the MPWMD, Cal-Am, the National Marine Fisheries Service (NMFS), the California Department of Fish and Wildlife (CDFW), and the United States Fish and Wildlife Service (USFWS). An important part of the study was documenting the character of sediment accumulated in Los Padres Reservoir (LPR) and evaluating how changes in sediment transport or management could affect the Carmel River. Potential dam and reservoir alternatives identified in the process were considered in the context of guiding considerations, initially proposed as evaluation criteria, and all work is summarized in this final report. Specific task information and focused study elements were described in technical memoranda produced at various points in the study. This section describes the purpose of this report, the process by which the study was conducted, general background information (e.g., the regulatory setting, Carmel River water rights, and previous and related studies), and the organization and limitations of this report.

1.1 Purpose and Scope

This final report is the primary deliverable for the *Los Padres Dam and Reservoir Alternatives and Sediment Management Study* (LP Alternatives Study). It has been developed following the fifth TRC meeting (TRC Meeting No. 4), at which study participants reviewed the alternatives with updates to address dam safety input received after TRC review of the draft final report, and facilitated input from stakeholders regarding alternatives to eliminate or retain. As presented in this report, the alternatives descriptions and their evaluation have been revised to address TRC and stakeholder comments on all previous works, including the draft final report.

This final report is provided in draft form for TRC review and will be revised following receipt of TRC and stakeholder comments. The purpose of this report is to summarize the LP Alternatives Study including the key background information relied upon, the technical information developed as part of the study, the process by which alternatives were developed and evaluated, the design intent of the alternatives developed, the advantages and disadvantages of the alternatives developed, the recommendations of the TRC, and outstanding uncertainties or additional information that would facilitate a decision regarding the long-term future of LPD and LPR.

1.2 Alternatives Study Process

The LP Alternatives Study was an iterative process throughout which concepts were presented, refined, and reformulated based on TRC and stakeholder review and discussion, and then presented again for further review. The TRC (including the California State Coastal Conservancy) was given the opportunity to review the initial scope of work for the LP Alternatives Study and the final scope of work included in the Request for Proposals was prepared by the MPWMD, Cal-Am, NMFS, and CDFW. This section lists tasks, deliverables, meetings, and reviews completed as part of the LP Alternatives Study. The final LP Alternatives Study schedule is provided in Attachment A. The schedule shows a gap in activity between 2019 and 2020 during which time MPWMD led the TRC and other collaborators through development, calibration, and review of the Carmel River Basin Hydrologic Model (CRBHM) (Section 1.3.4).

1.2.1 Tasks and Deliverables

This section lists the tasks and associated deliverables completed as part of the LP Alternatives Study.

Task 1: Feasibility Study Preparation

Task 1 was focused on the technical analyses and engineering required for concept development. The AECOM Team compiled and reviewed available background information to prepare for a concept development workshop with the TRC, and prepared workshop materials, including preliminary thoughts on alternative concepts based on experience with similar projects, evaluation criteria, and an evaluation process. Background review and opportunities and constraints associated with the dam, site topography, and sediment were identified. The information was compiled into a technical memorandum (TM); provided to the TRC for review prior to a workshop; presented and discussed at the workshop; and revised based on TRC comments. The review allowed TRC members to become familiar with the operational, physical, hydrologic, and biological setting of the LPD and potential effects of concept implementation to the Carmel River; the range of options that could be considered; and draft criteria to evaluate concepts. This information was important for identifying concepts and alternatives that are compatible with project constraints and that meet study objectives. This background information was used and updated, as appropriate, throughout the Study.

Deliverables

- Draft and Final Study Preparation TM (Appendix A)
- TRC Meeting No. 1 report, including draft and final meeting notes and meeting presentation

Task 2: Sediment Management Options

This task involved obtaining and analyzing sediment data in the reservoir, developing initial alternative descriptions, and evaluating the geomorphic effects of future changes in sediment load. This task included development of a field investigation work plan, a field investigation, laboratory analysis, and preparation of a TM.

The first subtask was the field investigation. The purpose of the investigation was to obtain, analyze, and characterize sediment accumulated in LPR. The sediment characterization evaluated the stratigraphy, sedimentology, and volume of alluvial sediment deposited behind LPD and farther upstream. A draft TM was provided for TRC review, revised based on TRC comments, and revised again in 2018 based on new information. This informed the development of alternatives for LPD and LPR, and more specifically informed sediment transport analyses and sediment management approaches.

The scope of the second subtask was to provide conceptual descriptions of alternatives to remove LPD and LPR, recover or increase storage at LPR, and manage accumulated sediment and future sediment inflow to the reservoir. The information was presented in the Alternatives Descriptions TM, which also identified potential effects, both positive and negative, associated with each alternative. The Alternatives Descriptions TM was provided for TRC review prior to TRC Meeting No. 2a. It was discussed at the meeting and comments were addressed in the subsequent Alternatives Development TM.

To understand changes in sediment load, the third subtask involved estimating the natural range of sediment transport in the Carmel River and simulating the geomorphic response to changes in sediment supply using a one-dimensional (1D) morphodynamic model. Sediment transport modeling produces a statistical range of channel responses for evaluation of alternatives, with focus on the trajectory of potential effects for various alternatives. The plan for sediment analysis was presented at TRC Meeting No. 2a. During development of the sediment transport model a series of short memoranda were prepared before and after each model run describing the methods and results of the run, which was reviewed by and discussed with the TRC. Then a comprehensive draft report was prepared and review by the TRC with comments addressed in the final.

Deliverables

- Field Work Plan
- Alternatives Descriptions TM (Appendix B)
- Draft, Final, and Revised Sediment Characterization TM (Appendix C)
- Nine Interim Sediment Effects (or sediment transport modeling) TM
- Draft and Final Sediment Effects TM (Appendix D)

Task 3: Evaluate Effects on Steelhead

This task involved evaluating and summarizing potential effects to steelhead and their habitats, in the context of the South-Central California Coast (S-CCC) steelhead population, associated with implementation of each alternative The analysis was to be used to inform further development of alternatives and then later to evaluate the refined alternatives. Potential effects to steelhead and their habitats resulting from the alternatives were evaluated and summarized. The analysis focused on habitat extent, passage through the reservoir area, passage over the dam, and water quality in the reservoir and downstream; and summarized effects to steelhead of varying levels of water supply and sediment transport in the river, and potential changes to steelhead habitats. A draft TM was provided prior to TRC Meeting No. 2b and was discussed at the meeting. The TM was revised based on written comments received from the TRC after the meeting.

Deliverables

- Draft and Final Effects to Steelhead TM (Appendix E)

Task 4: Identify Feasible Alternatives

This task included presenting the results of Task 2 and the initial results from Task 3 to the TRC, obtaining the TRC's input, and then developing a set of feasible alternatives, evaluating their benefits and impacts, and presenting the alternatives and evaluation to the TRC. One subtask was TRC Meeting No. 2, which ultimately was split into two TRC meetings, No. 2a and No. 2b (see Section 1.2.2), and another subtask was the fourth TRC meeting, TRC Meeting No. 3. One key subtask was to further develop the alternatives selected during TRC Meeting No. 2 (a and b), and focus on uncertainties concerning impacts, benefits, costs, environmental compliance, and permitting of alternatives. Unfavorable alternatives were dropped from consideration, reasons for them being dropped were described, and uncertainties associated with the remaining alternatives were identified. A TM was prepared for TRC review prior to TRC Meeting No. 3, its content was discussed at the meeting, and comments on the TM were addressed in the draft final report.

Deliverables

- Reports for TRC Meeting Nos. 2a, 2b, and 3, including draft and final meeting notes and meeting presentations
- Alternatives Development TM (Appendix F)

Task 5: Final Report

Task 5 involved documenting the LP Alternatives Study in this final report and presenting the final alternatives and their benefits and impacts. This included updating the alternatives to address comments received on the Alternatives Development TM, preparing a draft final report, TRC review of the draft, and revising the draft in consideration of TRC and stakeholder comments to produce the final report. Because new information with direct bearing on the alternatives described in the draft final report came to be known to the LP Alternatives Study participants after TRC review, a supplemental task order was provided by Cal-Am to add a fifth TRC meeting (TRC Meeting No. 4) and a second draft of the final report (revised draft final report) to the scope of work.

Deliverables

- Draft, Revised Draft, and Final LP Alternatives Study Report
- Report for TRC Meeting No. 4 report, including draft and final meeting notes and a meeting presentation

1.2.2 Technical Review Committee Meetings and Reviews

Throughout the LP Alternatives Study, the TRC was continually engaged through a series of meetings and document reviews. TRC comments and questions were discussed at meetings and on phone calls, and all TRC written comments were documented and addressed with report revisions or comment responses.

Meetings

Meetings were carefully planned to share information with the TRC, answer TRC questions, and obtain feedback from the TRC. Meeting reports, including presentation slides and meeting notes, are provided as Appendix G to this report, under separate cover. TRC meetings and participants are listed below.

TRC Meeting No. 1 – Study Preparation

- Ethan Bell, Stillwater (by phone)
- Madeleine Bray, AECOM
- Joel Casagrande, NMFS
- Shawn Chartrand, Balance
- Brian Cluer, NMFS
- Larry Hampson, MPWMD
- Shannon Leonard, AECOM
- Dennis Michniuk, CDFW (by phone)
- Kealie Pretzlav, Balance
- John Roadifer, AECOM
- Dave Stoldt, MPWMD (by phone)
- Jon Stead, AECOM
- Kevan Urquhart, MPWMD
- Marcin Whitman, CDFW

TRC Meeting No. 2a – Sediment Characterization, Alternatives Descriptions, and Sediment Transport Model Considerations

- Ethan Bell, Stillwater (by phone)
- Joel Casagrande, NMFS
- Trish Chapman, SCC
- Shawn Chartrand, Balance
- Brian Cluer, NMFS
- Ian Crooks, Cal-Am (by phone)
- David Crowder, NMFS (by phone)
- Aman Gonzalez, Cal-Am (by phone)
- Larry Hampson, MPWMD
- Dave Highland, CDFW
- Shannon Leonard, AECOM
- Katie McLean, AECOM
- Matthew Michie, CDFW (by phone)
- Dennis Michniuk, CDFW
- Kealie Pretzlav, Balance
- John Roadifer, AECOM
- Kevan Urquhart, MPWMD
- Marcin Whitman, CDFW

TRC Meeting No. 2b (virtual) – Review, Effects to Steelhead, Next Steps

- Ethan Bell, Stillwater
- David Boughton, NMFS
- Joel Casagrande, NMFS
- Beverly Cheney, MPWMD
- Thomas Christensen, MPWMD
- Christopher Cook, Cal-Am
- Ian Crooks, Cal-Am
- David Crowder, NMFS
- Mike Garello, HDR
- Seth Gentzler, AECOM
- Aman Gonzalez, Cal-Am
- TRC Meeting No. 3
- Cory Hamilton, MPWMD
- Larry Hampson, MPWMD
- Mandy Ingham, NMFS
- Jonathan Lear, MPWMD
- Shannon Leonard, AECOM
- Matthew Michie, CDFW
- Dennis Michniuk, CDFW
- Tim O'Halloran, Cal-Am
- Haley Ohms, NMFS
- Andres Ticlavilca, NMFS

TRC Meeting No. 3 (virtual) – Alternatives Development

- Krissy Atkinson, CDFW
- Ethan Bell, Stillwater
- Joel Casagrande, NMFS
- Thomas Christensen, MPWMD
- Megan Collins, AECOM
- Chris Cook, Cal-Am
- Ian Crooks, Cal-Am
- David Crowder, NMFS
- Mark Gard, CDFW
- Mike Garello, HDR
- Seth Gentzler, AECOM
- Aman Gonzalez, Cal-Am
- Cory Hamilton, MPWMD
- Larry Hampson, MPWMD
- Mandy Ingham, NMFS
- Jonathan Lear, MPWMD
- Dennis Michniuk, CDFW
- Chad Mitcham, USFWS
- Tim O'Halloran, Cal-Am
- Jon Stead, AECOM

TRC Meeting No. 4 (virtual) – Update Alternatives and Evaluation

- Krissy Atkinson, CDFW
- David Boughton, NMFS
- Joel Casagrande, NMFS
- Thomas Christensen, MPWMD
- Christopher Cook, Cal-Am
- Ian Crooks, Cal-Am
- Mark Gard, CDFW
- Seth Gentzler, AECOM
- Aman Gonzalez, Cal-Am
- Cory Hamilton, MPWMD
- Maureen Hamilton, MPWMD
- Larry Hampson, MPWMD
- Mandy Ingham, NMFS
- Jonathan Lear, MPWMD
- Katie McLean, AECOM
- Tim O'Halloran, Cal-Am
- Jon Stead, AECOM

Reviews

In addition to review of the LP Alternatives Study Scope of Work on January 17, 2017, discussion at meetings and on phone calls, and informal input solicited via email (e.g., November 11, 2022 request for input on criterion weighting and November 21, 2022 request for review of reformulated alternatives), the TRC was invited to provide written comments on key deliverables. All written comments from the TRC were addressed with revisions to the alternatives and their analysis and/or were provided a written comment response. Deliverables on which the TRC was invited to comment are listed below:

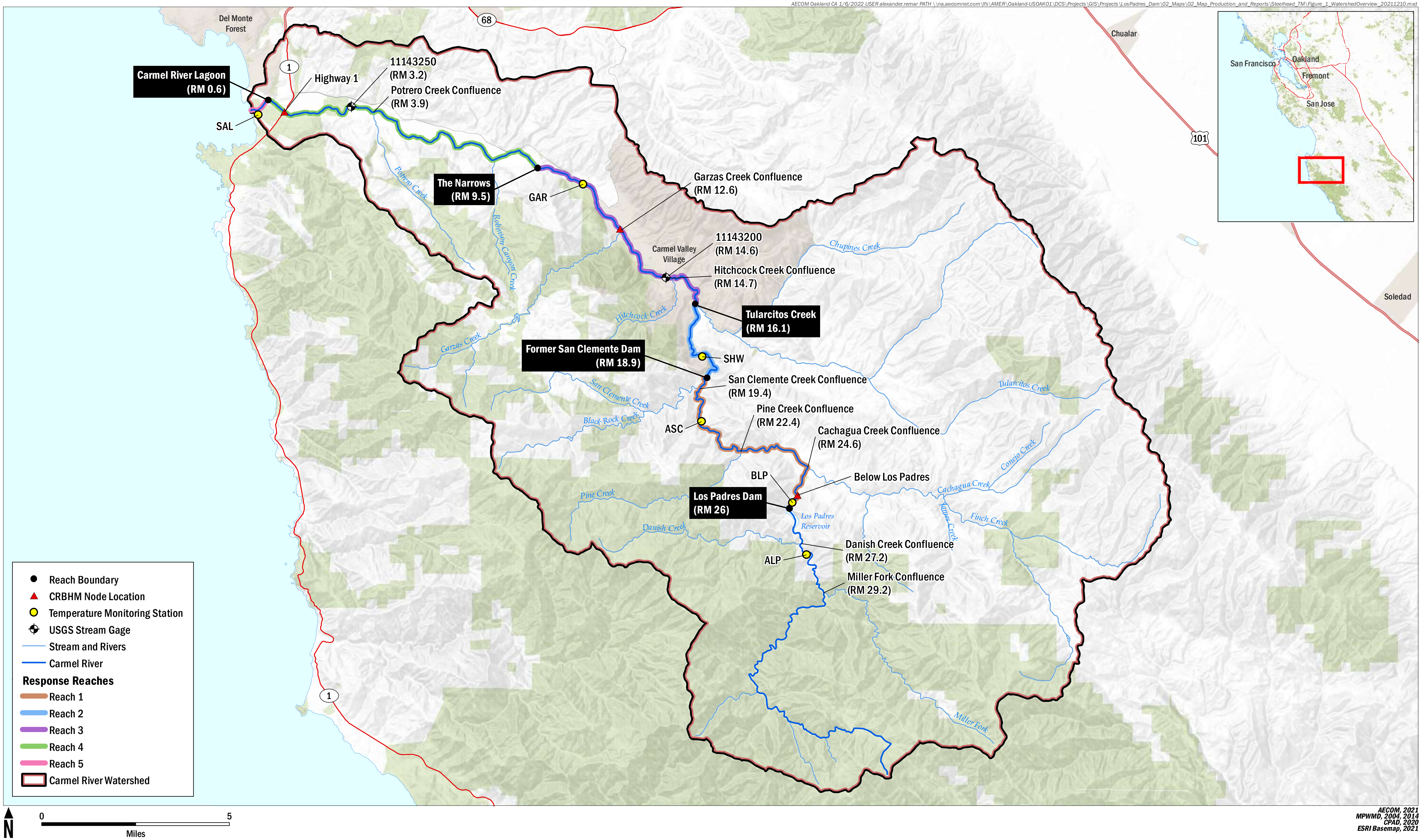
- TRC Meeting No. 1 Notes (August 8, 2017)
- Draft Study Preparation TM (October 20, 2017)
- Draft Sediment Characterization TM (November 20, 2017)
- Alternatives Descriptions TM (December 1, 2017)
- TRC Meeting No. 2a Notes (February 14, 2018)
- Nine Interim Draft Sediment Transport Model TMs (July through September 2018)
- Draft Sediment Effects TM (December 5, 2018)
- Draft Effects to Steelhead TM (September 27, 2021)
- TRC Meeting No. 2b Notes (November 4, 2021)
- Alternatives Development TM (March 29, 2022)
- TRC Meeting No. 3 Notes (May 4, 2022)
- Draft Table of Contents for Final Report (May 20, 2022)
- Draft Final Report (August 12, 2022)
- Revised Draft Final Report (February 3, 2023)

1.3 Alternatives Study Background

This section presents an overview of miscellaneous background information, including the study area, the regulatory setting, previous and related studies, and the organization and limitations of this document.

1.3.1 Study Area

LPD is located at river mile (RM, measured from the ocean) 26 on the Carmel River, which flows into the Monterey Bay National Marine Sanctuary about 5 miles south of Monterey, California (Cal-Am and MPWMD 2016) (Figure 1-1). The dam forms a 148-foot-high earth fill barrier along the river and creates LPR which extends roughly 1 mile upstream of the dam crest. The primary study area within which project actions were considered includes the reservoir, the dam, the dam's associated appurtenances, and the plunge pool that resides below the spillway of the dam. However, due to the nature of the actions considered, some activities would occur further from the dam (e.g., sediment disposal) and the effects of the actions contemplated in this report are considered from LPR downstream to Monterey Bay.



AECOM
Monterey Peninsula Water Management District
Los Padres Alternaitves Study

FIGURE 1-1
Carmel River Watershed Overview

1.3.2 Project Setting

Due to episodic flows and the highly erosive nature of the contributing watershed, LPR storage has shrunk about approximately 40 percent since construction of LPD. In 1995, the State Water Resources Control Board (SWRCB) reduced Cal-Am's water rights associated with the dam to 2,179 acre-feet (AF), due to siltation in the reservoir. The reservoir has not been dredged since it was built, but several accidental sediment sluicing events occurred using the outlet works in October 1981, due to a buildup of silt in the reservoir after the 1977 Marble-Cone fire, and extreme low water conditions in the reservoir (MPWMD 1981).

Downstream of LPD, there is significant armoring of the streambed and incision into floodplain deposits along the lower 16-mile alluvial portion of Carmel Valley because of sediment retention at both LPD and the former site of the San Clemente Dam (RM 18.9). San Clemente Dam, constructed from 1920 to 1921, and Old Carmel River Dam (approximately 1,700 feet downstream of San Clemente Dam), constructed in 1883, were removed in 2015. Their removal has improved steelhead passage and allows sediment from the 80-square-mile watershed upstream of San Clemente Dam, up to Los Padres dam, to be transported downstream.

During dry periods (normally from May through October), releases from LPR constitute most of the flow in the river downstream of LPD, where significant numbers of threatened steelhead can be found in some years (Cal-Am and MPWMD 2016). Although LPD and the associated reservoir currently has value as a water supply facility to meet municipal demand and enhance summer flow in the river, the reservoir is not designed to provide flood protection to downstream reaches. The last available Division of Safety of Dams (DSOD) visual inspection occurred in 2015 and the dam, reservoir, and all appurtenances were judged safe for continued use (DSOD 2015a). It has passed historical flows and provided safe operation during historical earthquakes.

NMFS has strongly encouraged Cal-Am to resolve steelhead passage issues (see Section 1.3.4, Carmel River Steelhead Fishery Science Studies) and other potential take issues involved with LPD (Cal-Am and MPWMD 2016). NMFS has also suggested that removal of LPD should be considered; however, NMFS recognized in the S-CCC Steelhead Recovery Plan that LPD is part of the regional water supply, and studies are required to come to a conclusion about the future of the dam. In 2013, a Cal-Am consultant evaluated dredging of reservoir sediments to recover storage (see Section 1.3.4 for a summary of this study); however, due to the high projected cost, this alternative has not been pursued.

In summary, current impacts associated with LPD and LPR sediment accumulation include (Cal-Am and MPWMD 2016):

- a disconnect in habitat and natural river functions between the upper and lower portions of the watershed;
- impaired upstream and downstream steelhead passage through the reservoir and at the dam, and habitat degradation downstream of the dam due to sediment starvation and armoring of the channel bed;
- reduced storage capacity, resulting in reduced dry season releases, loss of water rights, and inability to meet release requirements associated with the water right license for the dam; and
- degradation in the water quality of dry season releases (i.e., increased temperature, decrease in dissolved oxygen (DO), increase in anoxic releases, and increase in hydrogen sulfide).

Current benefits associated with LPD and LPR include (Cal-Am and MPWMD 2016):

- maintains a water right to help supply domestic water to the Monterey Peninsula;
- provides the only significant source of flow to the river downstream of LPD during dry periods and augments natural flow during dry periods to improve the quantity and quality of steelhead habitat downstream of LPD (Without reservoir releases, much of the river downstream of the confluence with Cachagua Creek would likely be dry or intermittent during the summer, in dry and critically dry

water year types. Reservoir releases can increase flow conditions during normal years, when unimpaired flows would likely be 1 or 2 cubic feet per second [cfs] and augmented flows are 5 or 6 cfs); and

- captures debris flows from the upper watershed that could affect downstream structures and properties.

1.3.3 Regulatory Setting

The regulatory setting at LPD is multifaceted and subject to several factors that govern its annual operation and long-term planning activities. It includes California Public Utilities Commission regulation that mandates Cal-Am serve its customers and an annual operations Memorandum of Agreement (MOA) among Cal-Am, MPWMD, and CDFW. Actions taken by SWRCB, NMFS, and the California State Coastal Conservancy in the past 25 years are among the primary regulatory drivers of fish passage (or other passage solutions such as dam removal) at LPD.

National Marine Fisheries Service Interest and Involvement

NMFS and the California State Coastal Conservancy have required Cal-Am to incrementally consider, fund, and address conditions that improve S-CCC steelhead populations in the Carmel River and address fish passage conditions at LPD. NMFS' jurisdiction is related to the presence of S-CCC steelhead. This Distinct Population Segment (DPS) of steelhead was listed as federally threatened in 1997. Critical habitat was designated September 2, 2005 (70 Federal Register [FR] 52488), and the DPS' status as threatened was confirmed (and clarified) in 2006 (January 5, 2006; 71 Federal Register [FR] 834). The S-CCC steelhead DPS includes all naturally spawned anadromous steelhead populations below impassable barriers in streams from the Pajaro River watershed (inclusive) south to but not including the Santa Maria River in northern Santa Barbara County, California, which includes the Carmel River.

On September 18, 2001, NMFS and Cal-Am entered into a Conservation Agreement that required Cal-Am to implement certain measures to reduce the impact of its operations in the Carmel River on steelhead and their habitat. In 1990, MPWMD determined that diversions were impacting Carmel River resources, and required Cal-Am to collect funds from its customers to pay for MPWMD's implementation of restoration and mitigation measures, including annual fish rescues; construction, maintenance, renovation, and operation of a rearing facility to hold rescued steelhead; monitoring of and improvements to the instream and riparian habitat; and monitoring the steelhead population (Cal-Am et al. 2009). In 2009, Cal-Am, NMFS, and CDFW negotiated a new agreement that modified the mitigation requirements and interim measures described in the original Conservation Agreement. With the 2009 agreement, Cal-Am committed to modifying operations to avoid take of steelhead or to obtain all necessary permits to authorize any remaining take before the expiration of the agreement.

On two occasions, NMFS has written letters to Cal-Am that clearly describe their opposition to maintaining LPD without modification. In 2011, NMFS encouraged Cal-Am to study the feasibility of removing LPD and indicated that NMFS was opposed to building any new dams on the Carmel River (NMFS 2011). In 2013, NMFS expressed concern that LPD may be causing take of S-CCC steelhead by impeding migration or altering downstream critical habitat (NMFS 2013a). In that 2013 letter, NMFS advised Cal-Am to determine the feasibility of:

1. Entirely removing the dam and restoring the reservoir area to its original environs; or
2. Improving the dam with appropriate permanent fish passage modifications that allow for unimpeded, safe, and effective upstream and downstream migration of all life stages of S-CCC steelhead.

In 2017 Cal-Am signed an MOA with NMFS and the California State Coastal Conservancy (NMFS 2017) committing to further studies, funding, and improvements over an additional 5-year period. The agreement indicates that, if LPD is to remain in place, Cal-Am shall perform the following required actions specific to fish passage:

1. Provide unimpeded upstream passage for adult and juvenile steelhead.
2. Provide unimpeded downstream passage for kelts, smolts, and juvenile steelhead.

Cal-Am and NMFS continue to collaborate on the implementation of elements of the MOA that include addressing NMFS' concerns with effects to steelhead from Cal-Am's continued operation of LPD. Removal of San Clemente Dam in 2015 has improved access for migrating steelhead to LPD thus increasing the level of importance for actions at LPD.

In the *South-Central California Steelhead Recovery Plan* (NMFS 2013b), NMFS identified the Carmel River population of S-CCC steelhead as a Core 1 population. Core 1 populations have the highest priority for recovery and form the nucleus of the recovery implementation strategy. LPD is identified as causing or contributing to a number of threats to the Carmel River steelhead population, including blocking or inhibiting the natural pattern of upstream and downstream migration of adult and juvenile steelhead; impeding access to the majority of the spawning and rearing habitat of the Carmel River Watershed; altering the natural surface flow; and reducing the recruitment of essential spawning gravels and sediments to support rearing habitat in the middle and lower reaches of the Carmel River (NMFS 2013b).

The recovery plan identifies critical recovery actions for the Carmel River at LPD (NMFS 2013b), including:

- Develop and implement operating criteria to ensure that the pattern and magnitude of groundwater extractions and water releases, including releases from San Clemente Dam and LPD, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead.
- Remove or physically modify San Clemente, Los Padres, and Old Carmel River Dams (note: prior to the removal or modification of these dams, appropriate investigations and environmental review should be completed to address regional water supply and environmental issues, including, but not limited to, any effects on the existing steelhead resources of the Carmel River watershed) to provide natural rates of steelhead migration to upstream spawning and rearing habitats; passage of smolts and kelts downstream to the estuary and ocean; and restoration of spawning gravel recruitment in the lower mainstem.
- In the interim, ensure provisional fish passage of both adult and juvenile *O. mykiss* around Los Padres, San Clemente, and Old Carmel River Dams; seasonal releases from San Clemente Dam and LPD; and the provision of spawning gravel and large woody debris in the lower mainstem to support all *O. mykiss* life-history phases, including adult and juvenile migration, spawning, and incubation and rearing habitats.

Although actions described in the recovery plan are recommendations or advisory in nature, the recovery plan is likely to carry substantial weight with regulatory and permitting agencies, including NMFS. Specific recovery actions relevant to the Los Padres Alternatives Study are listed below (NMFS 2013b).

- Car-SCCCS-4.1: Develop and implement water management plan for dam operations (or review and modify) (e.g., MPWMD Quarterly Water Budget and Low Flow MOA)
- Car-SCCCS-4.2: Develop and implement water management plan for diversion operations (or review and modify) (e.g., MPWMD Quarterly Water Budget and Low Flow MOA)
- Car-SCCCS-4.3: Provide fish passage around dams and diversions
- Car-SCCCS-9.1: Develop and implement a watershed-wide plan to assess the impacts of nonnative species and develop control measures
- Car-SCCCS-9.2: Develop and implement a nonnative species monitoring program

Water Rights and Orders

Cal-Am holds riparian, pre-1914 appropriative, and post-1914 appropriative water rights; the MPWMD holds a post-1914 appropriative water right; and Cal-Am and MPWMD jointly hold post-1914 appropriative water rights. Riparian water rights allow landowners whose parcels physically touch or overlie a water source to have a right to use water from that source as long as the property owner has not sold or otherwise subordinated the right to another party. The right is limited to what can be beneficially used on the riparian property.[1] Normally, SWRCB does not quantify or otherwise regulate riparian rights.[2] Appropriative water rights allow for water diversion at one point and beneficial use at a separate point. These rights do not require that the water right holder owns land adjacent to the water source. Pre-1914 water rights are appropriative rights acquired before the effective date of the Water Commissions Act (December 19, 1914). The Water Commissions Act formalized water appropriation in California and centralized appropriative water rights records under what is now SWRCB. Appropriative water rights issued after the creation of the Water Commissions Act are called post-1914 water rights. Obtaining post-1914 water rights requires the application for a permit from SWRCB, and applicants must provide information on where and how the water will be used, and when and how it will be diverted.

Notable among the water rights history in the Carmel River is SWRCB Order 95-10 (WR 95-10), which settled complaints that had been filed against Cal-Am for its diversion of water from the Carmel River. This order is summarized in the following paragraphs.

- The order stated that Cal-Am has a legal right to 3,376 acre-feet per year (AFY) (1,137 AFY from pre-1914 appropriative rights, 60 AFY from riparian rights, and 2,179 AFY from license 11866). It recognized the face value of License 11866 as 3,030 AFY, but noted that only 2,179 AFY was then physically available under the license due to siltation at LPR.
- The order imposed a cease and desist from diverting any water in excess of 14,106 AFY.
- The order stated that Cal-Am's total annual diversion is equal to 14,106 AF.
- The order mandated that Cal-Am find an alternative supply for 10,730 AFY of water and, pending the implementation of an alternative water supply, limit its diversions from Carmel Valley to 11,284.8 AF.
- The order required Cal-Am to divert Carmel River flow at the most downstream point in the well field downstream of San Clemente Dam and proceed upstream to satisfy municipal demand. This applies to both authorized and unauthorized diversions. As long as this order is in place, Cal-Am can use its well field for diversions. If Order 95-10 is rescinded, modified, or replaced, it is unclear how SWRCB will address diversions under License 11866 (see below) because the point of rediversion under this license no longer exists.

In 2009, SWRCB issued a cease-and-desist order (CDO) to Cal-Am that established a compliance timeline for cessation of Cal-Am's unlawful diversions from the Carmel River by December 31, 2016 (SWRCB Order WR 2009-0060). The timeline was based on implementation of the Coastal Water Project, which was terminated and is being replaced with several other projects now undergoing review with permitting agencies. SWRCB Order WR 2016-0016 extends the timeline for compliance with the original CDO, requiring that unauthorized diversions end by December 31, 2021, regardless of whether the envisioned projects are complete. Since 2009, Cal-Am has reduced its diversions well below the annual diversion levels set by WR 2009-0060; and beginning in January 2022, Cal-Am's annual diversions have been reduced to the amounts available under Cal-Am's lawful current rights. Reductions have resulted from various factors including conservation and efficiency measures, local supply projects, and a moratorium on increased water use within Cal-Am's service area imposed by SWRCB Order WR 2009-0060. To address the impacts of its diversions, Cal-Am has also applied significant resources to fishery conservation and habitat improvement programs.

Cal-Am is planning, for the long term, to replace the 10,730 AFY diverted from the Carmel Valley Aquifer with water produced via desalination, initially with the project identified as the Coastal Water Project

[1] Cal-Am and its predecessors claim that in the late 1800s and early 1900s, several riparian property owners along the Carmel River sold, subordinated, or gave waivers to their riparian rights. The Pacific Improvement Company, which was run locally by S.F.B. Morse, the founder of Pebble Beach, had actively pursued water rights in Carmel Valley. Morse desired to purchase water rights to build San Clemente Dam so that he could supply development projects on the Monterey Peninsula. The quantities of water sold or subordinated were not well documented; however, SWRCB recognized Cal-Am's pre-1914 right to 1,137 AFY as an appropriative right (see Order 95-10). It is unclear what, if anything, remains of the rights of the riparian properties that subordinated their rights to Cal-Am's predecessors.

[2] With Order 95-10, SWRCB quantified Cal-Am's riparian right as 60 AFY for purposes of setting a Carmel River authorized diversion limit under the Order.

(Cal-Am et al. 2009), and now with the Monterey Peninsula Water Supply Project (MPWSP) and others (SWRCB Order 2016 0016). However, maintaining existing water rights is a priority for the municipal water supply. With an associated water right of 3,030 AF, LPR is a large portion of Cal-Am's solely owned water rights in the Carmel River watershed. It is also 22 percent of the approximately 9,700 AF that the MPWMD estimated Cal-Am was pumping annually in 2022, or 22 percent of the current annual municipal water supply (Christensen, pers. comm. 2022).

The following lists, as well as Table 1-1, summarize all of Cal-Am and MPWMD's water rights in the Carmel River Watershed. Cal-Am's water rights include:

- Pre-1914 and Riparian Rights: Cal-Am has rights to 1,137 AFY from pre-1914 rights and riparian rights, quantified as 60 AFY for purposes of certain SWRCB orders. These rights are not subject to meeting instream flow requirements.
- 1985: SWRCB licensed Cal-Am (License 11866, Permit 7130A) to divert up to 3,030 AFY to LPR and San Clemente Reservoir between October 1 of each year through May 31 of the following year for municipal, domestic, industrial, and recreational use. License 11866 requires Cal-Am to release and maintain a flow of greater than or equal to 5 cfs in the Carmel River channel directly below the outlet structure of the LPD at all times during which water is being stored under this license.[3] There are no instream flow requirements for downstream withdrawals under this license; however, the license specifically lists only two points of diversion – at Los Padres Dam to storage and at San Clemente Dam for rediversion.
- 1995: See above.
- 1998: SWRCB issued Order WR 98-04, which amended WR 95-10. Modifications to the original order included requirements for Cal-Am to maximize production from the Seaside aquifer, minimize diversions from the Seaside aquifer under certain flow conditions, satisfy water demands by extracting water from its most downstream wells, conduct feasibility studies on shifting water deliveries to different existing sources, provide monthly reports on water diversion and pumping, and provide quarterly water budget reports.

Table 1-1 Cal-Am and MPWMD Water Rights in the Carmel River Watershed

Cal-Am	Water Rights (AFY)
Appropriative Right (Pre-1914)	1,137
Unquantified Riparian Right	NA
Appropriative Right (License 11866)	3,030
Appropriative Right (Permit 21330)	1,488
MPWMD	
Appropriative Right (Permit 20808A*)	2,426
Appropriative Right (Permit 20808B)	18,674
Appropriative Right (Permit 20808C*)	2,900
Total	**28,864**

Notes:

* These water rights are held jointly by Cal-Am and MPWMD.

AFY = acre-feet per year
Cal-Am = California American Water
MPWMD = Monterey Peninsula Water Management District

[3] The license allows temporary reductions in flow releases for operating purposes in accordance with an agreement with the California Department of Fish and Game (now CDFW) that predated the 1948 permit issued by the California Department of Public Works. Staff at Cal-Am, MPWMD, and CDFW are not aware of any copy of such an agreement. It may exist at the SWRCB offices.

- 2009: SWRCB issued a CDO (Order WR 2009-060) to Cal-Am that established a compliance timeline for cessation of Cal-Am's unlawful diversions from the Carmel River by December 31, 2016. This order was a follow-up to WR 95-10, and required Cal-Am to reduce its total diversion to 3,376 AFY. Conditions 1 through 3 of the order stated the following:

  1. Cal-Am shall diligently implement actions to terminate its unlawful diversions from the Carmel River and shall terminate all unlawful diversions from the river no later than December 31, 2016.

  2. Cal-Am shall not divert water from the Carmel River for new service connections or for any increased use of water at existing service addresses resulting from a change in zoning or use.

  3. Cal-Am shall adjust its diversions from the Carmel River in accordance with the outlined minimal reductions.

- 2013: SWRCB issued Permit 21330 to Cal-Am to divert up to 1,488 AFY from the Carmel River at San Clemente Reservoir, and at 26 wells that draw from the Carmel River Watershed. San Clemente Reservoir has been removed and some of the wells downstream have been decommissioned, thus reducing the points of diversion. Instream flow requirements limit the actual amount that can be diverted during the season of diversion (December 1 through May 31).

- 2016: SWRCB issued Order WR 2016-0016, which amended WR 2009-0060. WR 2016-0016 extended the deadline for Cal-Am to terminate unlawful diversion from the Carmel River to December 31, 2021. WR 2016-0016 also allows for an ongoing diversion level as long as specified progress toward alternative supplies is met, but sharply drops allowable diversions should the progress toward these supplies slip.

- 2017 – present: Cal-Am has partnered with MPWMD and Monterey One Water to use recycled water to replace a portion of the unauthorized Carmel River diversions.

MPWMD's water rights in the Carmel River Watershed include:

- 1995: SWRCB issued Decision Number 1632 and Permit 20808 to the MPWMD for 24,000 AFY for the New LPD, which was proposed to be about 1,800 feet downstream of the existing LPD. This water right contained minimum instream flow requirements for flow below the New LPD, at the Carmel River Narrows and Lagoon, and at San Clemente Dam. In 1995, a public vote failed on a bond issue to finance the New LPD, and the dam was never built.

- 1998: SWRCB issued Order WR 98-04, which amended Decision 1632. Modifications to the original decision included clarifying diversion periods for the New Los Padres Project, updating the construction start date, and limiting the total diversion of water in the Carmel River by Cal-Am and MPWMD combined to 16,000 AFY, or "such lesser amount identified in the Supplemental EIR [Environmental Impact Report] on the Carmel River Dam as annual beneficial use requirements associated with total project yield or the Cal-Am production limit." The New Los Padres Project and calls for similar proposals for a new dam downstream of the existing LPD have been consistently rejected based on concerns regarding damage to the river environment.

- 2007: Permit 20808 was subsequently split into three water rights permits: 20808A, 20808B, and 20808C. All three permits were required to be licensed by SWRCB by 2020. However, in 2020 MPWMD filed for an extension of time for 15 years to demonstrate maximum beneficial use under these permits. Diversion rights associated with Permit 20808 are junior to all other rights along the Carmel River. The 16,000 AFY diversion limit on Cal-Am and MPWMD diversions established in WR 98-04 were restated in these permits. Although Cal-Am and MPWMD's combined water rights exceed 16,000 AFY (see Table 1-1), the instream flow requirements applied to License 11866 and Permits 20808A, 20808B, and 20808C, and the instantaneous diversion rate requirements in Permits 20808A, 20808B, and 20808C, will effectively restrict total annual diversions to less than 16,000 AFY.

- Permits 20808A and 20808C are jointly held between MPWMD and Cal-Am for diversion of excess winter season flows to storage in the Seaside Groundwater Basin (aquifer storage and recovery [ASR]). Permit 20808A allows for diversion of up to 2,426 AFY from the Carmel River at San Clemente Reservoir, and at 26 wells that draw from the Carmel River Watershed. Permit 20808C allows for diversion of up to 2,900 AFY from the Carmel River Watershed.

- Permit 20808B is held by MPWMD for up to 18,674 AFY.

1.3.4 Previous and Related Studies

This section provides an overview of previous and related studies relevant to the LP Alternatives Study. These studies were considered or relied upon during the LP Alternatives Study. They are described here at different levels of detail depending on how important they were to the LP Alternatives Study and whether they are further described in later sections.

Sediment Transport Studies in Support of San Clemente Dam Removal

Between 2001 and 2007, MEI, Inc. evaluated release of up to 1,500 AF of sediment stored behind the former San Clemente Dam, and generally found that releases above the historic input would likely result in aggradation and potentially raise 100-year flood elevations in some locations along the alluvial reach; however, one of the constraints in the HEC-6T sediment transport model placed a scour limit of 1 foot. Essentially, the model allowed significant aggradation, but little degradation during periods when the system supply is limited. Although this was a conservative approach to estimating potential impacts, it is clear that periods of degradation result in a deeper channel that can store a significant volume of sediment without significantly raising flood elevations (MEI 2007).

Previous studies by MEI indicate that additional sediment delivered to the canyon reach should be transported through that upper reach relatively quickly (i.e., over the course of 6 to 41 years, depending on the volume of sediment) (MEI 2002a). Recent post-removal experience at the Carmel River Reroute and Dam Removal project appears to confirm this, and shows that there are beneficial effects (e.g., establishment of excellent spawning habitat), as well as some negative effects (pools filled in with sand) of increased sediment delivery. In the canyon reach, an increase in flood elevations due to channel aggradation is likely not a significant issue, due to the lack of human infrastructure (Cal-Am and MPWMD 2016).

Conditions in the lower reach are more complex (Cal-Am and MPWMD 2016). In some areas with extensive urban development in the 100-year floodplain, any increase in flood elevations due to an increase in sediment supply could be considered a significant impact. In other areas, where long-term degradation has caused incision into floodplain deposits and infrastructure is exposed, an increase of sediment could have a beneficial effect. What is unclear is how much material can be transported through the channel without a significant adverse effect on 100-year flood elevations.

Los Padres Dam Sediment Removal Feasibility Study

MWH completed a study for Cal-Am in 2013 that considered potential sediment management options for LPR, and ultimately proposed three mechanical removal alternatives (MWH 2013). The study reviewed reservoir sediment management options recommended by the United States Bureau of Reclamation (Reclamation), the United States Society on Dams, and the H. John Heinz III Center for Science, Economics, and the Environment; and evaluated their applicability at LPR (Table 1-2). The recommended and typically applied sediment management strategies, such as sediment re-routing, drawdown flushing, reservoir emptying, and siphoning, were determined to be impractical at Los Padres because of the dam configuration and design, and the reservoir operation constraints.

Table 1-2 Sediment Management Options Previously Evaluated at Los Padres Reservoir (MWH 2013)

Sediment Management Option	Description	Applicability at Los Padres Reservoir
No Action	No sediment removal would occur. This alternative is typically provided as a baseline for comparison against other removal methods.	No action will result in decreasing storage capacity and require planning for future change in operation.
Soil Conservation/ Sediment Inflow Reduction	Three methods are commonly used to reduce the sediment load entering the reservoir. Structural measures include terraced farmlands, flood interception and diversion works, bank protection works, check dams, and silt trapping dams. Vegetative measures include growing soil, water conservation forests, and reforestation. Tillage practice includes different farming practices.	Structural measures are impractical due to difficult access and impacts to steelhead spawning habitat. Vegetative measures are impractical due to steep, inaccessible terrain and disturbance to wilderness areas. Tillage is impractical because the watershed above the reservoir is not farmland.
Incoming Sediment Bypass/ Sediment Routing	Bypassing heavily sediment-laden flows during the flood season through a channel or tunnel.	Difficult to implement, given the sediment transport characteristics of the watershed and the high cost of developing the bypass (includes notable environmental impact as well).
Density-Current Venting	A density current is a sediment-laden reservoir inflow, which will flow along the bottom and remain unmixed with the rest of the water body because of a difference in density. It can be vented by opening bottom outlets and letting the density current flow out of the reservoir.	Difficult to implement, given the sediment transport characteristics of the watershed. Also, it results in release of a high sediment concentration into the downstream river that significantly impacts habitat and species.
Drawdown Flushing/ Lateral Erosion	Includes the lowering of the reservoir table so that a riverine flow establishes along the impounded reach. The river erodes a channel through the deposited sediment, and the flushing transports the sediment through the outlet and downstream.	Releases a high sediment concentration downstream, which significantly impacts habitat and species. Not achievable, given the reservoir configuration and outlet size.
Reservoir Emptying with Sediment Flushing	In comparison with the drawdown flushing, the reservoir emptying loses the whole water storage. The sediment is also transported to the downstream river through a lower gate.	Results in release of a high sediment concentration into the downstream river that significantly impacts habitat and species.
Siphon and/or Suction Dredging	Siphon dredging uses the head difference between the upstream and downstream levels of a dam as the source of power. At the end of the pipe, the sediment deposits are either released directly downstream, or further processed to separate the sediment and water. Suction dredging requires conventional energy sources (diesel fuel) to run the dredger that physically evacuates sediments from the reservoir bottom.	Requires a significant supply of water for removal of sediments as slurry. Analysis revealed difficulty in implementing efficient slurry dewatering and water recycling.
Mechanical Removal	Partial or full removal of reservoir sediment and storage at an appropriate disposal site. Removal methods include conventional excavation, and hydraulic or mechanical dredging. Conveyance methods include transport by sediment slurry pipeline, truck, or conveyor belt.	Requires a combination of methods. Clamshell dredging would be used in the lower areas of the reservoir, and dry excavation with scrapers would be used in the upper reservoir areas.

Mechanical removal methods were determined to be the only feasible sediment management strategy for restoring the reservoir capacity at LPR. As a result, the following three sediment removal alternatives were investigated and developed for evaluation:

- Alternative 1 would remove about 1.8 million cubic yards (CY), or an equivalent of 1,134 AF, of sediment to almost restore full original reservoir capacity. This alternative would involve removing about 810,000 CY of material in the upper reach of the reservoir in the dry, using conventional earth-moving methods when the reservoir is lowered during the construction season. In addition, approximately 1 million CY of sediment below the reservoir pool would be removed using a wet dredging method. The removed material would be placed in a proposed disposal site in the upstream watershed beyond the southwestern end of the reservoir, on Cal-Am's property (Figure 1-2). Access upstream of the reservoir would be achieved through improvements to the existing jeep road, which failed during 2018, 2019, and 2020 rockfall events (after this study was completed). Construction of this alternative would take 7 years at an approximate cost of $90 million. The cost range of recovered water supply would be $53,000 to $94,000 per AF, and would restore reservoir capacity to a total of 2,920 AF.

- Alternative 2 would remove a portion of the sediment in the upper reach of the reservoir using conventional earth-moving methods in the dry, when the reservoir is drawn down to an established minimum level. This alternative would remove approximately 810,000 CY, or an equivalent of 502 AF of sediment. The removed material would be placed in a proposed disposal site in the upstream watershed beyond the southwestern end of the reservoir, in Cal-Am's property. Access upstream of the reservoir would be achieved through improvements to the existing jeep road, which failed during 2018, 2019, and 2020 rockfall events (after this study was completed). Construction of this alternative would take 6 years, at an approximate cost of $47 million. The cost of recovered water supply would be $62,000 to $112,000 per AF, and would restore reservoir capacity to a total of 2,288 AF.

- Alternative 3 would remove a portion of the sediment in the lower reach of the reservoir using wet dredging methods from a barge. This alternative would remove approximately 900,000 CY, or an equivalent of 558 AF of sediment. The removed material would be placed in a disposal site on a flat terrace area immediately downstream of the dam (Figure 1-3). Construction of this alternative would take 7 years, at an approximate cost of $50 million. The cost of recovered water supply would be $59,000 to $108,000 per AF, and would restore reservoir capacity to a total of 2,344 AF.

Evaluation of the sediment removal alternatives found that providing any meaningful increase to the reservoir storage capacity would be very challenging due to steep terrain, lack of developed vehicle and equipment access to the upstream portion of the reservoir, limited feasible sediment disposal sites, inability to drain reservoir for construction, and a very short construction window each year. In addition, all alternatives would be difficult to implement, due to notable environmental impacts (e.g., steelhead and red-legged frog habitat) and very high costs relative to the gained benefits. The study recommended that any selected sediment removal concept undergo additional detailed study and careful planning that weighs the environmental impacts and project costs against the gained benefits of additional storage.

The alternatives contained in the MWH (2013) report were not discussed or visited in a forum such as the policy and technical advisory committees set up between 2000 and 2012 to evaluate alternatives and designs for the removal of San Clemente Dam and construction of the rerouted Carmel River (Cal-Am and MPWMD 2016). Although dredging and placing material upstream of LPR in one of the upper watershed sides or box canyons may be physically possible, similar alternatives at the San Clemente Dam site were investigated, and potential sediment storage sites were found to be either unsuitable for off-channel storage, or too expensive (Entrix 2008). This alternative was discussed at the LP Alternatives Study TRC Meeting No. 1, and the consensus was that the upstream dredge disposal site is unlikely to be the preferred disposal site, because it would necessitate construction of a road that would eliminate a section of the Carmel River channel upstream of the reservoir. This option would also require construction of a large retaining structure in the steep, undeveloped valley upstream of the reservoir to prevent the sediment from mobilizing. Due to the availability of potential downstream dredge placement sites that do not present such logistical challenges, this alternative was not carried through the LP Alternatives Study beyond the Alternatives Descriptions TM.

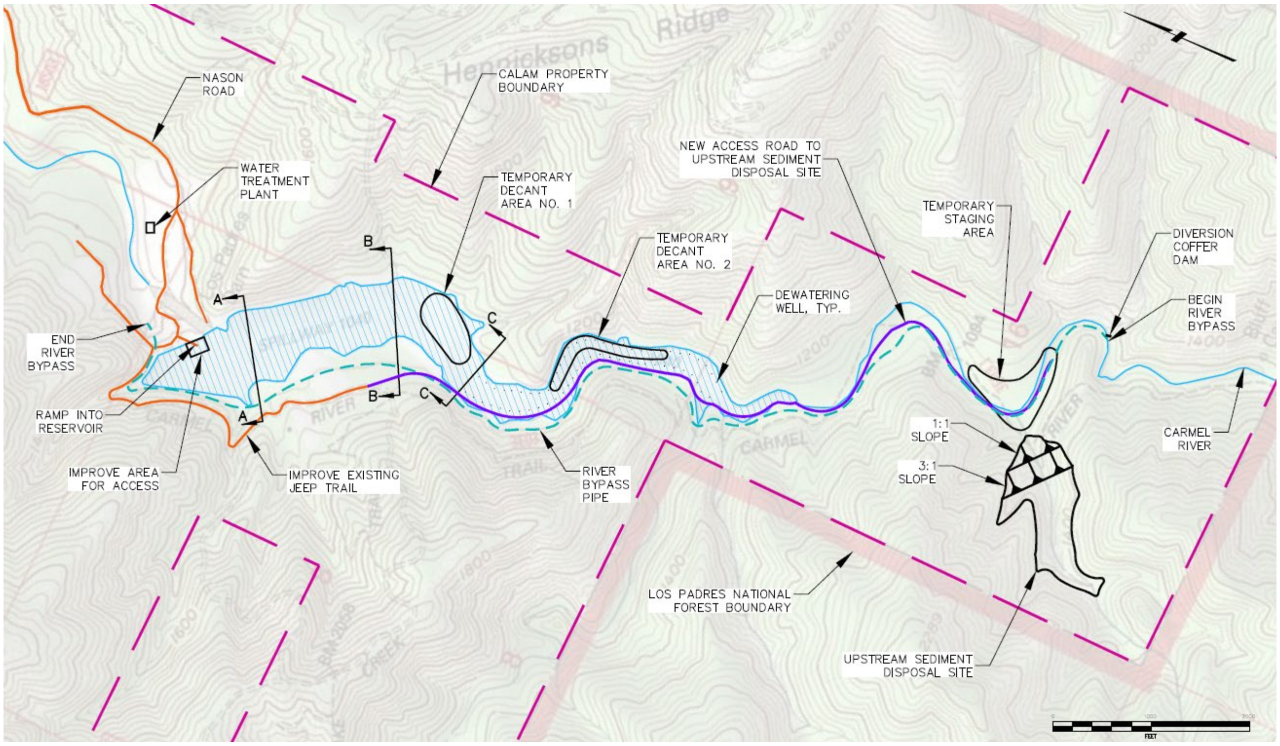


Figure 1-2 Potential Upstream Disposal Site from MWH (2013)

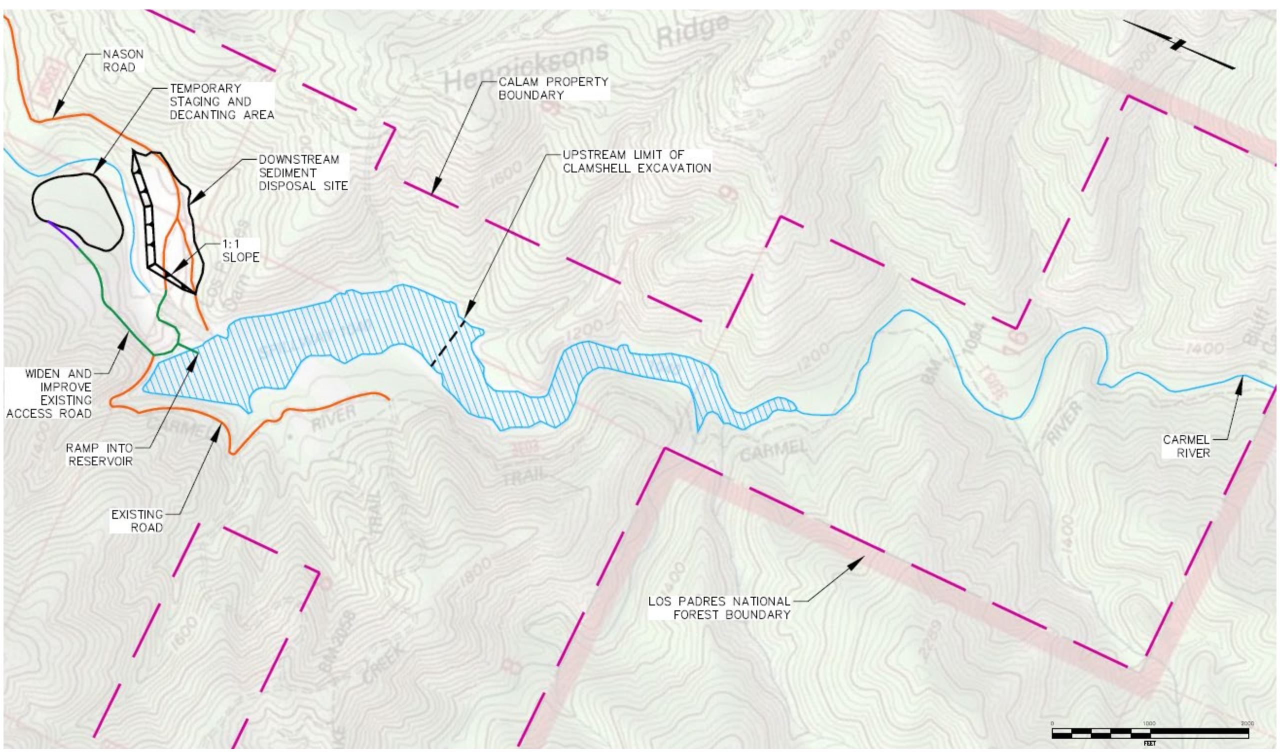


Figure 1-3 Potential Downstream Disposal Site from MWH (2013)

Los Padres Dam and Reservoir Long-Term Strategic and Short-Term Tactical Plan

The 2014 *Los Padres Dam and Reservoir Long-Term Strategic and Short-Term Tactical Plan* (Plan) was written by the MPWMD to assess options for water resource development and management of the upper Carmel River Watershed (MPWMD 2014). The Plan addressed the following three questions:

- Has MPWMD maximized the potential for water resources development in the watershed?
- What options or water development strategies are possible that—given today's requirements (e.g., consumptive demands, instream flows, fish bypass, water quality, and climate change sensitivity)—can serve a wider range of beneficial uses and better prepare for an uncertain future?
- How can any new water resource development effort integrate the current challenges and constraints posed by the basin's existing facilities?

The Plan identified the following water development alternatives:

- **Los Padres Reservoir Storage Enhancement**: This alternative could consist of dredging accumulated sediment or raising the dam by between 5 and 20 feet. As a temporary solution, this alternative would not resolve inevitable future sedimentation from natural erosion and sediment transport processes, including large-scale deposition events like the 1977 Marble-Cone fire.
- **Dredging** would be conducted by diverting the Carmel River along the reservoir and dam site; drawing down the elevation to 1,000 feet (North American Vertical Datum of 1988 [NAVD88]); and mechanically excavating sediment using conventional earthmoving equipment, hydraulic dredging using a suction dredge, or a barge-mounted clamshell or long-arm excavator. The Plan referenced the three dredging options described in the Los Padres Dam Sediment Removal Feasibility Study (MWH 2013, Section 2.2.3) and discussed the challenge of locating a suitable disposal area that would not be washed out during a large-scale erosion event (such as those caused by high-intensity rainfall, slope failure, or wildfire).
- **Los Padres Dam Removal**: Dam removal would have impacts on fish passage, water diversions, recreation, and flooding in the Carmel River Watershed. Due to LPR's high storage-to-yield ratio, removal of the dam would be unlikely to result in substantial effects on downstream hydrology and instream geomorphological response. However, the decision to remove LPD is complicated by two primary factors. First, it is the only impoundment on the Carmel River, and therefore provides the only means of managed flow control from headwater annual yield. Second, given the river's episodic, temporal, and highly variable inter-annual flow regime and downstream minimum flow requirements, sustaining the ability to meter out appropriate releases over the summer season provides a benefit to fish and habitat. The Plan concluded that maintaining some kind of upstream flow release control appeared to be vital. Other factors considered in the Plan were that the dam provides instream flow, which contributes to limited recharge of subsurface aquifer units along the Carmel River; and that dam removal may release accumulated sediment, which can have negative impacts (e.g., reducing downstream water quality) and/or positive impacts (e.g., restoring stream habitat through deposition).
- **New Lower Los Padres Dam and Reservoir**: MPWMD developed plans in the early 1990s to place a new Lower LPD downstream from the existing LPD. The new Lower LPD would be a 282-foot high roller compacted concrete dam measuring approximately 1,600 feet along its crest. The new LPR would extend 2.7 miles upstream, essentially inundating the current dam and reservoir, and extending a short distance up Danish Creek and into a small portion of the Ventana Wilderness. The new reservoir would provide additional water storage of up to 23,600 AF, and would increase the water surface area to 266 acres, compared to the 55 acres of the current LPR. Due to potential impacts on species listed under the federal Endangered Species Act (ESA), the project was unable to secure support from NMFS in the 1990s. However, the Plan concluded

that, with inclusion of state-of-the-art passage facilities, the new Lower LPD could now meet NMFS fish passage criteria[4].

- **Other alternatives considered**: The Plan considered developing storage off the Carmel River in one of four potential locations: Pine Creek Dam and Reservoir, Boronda Creek Dam and Reservoir, San Clemente Creek Off-Mainstem Dam and Reservoir, and Cachagua Creek Dam and Reservoir. The Plan also considered importing water from external sources, a hybrid alternative that would be combined with the MPWSP, and obtaining new water rights.

The Plan eliminated all alternatives, except the off-channel storage options, due to failure to meet perceived regulatory requirements (MPWMD 2014). Ultimately, a hybrid alternative consisting of both removal of the LPD and new off-mainstem storage development was determined to best meet the long-term needs of water supply, instream flows, and fish passage in the watershed, and represented the most effective means of maximizing beneficial use of the basin's available hydrology.

Carmel River Basin Hydrologic Model

MPWMD collaboratively developed the CRBHM, a linked surface flow and groundwater model using GSFLOW coupled to MODFLOW. The model covers the entire Carmel River watershed and includes historic precipitation, well, reservoir, and runoff data. Flow and aquifer levels are simulated on a daily time step at nodes throughout the watershed and routed through the mainstem and/or through the aquifer. Because specific output from this model was relied upon for use in the LP Alternatives Study, additional description of the CRBHM methods and how the model output was used in the study are described in Section 3.1.

Instream Flow Incremental Methodology Hydrologic Model

MPWMD also managed a steelhead habitat availability study under the scope of which their consultant developed an Instream Flow Incremental Methodology (IFIM) hydrologic model. The instream flow study for the Carmel River was prepared, using IFIM, by Normandeau (2019). Because specific output from this model was relied upon for use in the LP Alternatives Study, additional description of the IFIM methods and how the model output was used in the study are described in Section 3.1.2.

Los Padres Dam Fish Passage Study

A team of engineering and fisheries science consultants consisting of HDR, R2 Resource Consultants, Inc., and AECOM was retained by the MPWMD to prepare a study that investigated the technical feasibility and potential lifecycle costs of implementing permanent facilities at LPD to facilitate the upstream and downstream migration of S-CCC steelhead. The draft Fish Passage Feasibility Report presents the background information, study methods, results, and conclusions resulting from completion of the specific study plan developed for this effort (HDR et al. 2021). The study was to inform MPWMD, Cal-Am, NMFS, CDFW, and others regarding the feasibility, potential for fish passage success, level of effort, and cost of implementing viable fish passage facilities at LPD. The specific study plan included six tasks: four tasks to determine technical feasibility and identify fish passage alternatives, one task for alternative development and a decision point, and one task to complete a final report. The results of the study are the primary information considered in the LP Alternatives Study regarding fish passage for alternatives that retain LPD and LPR. See Section 3.2 for a description of reliance by the LP Alternatives Study on this fish passage study and Section 4.4.1 for a summary of the fish passage concepts carried forward from the fish passage study into the LP Alternatives Study (for alternatives that retain LPD).

Carmel River Steelhead Fishery Science Studies

NMFS' Southwest Fisheries Science Center recently completed several studies of Carmel River steelhead movement and abundance, including 1) using passive integrated transponder (PIT)-tagging to examine juvenile, spawner, and kelt movement through LPR (Ohms et al. 2022); 2) using PIT tagging data to estimate smolting rate and smolt production, as well as to examine steelhead movement patterns, in the Carmel River Watershed (Ohms et al. 2021); and 3) fitting generalized additive regression models to steelhead data from the Carmel River to understand the influence of flow on parr survival and length,

4 Further study and design would be required to determine the ability of a fish passage facility on the new Lower Los Padres Dam to meet NMFS fish passage criteria.

as well as using a linear regression model to predict adult returns based on streamflow (and the parr data) under a variety of water management scenarios (Boughton and Ohms 2022).

Of the studies completed, two have particular relevance to analysis of fish passage improvements at LPD and LPR: the PIT tagging study investigating the movement of juveniles, spawners, and kelts through LPR (Ohms et al. 2022); and the study modeling the impacts of water management scenarios on parr survival, parr length, and adult returns (Boughton and Ohms 2022). The following paragraphs summarize these two studies.

The Ohms et al. (2022) study involved PIT tagging two life stages of steelhead: juvenile steelhead were captured, tagged, and released upstream of LPR in fall 2017, fall 2018, and spring 2019, while adult steelhead were tagged at the LPD ladder trap and released into the reservoir near the spillway in spring 2019 (Ohms et al. 2022). Movement and survival past the reservoir and dam were monitored in 2019 and 2020 using PIT tag antennas in the mainstem Carmel River upstream of the head of the reservoir, inside the floating weir collector (FWC) entrance, at the FWC outflow pipe, in Carmel River downstream of the spillway, and further downstream in Carmel River at Sleepy Hollow and Scarlett Well.

Ohms et al. (2022) found that the reservoir slowed travel speeds for both juvenile outmigrants (0.04 to 0.08 river kilometer per hour [rkm/hr] compared to 0.32 rkm/hr in the river) and kelts (0.02 to 0.16 rkm/hr compared to 0.51 to 0.76 rkm/hr in the river). Only 20 percent of juveniles that entered the reservoir continued downstream of the dam, whereas most kelts (87 percent) that entered the reservoir were detected downstream of the dam. Most juveniles and kelts that moved downstream of the dam traveled over the spillway (64 percent of juveniles and 98 percent of kelts) rather than through the FWC. However, juveniles that did travel through the FWC moved downstream 36 hours faster than juveniles using the spillway, suggesting that travel through the FWC required less recovery time than travel over the spillway. Juvenile outmigration via both the spillway and the FWC ceased when spillway-crest water depths fell below 4.9 centimeters, and kelt outmigration through the spillway and the FWC ceased when spillway-crest water depths fell below 8.5 centimeters. Finally, the study compared the spillway-crest water depths at which juveniles and kelts ceased outmigration to historical reservoir water surface elevations to estimate that juvenile outmigrant passage over the spillway was severely to moderately limited in 40 to 55 percent of years from 2002 to 2021; and kelt downstream passage was severely to moderately limited in 45 to 80 percent of years. These findings suggest that many juvenile outmigrants are lost in the reservoir, that the reservoir slows juvenile and kelt outmigration, that juveniles and kelts move downstream primarily over the spillway (although it results in longer travel times compared to traveling through the FWC presumably due to longer recovery periods), that the FWC does not extend the passage window, and that insufficient spillway-crest water depths likely limit the migration window in many years.

A separate report of this study prepared for Cal-Am considered how opening the spillway notch, which was closed seasonally with flashboards from 1994 to 2016, would have affected the number of days the dam was passable (Ohms and Boughton 2021). If the notch had been kept open, water would have begun to flow over the spillway at 316.76 meters elevation, compared to 317 meters when the flashboards were in place. This hypothetical change would have extended the outmigration season, added an average of 81 passable days for juvenile outmigrants and an average of 107 passable days for kelts, and resulted in fewer years (5 to 25 percent of years) with severely or moderately limited juvenile outmigration and kelt downstream passage. Potential drawbacks of opening the spillway notch include possible injury or mortality of fish migrating over the spillway due to lower volumes of water passing through the spillway when water is flowing only through the notch, and less water available for summer releases to sustain rearing fish downstream if the notch is kept open for the entire migration season.

The Boughton and Ohms (2022) study modeled the effect of different Carmel River flow scenarios on steelhead parr survival and mean length, as well as on adult returns. In the first part of the study, generalized additive regression models were fit to approximately 30 years of fish data, including spawner counts from San Clemente and Los Padres dams and fall electrofishing parr densities, fork lengths, and channel wetted widths, to create a “parr model” that could predict how stream flow affected wetted area, parr density, and parr size at the end of the dry season. Next, a linear regression model (the “spawner model”) was used to predict adult returns using data from the parr model (specifically, parr abundance and size at the end of the dry season 2 and 3 years prior). The parr model and spawner model were calibrated to the historical baseline, consisting of flow data from the past 30 years in which the water right allowing annual extraction of 3,376 acre-feet was routinely exceeded. Results of the parr model suggest that spring low-flow was the best predictor of parr length, with higher spring low-flows resulting in larger parr lengths. Larger parr lengths are inversely correlated to density due to a process called self-thinning, in which larger fish defend larger territories, forcing smaller fish to seek out new territories or perish, and therefore resulting in lower fish densities. Summer median flow was the best predictor of parr density, with higher summer flows leading to a greater wetted habitat area, allowing fish to disperse and resulting in lower parr densities. Results of the spawner model suggest that parr size and abundance in a given year were correlated with spawner abundance 2 to 3 years later, with larger parr and/or a greater number of parr resulting in a greater number of spawners.

In the second part of the Boughton and Ohms (2022) study, the parr model and spawner model were run through five alternative flow scenarios to predict the effects of these flow scenarios on adult production relative to the historical baseline. The five alternative flow scenarios included an unimpaired scenario (no dams or water extraction by water company); a Los Padres Dam removal scenario (no dams, 3,376-acre-foot water right exercised); a scenario similar to the historical baseline except the annual 3,376-acre-foot water right was not exceeded; and two Los Padres dredge scenarios that would expand the water right to either 3,906 or 4,492 acre-feet per year. In all of these scenarios, population response was sensitive to infiltration conditions in the lower valley; the lower valley can support large parr, which have a better chance of surviving ocean conditions and returning to spawn as adults, but is vulnerable to loss of surface flow. If water infiltration in the lower valley was low, all of the alternative flow scenarios resulted in greater adult steelhead returns compared to the historical baseline. If water infiltration in the lower valley was high, then all alternative flow scenarios except one (the dam removal alternative) still resulted in greater adult steelhead returns compared to the historical baseline, although the increase in adult returns was smaller than if infiltration in the lower valley was low. If water infiltration in the lower valley was high, then the dam removal scenario resulted in slightly lower adult steelhead returns compared to the historical baseline because production in the upper watershed would increase, but it would be outweighed slightly by poorer production downstream due to lower summer flows. Because flow was the only variable in the model that represented steelhead habitat, other factors that would affect steelhead production were not accounted for. The model did not account for some benefits of dam removal on steelhead, such as improved upstream passage for adults and improved habitat conditions due to the restoration of sediment transport processes.

Various Geomorphic Data and Studies

For a summary of other studies reviewed, considered, and in some cases incorporated into the LP Alternatives Study, see Section 2.8 in Appendix A. The summary there includes additional, past geomorphic analyses of the Carmel River, past analyses of fire effects, active channel data, and previous sedimentation rates and reservoir trap efficiency.

1.4 Document Organization

This report is organized into the following sections:

- **Section 1: Introduction** provides the purpose and scope of the study, an overview of the LP Alternatives Study process, background information including a description of related studies, the organization of the report, and limitations.
- **Section 2: Existing Conditions** provides a summary of existing conditions associated with structures, physical, and biological conditions that are pertinent to the development of the alternatives presented herein.
- **Section 3: Technical Analyses** provides a description of technical analyses relied upon during development and analysis of the alternatives herein.
- **Section 4: Alternatives Development** provides a description of the framework used to develop and evaluate alternatives, the evolution of the alternatives over the course of the LP Alternatives Study, and alternatives and options eliminated after initial development.
- **Section 5: Dam, Reservoir, and Sediment Management Alternatives** provide overviews of each of the two remaining alternatives, describing key components, construction estimates,

operations and maintenance (O&M) considerations, sediment effects, effects to steelhead, uncertainties, and advantages and disadvantages.

- **Section 6: Cost Opinions for Alternatives** provides a description of the basis for cost development and a summary of estimated costs.
- **Section 7: Discussion** provides a comparison of key evaluation factors across the alternatives proposed for further consideration, highlights outstanding uncertainties, notes preferences and recommendations of the TRC and stakeholders, and indicates conclusions and next steps.
- **Section 8: References** provides a list of references from the main body of this report.

This report includes the following TMs and meeting records by reference as appendices under separate cover:

- Appendix A Study Preparation Technical Memorandum (AECOM 2017a)
- Appendix B Alternatives Descriptions Technical Memorandum (AECOM 2017b)
- Appendix C Revised Sediment Characterization Technical Memorandum (AECOM 2018)
- Appendix D Sediment Effects Technical Memorandum (Balance Hydrologics and UBC Geography 2019)
- Appendix E Effects to Steelhead Technical Memorandum (AECOM and Stillwater Sciences 2022)
- Appendix F Alternatives Development Technical Memorandum (AECOM 2022)
- Appendix G Technical Review Committee Meeting Records

1.5 Limitations

This work was performed in a manner consistent with that level of care and skill ordinarily exercised by other members of the engineering profession practicing in the same locality, under similar conditions and at the date the services are provided. The conclusions, opinions, and recommendations in this final report are based on a limited number of observations and data. It is possible that conditions could vary between or beyond the data evaluated. AECOM makes no other representation, guarantee, or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided.

Some background information and other data used by AECOM in preparing this TM have been furnished by third parties. AECOM has relied on this information as furnished and is neither responsible for, nor has confirmed, the accuracy of this information.

Conceptual or planning-level alternatives are uncertain by nature, given the typical lack of sufficient design parameters and analysis available during the planning phase. Although this TM strives to address key uncertainties related to feasibility and cost, additional investigation, analysis, and design are needed to adequately address the uncertainties. Analyses and results presented in this TM are for the current study only and should not be extended or used for any other purposes.

2. Existing Conditions

Existing conditions relevant to the LP Alternatives Study were initially described in the 2017 Study Preparation TM (Appendix A). As the overall study progressed, this information was relied upon for various analyses, and in some cases updated with more recent information. This section summarizes the most recent understanding of existing conditions relevant to the analyses and considerations that informed the development of the alternatives presented in Section 5 of this report. In some cases, additional information can be found in the Study Preparation TM.

2.1 Coordinate System and Datum

All elevations referenced in this report are given in feet, NAVD88, unless otherwise noted. The conversion from National Geodetic Vertical Datum of 1929 (NGVD29) to NAVD88 is approximately +2.9 feet (National Oceanic and Atmospheric Administration [NOAA] National Geodetic Survey Coordinate Conversion and Transformation Tool [NOAA 2022]) near LPD. HDR et al. 2021 assumed an average conversion of +2.68 feet because their study area included a larger reach of the Carmel River. The horizontal coordinate systems used for geographic information system and computer-aided design data, figures, and drawings are referenced to California State Plan, Zone IV, North American Datum of 1983 (U.S. feet), unless otherwise noted.

2.2 Topography and Bathymetry

The following data sets were available as part of the LP Alternatives Study:

1. **1947 Topographic Map.** Pre-dam topography was surveyed in 1947 and was available as a scanned as-built drawing sheet depicting 10-foot elevation contours, thalweg lines of Carmel River and Danish Creek, section lines, and a graph of area and capacity curves. The area covered by this survey extends from approximately 500 feet downstream of LPD, with a lower elevation of 900 feet (NGVD29) to approximately 3,600 feet upstream of the original pool extent. This survey extends to an upper elevation of 1,150 feet (NGVD29).
2. **2010 Light Detection and Ranging (LiDAR)) Topography – United States Geological Survey (USGS) Coastal California LiDAR.** The minimum contour interval, based on the vertical accuracy of the survey, is approximately 1 foot in areas not obscured by vegetation.
3. **2016 Bathymetric/Topographic Survey – HDR.** The 2016 bathymetric survey was not used for this TM due to inaccuracies in the data. The 2016 HDR topographic survey used the publicly available 2010 USGS LiDAR, reprocessed by HDR from the reservoir level up to elevation 1,092.9 feet, to address extensive classification errors (HDR 2016).
4. **2017 Bathymetric Survey – California State University, Monterey Bay (CSUMB).** These data were obtained June 3, 2017.
5. **2017 Unmanned Aerial System (UAS) Survey – USGS Pacific Coastal and Marine Science Center.** These data were obtained November 1, 2017, by UAS structure-from-motion photogrammetry. This survey captures the segment of the shallow upper reservoir, above elevation 1,040 feet, that the 2017 bathymetric survey vessel could not reach at the time of data collection. The UAS survey also captures an additional 2,100-foot segment of upland topography along the Carmel River before terminating roughly 500 feet downstream of the confluence with Danish Creek.
6. **2020 Bathymetric Survey – HDR.** This bathymetric survey was conducted by Bay Marine Services 2020 in support of HDR's design of the LPD outlet modifications drawings. The survey was concentrated around the proposed location of the new low-level outlet near the dam.

2.3 Los Padres Dam

LPD was built in 1948 and is currently owned by Cal-Am. Property immediately surrounding the dam and reservoir is owned by Cal-Am (Figure 2-1). The dam forms a 148-foot-high earth-fill barrier along the river and includes a 600-foot-long concrete spillway with an apron that spills water over a drop into the Carmel River. Although fish passage facilities are in place and operational, the dam and reservoir are a known fish passage impediment for both upstream and downstream migrating S-CCC steelhead, and impact downstream habitat for steelhead by blocking the natural sediment supply. This section includes descriptions of LPD, LPR, and the contributing LPD subwatershed.

2.3.1 Dam and Spillway

LPD is on the Carmel River approximately 7.5 miles southeast of Carmel Village, and 26 RM upstream of the Carmel River mouth. The dam was constructed from 1948 to 1949 by Macco Construction Company for the California Water and Telephone Company. The dam came under the ownership of Cal-Am in 1966. The original purpose of the dam was primarily to provide water storage for municipal and domestic supplies for the Monterey Peninsula. Currently, flow releases are made from the reservoir for water supply downstream and to regulate and maintain flows in the Carmel River during the dry season. Key features and data of note are presented below.

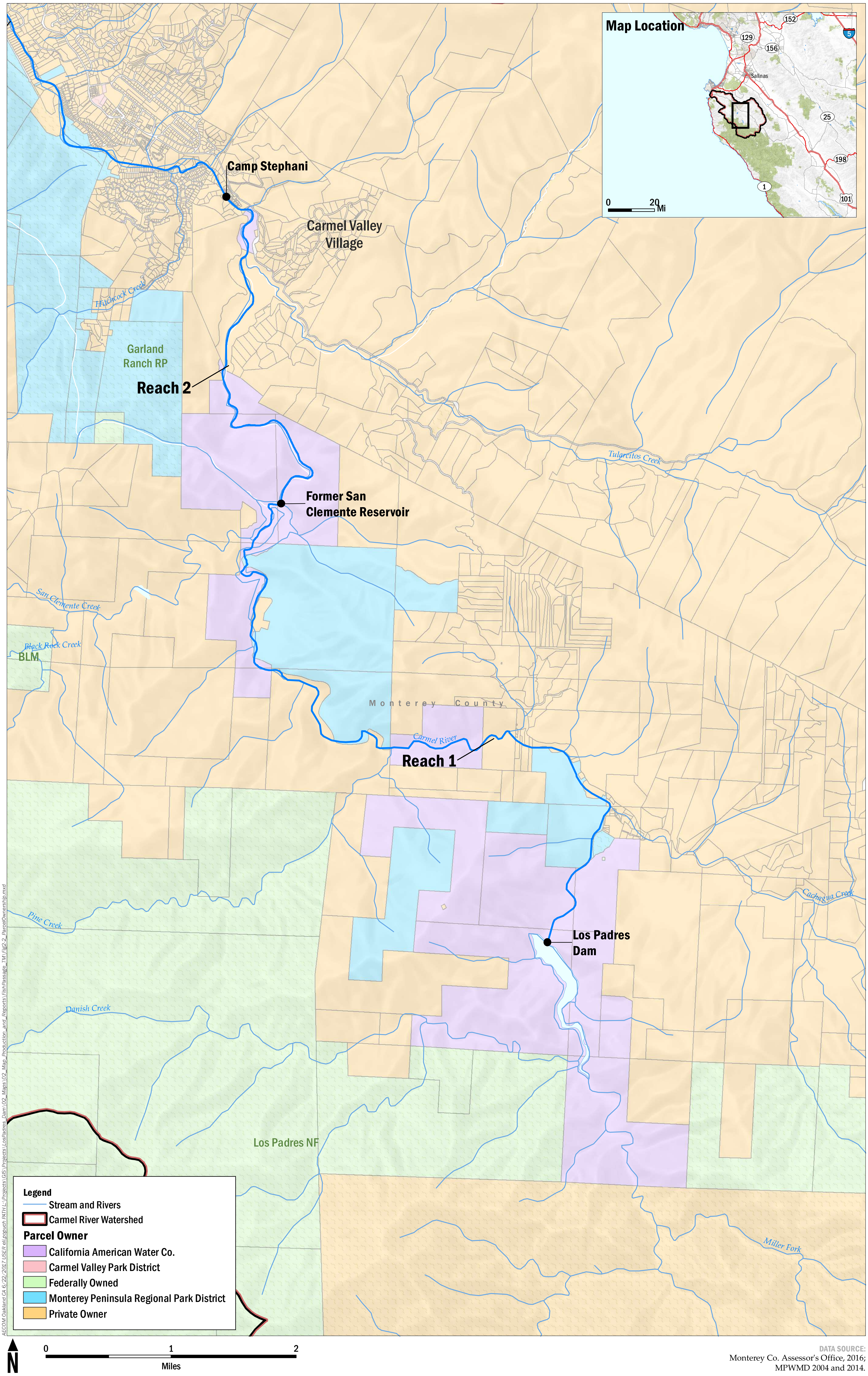
Foundation. As described by the California Department of Water Resources, DSOD (1980a), the downstream three-quarters of the dam foundation and extreme upstream toe were founded on bedrock (Figure 2-2). The rock at the right (eastern) abutment is granitic, with predominantly vertical jointing. One 4-foot-wide bedrock fault on the lower right abutment, containing an approximately 2-inch-wide gouge zone, was treated by excavating a shaft and backfilling with concrete to form a concrete plug. The rock at the left abutment is weathered mica schist and gneiss intruded by granitic rock. The contact between the mica schist and gneiss with the granitic rock is, in part, a 4-foot-wide faulted zone extending both upstream and downstream along the lower left abutment that has been partially healed by intrusive dikes. The rock in the channel section consists largely of extensively sheared and folded gneiss and mica schist. Portions of the rock foundation were grouted during construction. The right abutment foundation of the dam is topographically complex in that it includes an old stream channel separated from the main channel by a ridge with a top elevation of 1,013 feet that was uncovered during construction. The old stream channel drops to the right of the ridge, 50 feet down, to an elevation of 960 feet; and the main channel drops steeply to the left of the ridge, 100 feet down, to an elevation of 910 feet.

Embankment. The LPD embankment is a 148-foot-high, zoned, earth-fill dam with a crest length of 570 feet, a crest width of 12 feet, and a crest elevation that ranges from 1,060.0 to 1,060.6 feet (HDR et al. 2021) (Figure 2-3). The original design crest elevation was 1,060.9 feet. The upstream face slopes are 1.5H (horizontal):1V (vertical) for the uppermost 10 feet of the embankment, and 2.35H:1V below. The downstream face slopes are 2H:1V for the uppermost 10 feet, and 2.25H:1V below. As shown on Figure 2-4, the dam consists of seven zones (DSOD 1980a):

- Zone 1 (dam) and Zone 2A (upstream cofferdam) impervious embankment. Impervious embankment materials were variously described in compaction tests during construction as “sandy soil,” “organic soil,” “sandy loam,” or “sandy organic soil.”

- Zone 2 (dam). Zone 2 is a 12-foot-thick, free-draining, reasonably well-graded, clean sand, gravel, and crushed or broken rock, with a maximum particle size of 6 inches.

- Zone 3 (upstream zone). Zone 3 is a pervious upstream shell material consisting of 6-inch minimum to 1-cubic-yard maximum size cobble, boulders, and rock.



DATA SOURCE:
Monterey Co. Assessor's Office, 2016;
MPWMD 2004 and 2014.

AECOM

Monterey Peninsula Water Management District

Los Padres Dam and Reservoir Alternatives and Sediment Management Study

FIGURE 2-1

Parcel Ownership

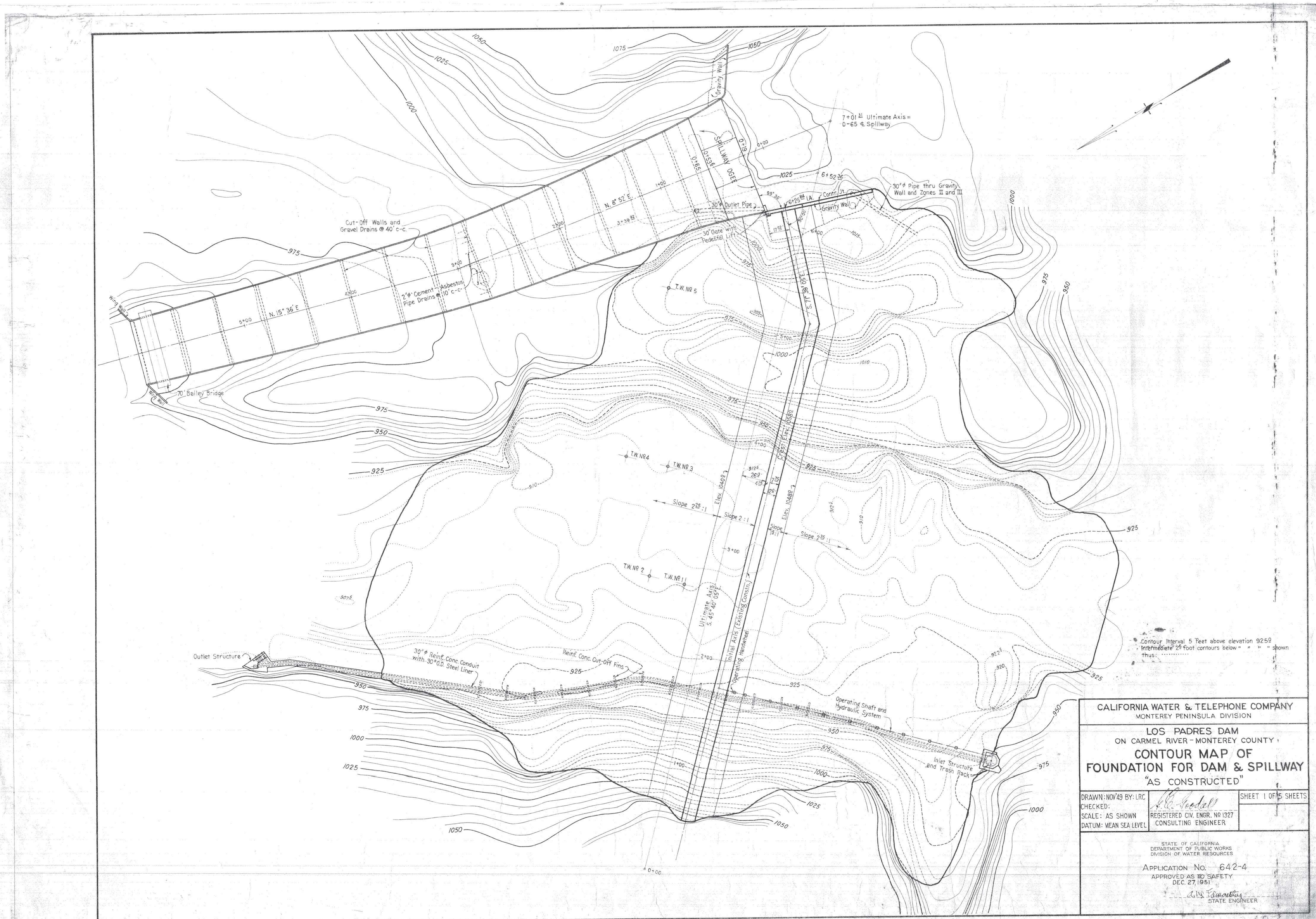


Figure 2-2

Los Padres Dam – Contour Map of Foundation for Dam and Spillway as Constructed

Figure 2-3 Downstream Face of the LPD Embankment

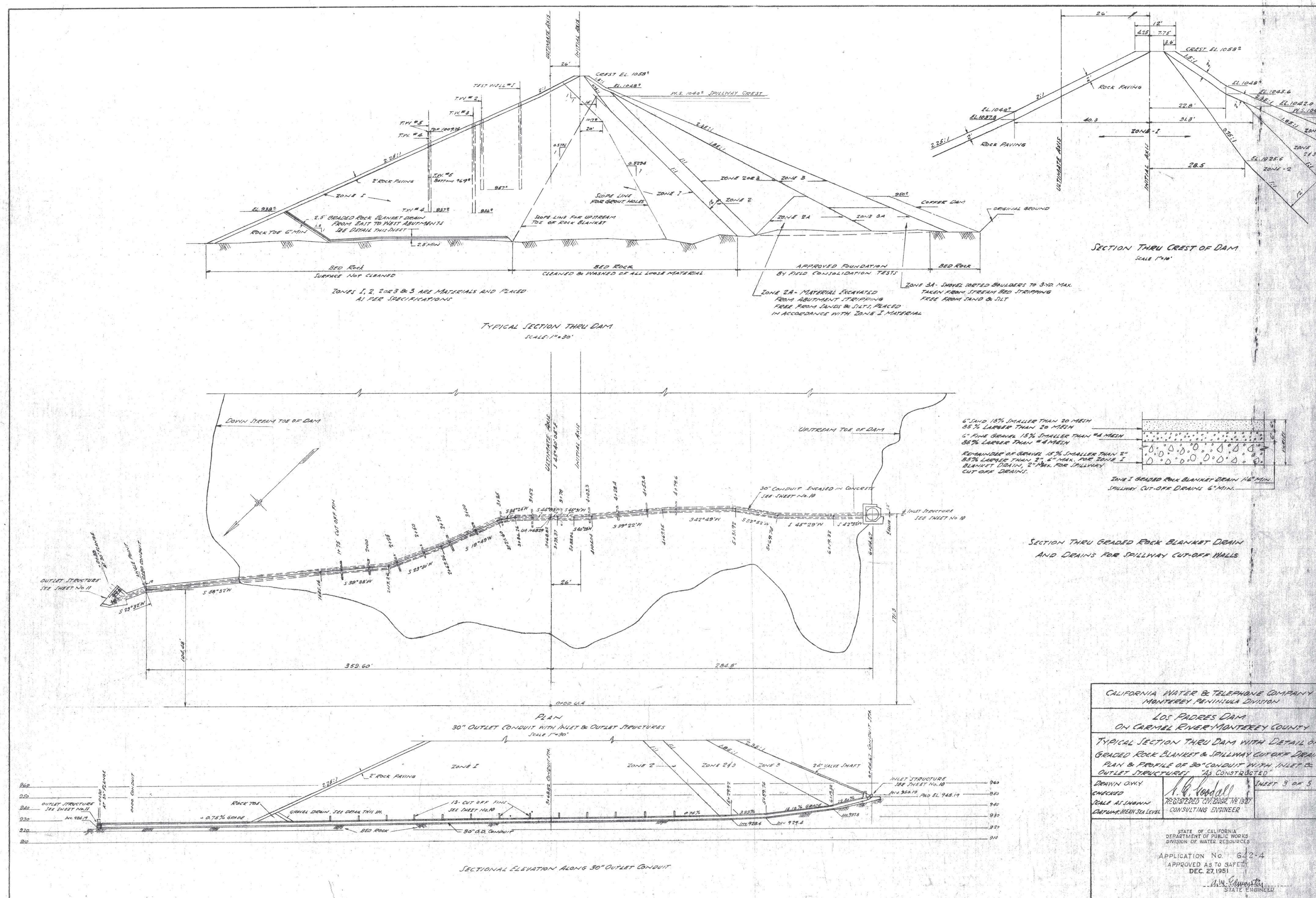


Figure 2-4
Los Padres Dam – Typical Section of Dam as Constructed

- Zone 3A (upstream rock toe). Zone 3A consists of boulders up to 3 CY in size, free of sand and silt.

- Gravel Drain (downstream blanket). The downstream blanket consists of an 18-inch-thick free-draining gravel placed on the bedrock foundation underlying a 6-inch-thick layer of fine gravel underlying a 6-inch-thick sand layer.

- Rock Paving and Downstream Rock Toe. These zones consist of 6-inch minimum size material for the rock toe and 200-pound maximum size for rock paving.

Spillway. The spillway consists of a 108.7-foot-wide ungated ogee crest section that ranges in elevation at the crest between 1,042.7 and 1,042.9 feet; and a 580-foot-long spillway chute that has upper and lower straight sections, with a transitional curved and super-elevated section between them (Figure 2-5, Figure 2-6). The curve in the spillway alignment was required to avoid the old stream channel found during construction at the right abutment described above. The width of the spillway chute varies from 98 feet where it joins the ogee crest section, to 59 feet at its lower end. The walls on either side of the ogee crest consist of an approximately 28-foot-high gravity wall on the right (eastern) side, and an approximately 45-foot-high gravity wall on the left (western) side. Flows discharge from the end of the spillway chute (elevation 951.67 feet) into a deep erosion hole (approximate bottom elevation of 900 feet) that formed below the end of the chute following construction. The spillway was modified in 1994 or 1995 to provide better fish passage across the ogee crest when flows across the spillway are low. According to DSOD's Memorandum of Design Review (DSOD 1993), the modifications included a 9-inch-deep, 3-foot-wide notch near the right side of the spillway crest, with notches in the sides to allow the placement of stop logs. A vehicle railcar bridge currently spans the concrete spillway toward the downstream end.

Figure 2-5 Los Padres Dam Spillway Looking Upstream from the Bailey Access Bridge

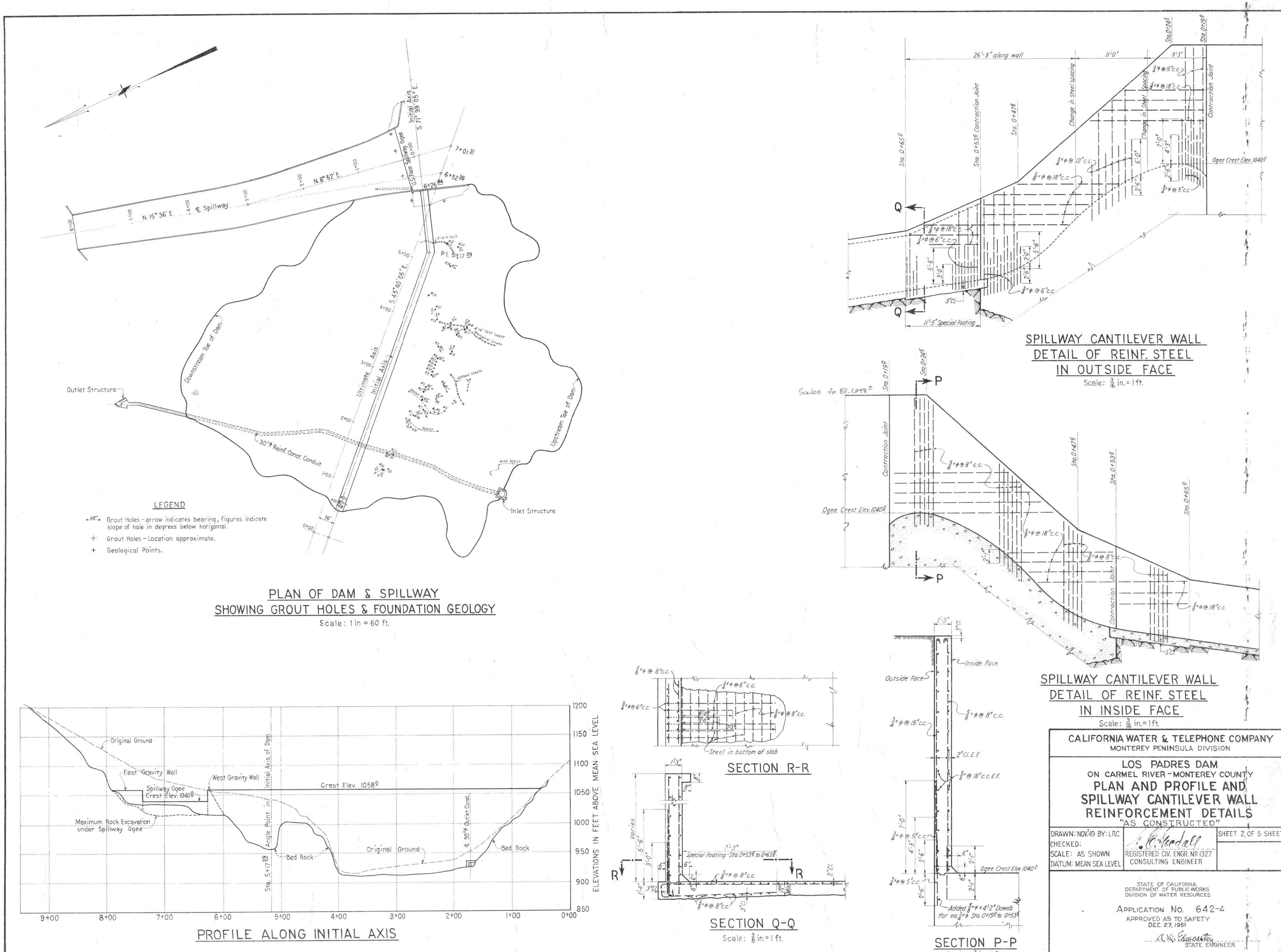


Figure 2-6

Los Padres Dam – Plan and Profile and Spillway Cantilever Wall Reinforcement Details as Constructed

Outlet Works. There is a low-level outlet works and high-level outlet works, as described below. The original outlet works was designed for combined operation of the low- and high-level outlets to allow the reservoir to be drained to 50 percent of the original storage in 7 days (DSOD 1980a).

a. The low-level outlet works consist of a 30-inch-diameter pipe encased in reinforced concrete that penetrates through the western base of the dam (see Figure 2-2). The upstream invert of the outlet pipe is at an approximate elevation of 960 feet. A three-sided open-top intake structure equipped with a movable grated steel trash rack and a 30-inch hydraulically operated slide gate is situated at the upstream end of the outlet pipe. An array of release valves is present at the downstream end. A large valve exists to evacuate flow from the reservoir in an emergency release situation; smaller valves route flow to the existing adult fish collection facility and the bypass channel that unites downstream with the Carmel River. Water conveyed to the 12-inch supply branch discharges to both the fish trap and to a point about halfway up the Denil ladder to provide attraction flow for migrating adult steelhead. Water conveyed to the bypass channel provides instream flows when the downstream passage facilities and/or the fish ladder are not in operation (Figure 2-7). The actual flow capacity of the low-level outlet has not been verified. In the past, flow releases have typically been limited to 10 cfs, as measured at the river gage below LPD. Rockslides originating from the left bank of the reservoir occurring in 2018, 2019, and 2020 have covered the existing lower outlet with mud, rock, and debris, and reduced its overall reliability and capacity. Despite several attempts by divers contracted by Cal-Am to investigate and clear debris from the trash rack, the capacity of the lower outlets remains diminished. Throughout the summer of 2021, the lower outlet had only been able to convey between 1 and 3 cfs downstream of the dam (HDR et al. 2021). A new low-level outlet is currently under design and will equal or exceed the designed capacity of the original outlet works. The proposed invert of the new low-level outlet is at an elevation of 981.8 feet.

b. The high-level outlet works consist of a gated 30-inch-diameter concrete-encased outlet pipe through the left side of the spillway ogee crest. The pipe terminates at the spillway chute floor, where it meets the downstream end of the ogee crest. The slide gate is controlled by an operating shaft connected to a hand wheel at the top of the right abutment gravity wall. The invert of the slide gate is at an elevation of 1,020 feet, approximately 23 feet below the spillway crest. The high-level outlet works is no longer used, having been replaced by the outlet associated with the fish diversion structure described below.

Reservoir Siphon. The siphon and pertinent infrastructure were installed in 2021 as a temporary water supply strategy to restore flow to the existing adult fish collection facility and maintain downstream flow in the Carmel River while the capacity of the low-level reservoir outlet is being restored. The siphon consists of a 16-inch-diameter high-density polyethylene pipe, debris rack, priming branch, and connection to the existing upstream trap water supply pipe gate valve. The siphon pipe is attached to the western wall of the spillway and supplies surface water from LPR, down the interior of the existing spillway, to the existing low level outlet discharge piping. The siphon inlet is at an elevation of 1,002 feet; a minimum 3 feet of water depth is required above the debris rack. As the reservoir approaches elevation 1,005 feet, the flow reduces and thus the lower limit of operation is at about elevation 1,010 or 1,011 feet. Although the siphon can produce up to 19 cfs, a throttling valve near the bottom of the siphon can reduce flows down to 2 cfs (HDR et al. 2021).

2015 Fish Diversion Structure. A fish diversion structure was constructed in the upstream approach to the spillway ogee crest in 2015. The diversion structure is a FWC and consists of a 2-foot-wide overshot ramp gate on a floating barge. After flow passes over the weir, it enters an 18-inch-diameter pipe that discharges at the downstream end of the dam's tailrace pool. The FWC has a capacity of approximately 10 cfs but can be increased to approximately 15 cfs with the adjustment of ballast.

Figure 2-7 Photograph of the Outlet Discharging into the Bypass Channel Downstream of LPD

2.3.2 Maintenance and Modifications

Significant maintenance or modification of the dam and its appurtenant structures that was noted in our review of the data for the dam is described in the following paragraphs.

Maintenance and modification activities of note include the following:

- 1951 Additional Grouting at Left Abutment – Additional grouting was performed in the left abutment in 1951 to reduce significant seepage through the left abutment that was observed in 1949 during initial filling of the reservoir (DSOD 1980a).
- 1958 Slide in Right Side of Downstream Shell – In April 1958, a small shallow slide on the right side of the downstream shell occurred following about a week of heavy rain totaling about 9 inches. The slide was about 110 feet wide and 85 feet long in plan (DSOD 1958). The slide was repaired by installing a drain system, consisting of an approximately 160-foot-long, 3-foot-deep by 3-foot-wide trench with a 6-inch-diameter perforated asphalt-dipped pipe surrounded by gravel backfill in the area of the toe of the slide, and ballasting the lower half of the slide with a covering up to 12 feet thick of large rock.
- 1985 Spillway Modification – The spillway was modified in September 1985 to improve fish survival off the end of the spillway chute (DSOD 1993). The modifications included construction of a steel apron at the end of the chute to direct fish into the pool under the end of the chute, and blasting of some rock below the steel apron.

- 1992 through 1995 Spillway Modification – The spillway was modified to provide better fish passage across the ogee crest when flows across the spillway are low. The modifications included making a small notch, which—based on DSOD's Memorandum of Design Review (DSOD 1993)—was to include a 9-inch-deep, 3-foot-wide notch near the right side of the spillway crest with notches in the sides to allow the placement of stop logs. In 1994, the depth of the notch was modified with a concrete pour (Highland, CDFW, pers. comm. 2017). A section of bedrock below the spillway extension was removed with explosives in 1995 to allow downstream migrants to fall directly into the plunge pool instead of impacting on the rock.

- 2003 and 2005 Dam Crest Maintenance – The spillway crest was raised approximately 1.5 feet in January 2003, and widened to a minimum of 12 feet in September 2005 (DSOD 2006). The work to restore the dam crest to the design elevation and width was required to address settlement of the crest that occurred after construction.

- 2015 Fish Diversion Structure – A fish diversion structure was constructed in the upstream approach to the spillway ogee crest during 2015. The fish diversion structure includes the following features (DSOD 2015b):

    - A behavioral guidance system (BGS) consisting of multiple 10-foot-deep, 20-foot-wide steel panels supported by floaters that stretch diagonally across the approach channel from the upstream right side of the channel downstream to the FWC at the left side of the approach channel, 50 feet upstream of the ogee crest. The BGS guides fish toward the FWC and is designed to disengage during a 25-year event (DSOD 2015b) to not block the spillway during larger flows.

    - The FWC, which has a floating weir that supports a truss and 18-inch-diameter pipeline supported by four concrete-encased steel pipe piles drilled and embedded in rock that allows fish to pass from the BGS toward the spillway.

    - An upstream debris boom that provides protection to the BGS and FWC.

    - An 18-inch-diameter fixed pipeline that starts at the upstream face of the ogee crest, penetrates the crest structure, runs 125 feet in the spillway channel against the left wall supported on a shelf 2 feet above the spillway floor to spillway station 1+50, and then penetrates the left wall of the spillway and runs outside the spillway to the Carmel River to a point downstream of the plunge pool below the end of the spillway chute.

The impact of the fish diversion system to spillway capacity was evaluated by HDR (2012) and DSOD (2015a). Because the BGS is designed to disengage at flows greater than the 100-year event, the impact to passage of the probable maximum flood (PMF) was determined to be minimal.

2.3.3 Dam Surveillance

Dam surveillance instrumentation at LPD includes five test wells on the downstream slope of the dam, two 6-inch Parshall flumes measuring seepage, and six survey monuments along the crest of the dam. Four of the five test wells (Test Wells 1 through 4) and the two flumes are generally measured daily during the work week. The fifth test (Test Well 5) began to be measured again at a less frequent rate starting June 2014. The survey monuments are measured once every 2 years. The last survey reviewed was made on September 10, 2013 (Cal-Am 2015).

2.3.4 Dam Safety Considerations

The Federal hazard classification for LPD is high, and the total class weight for the dam is 32 (out of a maximum of 36) given its height, storage capacity, and the communities of Cachagua, Carmel Village, and Carmel downstream of the dam. Based on the data reviewed, the dam and its appurtenant works appear to be performing satisfactorily (DSOD 2015a). Alternatives for LPD will be reviewed by DSOD for their potential impact to dam safety. The areas of review could include the following:

- Proposed facilities that would directly impact the dam or its appurtenant structures and their interaction with the dam during normal operations, during extreme flooding conditions, or during a seismic event.
- Proposed facilities that have the potential for resulting in erosion of the dam if such facilities were to fail during normal operations, during extreme flooding conditions, or during a seismic event.
- Proposed facilities that could reduce the capacity of the spillway.
- Proposed facilities that have the potential for reducing the capacity of the spillway if such facilities were to fail during normal operations.

Hydrologic analyses that have been performed for the dam indicate that the ability of the spillway to pass the hydrometeorological report (HMR) 36 derived PMF is marginal (DSOD 2015b). See Section 3.3 for additional information regarding the PMF and updated PMF analysis.

2.3.5 Geologic Considerations

The rock at the right (east) abutment is granitic rock with predominantly vertical jointing (DSOD 1980a). The rock at the left (west) abutment is weathered mica schist and gneiss intruded by granitic rock. The contact between the mica schist and gneiss with the granitic rock is, in part, a 4-foot-wide faulted zone extending both upstream and downstream along the lower left abutment that has been partially healed by intrusive dikes. Much of the rock in the channel section is extensively sheared and folded gneiss and mica schist. The bedrock on the left (west) and right (east) banks above and downstream of the dam are surface masked by colluvium and debris slides of varying thickness.

Bedrock in the spillway approach and upstream of the spillway crest is very hard, fractured gneiss and/or schist, based on logging of 15 piers installed up to 15.5 feet into bedrock for the Downstream Fish Passage Project in 2015. Where the bedrock could be observed, joints and fractures were described as having a spacing of 4 inches to 2 feet, with tight to extremely narrow apertures and without healing (HDR et al. 2021).

Rockslides have occurred along the reservoir canyon walls directly across the lower reservoir from LPD in 2018, 2019, and 2020. The failed slope is mostly composed of severely fractured and sheared weathered schist cut by granitic intrusions that is part of a larger ancient deep-seated bedrock landslide. The rock that is failing out of the steep slope above the reservoir is so severely sheared that it now behaves mechanically more like a breccia than like a body of schist bedrock (Zinn Geology 2021).

2.3.6 Fish Passage

In 1984, Cal-Am modified the LPD spillway with the addition of a concrete curb in the lower 200 feet of the spillway (Figure 2-5), added a 16-foot steel extension to the end of the spillway, and removed bedrock from the right bank of the downstream plunge pool. These improvements were intended to concentrate downstream passage of fish to the right side of the spillway, improve hydraulic depth, and to direct fish away from the bedrock at the end of the spillway and into the plunge pool.

About 250 feet downstream of the dam on the left bank, a Denil ladder (Figure 2-8) is in operation which allows upstream migrating steelhead to ascend into a small trapping facility (Figure 2-9). Steelhead are transferred from the trapping facility to a truck via water-to-water transfer, transported upstream of the dam crest, and released in the reservoir. Until rockslides occurring in 2018, the existing adult collection facility functioned well for the current size of the annual migration. It appeared to provide acceptable conditions for holding small numbers of adult fish over short periods of time while the water-to-water transfer methods have been acceptable for operations with the low daily numbers of fish observed to date. Observers and members of the TRC have questioned the effectiveness of the current ladder structure and ability to access the holding gallery within the trapping facility at lower flows between 20 and 40 cfs[5].

[5] Members of the TRC and Consultant Team participate in bi-weekly calls to discuss current operations and revisions to the existing fish passage facilities. Observations from the public, concerns with the ladder entrance, and overall effectiveness of the existing facility are discussed regularly among all participants and documented via informal meeting notes.

Figure 2-8 Denil Type Fish Ladder and Auxiliary Water Supply Pipe Below Los Padres Dam

Figure 2-9 Trapping Facility and Water Supply Pipe from the Reservoir Low-Level Outlet

Water for the existing adult collection facility and fish ladder can be provided by three separate sources: a cross-connection branch to the low-level reservoir outlet; the reservoir siphon installed in 2021, and a cross-connection branch with the juvenile bypass pipe which can only be used when the FWC is not providing downstream fish passage. Water suppling the fish collection facility is conveyed to two locations: the fish trap; and to a point about halfway up the Denil ladder to provide attraction flow for migrating adult steelhead. After the rockslides occurring in 2018, flow to the adult collection facility via the low-level reservoir outlet has been diminished and unreliable, emphasizing the need for redundant systems and ability to supply water from multiple sources.

In addition to the LPD spillway, a FWC upstream of the spillway provides downstream passage for out-migrating juvenile and adult steelhead (Figure 2-10). The FWC includes a gravity fed, 30-foot-long by 22-foot floating collection barge fixed into horizontal position on four steel pilings. An articulated pipe bridge support structure connects to the spillway face which allows for a vertical floatation range of approximately 10 feet. Water and fish that enter the collector are conveyed downstream via a 1,100-foot-long steel fish bypass conduit to a release point approximately 175 feet downstream of the spillway (Figure 2-11). A fish guidance system is located at the collector inlet which consists of a linear array of floats which support 10-foot-tall steel panels that hang vertically in the water column. A debris boom with 2-foot debris screens exists upstream of the fish guidance system to help exclude debris from entering the fish bypass system.

Figure 2-10 Floating Weir Collector for Downstream Fish Passage at Los Padres Dam

Figure 2-11 Fish Bypass Outfall Downstream of Spillway Plunge Pool and Fish Ladder

2.3.7 Operation and Flow Augmentation

LPD operates under periods of unregulated spill and active outlet control dependent upon existing and anticipated annual water conditions. Spill occurs any time pool elevations exceed the elevation of the existing ogee spillway crest (1,042.78 feet [NAVD88]). In this scenario, inflow is typically equal to outflow except for operational flows which are used for the existing smolt bypass facility, fish ladder, and adult trap facilities. Operational flows for the existing fish facilities typically equate to a combined total of 10 to 20 cfs, which is conveyed through both surface water (FWC and reservoir siphon) and the low-level outlet. Spill generally occurs between December and June with only a few documented occurrences as early as October or November. The active outlet control scenario occurs anytime pool elevations decrease below 1,042.78 feet (NAVD88). During periods of active outlet control, flow downstream of LPD is governed by the operational requirements of the existing fish passage facilities as agency regulated targets set by committee for each individual water year. Figure 2-12 illustrates the various flow pathways which may occur during passive spill or active outlet control scenarios.

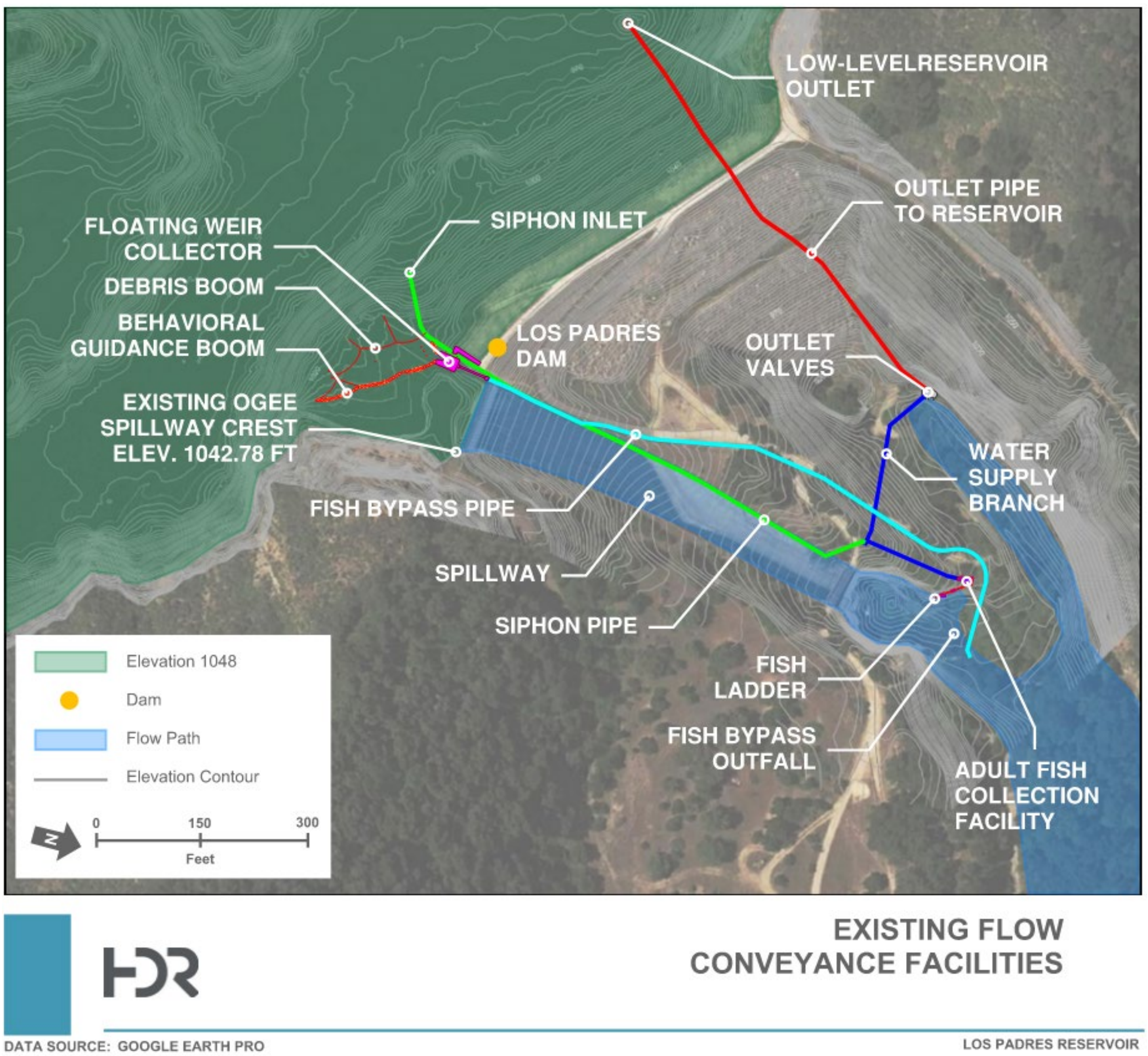


Figure 2-12 Illustration of Los Padres Dam Flow Conveyance Facilities

CDFW has a duty to protect fish and wildlife resources of the State of California. The MPWMD, pursuant to its rules and regulations, establishes a water supply strategy and water budget for the Monterey Peninsula. Cal-Am supplies water to the Monterey Peninsula and must comply with SWRCB Order 95-10, as amended. CDFW, MPWMD, and Cal-Am have a mutual objective to maximize surface flow in the Carmel River to the extent feasible from June through December each year. CDFW, MPWMD, and

Cal-Am therefore enter into an MOA each year which provides anticipated flow releases based upon actual and projected Carmel Valley rainfall, runoff, storage, and production needs, with the intent of enhancing fishery habitats in the lower Carmel River. This is achieved by establishing a minimum storage pool at LPR and establishing a rate and schedule for the release of flows downstream of LPD. The actual rate of drawdown is monitored and the schedule for releases can be modified through facilitation of low-flow subcommittee meetings which occur on an as-needed basis throughout the operational season.

Order 95-10 states that the minimum bypass flow of 5 cfs measured just downstream of the dam shall be maintained when active storage is present in the LPR. In practice, low flow rates vary depending on seasonal rainfall, and typically range between 3 and 8.5 cfs between May and December below LPD when spill at the LPD spillway is no longer present. In 2004, a minimum pool at Los Padres was set at elevation 983 feet (NAVD88), or approximately 91 AF of storage; however, an attempt is made each year to limit pool reduction at LPR down to 1,003 feet (NAVD88). Slope instability and entrainment of debris and sediment have been known to occur when pool elevations are drawn down lower than 1,003 feet (NAVD88). These past infrequent events have occluded the low-level outlet and required special maintenance strategies to rectify.

In addition to Cal-Am pumping, there are a few surface diversions upstream of the former San Clemente Dam site and about 300 private wells in the Carmel Valley Alluvial Aquifer. Most of the non-Cal-Am pumping is not subject to SWRCB jurisdiction. MPWMD requires all non-Cal-Am pumpers to file annual production reports; collectively, these non-Cal-Am diversions total between 2,000 and 2,400 AFY, with about 60 percent of diversions occurring in the dry season (June 1 through November 30). Average annual outflow from the Carmel River watershed is about 72,000 AFY.[6] Median flow measured at Don Juan Bridge in Garland Park at RM 10.8 during the dry season is less than 3,700 AF,[7] whereas well production during the dry season has been reduced to approximately 1,940 AF in 2022. A portion of the lower river downstream of RM 8 has dried up in most years, which results in a cone of depression forming downstream of RM 8.

2.4 Los Padres Reservoir

The design plans for LPD show that LPR originally had a storage capacity of 3,030 AF, whereas the dedication plaque on the east abutment states 3,100 AF. The former number is usually cited, which coincides with the water right license for the dam (Cal-Am and MPWMD 2016). A study in 2009 (Smith et al. 2009) estimated the remaining storage at 1,786 AF, with reduced storage due to sedimentation in the reservoir; as shown below in Table 2-1 and described in detail in Appendix C, AECOM revised the original storage number to 2,720 AF and the remaining storage capacity to 1,601 AF, based on the latest available information.

Table 2-1 Reservoir Capacity

Description	As-Built Quantity (acre-feet)	Adjusted[1] End Area Approach Quantity (acre-feet)
Reservoir capacity at NMWS (1947)	3,030	2,720
Reservoir capacity at NMWS (2017)	—	1,601

Notes:

[1] Adjustment = 1,0247 x End Area Approach Quantity

NAVD88 = North American Vertical Datum of 1988
NMWS = normal maximum water surface (at spillway crest maximum elevation of 1,042.9 feet NAVD88)

Source: Appendix C

[6] Measured at the USGS near Carmel gauge for water years 1962 to 2015.
[7] MPWMD gauge data for water years 1993 to 2016.

AECOM used an adjusted end-area method to estimate sediment volumes (Appendix C). This method was extended to the reservoir capacity to derive a total reservoir capacity of 1,601 AF (in 2017), as summarized in Table 2-2. An updated stage-storage curve is summarized in Table 2-2 and depicted in Figure 2-13. These results do not take into account the left bank rockslides that occurred in 2018, 2019, and 2020, but a cursory review of bathymetry in that area suggests it would not significantly alter the stage-storage numbers.

Table 2-2 Reservoir Capacity Summarized by Water Surface Elevation

Elevation (feet, NAVD88)	Volumetric Capacity (acre-feet)
1,052.5 (optional future)	2,226
1,042.9 (NMWS)	1,601
1,037.90	1,358
1,032.90	1,132
1,027.90	931
1,025 (spillway reservoir terrace for offloading)	832*
1,022.9 (high-level outlet)	761
1,017.90	630
1,013.3 (Siphon lowest operating level)	530*
1,012.90	522
1,007.90	428
1,002.90	342
997.9	265
992.9	198
987.9	137
982.9	82
981.8 (proposed low-level outlet invert)	72*
977.9	39
972.9	10
967.9	0
962.9	0
953.13 (inoperable low-level outlet)	0
952.9	0

Notes:

* Estimated with linear interpolation

NAVD88 = North American Vertical Datum of 1988
NMWS = normal maximum water surface (at spillway crest maximum elevation of 1,042.9 feet NAVD88)

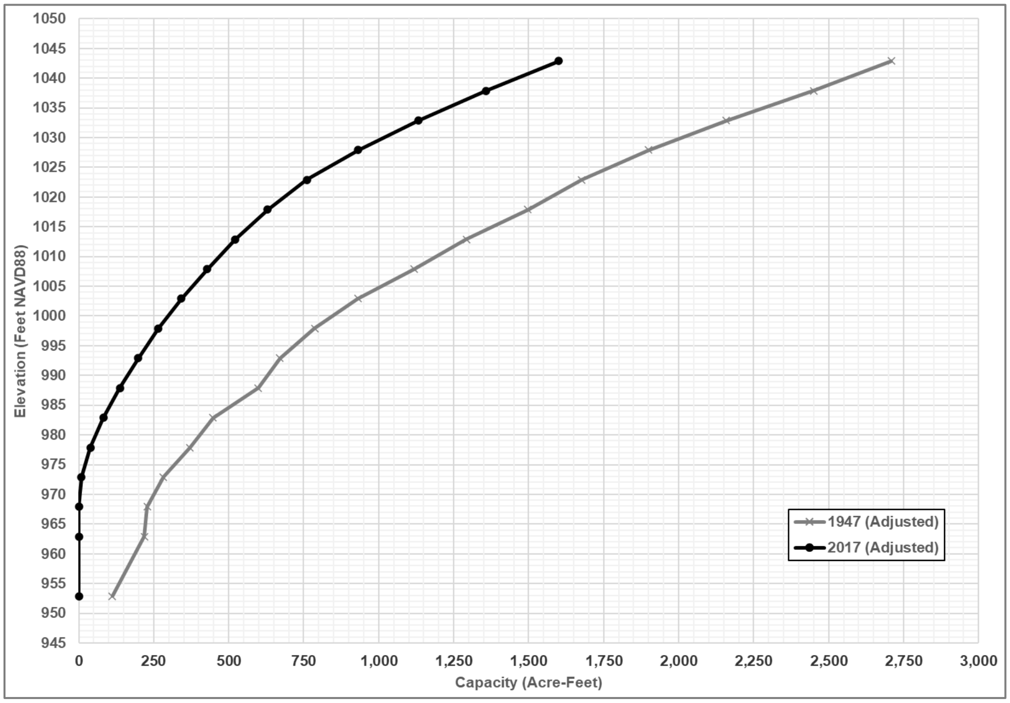


Figure 2-13 Los Padres Reservoir Stage-Storage Curve

Current reservoir storage is small relative to the median annual inflow (estimated at about 28,000 AFY), and the reservoir normally fills and spills each winter (Cal-Am and MPWMD 2016). Releases during periods of very low storage can be both warmer than incoming flow and anoxic (with low or no DO).

Stage data available from an automated stage recorder were plotted for water years 2002 through 2019 on Figure 2-14. Each year the reservoir drops below its spillway elevation during the dry season.

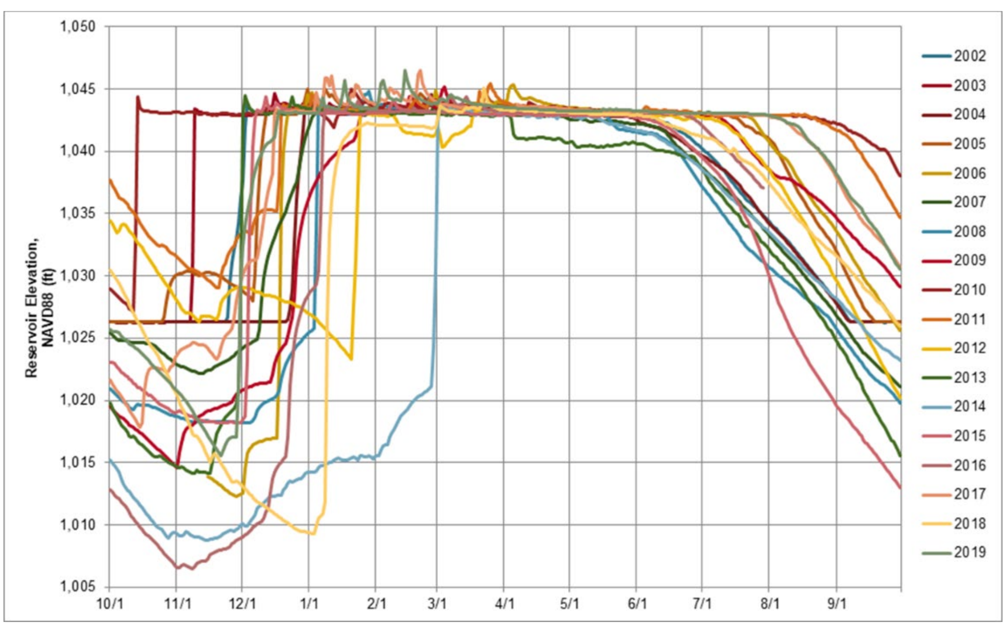


Figure 2-14 Los Padres Reservoir Elevations for Water Years 2002 through 2019

2.4.1 Accumulated Sediment

A significant component of the LP Alternatives Study was a focused study to obtain, analyze, and characterize the sediment accumulated in LPR. To investigate subsurface conditions of submarine sediment in LPR, soil borings were collected in 2017 using a drill rig mounted on a platform barge (Figure 2-15). The investigation also involved reconnaissance of the river channel and sediments stored upstream of the reservoir pool, including Wolman pebble counts and photo documentation of surficial sediments (Figure 2-16). Methods and results of the sediment characterization study, beyond those summarized in this section, are detailed in Appendix C.

The sediment stored in LPR is divided into three zones, based on stratigraphy and depositional environment:

- Zone 1 – the downstream pro-delta basin
- Zone 2 – the main delta body
- Zone 3 – upstream alluvial deposits

These zones are depicted in plan and profile view in Figure 2-17 and Figure 2-18. The alignment of the profile view (longitudinal section) follows the adjusted 1947 thalweg from the dam to Station 55+00, and the 2010/2016 thalweg upstream of Station 55+00. The boundary between the zones is complex due to variations in the reservoir level at the beginning of each water year, the rate at which the reservoir filled each water year, the wetness of each water year, and other factors such as soil availability for erosion following fires in the watershed.

The adjusted sediment volumes documented in Appendix C and the revised reservoir capacity described above are summarized in Table 2-3. These values were used to calculate an average sediment deposition rate in and directly upstream of the reservoir, and an average reservoir storage loss rate. The volumes in Table 2-3 incorporate sediment input resulting from the 1977 Marble Cone Fire and subsequent storm events. The volume of sediment deposited in the reservoir originating from the left bank rockslides occurring in 2018, 2019, and 2020 is not included in the sediment volume summary below, but is estimated to be less than 1 percent of the total impounded sediment.

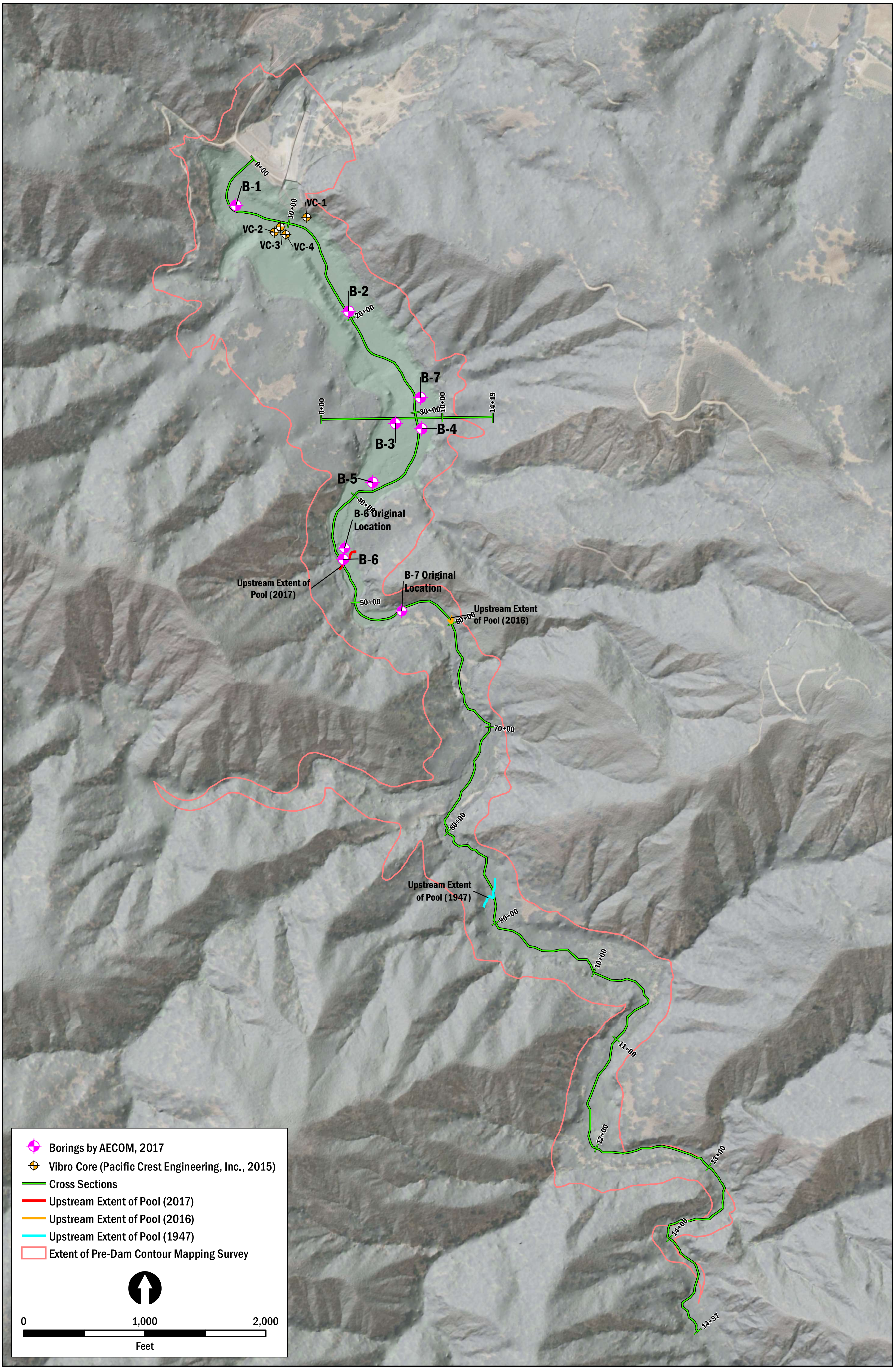
The calculation of the average sedimentation rate considers accumulated sediment volumes both above and below the normal maximum water surface (NMWS) of 1,042.9 feet. This rate was used to determine the Alternative 4 (Recover Storage Capacity with Excavation) goal for periodic removal of sediment, an alternative eliminated from further consideration (Section 4.3) to maintain the existing reservoir capacity.

Table 2-3 Estimated Sediment Volume Summary

Description	Quantity (AF)
Original 1947 reservoir capacity at NMWS	2,720
2017 reservoir capacity at NMWS	1,601
Sediment volume below NMWS	1,120
Sediment volume above NMWS	138
Total sediment volume	**1,258**

Notes:
AF – acre-feet
NAVD88 = North American Vertical Datum of 1988
NMWS = normal maximum water surface (at spillway crest maximum elevation of 1,042.9 feet NAVD88

Sources: Appendix C



AECOM
Los Padres Dam Alternatives Study

Figure 2-15
Location of Reservoir Borings

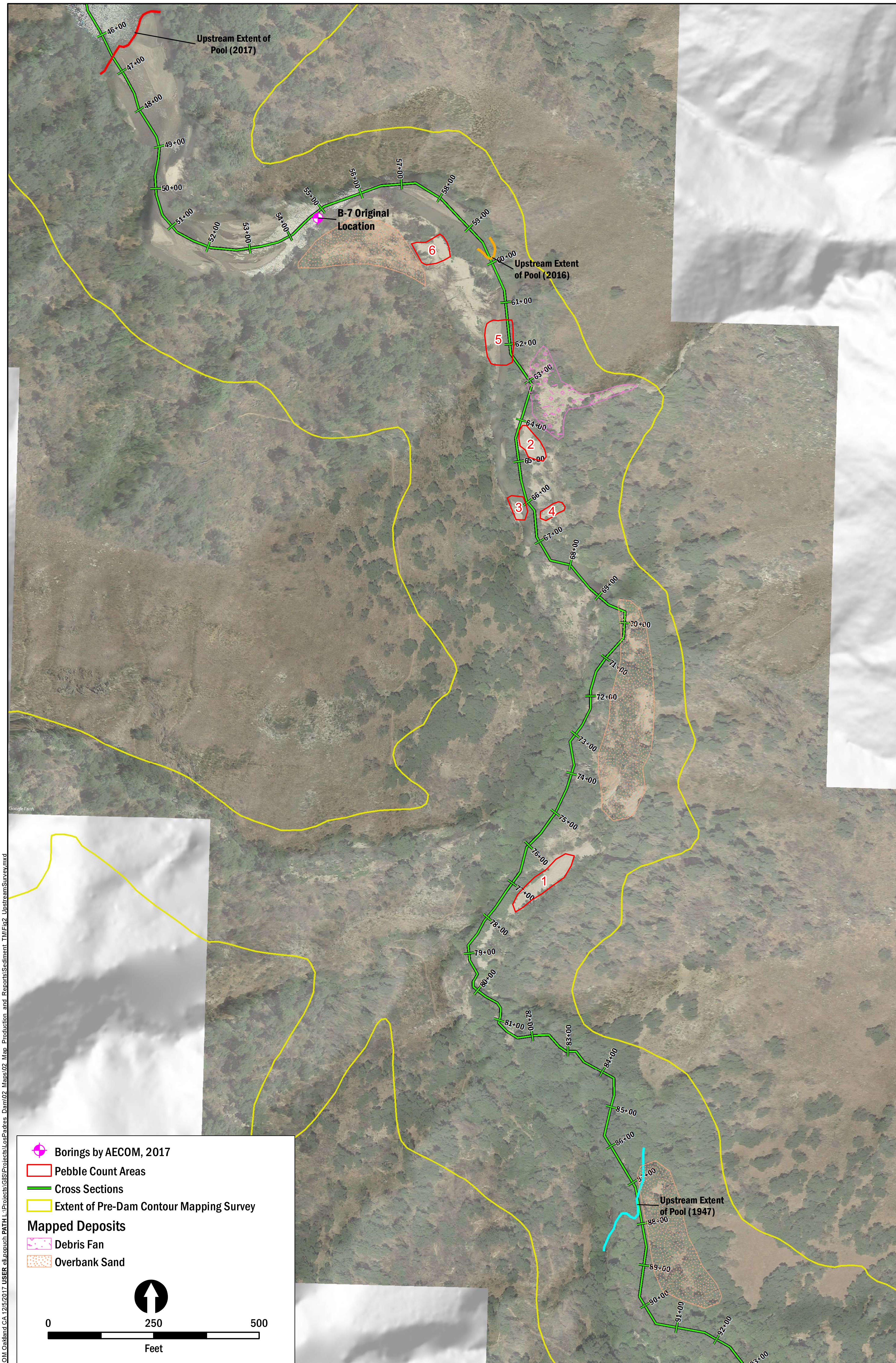


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Figure 2-16
Upstream Survey

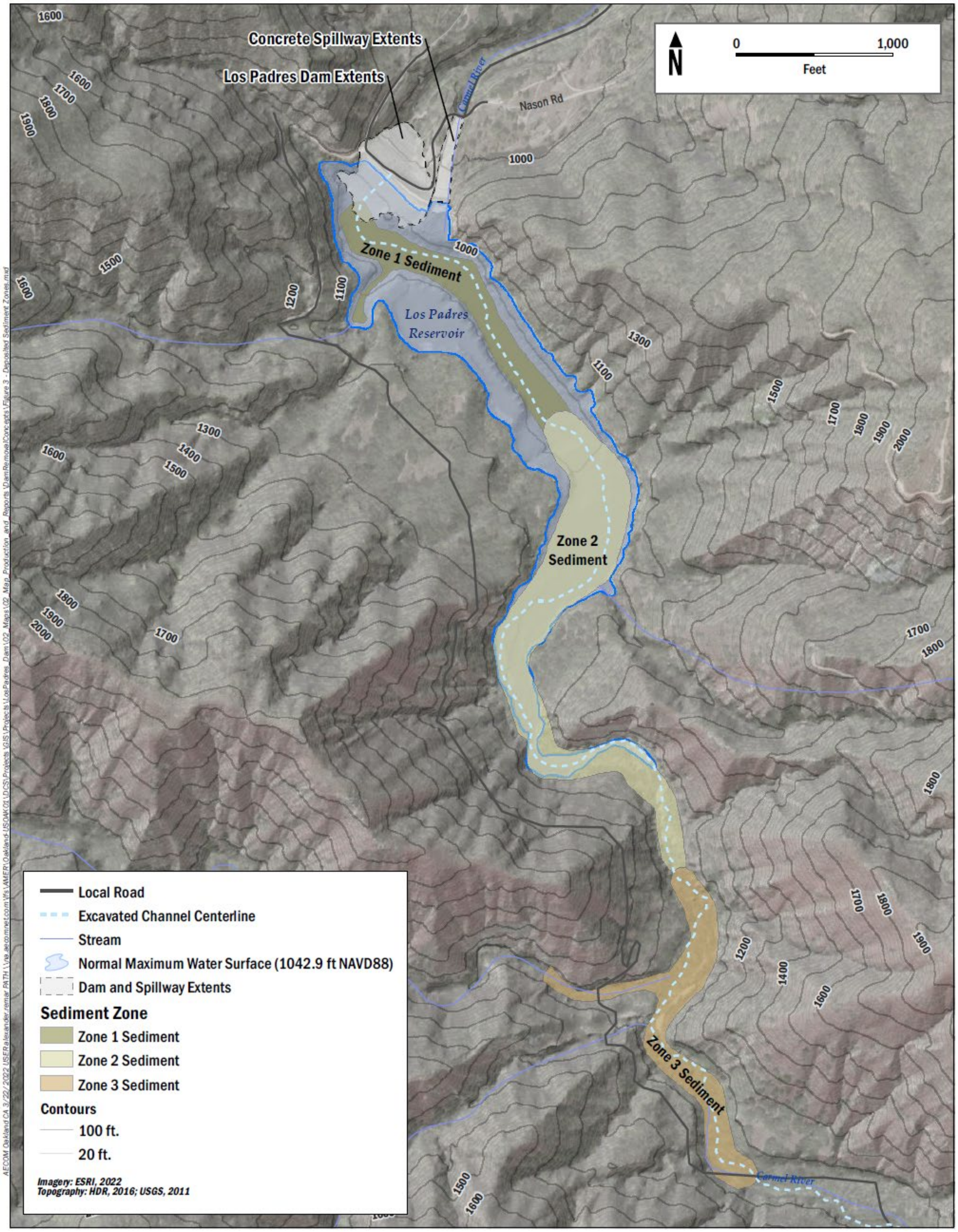


Figure 2-17 Plan View of Accumulated Sediment Zones

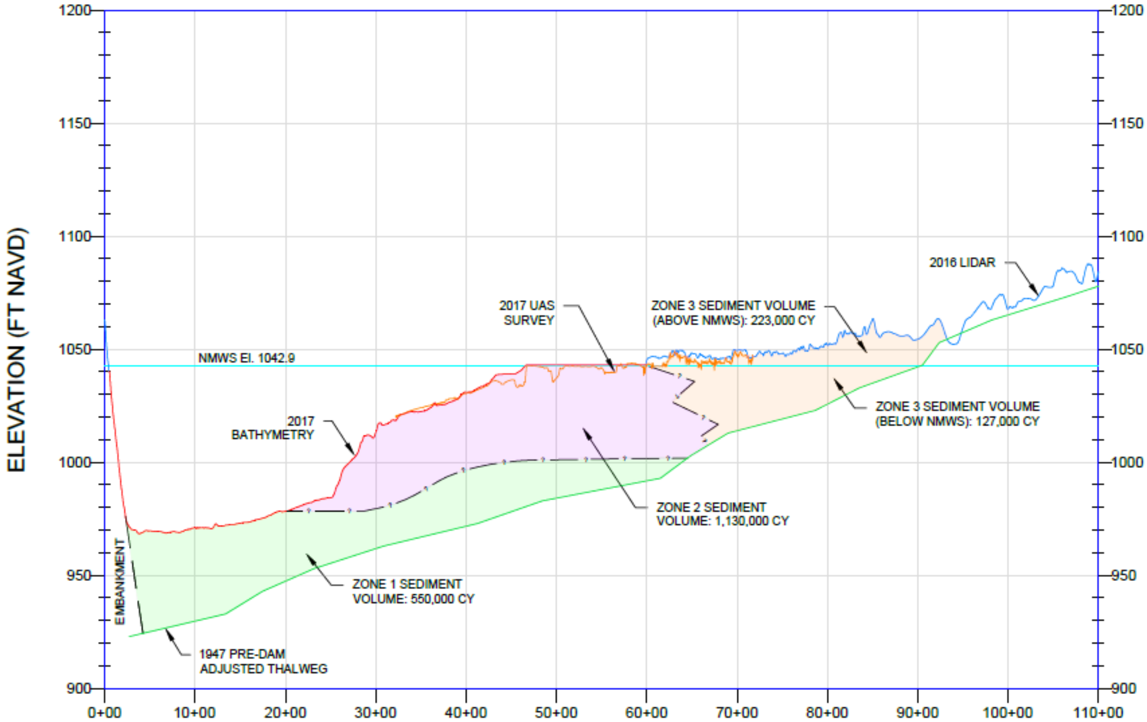


Figure 2-18 Profile View of Accumulated Sediment Zones

Dividing the total accumulated sediment volume by the number of years since the dam was constructed to the 2017 data point (70 years) yields an average sediment deposition rate of approximately 18 AFY. Subtracting the 2017 reservoir capacity from the original 1947 reservoir capacity, and then dividing by the number of years between the data points, yields an average reservoir storage loss rate of approximately 16 AFY.

Estimated sediment size-class amounts for the three zones are summarized in Table 2-4. AECOM estimated the proportion of different grain-size classes composing the sediments in Zones 1 and 2, based on sediment borings, Unified Soil Classification System sediment distribution data, laboratory gradation results, and engineering judgment, as summarized in Appendix C.

Table 2-4 Estimated Sediment Size-Class Amounts

Area	Cobble/Gravel (4.75 to 300 mm)	Sand (0.075 to 4.75 mm)	Silt (<0.075 mm)	Clay (<0.075 mm)	Organics (n/a)
Zone 1	2 to 5%	25 to 35%	50 to 60%	8 to 15%	5 to 10%
Zone 2	5 to 10%	65 to 75%	15 to 25%	2 to 5%	<2%
Zone 3 below NMWS	25 to 35%	60 to 70%	5 to 15%	0 to 5%	<2%
Zone 3 above NMWS	35 to 45%	55 to 65%	0 to 10%	0 to 5%	<2%

Notes:

Estimates for Zone 3 were approximated, based on a correlation to the coarsening upstream Zone 2 deposits and surficial observations, not on subsurface data or quantitative surface data.

mm = millimeters
NAVD88 = North American Vertical Datum of 1988
NMWS = normal maximum water surface (at spillway crest maximum elevation of 1,042.9 feet NAVD88)

Sources: Appendix C

2.4.2 Contributing Watershed and Fire Considerations

The LPR contributing watershed drains a 44.8-square-mile area that is partly National Forest and partly Ventana Wilderness (Figure 2-19, Figure 2-20). The watershed is rural in nature, with approximately 0.3 percent of the watershed classified as developed; and 39.6 percent of the watershed covered by forest. The elevations in the watershed range from 920 to 5,050 feet, with a mean basin elevation of approximately 3,000 feet. The mean annual precipitation is 39.1 inches.

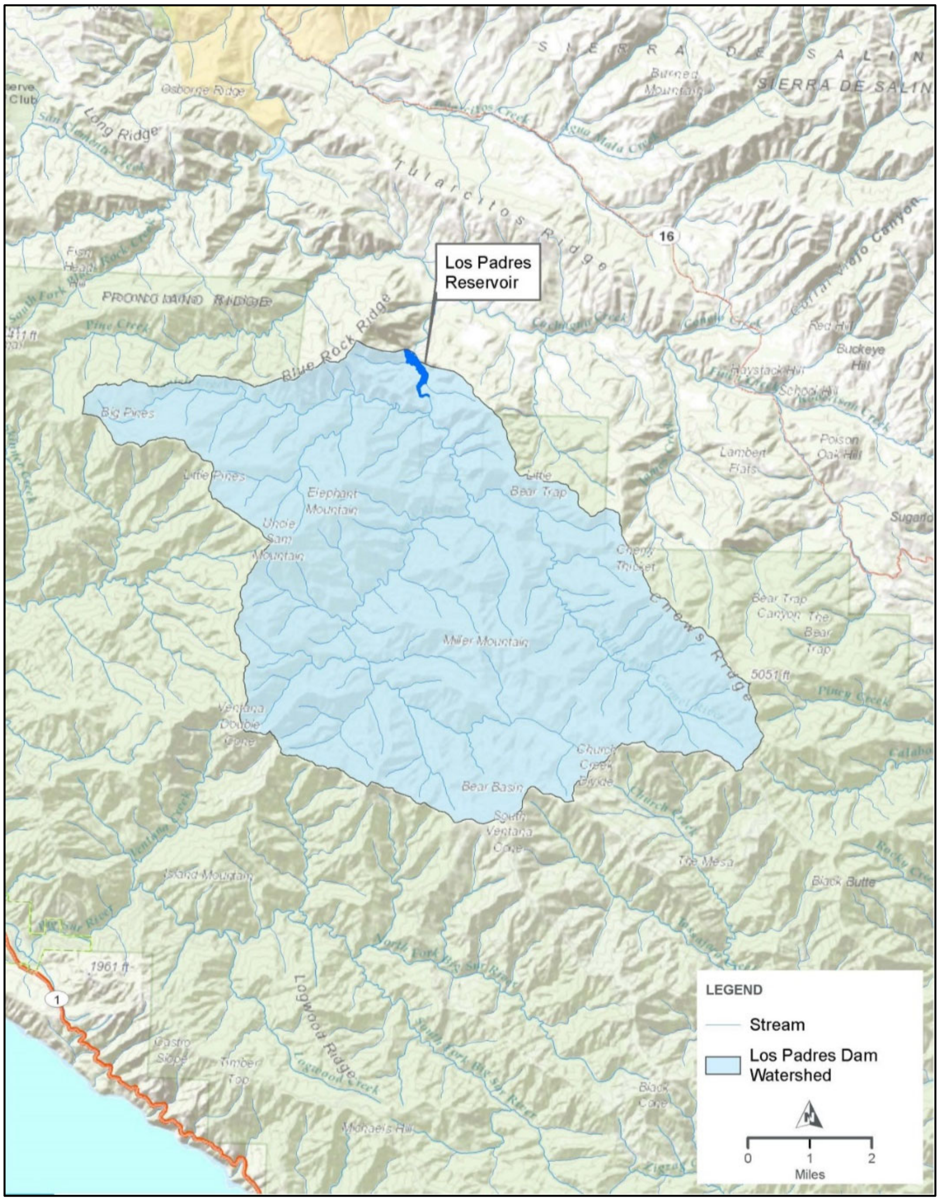


Figure 2-19 Contributing Basin Area for Los Padres Reservoir

Figure 2-20 Carmel River Upstream of Los Padres Reservoir, Upstream of Miller and Bruce Forks

The upper watershed is steep and prone to episodes of erosion; periodic large wildfires can be followed by very wet periods with high rates of erosion. The United States Forest Service (USFS) manages virtually the entire contributing watershed. USFS land management policies—particularly for fire management—can have a direct effect on the volume of sediment and large wood that enters the reservoir.

Most of the upper Carmel River watershed contributing to LPR has been burned several times in the past few decades (Cal-Am and MPWMD 2016). The watershed above LPD was burned severely in the 1977 Marble-Cone fire. Subsequent fires that have occupied the footprint of the Marble Cone fire include the 1999 Kirk Complex fire, 2008 Basin Complex fire, and 2016 Soberanes fire.

Based on conversations between MPWMD and the California Department of Forestry and Fire Protection (CAL FIRE), LPR is sometimes used as a water source for fire suppression. Although the quantity of water supplied by the reservoir over the life of a fire may not be significant, LPR is sometimes used as a dip point in the initial attack on fires and is important for fire suppression in that sense, especially for the communities of Cachagua, Jamesburg, and Tassajara (Hampson, pers. comm. 2018). A log of water usage from the Soberanes Fire showed approximately 62,000 of 4,123,000 gallons (or 2 percent and eight of 603 “dips”) of water used to fight the Soberanes Fire in July and August 2016 as having been dipped from LPR.

An initial assessment of the 2016 fire impacts was completed in late September 2016 by CAL FIRE. Portions of the Carmel River watershed south of the river and outside of the LPD sub-watershed burned in the 2016 fire had no recent fire activity, and had the highest proportions of moderate and high soil burn severity (CAL FIRE 2016). In the LPD sub-watershed, the Basin Area Emergency Response team estimated that up to 80 AF of debris could flow to LPR as a result of a 10-year-magnitude storm. As of mid-October 2016, approximately 50 percent of the contributing watershed was burned; however, most of the burned areas that are considered high risk for debris and increased runoff are outside of the watershed contributing to LPD.

At the end of October 2016, the fire was at 100 percent containment, and several early season storm events had passed through the burned areas with moderate to heavy rain. Although no specific estimates of sediment deposition for water year 2017 alone are available, during the sediment characterization study described in Section 2.4.1 AECOM found that several feet of sediment aggradation had occurred at the upstream end of the reservoir pool during water year 2017 and that the sediment delta had moved further into the reservoir and reduced the upstream extent of the pool by roughly 1,000 feet (Figure 2-21). A comparison of 2008 and 2017 bathymetry provided by CSUMB also shows considerable deposition at the upstream extent of the reservoir pool during that approximately 9-year period (Figure 2-22).

Flows in the Carmel River vary from year to year and by season. More than 90 percent of the average annual precipitation typically occurs between November and April, with the highest rainfall amounts occurring in January and February (Entrix 2008). Inflows to LPR are generally lower for the rest of the year, from May to October. Inflow to LPR is measured once a month by MPWMD upstream of LPD (MPWMD 2008). Figure 2-23 shows instantaneous inflow, measured by MPWMD once each month from June through December, for years in which inflow fell below 5 cfs during at least 1 month. Figure 2-24 shows inflows for years in which inflow never fell below 5 cfs. Together, these figures show that, for a little more than two-thirds of years between 1990 and 2021, inflow to LPR fell below 5 cfs for a few months of the year. During the dry season, downstream reaches of the Carmel River can go dry due to groundwater withdrawals and low tributary inflow (Entrix 2008).

Figure 2-21 Photograph Showing Sediment Delta Encroachment on Reservoir Pool, 2017

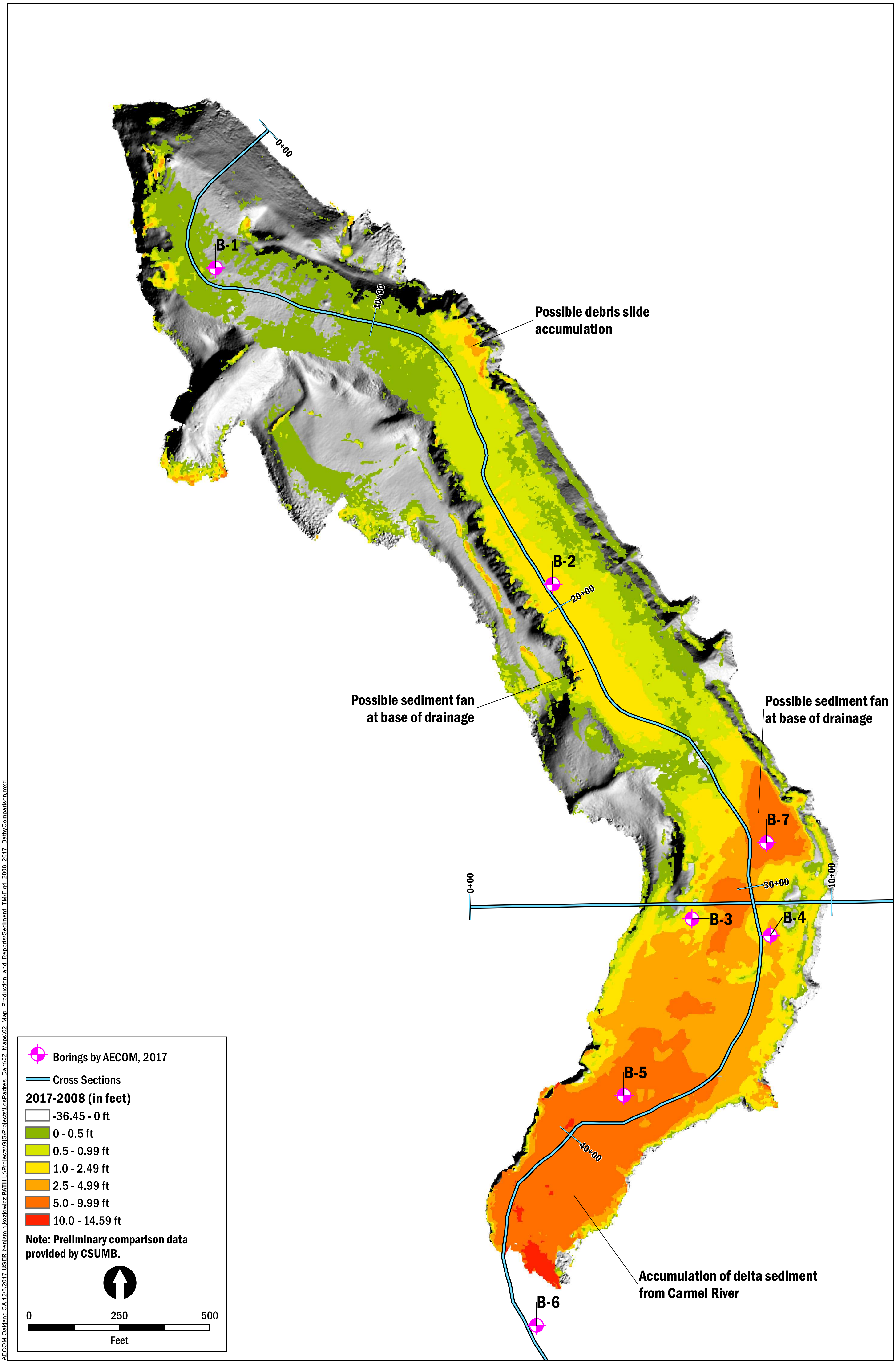


Figure 2-22

Preliminary Comparison of 2008 Bathymetric Survey and Preliminary 2017 Bathymetric Survey

Figure 2-23 Carmel River Inflow (cfs) to Los Padres Reservoir during Years in which Inflow Fell Below 5 cfs

Source: MPWMD unpublished data

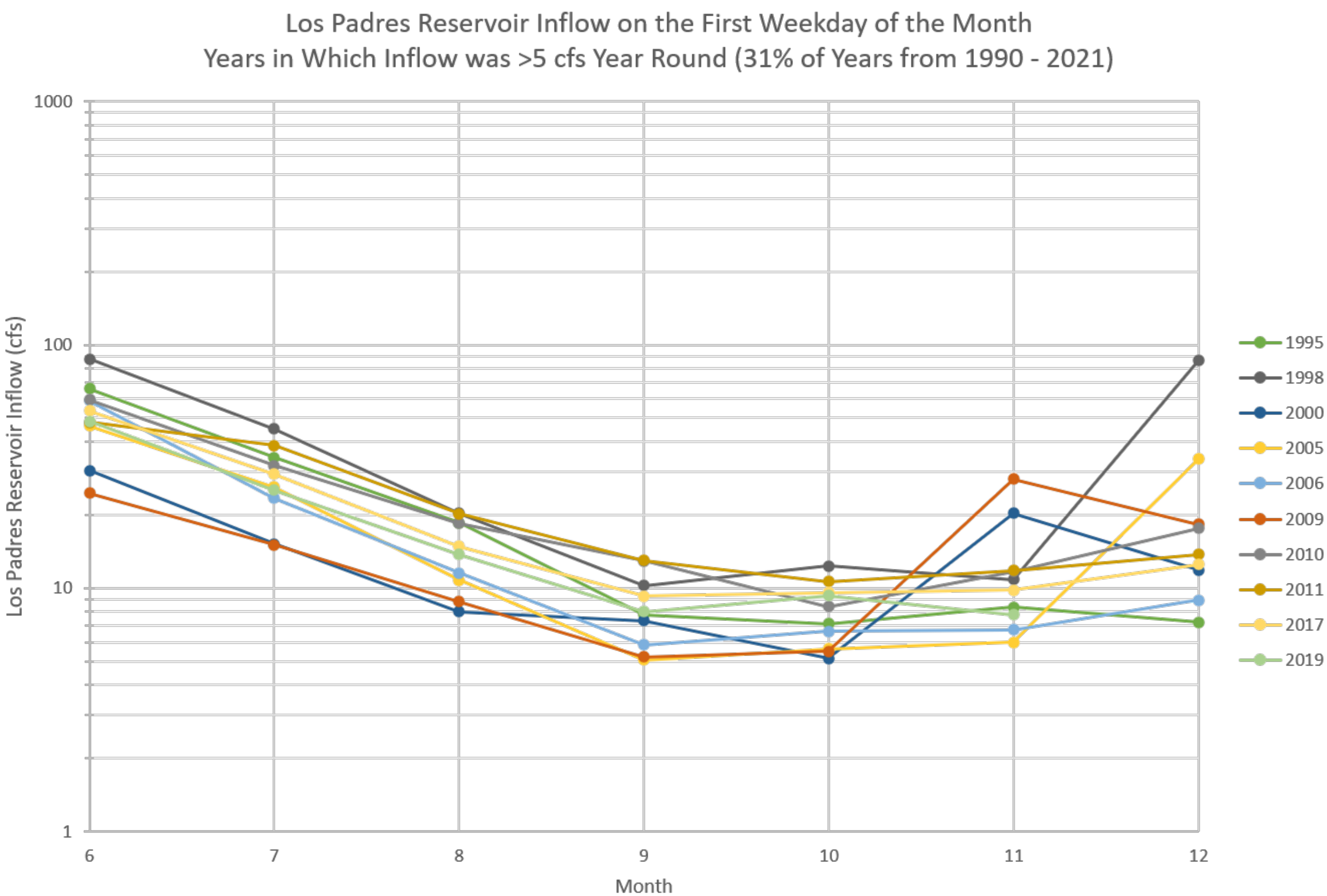


Figure 2-24 Carmel River Inflow (cfs) to Los Padres Reservoir during Years in which Inflow did not Fall Below 5 cfs

Source: MPWMD unpublished data

2.5 Hydrology

Streamflow data for the Carmel River are available at six locations downstream of LPD, including four MPWMD gaging stations and two gaging stations operated by the USGS, with 15-minute flow data available for varying periods of record. Data for flow through LPR are provided primarily by two gages. The first location is the USGS gage near Carmel Valley Village (USGS No. 11143200, Carmel R. at Robles del Rio which has a period of record from August 1, 1957, through April 7, 2020 [n=62], see Figure 1-1); the second is a gaging station directly below LPD, operated by MPWMD (period of record October 1, 2001, through April 7, 2020). Figure 2-25 illustrates the variability of all annual hydrographs of the Carmel River flows for water year 2002 through 2019 from the MPWMD gage below LPD. The gage below LPD is calibrated on a regular basis by MPWMD and is typically within 5 percent of the actual streamflow at that location (MPWMD 2016).

Available hydrologic data were obtained, and preliminary analyses were performed in support of the Los Padres fish passage study (HDR et al. 2021). Results of the flood frequency and flow duration analyses are provided in Section 3.3.

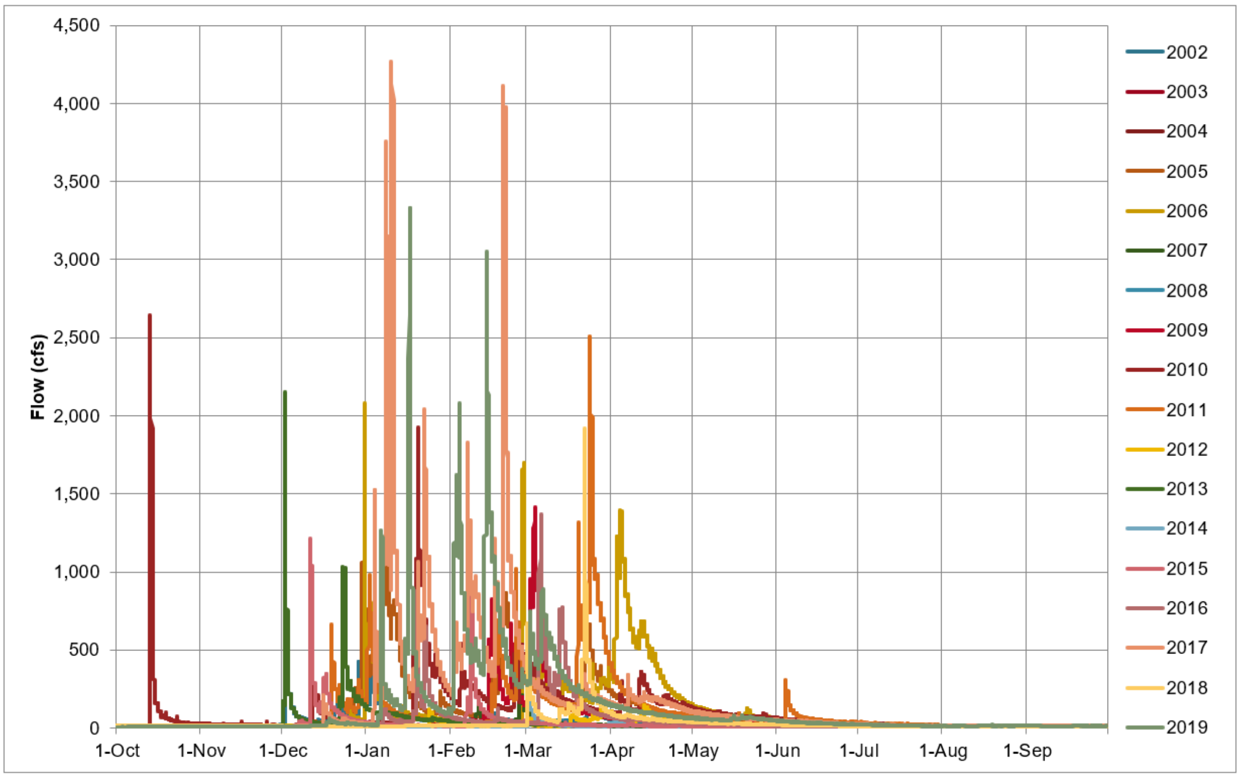


Figure 2-25 Carmel River Flows at the MPWMD Gauge Below Los Padres Dam (Water Years 2002 – 2019)

2.6 Water Temperature and Quality

MPWMD and Cal-Am measure various water quality parameters at LPR. This includes water temperature and DO, which have been recorded throughout the years at irregular intervals, with more frequent measurements taken in recent years. Water temperature has a controlling influence on habitat suitability for all steelhead freshwater life stages. In the most general sense, temperatures lower than 20 degrees Celsius (°C) (68 degrees Fahrenheit [°F]) are considered suitable for rearing steelhead (Hayes et al. 2008); higher temperatures also can support rearing, depending on food availability, DO levels, and other factors. For example, as pool temperatures increase above 22°C, juvenile *O. mykiss* may move into temperature-stratified pools to seek cooler waters (Nielsen et al. 1994), and in laboratory studies have been shown to tolerate temperatures as high as 29.6°C for short periods of time (Myrick and Cech 2001). Streams such as the Carmel

River experience daily temperature fluctuations because stream water warms during the day and cools at night, a pattern that changes across seasons. As a result, *O. mykiss* do not respond to the average stream temperature, but instead acclimate to a temperature between the mean and daily maximum temperatures (Hokanson et al. 1977). Although the relationship between *O. mykiss* growth and temperature is complex, for the purposes of comparing alternatives, this analysis focuses on average temperatures at various locations in the Carmel River and the direction of anticipated change associated with each alternative.

Like temperature, DO is an important water quality parameter for aquatic organisms. Studies have linked DO to *O. mykiss* health. The typical minimum DO levels for steelhead without causing impairment is 8 milligrams per liter (mg/L) (Bjornn and Reiser 1991). Although they can survive DO levels as low as 5 mg/L, growth, food conversion efficiency, and swimming performance will be impaired. Numerous studies have reported that salmonids have no impairment if DO levels averaged 9 mg/L (Davis 1975). On the other hand, centrarchids such as the largemouth bass can tolerate DO levels between 4 and 8 mg/L (Stuber et al. 1982). A substantial reduction in energetics and metabolism occurs below 4 mg/L and DO levels below 1 mg/L are considered lethal to both salmonid and centrarchid species (Stuber et al. 1982).

LPR temperature profiles are provided in Figure 2-28. DO profiles are provided in Figure 2-26. These plots show that water temperatures in LPR are stratified during spring and early summer, with low DO levels at cooler depth during periods of stratification, and generally mixed with no stratification in late summer and winter. DO concentrations below LPD are generally above 8 mg/L, occasionally dipping below (Figure 2-27).

Downstream releases during times when the spillway is not flowing have occurred primarily from a low-level outlet at elevation 953 feet (NAVD88), and in recent years from a FWC at the reservoir's surface. As described in Section 2.3.1, due to rockslides first mobilized in 2018, the low-level outlet is partially clogged and in 2021 was only able to release 1 to 3 cfs to downstream. A siphon was installed to restore flow to the existing adult fish collection facility while the capacity of the low-level reservoir outlet is being restored. Theoretically, the lowest operating level of the siphon is about elevation 1,010 feet (NAVD88). However, the siphon failed for unknown reasons in 2021, when the water surface elevation reached approximately 1,022 feet (NAVD88).

Because LPR does not store a large, deep, cold-water pool and is generally drawn low and/or mixed by late summer, water released downstream of LPR is nearly always warmer than the water entering the reservoir from upstream (Figure 2-29). Some temperature stratification occurs in late spring and early summer but based on the temperature of water in the Carmel River above and below LPR, this appears to primarily represent warming of the reservoirs surface as opposed to retention of cold water stored during the winter. Although not shown in Figure 2-29, the reservoir also reduces the range of daily temperature fluctuations immediately below LPD. Cal-Am intends to install a new low-level outlet in a location expected to be less impacted by rockslides in late-summer 2023, assumed to be at elevation 974 feet based on preliminary designs, which is approximately 20 feet higher than the existing low-level outlet. Based on typical water surface elevations in late summer (August) of around 1,030 to 1,043 feet (Figure 2-14), the outlet will be around 56 to 69 feet deep (17 to 21 meters). This depth of outlet will access the cooler water measured in LPR during spring and early summer but is not anticipated to prevent warming of the water released from LPR to downstream reaches relative to inflow—especially in late summer and early fall, when the reservoir tends to be mixed and without a cold-water pool.

MPWMD conducts continuous water temperature monitoring at six stations throughout the Carmel River (MPWMD 2017a):

1. ALP	Above LPD	(RM 27.0)
2. BLP	Below LPD	(RM 25.4)
3. ASC	Above San Clemente Dam	(RM 18.5)
4. SHW	Sleepy Hollow Weir	(RM 17.1)
5. GAR	Garland Ranch Regional Park	(RM 10.8)
6. SAL	South Arm Lagoon	(RM 0.1)

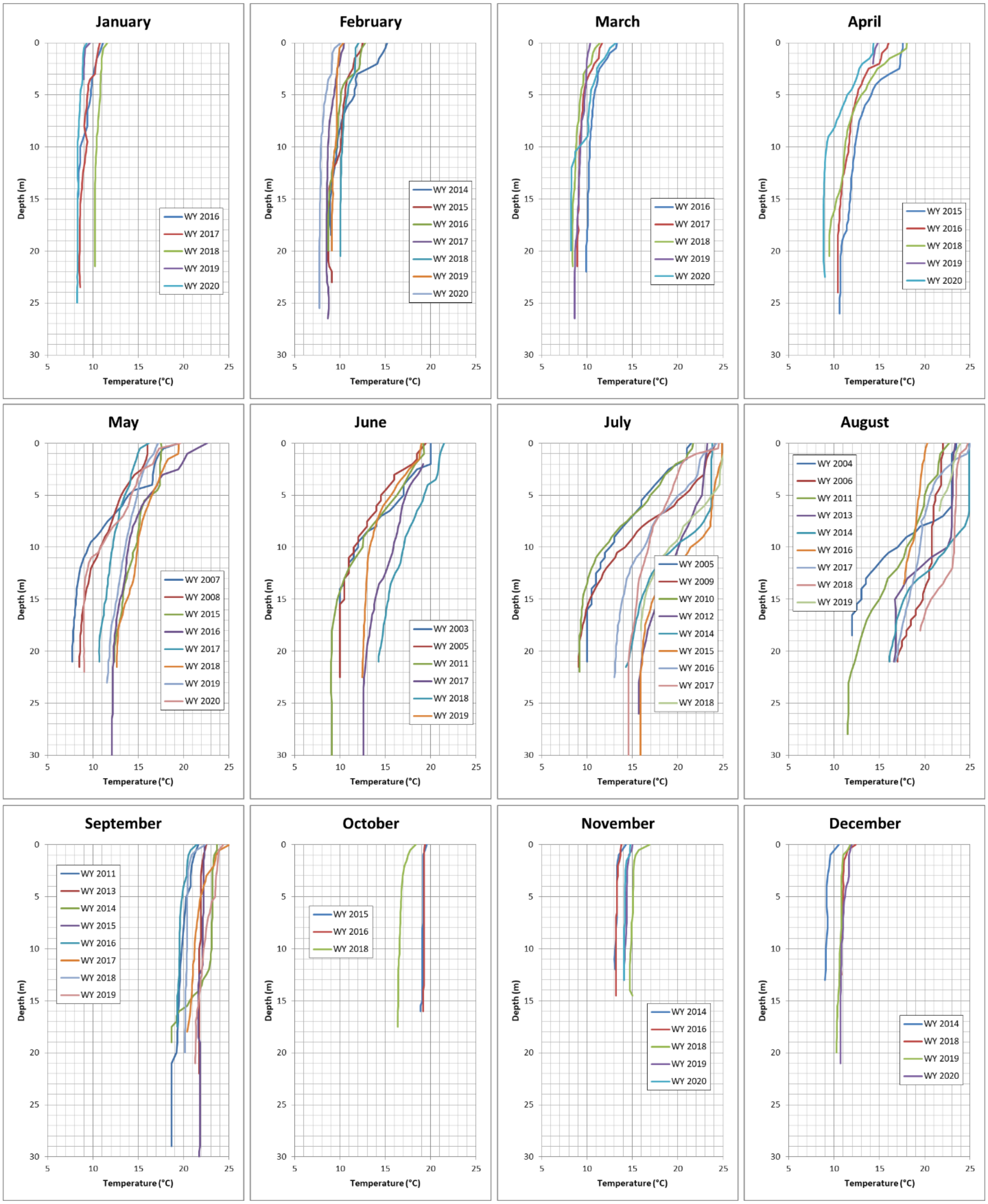


Figure 2-26 Los Padres Reservoir Water Temperature Profiles

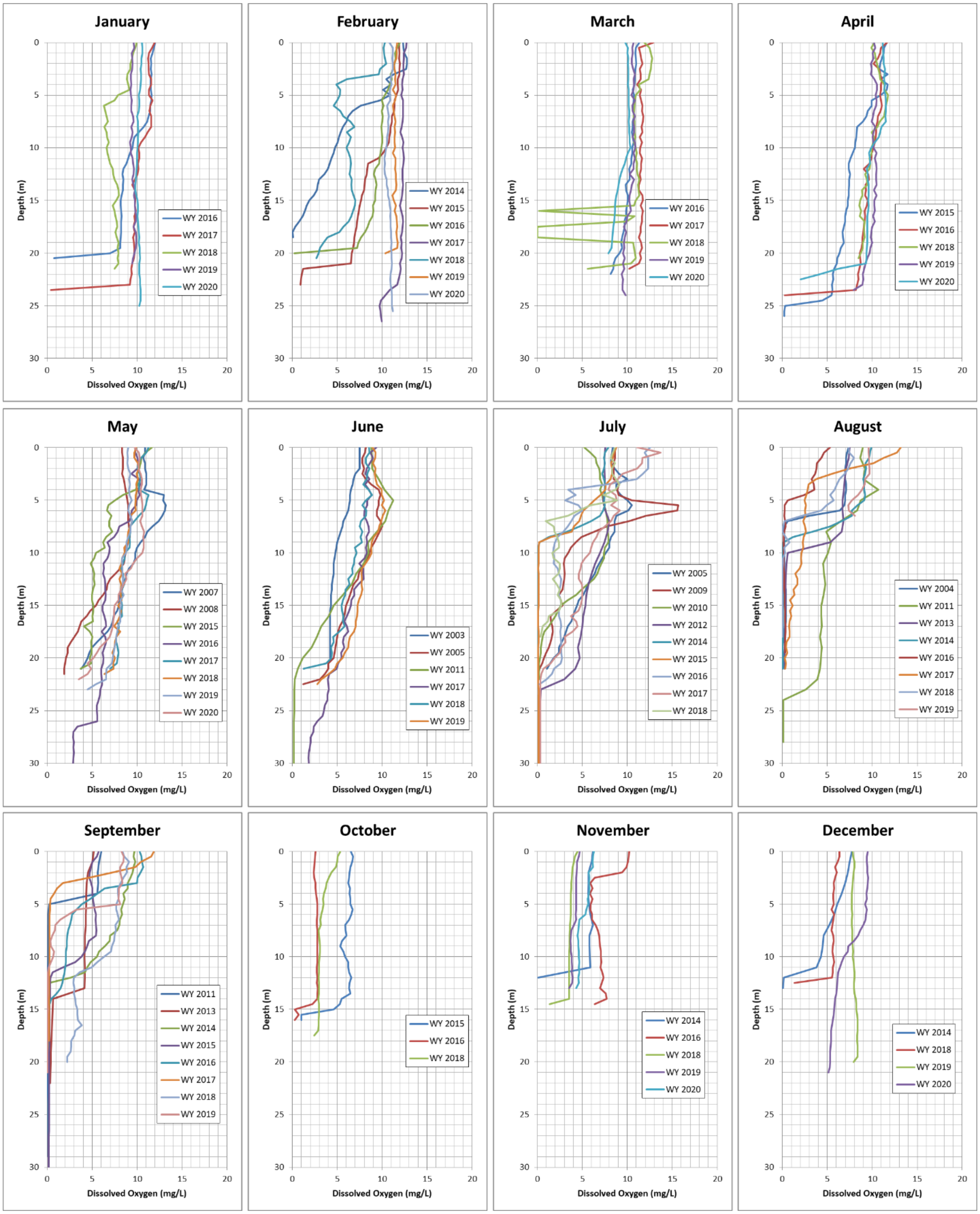


Figure 2-27 Los Padres Reservoir Dissolved Oxygen Profiles

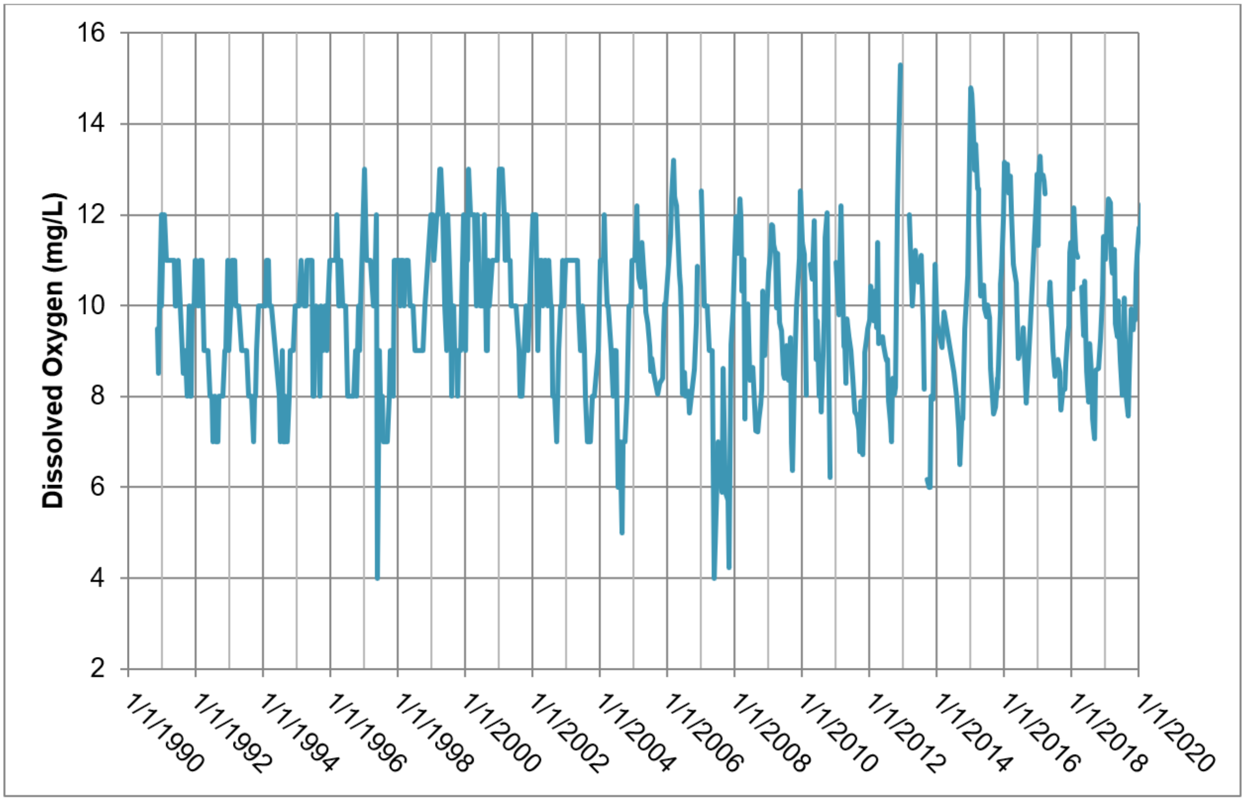


Figure 2-28 Carmel River Dissolved Oxygen below Los Padres Dam

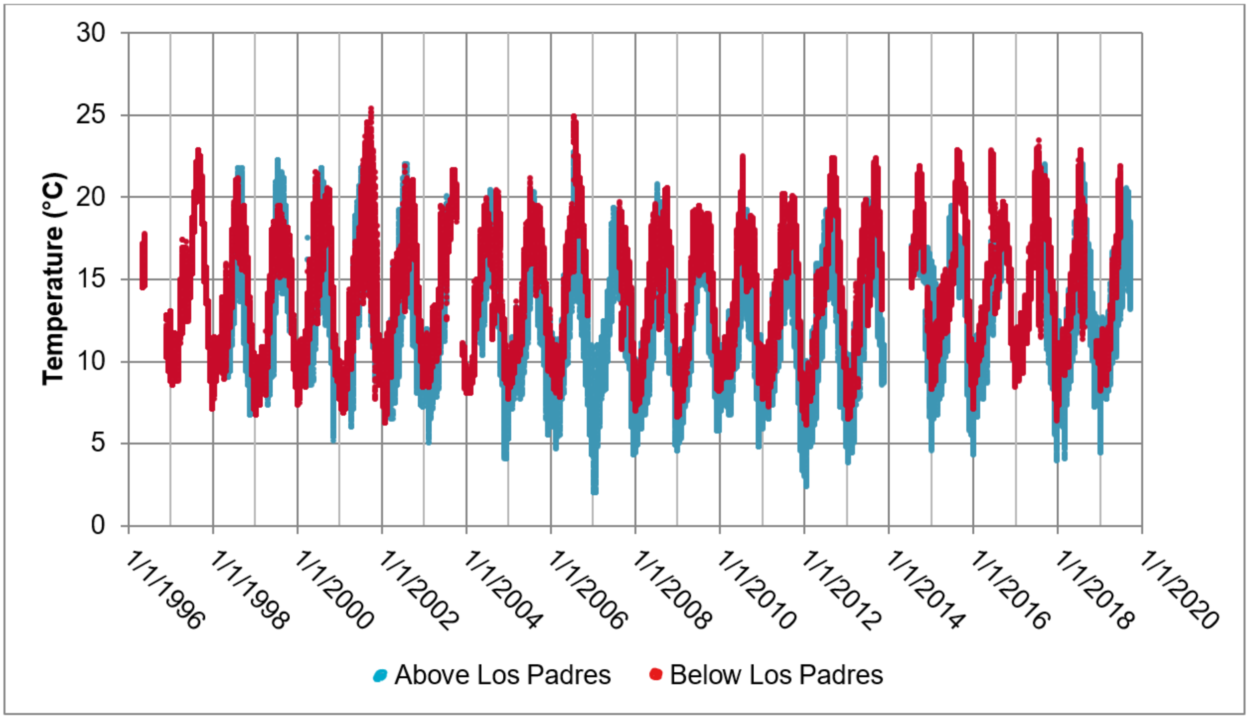


Figure 2-29 Carmel River Water Temperature above and below Los Padres Reservoir

Water temperature monitoring provides an indication of current temperature suitability for steelhead in the Carmel River. Figure 2-30 shows that water temperatures at the most upstream station (upstream of LPR near Danish Creek, Figure 1-1) are consistently the coolest of all the stations. During certain times of the year (e.g., September and October before removal of San Clemente Dam), water temperatures at the station below LPD are the highest of all the stations. In some months (e.g., April), water temperatures consistently warm as water moves downstream; in other months (e.g., September), water temperatures fluctuate as water moves downstream; and there may be a cooling effect as water moves downstream, depending on air temperature, riparian shading, and hyporheic exchange. This cooling effect may have been reduced by the presence of the former San Clemente Dam, and may still be reduced as riparian vegetation continues to establish on the margins of the river in the dam removal project area.

During warm, summer months, extensive algae blooms have been observed at LPR (Figure 2-31). With the recent change in operations to release of water from closer to the reservoir surface through the downstream fish bypass, in summer 2017 algae from the reservoir's surface waters was translated downstream and was noticeable in the Carmel River. The noticeable change in water clarity and temperature resulted in complaints to the MPWMD and a decision was made to turn off the fish bypass and switch back to releasing water from the lower outlet until conditions improved. It is currently unknown whether the recent algae blooms in LPR are of the toxic, blue-green variety (cyanobacteria) that have been found in many California waterways but the algae does appear visually similar to that variety.

The MPWMD has also measured surface water quality at three sampling locations in the Carmel River on a semi-monthly basis since 1991. The locations are: 1) below LPR at RM 25.4; 2) below the former San Clemente Reservoir at the Sleepy Hollow Weir at RM 17.1; and 3) at the Carmel River Lagoon at RM 0.1. The following chemical and physical parameters were measured: temperature, DO, carbon dioxide, pH, specific conductance, salinity, and turbidity. These locations provide water quality information (with an emphasis on suitability for rearing juvenile steelhead) for releases below the dams and in the surface layer of the lagoon (MPWMD 2017b). Vertical profiles of salinity, DO, and temperature are measured in the Carmel River Lagoon by MPWMD. Some of the negative water quality factors that have been observed include chronic poor water quality in the Carmel River lagoon, especially in the fall; and high fall temperatures and episodically detectable hydrogen sulfide levels below LPD.

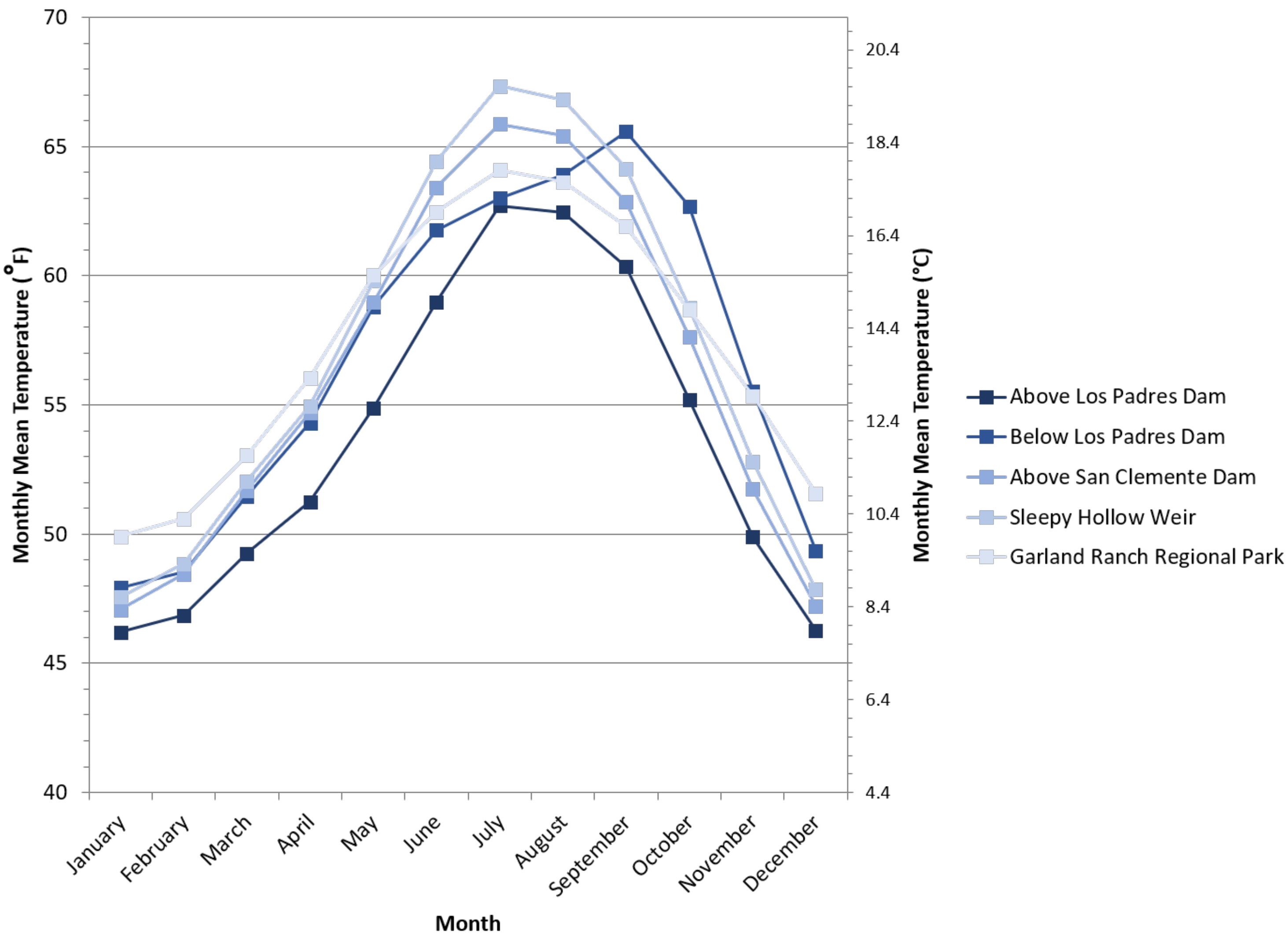


Figure 2-30 Average of Daily Carmel River Water Temperature for a Given Month before San Clemente Dam Removal (January 1996 through May 2014)

Source: MPWMD Unpublished Data

Figure 2-31 Algae in Los Padres Reservoir, August 31, 2017

In addition to water quality monitoring performed by MPWMD, monitoring of the Carmel River and San Clemente Reservoir was also performed to support studies prior to the removal of San Clemente Dam. In 2002, pore water and surface water measurements were collected to characterize conditions in the Carmel River and San Clemente Creek upstream of the former San Clemente Reservoir. Analyzed parameters included metals, hardness, total dissolved solids, pH, specific conductivity, and ionic chemistry. From 2003 to 2006, daily measurements were made for periods of 5 weeks or more during reservoir drawdown periods. Measured water quality parameters included temperature, DO, pH, specific conductivity, and turbidity (Entrix 2008).

Most results for metals were below the laboratory’s reporting limits. Detected metals were below established criteria for aquatic life and human health protection. Hardness results indicated a good buffering capacity against changes in pH and metals concentrations (Entrix 2008). The results of the studies showed that the water quality in the measured reaches was generally good during the monitoring periods, and the quality was not affected by the drawdown activities.

Samples of sediments collected from LPR during the July 2017 investigation were analyzed for chemical constituents to understand potential effects to fish and other downstream uses (Appendix C). Although there is little development and no industry in the watershed, there was concern that the wildfire-dominated landscape above LPR contributes sediment to the reservoir that could pose a water quality problem if released into the river downstream, either through dam removal with sediment release or through sediment management releases. Chemical analyses of the sediment samples collected during the 2017 investigation are indicative of being impacted by wildfires that have occurred in the watershed above the reservoir. However, metal and PAH concentrations were found to be at or below the lowest range of the aquatic effect thresholds. The metals found at the threshold levels (chromium, nickel, and zinc) are typically not enriched during wildfires, and concentrations likely reflect natural background levels in the watershed. Overall, the results do not indicate any significant issues for sensitive and special-status aquatic species or atypical issues with protection of workers during handling of reservoir sediment.

2.7 Geomorphic Data, Considerations, and Analyses

Development of geomorphic and sediment transport information for the Los Padres Alternatives Study consisted of five steps: (1) review of preexisting information (Appendix A), (2) field investigation and characterization of sediment accumulated in LPR (Appendix C), (3) development of sediment rating curves and a coarse sediment transport model and analysis of various sediment actions at LPD and LPR specific to the Los Padres Alternatives Study (Appendix D), and (4) extrapolation from sediment rating curves and other readily available information to develop a preliminary assessment of the potential for elevated concentrations of suspended sediment following evacuation of fine sediment from LPR (Appendix E, Section 2.2). Background information reviewed and in some cases incorporated into the LP Alternatives Study is described in Section 1.3.4, Appendix C, and Appendix D. Field investigation and characterization of accumulated sediment is incorporated at various locations in this report and described in detail in Appendix C. Development of sediment rating curves and the bedload sediment transport analysis used in the LP Alternatives Study are described briefly in Sections 3.6 and 3.7 and in detail in Appendix D. The suspended sediment analysis first presented in the Effects to Steelhead TM (Appendix E) is described in Section 3.9.

2.8 Downstream Flooding Studies and Historic Flooding

This section identifies frequently flooded areas based on existing maps and data. Existing data sources identified include the following:

- Carmel River Sediment-Transport Study (MEI 2002a): This study was conducted to analyze how much sediment could be released from San Clemente Dam before it becomes a flood risk/ property loss problem. The study included topographic mapping of a 19 mile river reach, developing a sediment-transport model, and running the model under 11 scenarios.
- Evaluation of Flood Hazards Associated with Seismic Retrofit Alternatives for San Clemente Dam (MEI 2002b): This study included the development of a floodplain model of the reach downstream from San Clemente Dam to evaluate potential flooding impacts of different sediment release scenarios. In addition, the relative increase in property damage under each scenario was evaluated, and a reconnaissance-level identification of feasible alternatives for mitigating increases in damage was conducted.
- San Clemente Reservoir and Carmel River Sediment-Transport Modeling to Evaluate Potential Impacts of Dam Retrofit Options (MEI 2003): For this study, models were developed to simulate erosion processes in the San Clemente Reservoir under three dam retrofit/removal scenarios. Results from this model were evaluated to estimate the impact of each scenario on flooding, channel stability, and habitat conditions in the river downstream from the dam.

Federal Emergency Management Agency (FEMA) flood insurance rate maps were reviewed to identify areas in a FEMA 100-year or 500-year floodplain. Other resources listed above were reviewed to identify areas that may be in floodplains subject to more frequent flooding.

The nearest community to LPD is the small community of Cachagua, about 1 mile downstream from the dam. Most of the community is in a FEMA 100-year “A” flood zone. An “A” flood zone is considered approximate, so the actual flood zone may be larger or smaller. The only instance of significant flooding identified for this community was in 1995, when about 100 to 150 residences were damaged by a large flood in March (Monterey County 2003). No other descriptions of flooding in the community were found. The March 1995 storm is the largest storm of record out of 60 years of data at the Robles Del Rio USGS gaging station on the Carmel River (#11143200). There are no other communities between Cachagua and the former location of San Clemente Dam, although there are a few scattered homes along the river downstream of Cachagua.

According to testimony by Larry Hampson, Water Resources Engineer with MPWMD, flooding starts in Carmel Valley Village when river flows exceed about 7,000 cfs (Hampson 2008). According to data in Section 3.4, this corresponds to slightly less than a 10-year event at the Robles Del Rio gage. Mr. Hampson also reported that there were 94 repetitive-loss structures (structures with two or more flood insurance claims of $1,000 or more within a 10-year period) in the Carmel River Valley (Hampson 2008). Sixty-nine of these are in Mission Fields area (just downstream of the Highway 1 Bridge), and the remaining 25 are scattered along the length of the river in Carmel Valley. Most of the repetitive loss properties are included on the list because of loss during the January and March 1995 storms. Only 14 properties had losses during other events. Eight properties had more than two losses.

The largest event on record, March 1995, resulted in 400 residences and 68 businesses damaged in Carmel Valley, with 2,500 evacuations. In Mission Fields, 220 residences were damaged, and all residences were evacuated. In addition to these damages, 80 residences in Robles Del Rio were damaged, plus the residences in Cachagua mentioned above. A similar storm in February 1998 resulted in much less damage due to improvements after 1995 (Hampson 2008).

2.9 Carmel River Downstream of Los Padres Dam

The Carmel River Watershed is approximately 255 square miles originating in the Santa Lucia Mountains and terminating at the Carmel Lagoon into Carmel Bay just south of the town of Carmel-by-the-Sea (Figure 1-1 from Section 1). The northern portion of the watershed is considerably drier than the southern portion, with mean annual precipitation ranging from 21 inches per year in the Tularcitos tributary watershed to over 55 inches per year in the Santa Lucia Mountains. Most precipitation occurs between November and April, producing highly variable annual peak flows.

This section describes the Carmel River downstream of LPD based on the characteristics of specific reaches. Based on factors including geology, channel width, and slope, the Carmel River was divided into two main reaches: the Canyon (Upper) Reach, and the Alluvial (Lower) Reach. These two main reaches were further subdivided as described below (and shown in Figure 1-1).

2.9.1 Canyon (Upper) Reach

The canyon reach of the Carmel River extends from LPD at RM 25 downstream to Tularcitos Creek at RM 16. The canyon reach is predominantly steep, confined in a canyon, dominated by bedrock outcrop control, and has more capacity to transport sediment than there is supply (Cal-Am and MPWMD 2016). Tributary inputs of sediment are highly episodic. In this reach, active channel alluvial deposits are typically shallow, frequently scoured and redeposited, and generally much coarser than in the downstream alluvial reach. The canyon reach was subdivided at the former San Clemente Dam to form the upstream Reach 1 and downstream Reach 2.

Reach 1 (Los Padres Dam to Former San Clemente Dam)

The basin upstream of the former San Clemente Reservoir is approximately 125 square miles, and is extremely rugged, with peaks rising up to about 5,000 feet above sea level. The mainstem in this upper basin passes through steep, V-shaped canyons underlain by Sur Series metamorphic rocks and by Mesozoic granitic rocks. The channel through this reach is a gravel-cobble stream, with limited areas of sand and silt (Figure 2-32). Sediment thicknesses in the upper basin are not well documented, but are estimated to be 5 to 15 feet thick, except in the reservoir inundation areas, where the sediment thickness increases dramatically (MPWMD 1989).

The two main tributaries to Reach 1 are Cachagua Creek and Pine Creek. Even though Pine Creek has a drainage area one-sixth the size of Cachagua Creek’s, it produces more runoff, because the Cachagua Creek watershed is in a rain shadow (MPWMD 1989). The total annual tributary bedload input from the two creeks was estimated to range from 265 to 1,920 tons per year for events with recurrence intervals ranging from 1.5 to 10 years.

There is some low-lying housing in proximity to the river near the confluence with Cachagua Creek.

Figure 2-32 Photograph of Reach 1 not far downstream of LPD

Reach 2 (Former San Clemente Dam to Tularcitos Creek at RM 16)

With the removal of San Clemente Dam in 2015, the river is able to capture some of the sediment that was stored in the upper portion of the reservoir, and transport it downstream, in addition to transporting sediment from upstream through the former dam and reservoir location. This occurred in the winter of 2016, with the effect being formation of several gravel bars in the reroute reach, and sand deposition further downstream (CSUMB 2016). It is uncertain how fluvial processes will change downstream of the former dam site. Early indications after an average winter in 2015-2016 were that with the increase of sediment supply, fine material winnows quickly out of steeper runs, leaving gravel behind; but the fine material collects in deeper pools (Cal-Am and MPWMD 2016). The average grain size of bed material between San Clemente Dam and Sleepy Hollow (near RM 17) was characterized as 203 millimeters (mm) (Appendix L in Entrix 2008).

Alluvium begins to deepen near the Sleepy Hollow Bridge at RM 17.3 (the only bridge across the river in this reach) (Figure 2-33), and reaches a depth of about 50 feet near the Cal-Am Russell wells at RM 16.2 (Cal-Am and MPWMD 2016). The average grain size of bed material between Sleepy Hollow and Tularcitos Creek was characterized as 152 mm (Appendix L in Entrix 2008).

Estimates of available sediment supply in this reach are associated with estimates of reservoir sedimentation rates based on periodic bathymetric surveys at San Clemente Reservoir, and direct measurement of sediment transport (Matthews 1989; Hampson 1995). The average annual sediment load at the former San Clemente Dam site is estimated to vary between about 5 and 20 AFY, with some years considerably higher (Hampson 2011). As is the case with the long-term sedimentation rate of LPR, the long-term rate of sediment inflow in the mainstem at San Clemente Reservoir was heavily influenced by two discrete events: the Miller Canyon fire in 1924; and the Dormody slide in the late 1970s and early 1980s.

Between episodes of erosion, the mainstem develops into an armored gravel-cobble bed stream with complex stretches of riffles, runs, and deep pools (Cal-Am and MPWMD 2016). This was the state of the stream in 2016, except in the reach immediately downstream of the former San Clemente Dam site, where sand from the Carmel River Reroute project has deposited in many of the pools (CSUMB 2016). After the winter of 2016-2017 additional sand depositions in pools, runs, and overbank areas was observed further downstream.

Figure 2-33 Photograph of Reach 2 near the Sleepy Hollow Bridge

2.9.2 Alluvial (Lower) Reach

The alluvial reach extends from Tularcitos Creek at RM 16 downstream to the Pacific Ocean. The alluvial reach was subdivided at the Narrows at RM 9.8, and at the Carmel River Lagoon just upstream of the mouth to form Reach 3 (from Tularcitos Creek to the Narrows), Reach 4 (from the Narrows to the Lagoon), and Reach 5 (from the Lagoon to the ocean).

Reaches 3 and 4 (Tularcitos Creek to Carmel River Lagoon)

The Carmel River exits from the highly confined canyon- and bedrock-controlled reach after the confluence with Tularcitos Creek at RM 16. Between the 1920s and 1960s, the river and adjacent floodplain were converted from a wide, shallow, meandering system that was braided in sections to a moderately incised, less-sinuous, single-thread channel (Cal-Am and MPWMD 2016). Dam building, gravel mining, road building, floodplain development, and channel maintenance activities (bulldozing to remove vegetation) combined to constrain the active channel alignment. Sinuosity in the lower 16 miles is estimated to have dropped from about 1.3 at the beginning of the 20th century, to about 1.15 currently. Degradation in the active channel of up to 15 feet has been documented (Kondolf 1983). Many of the previously allowed development activities in the channel and floodplain are now either prohibited or severely restricted.

Although no episodic or chronic erosion has occurred since 1998, the lower 16 miles of the Carmel River are likely not in a state of equilibrium (Cal-Am and MPWMD 2016). It is more likely that restoration and natural recruitment of streamside vegetation over the past several decades has raised the threshold flow at which chronic erosion occurs, and hardscape prevents episodic erosion that would cause a shift away from the present-day meandering single-thread system.

Alluvium progressively deepens from less than 50 feet at the confluence with Tularcitos Creek, to more than 200 feet near the mouth of the river (Cal-Am and MPWMD 2016). After flowing past the Tularcitos Creek confluence at RM 16, the valley progressively widens, the river's transport ability diminishes, and the alluvial aquifer reaches a maximum width of about 0.5 mile (Figure 2-34). This lower reach can be placed in the transition zone between being a single-thread or braided channel (Kondolf and Curry 1986). There are few bedrock outcrops in this reach. Changes in sediment supply, diversions for municipal supply, health of streambank vegetation, floodplain development, and the presence of hardscape on the streambanks combine to influence the form of the active channel. Since the late 1960s, about 40 percent of the left streambank and 47 percent of the right streambank along the lower 16 miles of the river have had at least one form of hardscape protection introduced, and are somewhat to highly resistant to erosion (Cal-Am and MPWMD 2016). Degradation in the lower 10 miles (Reach 4) was estimated at 0.25 foot per year in the mid-1960s to mid-1970s (USGS 1983); more recently, the long-term rate appears to be a little less than 0.2 foot per year (Graham Matthews and Associates 2008).

Figure 2-34 Two photographs of Reach 3 within Garland Park

Due to historical sediment retention at the two main-stem reservoirs, long-term sediment transport capacity in the lower reach has been greater than supply, and the lower reach is considered sediment-starved (Cal-Am and MPWMD 2016). This has resulted in armoring in the active channel, formation of a meandering single-thread channel in the alluvial reach, and historical degradation of the thalweg, as evidenced by periodic field surveys. However, as described below, periods of episodic erosion have occurred in which the alluvial reach was transport-limited, and long reaches of the river became braided and were destabilized.

Most of the streambanks in the lower 16 miles of the Carmel River are formed of unconsolidated sands and gravels that are easily eroded in the absence of vigorous vegetation or other stabilizing component such as hardscape (Cal-Am and MPWMD 2016). This reach is flanked by housing and other property development, and is currently crossed by 18 bridges. Gravel mining operations between the 1920s and the 1970s removed an unknown, but significant, quantity of material from the active channel (CDMG 1966). Operations to clear the active channel of riparian vegetation were routine up until the early 1980s. Diversions for municipal use annually dewater several miles of the river, and cause stress and mortality of streamside vegetation.

In the lower 16 miles of the river, there were two notable periods with episodic erosion during which the stream had an excess supply of sediment (i.e., 1978-1983 and 1993-1998) (Cal-Am and MPWMD 2016). The first episode occurred after severe drought; increased well production in 1976-1977 brought aquifer levels between RM 5 and RM 15 to as much as 50 feet below the riverbed. Most streamside vegetation in this reach died by the end of 1977, and several areas were subsequently cleared of dead vegetation by bulldozer. In the ensuing wet period, about 8 miles of the river's streambanks were destabilized (Kondolf 1983). Testimony given before SWRCB in 1992 and 1994 established a clear link between Cal-Am's pumping, and the loss of vegetation along the streamside corridor (Cal-Am and MPWMD 2016). After most of Cal-Am's well pumping was transferred downstream in the mid-1980s to between RM 3 and RM 8, the lower portion of that reach became destabilized. Following the second notable episode of erosion, caused by high flows in 1993, 1995, and 1998, intensive restoration efforts were required, including use of rock slope protection that incorporated native riparian vegetation.

During these periods of episodic erosion, the river generally responded by widening through streambank avulsion and forming depositional areas in the active channel downstream of eroded sections (Cal-Am and MPWMD 2016). The erosion and depositional process continued in a feedback loop that moved downstream over a period of years. This process tends to shift the active channel toward a sand-bed stream. In some reaches, a stable single-thread channel with an active width of 70 to 100 feet and fringed with dense vegetation was transformed into wide, braided reaches of up to 800 feet wide, with little or no vegetation remaining (e.g., the widening of the area upstream of Schulte Bridge at RM 6.7 between 1977 and 1980; and the erosion and widening that occurred at Rancho Cañada golf course in 1998 at RM 3).

Subsequent to these periods, the stream returned to being supply limited (Cal-Am and MPWMD 2016). Therefore, the “frequent flows” of up to the 10-year magnitude served to winnow out material smaller than gravel-sized, and create vertical complexity in the lower 16 miles; however, in general, the limits of the active channel are shaped by infrequent large-magnitude floods coupled with installation of hardscape to restrain the river after high flows. The typical reaction to episodic erosion has been to fortify unstable streambanks with hardscape, including reinforcing streambanks by placing riprap, gabions, concrete rubble, post and wire, car bodies, and even car tires along the river’s banks. Since 1983, many of these practices have been prohibited, and MPWMD and other regulatory agencies have encouraged biotechnical stabilization, with rock riprap and gabions allowed under limited circumstances.

Many of these treatments have occurred on the outside of meanders (Cal-Am and MPWMD 2016). Due to requirements since the early 1980s to mitigate for some of the impacts from installing hardscape, riparian vegetation is incorporated into the hardscape. Areas that are dewatered during dry periods are irrigated to reduce stress on riparian vegetation. The result is that most of the lower 16 miles of the river are fringed with riparian vegetation and encroachment into the center of the active channel is common. MPWMD conducts an annual program to selectively remove vegetation in areas where debris dams could form; however, few trees are wholly removed and the vegetation quickly grows back.

Most of the lower 16 miles of river are currently a single-thread channel due to supply limitations, or “sediment starvation” (Cal-Am and MPWMD 2016) (Figure 2-35). In some reaches, degradation since the late 1990s has reached up to 6 feet, and the stream has been transformed from a sand bed to gravel-cobble bed. With one exception between RM 3 and RM 4, the lower 16 miles of the alluvial reach have not undergone significant erosion since 1998. This relatively stable period has occurred despite several peak flows that previously would have caused widespread erosion and streambank collapse. Some reaches in the lower 16 miles in the alluvial portion of the river are notable for their bedrock outcrops along the channel that impose lateral and vertical controls to channel migration.

Tributary input of sediment in the lower reach appears to coincide with episodes of erosion in the mainstem (Cal-Am and MPWMD 2016). It is likely that low-flow years with chronic erosion in the tributaries result in deposits of material that are stored in the active channels, and moved down to the mainstem only during relatively high-flow years.

Figure 2-35 Two photographs of Reach 4, between the Narrows and Carmel River Lagoon

Reach 5 (Carmel River Lagoon to the Ocean)

The Carmel River Lagoon and its associated wetlands cover an area of approximately 100 acres at the mouth of the Carmel River (MPWMD 2005). The lagoon area is shown on Figure 2-36. The lagoon morphology varies by season. In the summer and fall, lagoon levels are generally static, except for occasional filling events from ocean waves overtopping the beach berm. After filling events, when the mouth is still closed, lagoon levels gradually lower, primarily through exfiltration through the barrier beach. The lagoon generally begins to fill after runoff from winter storms is able to advance downstream to the lagoon. Once it fills, the Monterey County Public Works Department will use bulldozers to artificially breach the sand bar at the mouth to allow runoff to discharge to the ocean. The outlet typically remains open (or has temporary closures) through early spring. As flows in the Carmel River decrease in the spring or summer, the beach berm forms to close off the mouth of the lagoon until the following rainy season (MPWMD 2005). Figure 2-37 shows the range of flows measured when the mouth of the lagoon was open to the ocean.

2.9.3 River-Bank Structural Protection

MEI's (2002a) Carmel River Sediment-Transport Study provides descriptions of several reaches along the Carmel River, including whether the banks are armored. Note that the subreach numbers shown on Figure 2-38 and Figure 2-39 are not the same reach numbers used in this study. Overall, about 40 percent of the total length of bank has been hardened. Figure 2-39 shows the percentage hardened in each reach. Additional summary of the bank protection by subreach is provided in Appendix A.

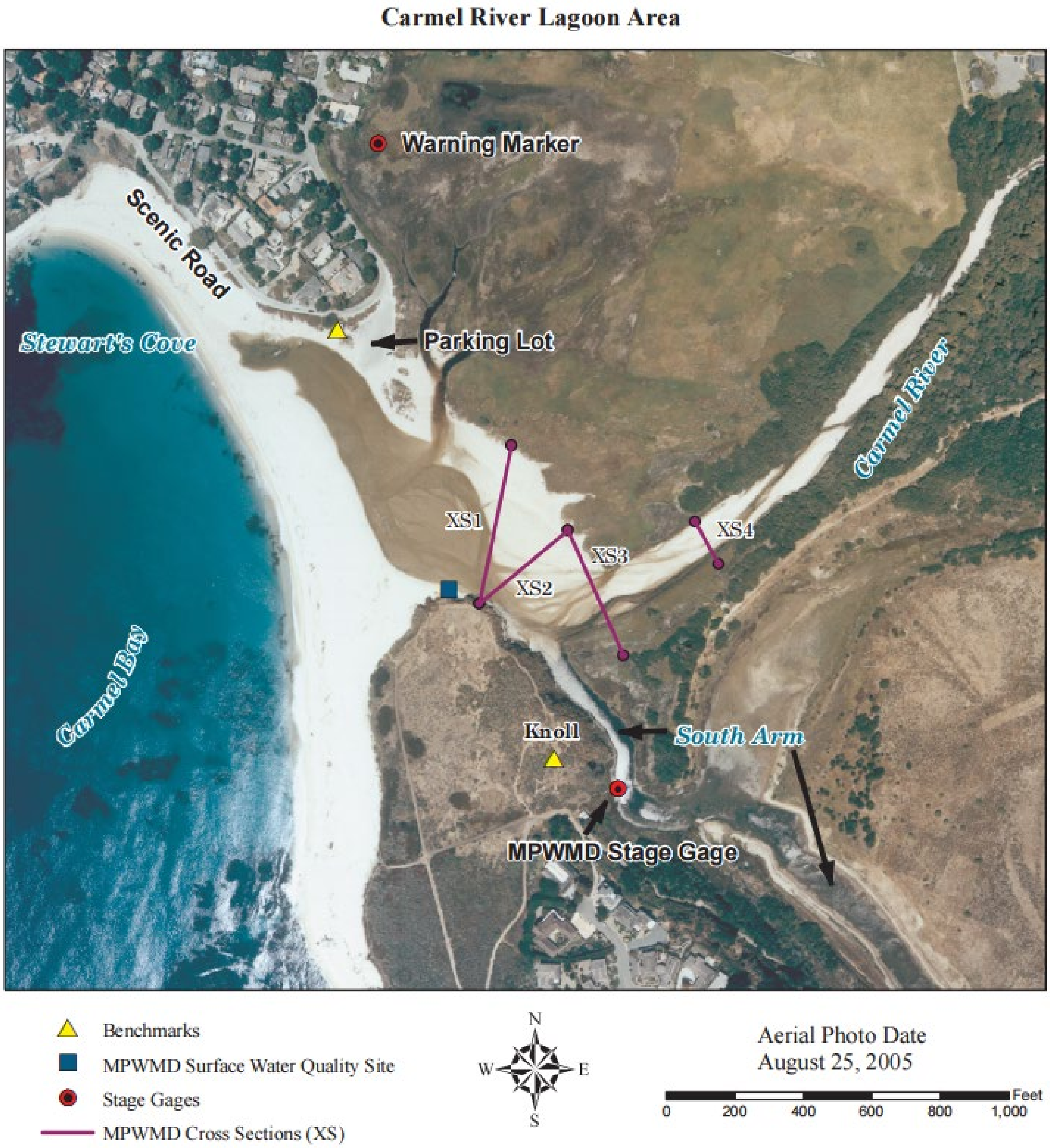


Figure 2-36 Carmel River Lagoon Area

Source: MPWMD 2005

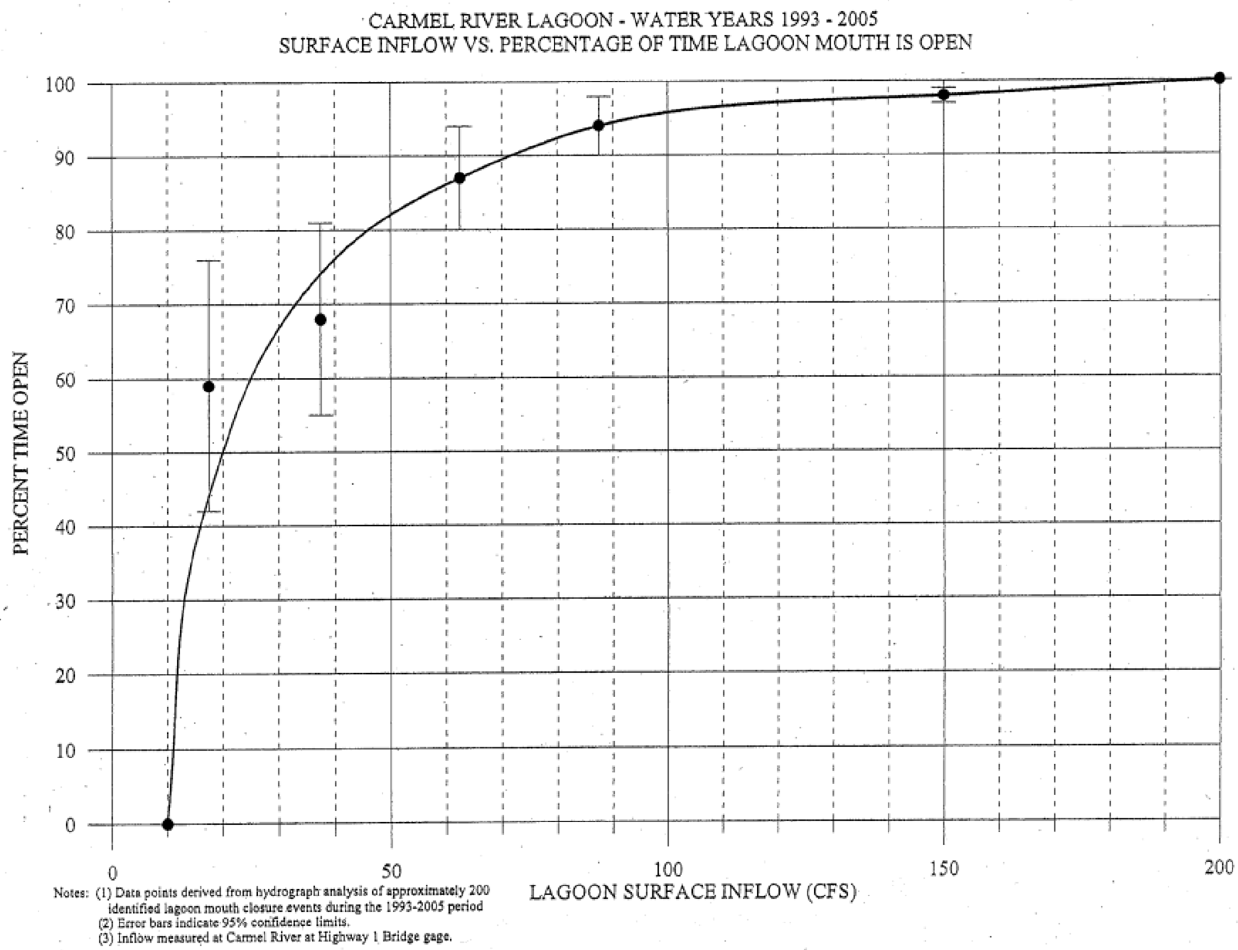


Figure 2-37 Carmel River Discharge when Lagoon Mouth is Open

Source: MPWMD 2005

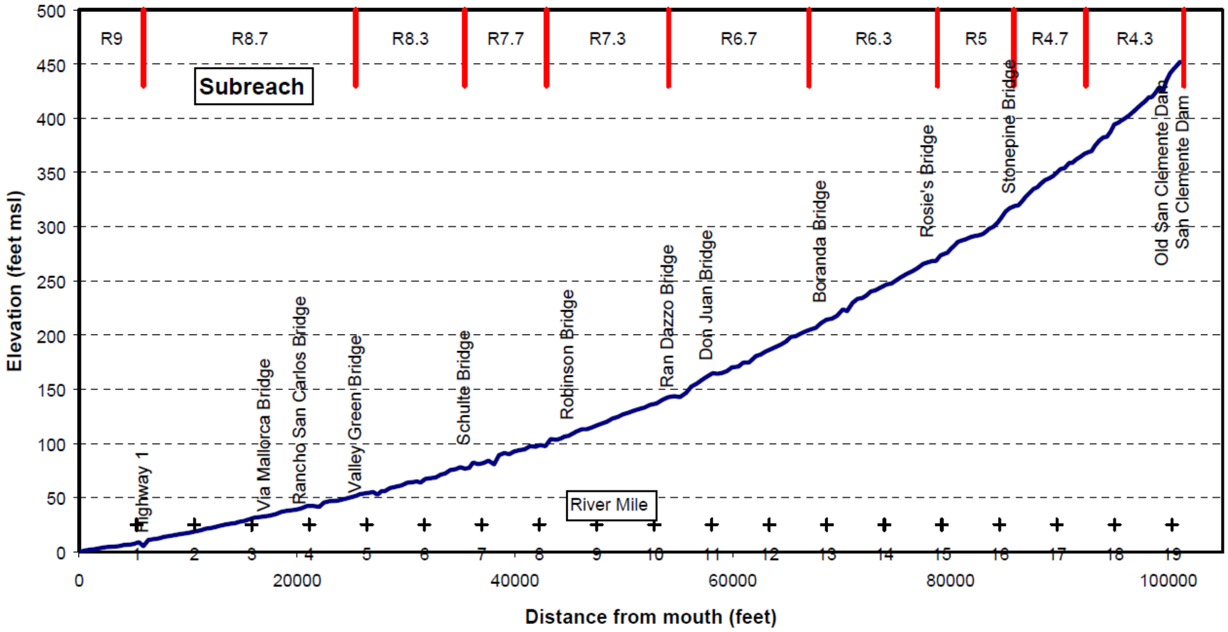


Figure 2-38 Longitudinal Profile of the Carmel River

Source: Figure 2.1 from MEI 2002a

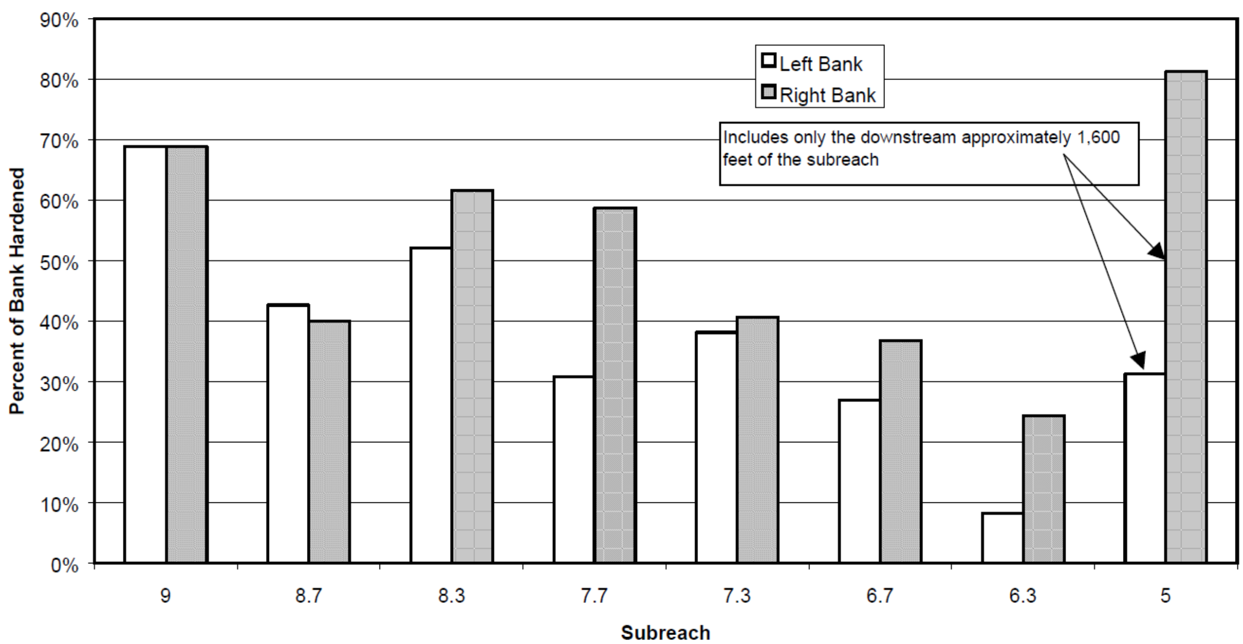


Figure 2-39 Percent of Total Bank Length with Hardened Bank Protection, by Subreach

Source: Figure 2.4 from MEI 2002a

2.10 Steelhead

Steelhead found in the Carmel River watershed belong to the S-CCC DPS, which is listed as threatened under the ESA (62 FR 43937, 71 FR 834). The Carmel River once contained the largest steelhead run in the range of the S-CCC steelhead DPS (NMFS 2012). The Carmel River population of S-CCC steelhead is considered an important population within the DPS because it likely acts as a source population for the smaller coastal drainages, which are not considered viable by NMFS and may not be able to persist without straying from the Carmel River population. Moreover, the Carmel River Watershed is considered unique from the other watersheds supporting the DPS in that the Carmel River population possesses both interior and coastal population attributes. These attributes may provide more resistance to environmental variability and may aid in maintaining genetic diversity. For these reasons, the Carmel River population of S-CCC steelhead is considered highly valuable compared to other populations within the DPS (NMFS 2013b).

2.10.1 Watershed Overview

The Carmel River Watershed contains abundant suitable habitat for S-CCC steelhead. Access to much of this habitat is currently influenced by the presence of LPD, where a trap-and-haul facility provides upstream passage, and a bypass pipe and the dam's spillway provide downstream passage. The watershed contains extensive (>50 miles) steelhead spawning and rearing habitat in the mainstem and tributaries (MPWMD 2004) (Figure 1-1). However, portions of the Carmel River continually dry back in the summer months, which limits available rearing habitat. Due to this frequent dry back, MPWMD began a voluntary juvenile steelhead rescue program in the late 1980s, which was subsequently incorporated into an adopted Mitigation Program in November 1990 (MPWMD 1990). SWRCB Order 95-10 stated that Cal-Am is to implement all measures in the MPWMD Mitigation Program that MPWMD does not implement after June 30, 1996, including rescuing stranded steelhead (SWRCB 1995). SWRCB required Cal-Am to take on this contingent liability in Order 95-10 because the MPWMD program had been authorized for a 5-year period ending in November 1995. Subsequently, MPWMD's board reauthorized the program annually through the budget process and MPWMD continues to rescue fish stranded due to dry back.

Ohms et al. (2021) developed an inferred dry map of the Carmel River watershed based on records of MPWMD fish rescue relocations (Figure 2-40). The inferred dry map was generated by analyzing MPWMD's notes on when fish rescues occurred and assuming that sections of streams listed as rescue sites subsequently dried up. The map was later adjusted based on gauge data and electrofishing data if either source indicated that surface flow was retained. Ohms et al. (2021) concluded that the lower portion of the Carmel River consistently dried up in all but the wettest years, likely due to groundwater pumping, and that portions of Reach 3 also consistently go dry; these dry sections expand during drought years.

The historical population of S-CCC steelhead in the Carmel River Watershed prior to the construction of San Clemente Dam (built in 1921) and LPD (built in 1949) was estimated to be between 1,500 and 8,000 adults annually (Becker et al. 2010). Other qualitative estimates place the pre-dam population closer to 12,000 (Snider 1983). In their Biological Opinion for the Carmel River Reroute and San Clemente Dam Removal Project, NMFS (2012) estimated that habitat in the Carmel River Basin could support roughly 4,000 adult steelhead annually—with the habitat upstream of LPR potentially supporting around 2,000 fish, the habitat between Los Padres and San Clemente reservoirs potentially supporting 1,000 fish (Response Reach 1), and the habitat downstream of San Clemente Dam potentially supporting around 1,000 fish (Response Reaches 2–5). A 1986 Biological Assessment for the Carmel River (as cited in Becker et al. 2010) indicated that, "above LPR the steelhead have access to 14.4 miles of the Carmel River and the tributaries, all of which contain large amounts of spawning and rearing habitat."

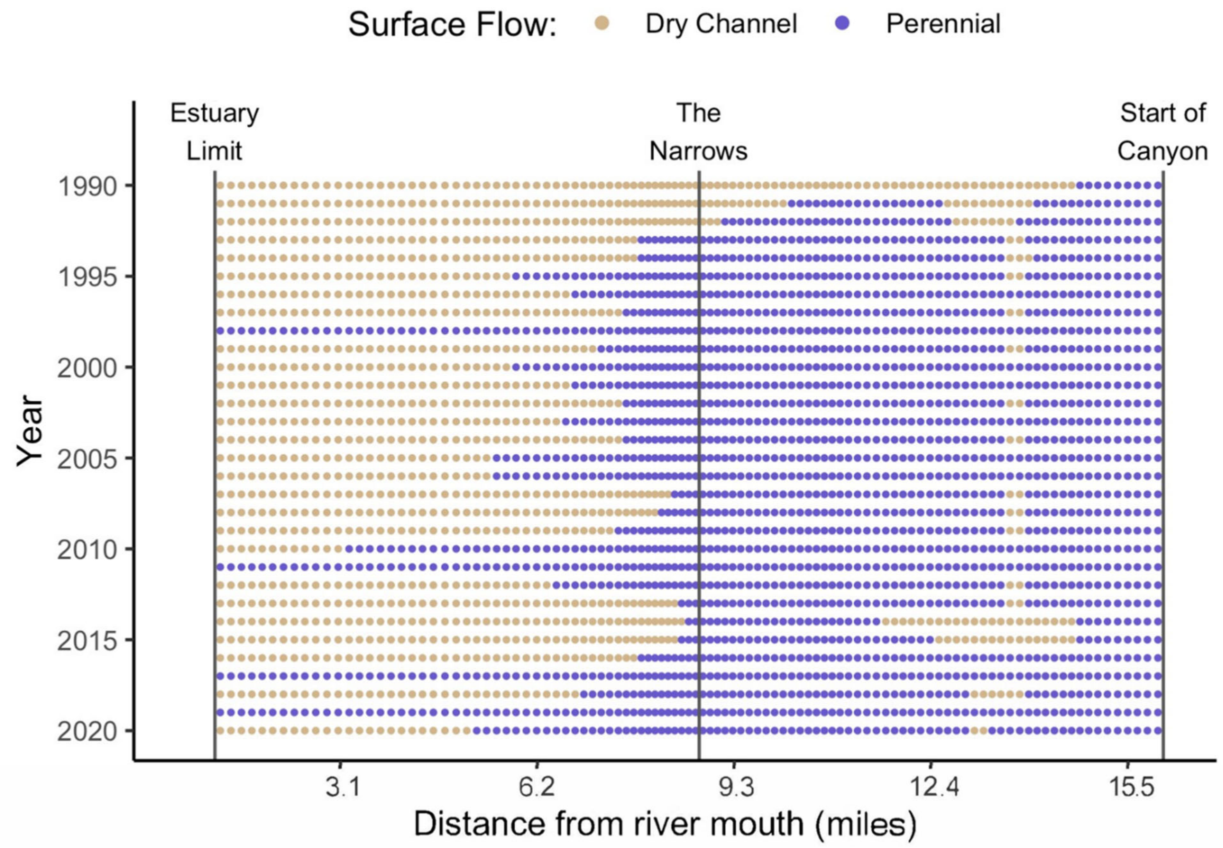


Figure 2-40 Map of the Maximum Extent of Dry Channel Each Year, as Inferred from Records of Fish Relocations

Source: Provided by D. Boughton (revised from Ohms et al. 2021), scale converted by AECOM

Currently, adult steelhead return annually to the Carmel River watershed; however, large fluctuations in abundance occur each year (Figure 2-41). Factors that influence interannual variation in returning adults include parr size and abundance 2 and 3 years prior, which are in turn influenced by spring low-flows and summer median flows (Boughton and Ohms 2022). Ocean conditions also influence the number and condition of returning adults. The CDFW and MPWMD survey data on juvenile steelhead density at annually sampled index sites in the Carmel River also show large annual fluctuations, periods of juvenile steelhead absence during droughts, and a generally declining trend in juvenile abundance from 2000 to 2013 (MPWMD 2015a). The decline of steelhead in the watershed was likely due in part to the presence of Old Carmel River Dam, San Clemente Dam, and LPD (Figure 1-1) (which have been partial barriers to historic spawning and rearing habitat); streamflow reductions due to water diversion from wells downstream of San Clemente Dam; and habitat fragmentation and degradation (MPWMD 2004; NMFS 2012). Although there was in increase in returns in the 1990s, when considering the number of returns per parent from 3 to 4 years prior, there has been a consistent decline in the population since 2000 (Ohms et al. 2021). In 2015 removal of San Clemente Dam enhanced the ability for both upstream and downstream migrant steelhead to move through that reach of the river. Removal of San Clemente Dam is expected to reestablish natural river processes throughout approximately 25 miles of critical habitat for steelhead in the Carmel River and provide multiple benefits for the Carmel River steelhead population (NMFS 2012). The many benefits of removal of San Clemente Dam could, in time, result in a greater number of adult steelhead arriving at LPD.

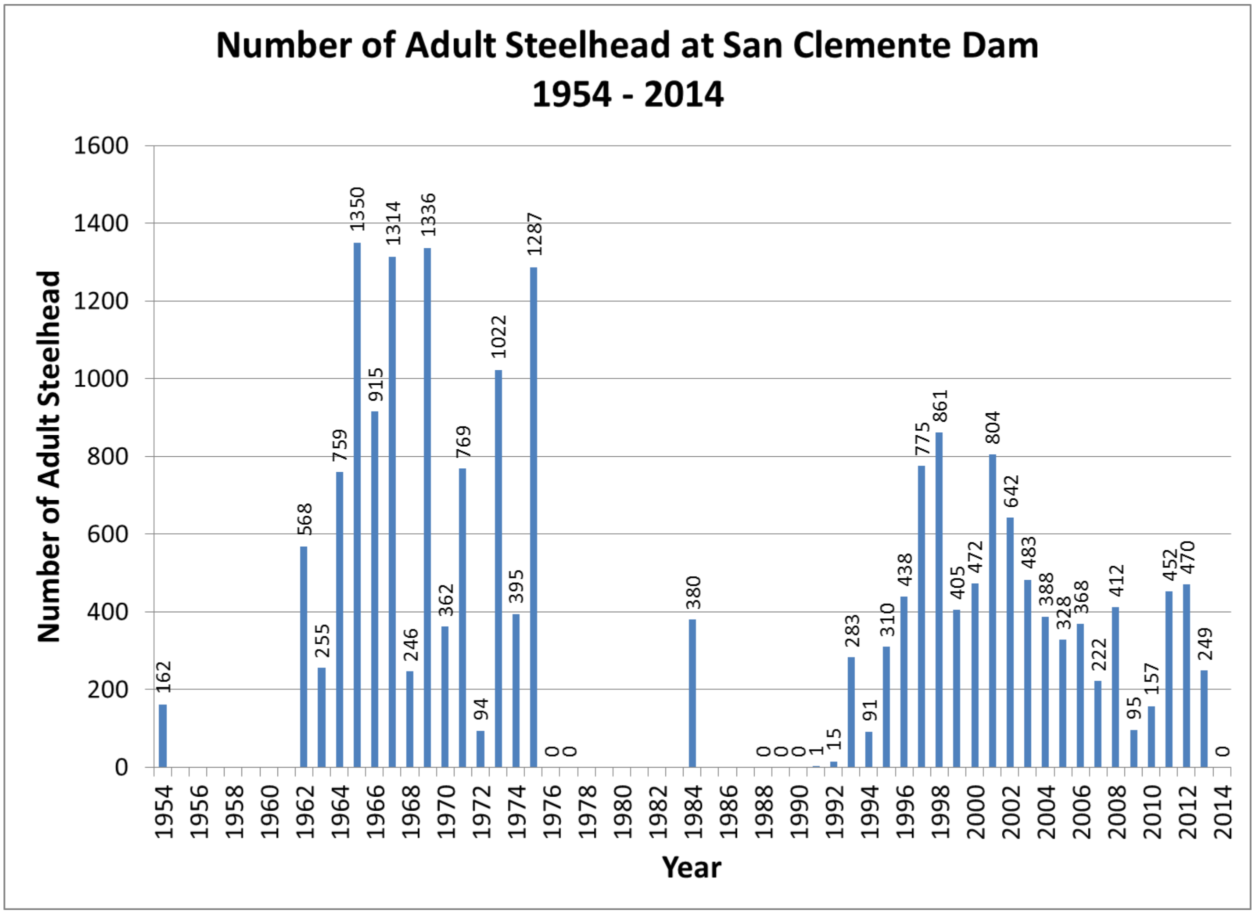


Figure 2-41 Number of Adult Steelhead at the San Clemente Dam (1954 – 2014)

Juvenile steelhead monitoring efforts in the Carmel River conducted by Boughton et al. (2020) from 2017 through 2019 evaluated juvenile steelhead distribution throughout four different reaches of the Carmel River: the valley portion of the mainstem (Tularcitos Creek to the estuary); the canyon portion of the mainstem (LPD to Tularcitos Creek); the upper watershed upstream of LPR; and the set of southern tributaries draining the northernmost portion of the Santa Lucia Mountains. Results indicate that juvenile steelhead densities were essentially the same throughout the survey reaches in 2017 and 2018 and ranged from approximately 20,000 to 30,000 fish per reach. Juvenile steelhead abundances increased each year in the canyon and valley sectors of the Carmel River by 20 to 150 percent and were estimated to be 42,000 and 52,000, respectively (Boughton et al. 2020). Boughton et al. (2020) also found high densities of juvenile steelhead upstream of LPR and in the southern tributaries after a period of prolonged drought, indicating that these areas likely provide drought refugia. Ohms et al. (2021) found that continued dewatering of the lower Carmel River is a detriment to juvenile steelhead rearing and that average fish production in Reaches 1 through 3 is nearly 4.5 times higher than in Reach 4.

Juvenile rearing habitat availability is summarized from various sources in Table 2-5 and is shown on Figure 2-42. An effort has been made to distinguish between seasonal (or intermittent) and perennial rearing habitat displayed in Figure 2-42; however, in drought years additional reaches may only provide seasonal habitat, and in wet years additional habitat may be wetted year-round. For example, following prolonged drought, the Carmel River Steelhead Association reported that all habitat in the Cachagua Creek drainage accessible to anadromous steelhead dried in 2021, and perhaps again in 2022 (Casagrande, pers. comm. 2023).

Table 2-5 Summary of Juvenile Rearing Habitat Distribution in the Carmel River Watershed

Reach[1]	Estimated Age 1+ Rearing Habitat (ft^2)	Proportion of Total Available Rearing Habitat (Percent)	Rearing Density (Low, Moderate, High)[2]
Response Reach 1 (at 5 to 16 cfs)	590,553	23	High
Response Reach 2 (at 5.6 cfs)[3]	284,787	11	Moderate
Response Reach 3 (at 5.6 to 8.5 cfs)	629,562	24	High
Response Reach 4	Seasonally dry	0	Low
Response Reach 5	No data	No data	High[4]
Total in mainstem Carmel River downstream LPD	1,469,093	57	
Tributaries to Carmel River downstream LPD[5,6]	180,421	7	Moderate to high
Total downstream LPD	1,649,514	64	
Carmel River and tributaries upstream of LPD[6]	937,623	36	Low to high
Total in watershed	**2,587,137**		

Notes:

1 Response reaches are: 1) the inter-dam reach between LPD and the former San Clemente Dam; 2) San Clemente Dam to Tularcitos Creek; 3) Tularcitos Creek to the Narrows; 4) from the Narrows to the Carmel River lagoon; and 5) from the lagoon to the ocean (Figure 2-42.

2 Based on three-pass MPWMD electrofishing surveys at index sites (MPWMD 2015a): low (< 0.50 fish/foot), moderate (0.51 to 0.75 fish/foot), high (>0.76 fish/foot).

3 Does not include rearing habitat that was previously inundated by the former San Clemente Reservoir.

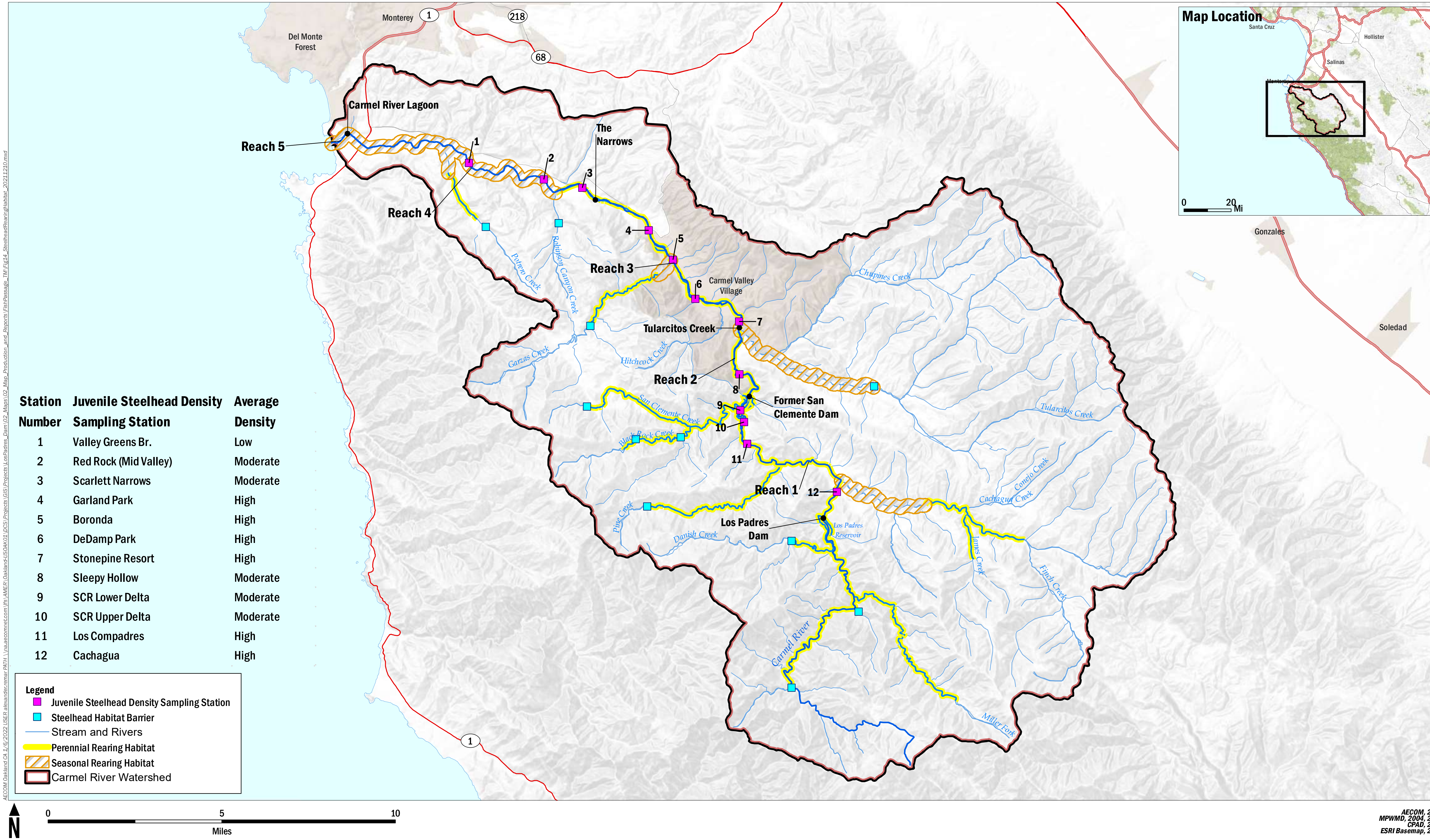
4 Productive rearing observed (Alley & Associates 2014).

5 Survey of tributaries downstream of LPD did not include potential habitat in tributaries, including Pine, Tularcitos, Garzas, and Robinson Canyon Creeks.

6 Density data based on Snider (1983), as cited in MPWMD (2004).

cfs = cubic feet per second
ft^2 = square feet
LPD = Los Padres Dam
MPWMD = Monterey Peninsula Water Management District

Sources: Alley & Associates 2014; MPWMD 2004; MPWMD 2015a; Snider 1983



Station Number	Juvenile Steelhead Density Sampling Station	Average Density
1	Valley Greens Br.	Low
2	Red Rock (Mid Valley)	Moderate
3	Scarlett Narrows	Moderate
4	Garland Park	High
5	Boronda	High
6	DeDamp Park	High
7	Stonepine Resort	High
8	Sleepy Hollow	Moderate
9	SCR Lower Delta	Moderate
10	SCR Upper Delta	Moderate
11	Los Compadres	High
12	Cachagua	High

AECOM
Monterey Peninsula Water Management District

Los Padres Dam and Reservoir Alternatives and Sediment Management Study

FIGURE 2-42

Steelhead Rearing Habitat

2.10.2 Los Padres Reservoir and Upstream

Annual adult steelhead counts at the LPD fish trap range from 0 to 558 fish (Figure 2-43). Several of the years in which no adult steelhead were captured in the Los Padres fish trap were drought years (1976 and 1977, the early 1990s, and 2014 through 2016) during which the lagoon was not open or open only for brief periods. In 2019, the last year shown in Figure 2-43, 126 adult steelhead were counted at LPD. In both 2020 and 2021, 65 adults were counted at LPD.

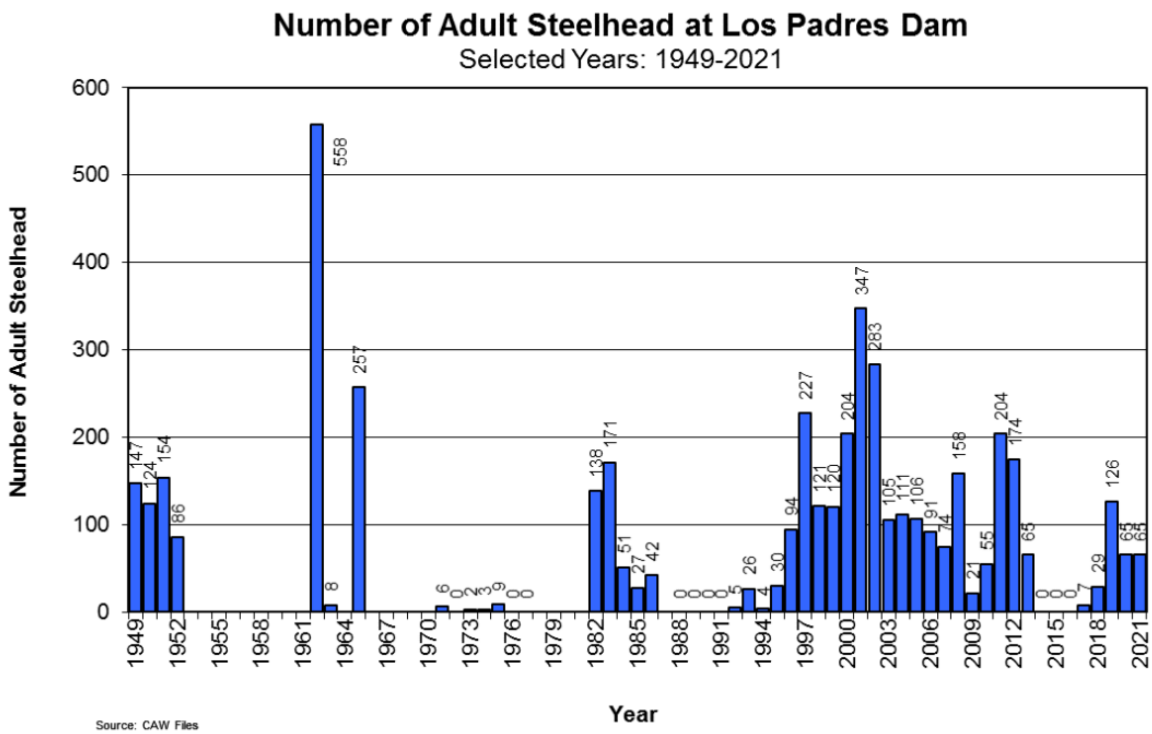


Figure 2-43 Number of Adult Steelhead Counted at the Los Padres Dam (1949 – 2021)

There is limited information on juvenile steelhead occurrence in and emigration through LPR; however, a pair of studies conducted by the MPWMD and a recent study by NOAA provide some insight. In 1996 and 1999, a box trap and weir were installed just upstream of the LPR and a screw trap was installed below the LPD spillway (MPWMD 2015b). The results of this study are presented in Table 2-6. The box trap upstream of the reservoir captured all the flow into the reservoir, so the number of steelhead caught reflects the total smolt migration during the period the trap was operational. Because the screw trap downstream of the spillway only covered a fraction of the total flow, an estimate of the total number of migrating smolts was calculated based on the number of smolts caught and the proportion of the river covered by the trap. During both years of the study, the number of smolts caught downstream of the spillway was greater than the number of smolts caught upstream of the reservoir (MPWMD 2015b). This suggests that the reservoir influences the migration patterns of juvenile steelhead in one of several possible ways including, but not limited to: serving as a rearing area or as a temporary holding area for smolts and juveniles that migrate into the reservoir from upstream rearing habitat; acting as a physical or biological barrier to downstream migration due to some thermal or water quality condition that impedes transit; and/or acting as a refugia for predators that consume smaller fish attempting to pass through the reservoir.

Table 2-6 Results of MPWMD Steelhead Smolt Study at Los Padres Dam

Study Year	Trap Location	Dates of Trap Operation	Number of Steelhead Smolt Caught
1996	Upstream of reservoir	April 6–May 15 (40 days)	52
1999	Upstream of reservoir	March 13–24; April 28–June 2 (44 days)	37
1996	Downstream of spillway	March 17–May 23 (68 days)	96 (estimated 423 migrating smolts total)
1999	Downstream of spillway	March 2–June 2 (91 days)	1,275 (estimated 4,089 migrating smolts total)

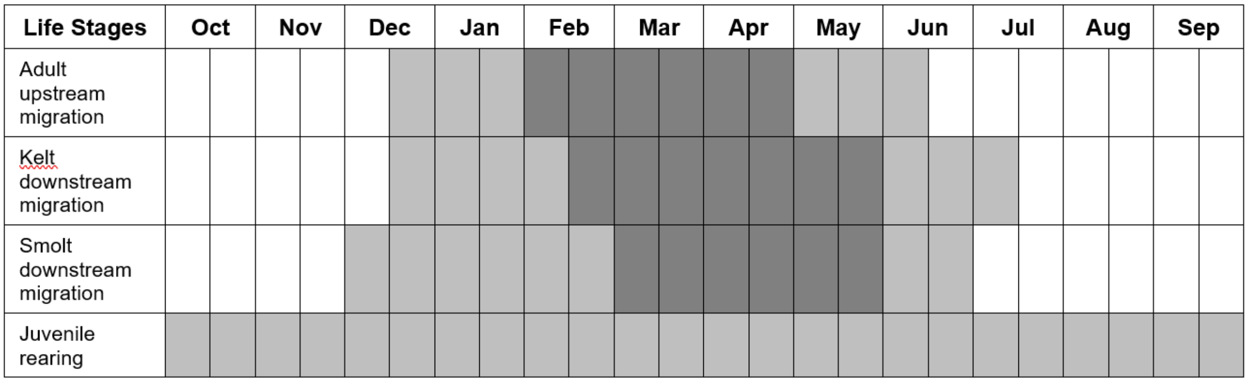
LPD and LPR are partial barriers to both upstream and downstream steelhead passage, so it is possible that the *O. mykiss* population upstream of LPD expresses a resident life history strategy more frequently than it would in the absence of the dam. In 2019 Boughton et al. (2020) captured and installed PIT tags in 345 downstream migrants moving from the upper watershed toward LPR. Boughton et al. (2020) reported that about 75 percent of downstream migrants did not pass through the reservoir and could either be adopting an adfluvial life-history or suffering predation in the reservoir. Observations of large (> 250 mm fork length) *O. mykiss* upstream of the reservoir led CDFG (1995) to assume the potential of an adfluvial life history in the upper Carmel River watershed, where *O. mykiss* are obtaining substantial food resources in the reservoir.

MPWMD estimates that LPD limits access to about 50 percent of the spawning habitat for the Carmel River and 42 percent of rearing habitat (MPWMD 2004, as cited in NMFS 2012). Removal of this dam would be expected to reestablish natural river processes throughout approximately 27 miles of critical habitat for steelhead in the Carmel River. It would have a number of benefits for the Carmel River steelhead population, including enhanced downstream passage conditions for juveniles, kelts, and smolts; and upstream passage for juveniles and adults. It would improve juvenile and adult mobility in the dam removal project area, and provide access to a greater range of habitat (NMFS 2012). Infiltration conditions in the lower valley will likely influence steelhead response if LPD is removed. Boughton and Ohms (2022) modeled the historical baseline flow and five alternative flow scenarios, including removal of LPD; they found that LPD removal yielded slightly higher adult returns if infiltration conditions in the lower valley were low, but slightly lower adult returns if infiltration in the lower valley was high. In the scenario in which LPD was removed and infiltration in the lower valley was high, steelhead production in the upper watershed would increase, but would be outweighed slightly by poorer production downstream due to lower summer flows. The model focused on the effects of flow on steelhead and therefore did not account for some benefits of dam removal, such as improved upstream passage for adults and the restoration of sediment transport processes.

Although available spawning habitat and rearing habitat (especially in relation to instream flows) are not well documented upstream of LPD, limited information suggests that even during periods of low flow, the Carmel River upstream of LPD can support high densities of *O. mykiss*. For example, in July 1994 the California Department of Fish and Game (CDFG) (1995) sampled upstream of LPR and estimated densities of approximately 4,000 *O. mykiss* per mile when streamflow was less than 1 cfs. CDFG estimated similar densities of approximately 4,700 fish per mile when streamflow was much higher (close to 11 cfs) the year prior, in July 1993 (CDFG 1994). Population estimates by CDFG (1995) over a 5-year period from 1989 to 1994 suggest that the *O. mykiss* population upstream of LPR was stable during that period.

2.10.3 Migration Timing

In the Carmel River, steelhead migration at all anadromous life stages generally occurs in the winter and spring. Detailed information on migration periodicity is provided in the following section, with a summary of anticipated migration timings provided in Figure 2-44.



Note: Light gray cells represent the general period of anticipated migration, while dark gray cells indicate the anticipated periods of peak migration.

Figure 2-44 Summary of Steelhead Life History Timing in the Carmel River

Adult Upstream Migration

Data collected at the LPD adult fish trap shows that upstream migration past the dam occurs from mid-December to the end of May with peak migration occurring between February and April (Figure 2-45) (MPWMD 2016). The termination of migration at the end of May could be due to the San Clemente Dam ladder being closed by late April or early June due to low flows or the San Clemente dam safety drawdown operations that occurred after 2002. Therefore, it is plausible that these factors truncated the run timing, and that anthropogenic influences potentially eliminated the late-season element of the adult migration.

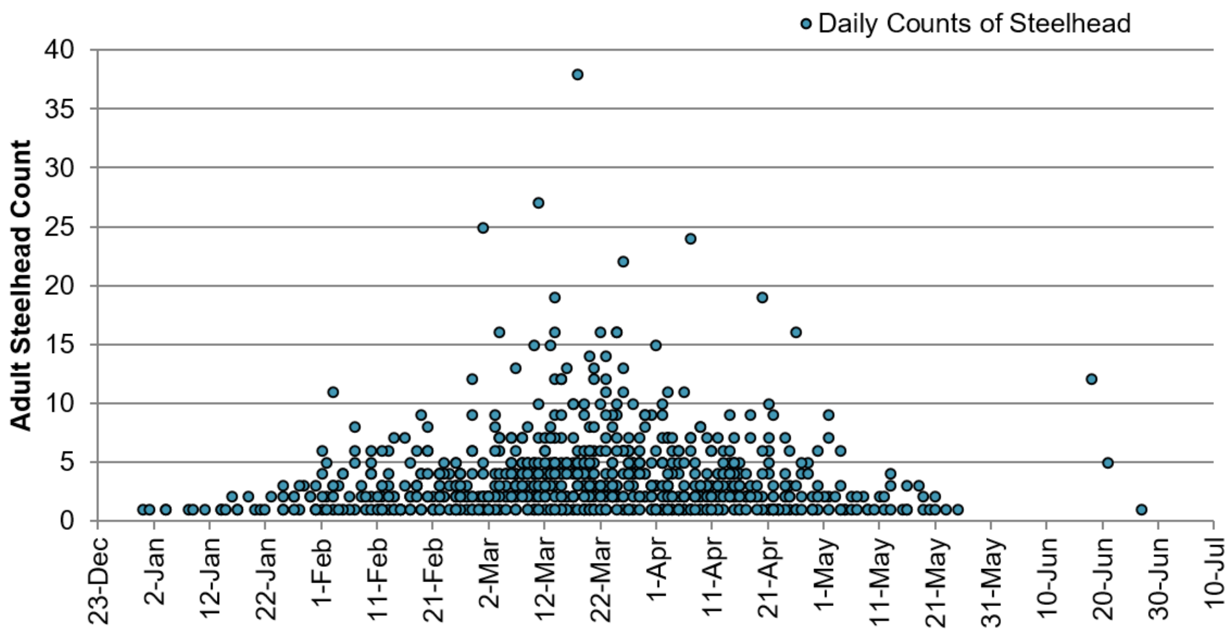


Figure 2-45 Daily Counts of Adult Steelhead at the Los Padres Dam Trap (1995 – 2019)

Adult steelhead migration in the Carmel River Watershed is correlated with the following environmental factors: (1) breaching of the Carmel River Lagoon, (2) minimum navigational flows, (3) attraction flows, and (4) other physical and biological factors. The sand bar at the mouth of the Carmel River Lagoon must breach to allow entry to the watershed; in the 3-year period between 1988 and 1990 the sand bar did not breach and, as a result, no steelhead entered or left the watershed. Based on discussion at the LPD Fish

Passage Study TRC Meeting No. 1, the sandbar at the lagoon is typically not breached until 1 to 14 days after LPD spills, not before, and rarely breaches without a spill from the dam (HDR et al. 2021).

There is more information to describe minimum navigational flows in the lower Carmel River than there is farther upstream. Evaluation of minimum navigational flows is typically based on a very conservative set of criteria that is meant to be protective of fish if the flow numbers are used to guide the release of water from storage to support fisheries in regulated rivers. However, a motivated steelhead may be able to migrate past critical riffles or other impediments at flows lower than the minimum estimated using established criteria and methods. Based on discussion at the LPD Fish Passage Study TRC Meeting No. 1, minimum navigation flows, or flows required for steelhead to pass natural and anthropogenic barriers, are thought to be on the order of 20 to 40 cfs (HDR et al. 2021). Similar minimum navigational flows for the Carmel River have been estimated at other points in time: a USFWS instream flow study reported that 30 cfs was sufficient to allow for passage in the lower reach of the Carmel River (USFWS 1980) and Kelley and Dettman (1981) identified 50 cfs as the minimum transportation flow for the river.

Attraction flows, or flows required to attract migrating steelhead, are typically greater than the minimum transportation flows (Snider 1983). Snider (1983) noted that arrival of the first adult steelhead from 1964 to 1975 was almost always preceded by flows of 200 cfs or greater, and that years where peak flows did not exceed 100 cfs had the lowest numbers of adult migrants. Adult migration is also influenced by preceding flows and climatic conditions, the proportion of the run that has already migrated, and possibly other factors like sexual maturity and turbidity (Shapovalov and Taft 1954). Correlation with mean daily river flows and number of fish collected at the LPD indicates that most fish collected during the period of record from 1995 to 2019 occurred at mean daily flows between 20 and 200 cfs with an overall range from 10 to as high as 1,700 cfs (HDR et al. 2021).

Post-spawning Adult Downstream Migration

Kelt downstream migration is expected to occur between mid-December and mid-July (Figure 2-44). Only landlocked kelts are anticipated to migrate between December and the first half of February. The period of peak migration rates is anticipated to occur between mid-February and the end of May (HDR et al. 2021).

Juvenile Downstream Migration

There are three principal life-history groups in the S-CCC steelhead DPS: fluvial-anadromous (fish that rear in the mainstem and tributary streams), lagoon-anadromous (fish that migrate downstream to rear in the Carmel River Lagoon during their first or second summer), and freshwater resident (NMFS 2012). Lagoon-anadromous steelhead typically only require one growing season to reach smolt size, while fluvial-anadromous fish generally grow more slowly and may rear for up to 3 years before undergoing smoltification (Moyle 2002). The period of active steelhead smolt downstream migration begins in December and continues through June, with the majority migrating in March, April, and May (Figure 2-44). Larger fish tend to emigrate earlier in the season, and Snider (1983) found that juvenile steelhead in the lower Carmel River Watershed emigrated earlier than those above LPD, which was likely due to more favorable growing conditions producing larger fish in the lower watershed.

Movement patters of fish PIT tagged within the Carmel River between 2017 and 2021 exhibited similar migration behavior with peak downstream movement occurring between March and April with higher numbers in February and May (Ohms et al. 2021). However, the most recent study conclusions suggest that smaller fish move downstream at the early and later tails of the smolt season, whereas larger fish move downstream during March and April. Although not analyzed for this report, the Smolt Spy Camera on the FWC has shown relatively large numbers of small (estimated at ≤50 mm) yearling fish approaching or passing through the FWC in January and February (Casagrande, pers. comm. 2022). By June PIT tag detections declined significantly, indicating the end of downstream smolt or juvenile emigration (Ohms et al. 2021).

Timing of smolt emigration is influenced by numerous factors in addition to fish size including streamflow, water temperature, photoperiod, food availability, and chemical factors like DO levels (Shapovalov and Taft 1954; Hoar 1988; Wedemeyer et al. 1980). Snider (1983) reported that high spring flows lasting at least through June appeared to be necessary to allow smolt emigration and a 1996 MPWMD study of smolt emigration found that two storm events correlated with large increases in the number of captured smolts (MPWMD 2015b). These studies support the conventional wisdom that smolt emigration timing correlates with large flow events in the winter and spring (Cramer and Lichatowich 1978; NMFS 2012). However, there is also evidence that smolts may initiate migration earlier in the season in response to lower-than-average flows: Shapovalov and Taft (1954) found that low flows and high-water temperatures, which are typically correlated with dry water years, advance the timing of smolt emigration. The complex hydrological patterns and numerous environmental and biological factors that influence smolt emigration make predicting emigration timing and understanding emigration cues difficult, as there are multiple simultaneous and sequential events that trigger emigration.

2.10.4 Other Species Considered

Although steelhead are the focal species of the Los Padres Alternatives Study, providing passage for Pacific lamprey (*Entosphenus tridentatus*), and preventing increases in the distribution and abundance of nonnative species, particularly predatory brown trout (*Salmo trutta*), have also been considered.

Pacific lamprey historically occupied the Carmel River Watershed and are considered currently present in the watershed (USFWS 2012; Goodman and Reid 2015). They historically occupied up to 832 square kilometers of the watershed and their current distribution is about half of historical levels (USFWS 2012). Their population size is unknown and, while it is believed their abundance has declined, the degree of population decline is also unknown (USFWS 2012). The main stem of Carmel River and San Clemente Creek likely provide suitable habitat for Pacific lamprey, but most tributaries are likely too small, high gradient, or seasonal to support the species (Goodman and Reid 2015). However, the watershed has not been adequately surveyed for Pacific lamprey and their abundance and distribution is not well-understood. There have been anecdotal reports of observations of Pacific lamprey upstream of the former San Clemente Dam site since the dam was removed in 2015.

Although steelhead have been relatively well-studied, there are limited data on the composition of other fish species in the Carmel River Watershed. CDFW electrofishing studies upstream of LPR found brown trout, an introduced species that preys on juvenile *O. mykiss*, at a density of 8 trout per mile in 1993 (CDFG 1994). There seemed to be a downward trend in brown trout composition upstream of LPR; brown trout made up 12 percent of the trout population in 1989, 2 percent in 1992, and only 1 percent in 1993 (CDFG 1994). However, when the surveys were repeated in 1994, the brown trout density had risen to 754 trout per mile and brown trout comprised 9 percent of the trout population (CDFG 1995). CDFW electro-fished upstream of LPR in 2003 and observed brown trout up to 7 inches in fork length, and again in 2005 and observed a few brown trout up to 14 inches (Highland, CDFW, pers. comm. 2017). There have been no recent surveys of brown trout in the Carmel River Watershed, but they are believed to occur throughout the watershed and there are anecdotal reports that they are abundant in LPR.

A fish capture and relocation effort was conducted in the plunge pool downstream of LPD from June 29 to July 2, 2015 (ESA 2015). In addition to *O. mykiss*, brown trout, mosquitofish (*Gambusia affinis*), and threespine stickleback (*Gasterosteus aculeatus*) were captured. Of the 20 brown trout captured, five were larger than 20 inches and one was in the 14- to 16-inch range. Signal crayfish (*Pacifastacus leniusculus*) and swamp crayfish (*Procambarus clarkia*) were also encountered.

3. Technical Analyses

This section describes specific analytical methods used to evaluate or compare the Los Padres dam, reservoir, and sediment management alternatives described in Section 5. Some of these methods were used by others in supporting or related studies and some are methods employed by the AECOM Team, developed and presented in previous reports or TMs. Specific analyses described in this section include water availability, fish passage, flood frequency, PMF, flood frequency, flow duration, and development of sediment rating curves, bedload sediment transport analyses, and a preliminary analysis of suspended sediment and its effects on steelhead. Although the original presentation and source of the methods and analyses varies, they are all presented in this section. The results of these specific analyses as well as other, more general, qualitative analysis are discussed in the context of the dam, reservoir, and sediment management alternatives in Section 5.

3.1 Water Availability

Nearly all elements of juvenile steelhead rearing habitat are strongly influenced by instream flows, which affect rearing habitat area, the depth and volume of pools, connectivity between habitat types, water velocity, and water temperatures. Streamflow also dictates the quantity of drifting invertebrates that reach feeding steelhead (Harvey et al. 2006); higher summer flows allow steelhead to better maintain feeding rates during periods of higher water temperatures, when metabolic demands are greater (Krug et al. 2012).

NMFS has been studying steelhead in the Carmel River (Section 1.3.4). Ohms et al. (2021) used a nonlinear regression fit to a stock-recruitment model to estimate the relative steelhead production in the Carmel River, based on juvenile steelhead density, environmental variables, and the number of adult spawning fish. More recently, Boughton and Ohms (2022) used generalized additive regression models to predict the effects of flow on juvenile steelhead size, density. In both models, flow was closely tied to juvenile production. Juvenile production increases with summer flows because higher summer flows increase the wetted habitat area available for fish to rear (Ohms et al. 2021). This positive relationship between juvenile production and summer flow exists up to about 9 cfs of median summer flow, the point at which further increases in summer flow have diminishing effects on the wetted habitat area. Above 9 cfs, there is a negative relationship between summer flow and juvenile production (Ohms et al. 2021), likely mediated by the effect of spring flow (Boughton and Ohms 2022). High spring low-flows (which are correlated with high summer flows) result in larger juveniles (Boughton and Ohms 2022), and there is an inverse relationship between juvenile steelhead size and density (a process called self-thinning), with large fish defending larger territories and driving smaller fish to disperse or perish (Dunham and Vinyard 1997). The Carmel River models suggest that high spring low-flows produce larger juveniles that are more likely to survive ocean conditions in adulthood; there is an inverse relationship between juvenile size and density due to self-thinning, so years with high flows may produce larger but fewer juveniles; and higher summer median flows benefit juvenile production up to the point where wetted habitat area is maximized and the Carmel River is connected to the lagoon. The Ohms et al. (2021) model found that variation in local flow (as represented by flow measured in the canyon [Sleepy Hollow gauge], upper valley [Don Juan gauge], and lower valley [Near Carmel gauge]) was a better predictor of juvenile production than upstream, pre-infiltration flow (a general measure of flow prior to infiltration into the aquifer). The Boughton and Ohms (2022) model found that adult steelhead returns were influenced by infiltration in the lower valley, with higher adult returns predicted when infiltration in the lower valley was low. The results of both models suggest that infiltration into the aquifer is an important influence on steelhead productivity, above and beyond the effects of water releases from LPR, as evidenced by the lower river routinely drying out while releases are being made from LPR.

In central California watersheds, the most geographically restricted habitat type is probably summering habitat, due to the Mediterranean climate and the general aridity of the region (Boughton and Goslin 2006). In their assessment of suitable steelhead habitat, NMFS researchers Boughton and Goslin (2006) state that steelhead over-summering habitat is thought to have a restricted distribution, more so than winter spawning and rearing habitat. Citing Spina et al. (2005), Boughton and Goslin (2006) further conclude that low summertime flows are probably an important limiting factor for steelhead in arid California watersheds, given the prevalence of intermittent streams in the region. Furthermore, the habitat requirements and critical environmental factors for different age classes of juvenile steelhead are relatively similar, but as fish grow, they require more space for foraging and cover. Because of their larger size, older juvenile steelhead (age 1+/2+) have higher energetic demands; they require deeper, more complex pools, and large rocky substrate or in-channel wood for cover while feeding (Hartman 1965; Fontaine 1988; Spina 2003). Rivers can typically support far fewer older and larger age 1+ trout than age 0+ trout. This results high rates of mortality during the first year of life, as fish grow and encounter habitat limitations that constrain the number of larger and older fish that can be supported (Elliott and Hurley 1998). Therefore, flow requirements for age 1+ juveniles are considered to be especially critical for steelhead in the Carmel River watershed.

Currently, water availability in the Carmel River downstream of LPD during the dry season is controlled by seasonal hydrology and water release operations at LPD. The ability to provide reservoir releases at specific rates and locations has been affected by episodic rockslides, including a series of rockslides that has limited use of the low-level outlet over the past several years. Recent research suggests that future interannual sediment yield variations will become more extreme, and episodes of sediment deposition will become more frequent (East et al. 2018). Although Cal-Am is planning a new low-level outlet that would improve reliability, water available for maintaining steelhead summer and fall rearing habitat downstream of LPD will continue to depend on mechanical infrastructure if LPD is in place, and could be subject to unpredictable operational issues affecting reservoir releases. The following subsections describe how hydrologic and hydraulic models are used to compare water availability and its effects on steelhead across alternatives in this report.

3.1.1 CRBHM and Water Availability

The CRBHM was developed to evaluate hydrologic effects related to changes in water supply, groundwater pumping, and climate change in the Carmel River watershed. Considerable time was spent by MPWMD and their collaborators reviewing and calibrating the CRBHM in coordination with the TRC, some of which is captured in meeting summary presentations prepared by MPWMD (presentations provided as Attachment A to the Effects to Steelhead TM [Appendix E, provided under separate cover]). Nash-Sutcliffe Efficiency (NSE) values were used to evaluate the ability of the CRBHM to predict actual streamflows. From these presentations, we know that NSE values of 0.65 and greater are considered acceptable and that NSE values calculated for the CRBHM ranged between 0.72 and 0.78 for each model node, on a daily timestep, during the low-flow period of April through October. MPWMD described how the CRBHM often shows streamflows in response to the first rains of each water year that are not actually observed in the Carmel River, and how efforts to eliminate this artifact from the model created other issues. The root mean square error (an indication of how concentrated the data are around the line of best fit) of the calibrated model for daily low flow (May through September) under 50 cfs for different stream gages ranges from 8.5 cfs to 11.9 cfs.

In this report, the water availability analyses focus on low flows from July through September. MPWMD has pointed out that in many years the modeled spring recession is a good predictor of observed flows, and the model shows seasonal drying in many areas where drying is observed in the lower Carmel River. MPWMD also noted that where model predictions of spring recession deviated from observed values, the predicted flow was higher than observed in some years and lower in others; calibration efforts sought to balance these deviations. Currently, D. Boughton (Boughton, pers. comm. 2021) is working on a comparison of the outputs of the CRBHM with measured gauge data showing that infiltration in the lower Carmel River is consistently underestimated by the model. Although there is uncertainty in the absolute, instantaneous flow rates predicted by the CRBHM, relative differences are emphasized in this report when comparing the effects of the alternatives on water availability. Notably, MPWMD has stated that if the CRBHM overpredicts flow rates during a given year, that same deviation is seen across all model scenarios—in which case, the relative comparison is still useful for perceiving differences among alternatives.

The following CRBHM scenarios, including any uncertainty or inaccuracy associated with the model predictions, are used to assess the potential effects of the current dam, reservoir, and sediment management alternatives on water availability and steelhead, based on the analysis previously presented in Appendix E:

- **LPD Remains, Cease and Desist Order, No Sediment Management:** This model is configured to represent CDO pumping (3,376 AFY) and ASR diversions, with the LPR in place with its current storage and operation. MPWMD determined that the most likely CDO-compliant pumping of 3,376 AFY would be carried out by pumping 600 AF from June through November (100 AF per month). The remaining 2,776 AF would be pumped out from December through May (462.7 AF per month). It was understood that summer pumping would be minimized to help steelhead in the lower river, but 100 AF of pumping per month was required to keep the Begonia Iron Treatment Removal Plant operating. All pumping would occur in lower Carmel Valley at Cal-Am's Cañada, Cypress, and Pearce wells, in accordance with the existing State Board Order that requires pumping in the lower valley instead of wells higher in the system. This applies to the latest **Alternative 1**, as described in Section 5 of this report.
- **Remove LPD:** This model is configured to simulate removal of LPD, with a water right of 3,376 AFY, which reflects the CDO pumping. All pumping remains in lower Carmel Valley at Cal-Am's Cañada, Cypress, and Pearce wells, in accordance with the existing State Board Order that requires pumping in the lower valley instead of wells higher in the system. In addition to pumping that complies with the CDO, ASR diversions are accounted for. This applies to the current **Alternative 2**, as described in Section 5 of this report.
- **Storage Expansion (Rubber Dam):** This model is configured to simulate installation of a rubber dam and dredging of LPR, with a water right of 4,492 AFY, which reflects additional storage capacity at LPR (3,295 AF) and pre-1914 and riparian rights (1,197 AF). This assumes that a new water right would allow additional pumping in the Carmel River Basin above the 3,376 AFY CDO limit. The model scenario assumes that diversions remain in lower Carmel Valley at Cal-Am's Cañada, Cypress, and Pearce wells. Summer pumping is fixed at 100 AF per month, so the new winter pumping was set at 3,892 AF (4,492 - 600 = 3,892) or 648.7 AF per month, December through May. Water released from LPR would provide instream, environmental flows until it is picked up by the lower wells. This applies to the latest **Alternative 3**, as described in Section 5 of this report.

Output from the CRBHM was used to develop several sets of figures, initially presented in Appendix E, updated and used in this report to compare the current alternatives, each of which incorporates uncertainty inherent in the model predictions. The figures include flow exceedance curves for the Carmel River at Highway 1 (Figure 1-1). Exceedance curves graphically display the probability that a flow of a given magnitude will be exceeded at a given location. Due to the limiting factors associated with low summertime flows, exceedance curves were generated to compare flow conditions among alternatives during the low-flow period (July through September) using CRBHM model years (1992 through 2015) for all water years (Figure 3-1). Exceedance curves were also generated using average flow conditions during dry and critically dry years to compare alternatives during years when Carmel River steelhead would be most susceptible to differences in water availability (Figure 3-2). When applied to the dry season, the exceedance curves provide a relative comparison of the percentage of time that rearing flows are equaled or exceeded under each alternative. Over time, dry season flow exceedance probability associated with Alternatives 1 and 3 would diminish due to sediment accumulation and storage loss.

Data summarized from the CRBHM were also used to develop maps that display the predicted downstream extent to which critical flows extend in the Carmel River under the proposed alternatives during the dry season (July through September) of normal water years, including flows exceeding 0.5 cfs, 3 cfs, and 5 cfs (Figure 3-3 through Figure 3-5). The low-flow values were selected for comparison because they encompass the range of flows within which the extent of steelhead summer rearing habitat can be affected by small changes in flow. Due to the low flows presented in these figures, relative to the error inherent in the CRBHM, these figures should be used to compare and assess the relative effect of alternatives on downstream flow, rather than the absolute magnitude or absolute extent of flow under any given alternative. Results of the water availability analysis, including interpretation of these figures, are discussed in the context of Los Padres dam, reservoir, and sediment management alternatives in Sections 4 and 5.

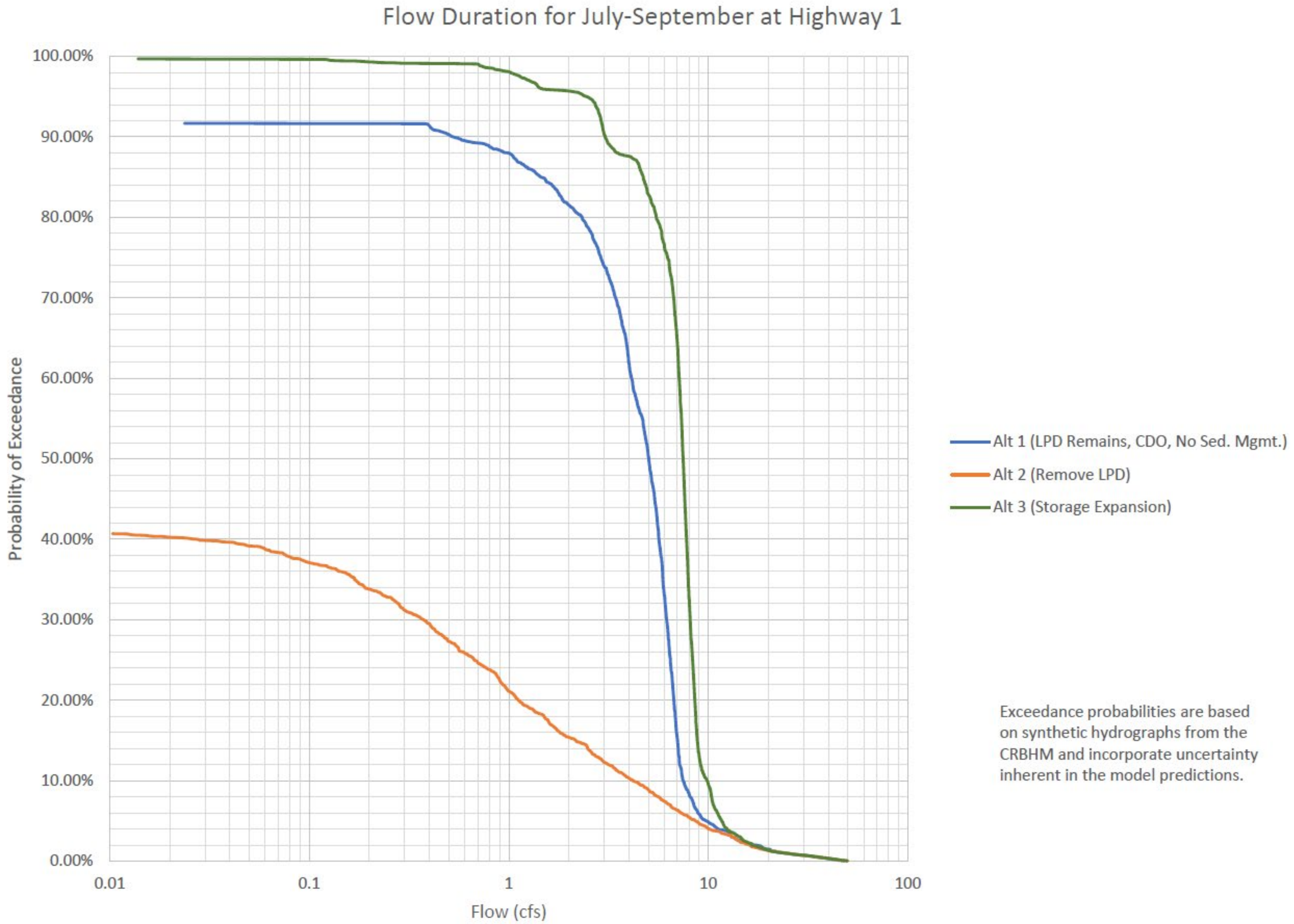


Figure 3-1 CRBHM Flow Exceedance Probability Curve for the Carmel River at Highway 1 for all Water Years during Low Summer Flow Conditions (July through September)

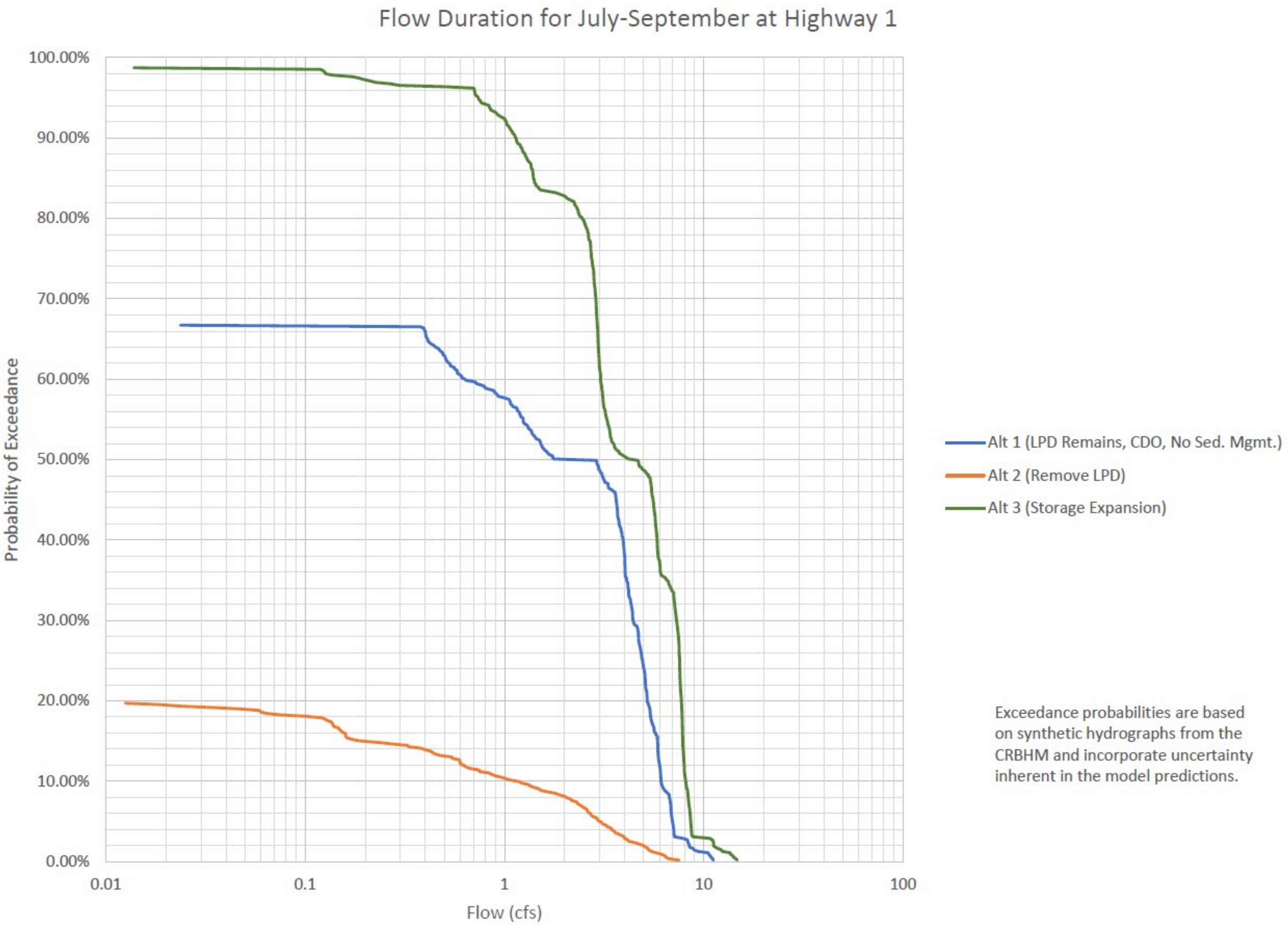
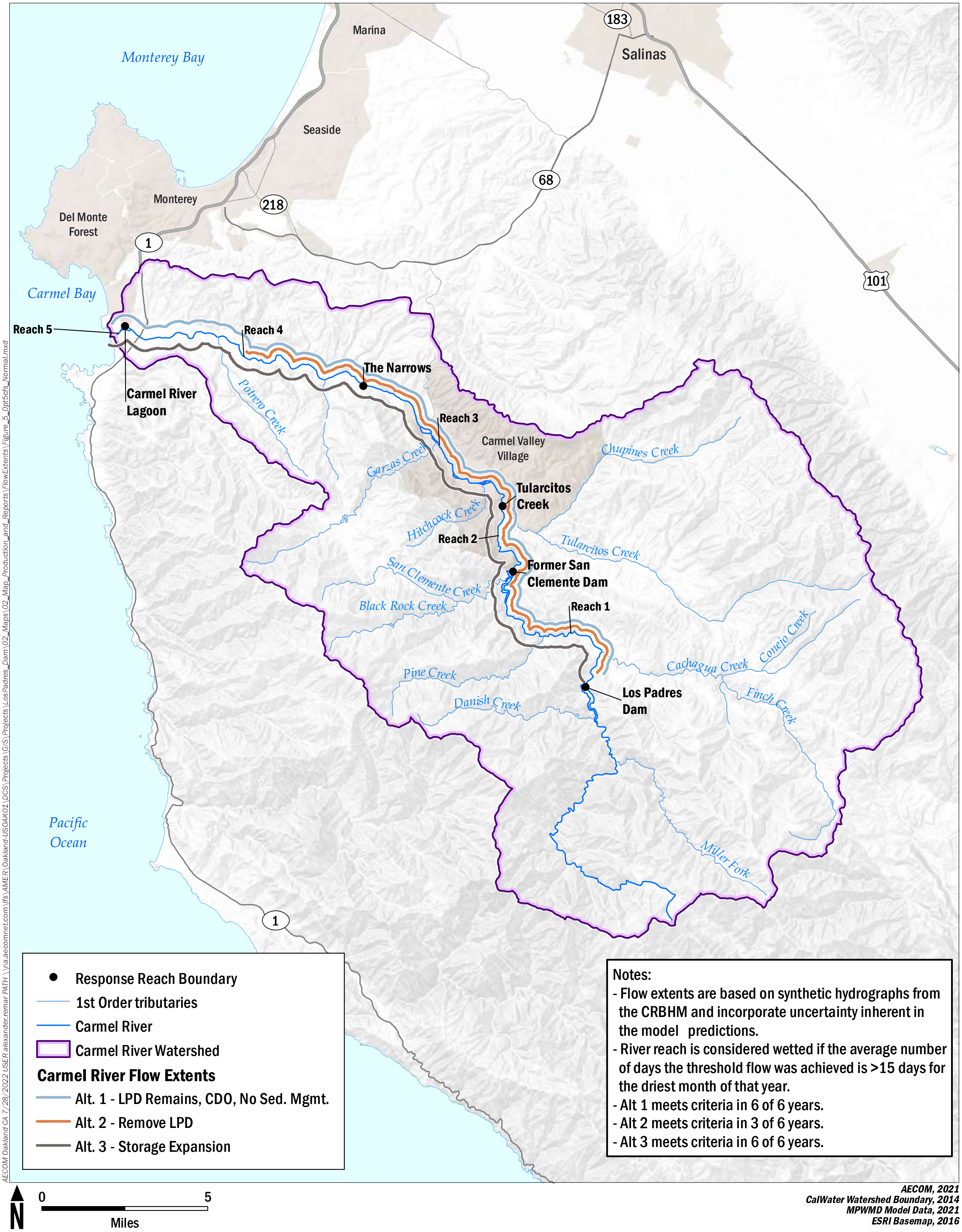


Figure 3-2 CRBHM Flow Exceedance Probability Curve for the Carmel River at Highway 1 for Dry and Critically Dry Water Years during Low Summer Flow Conditions (July through September)



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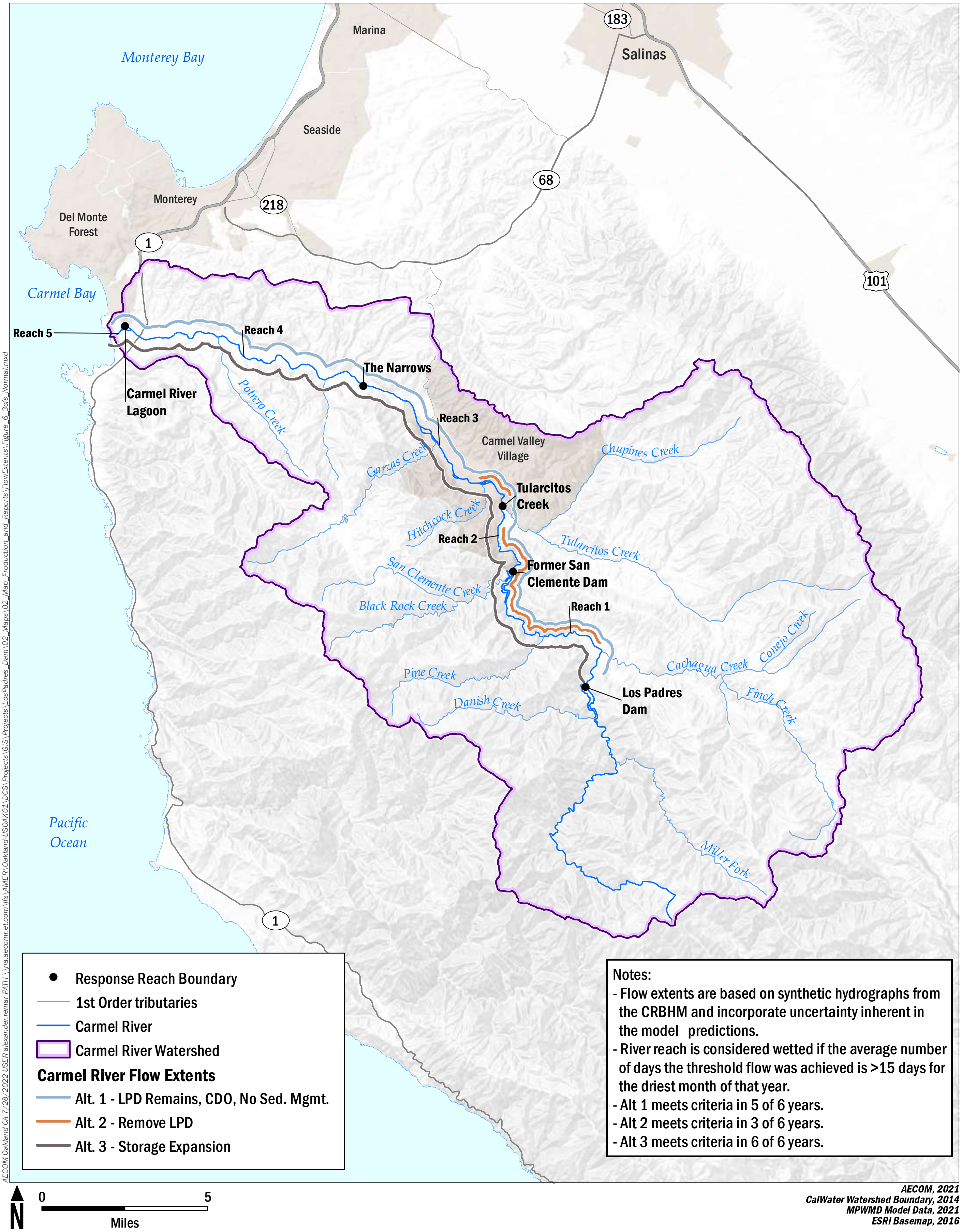
Los Padres Alternatives Study

FIGURE 3-3

Extent of Carmel River Flows (0.5 cfs) in July through September under LPD Alternatives during Normal Years



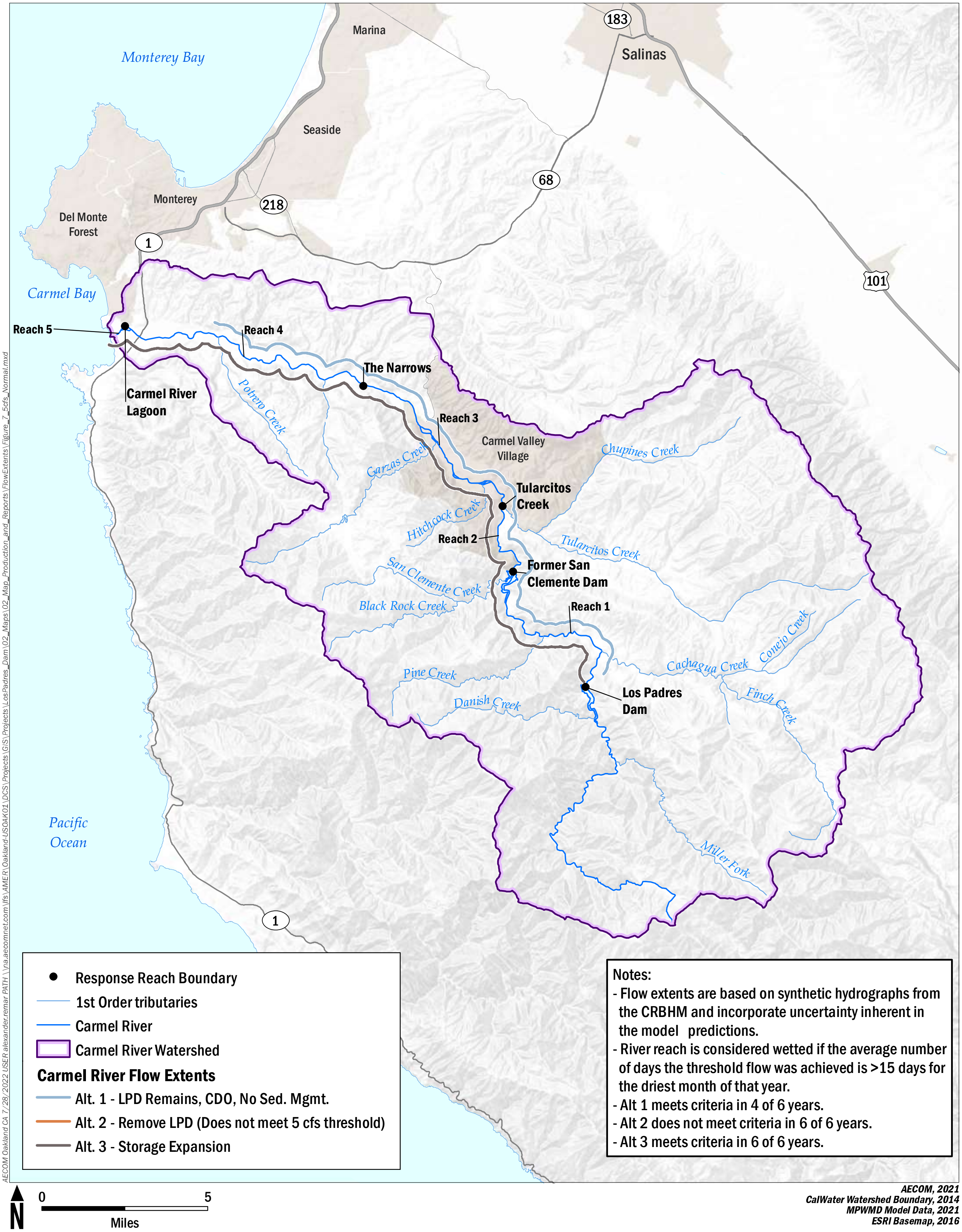
AECOM Oakland CA 7/28/2022 USER alexander.remar PATH \\na.aecomnet.com\lfs\AMER\Oakland-USOAK01\DCS\Projects\GIS\Projects\LosPadres_Dam\02_Maps\02_Map_Production_and_Reports\FlowExtents\Figure_6_3cfs_Normal.mxd

AECOM, 2021
CalWater Watershed Boundary, 2014
MPWMD Model Data, 2021
ESRI Basemap, 2016

AECOM
Monterey Peninsula Water Management District
Los Padres Alternatives Study

FIGURE 3-4

Extent of Carmel River Flows (3 cfs) in July through September under LPD Alternatives during Normal Years



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Los Padres Alternatives Study

FIGURE 3-5

Extent of Carmel River Flows (5 cfs) in July through September under LPD Alternatives during Normal Years

3.1.2 Steelhead Habitat in Relation to Instream Flow

The IFIM model was developed with 1D and two-dimensional (2D) modeling capability to evaluate changes in steelhead habitat resulting from alternative water supply assumptions (Normandeau 2019). MPWMD completed habitat mapping from the ocean to LPD in 2014 and 2015 and established transects for flow measurements, which were completed in 2016. The initial study results were presented in a report prepared by Normandeau Associates, Inc. (Normandeau 2019) and refined habitat duration curves for eight operational scenarios were provided in February 2021 (Normandeau 2021).

The results of the IFIM were intended to support a variety of studies and efforts in connection with managing the Carmel River lagoon, evaluating options for the future of LPD, and evaluating operational changes due to proposed water supply projects that replace Carmel River diversions. Suitable steelhead habitat was mapped and modeled under a range of flows. NMFS (2018) provided extensive review of the IFIM report, and strongly stated that the IFIM results should not be used in isolation from other analysis to set instream flow targets in the Carmel River. NMFS was concerned with the accuracy of the results in recognition of changing channel morphology, use of habitat suitability criteria, and limiting factors for steelhead in the watershed. The results of the IFIM were used to assess general patterns in rearing habitat availability for steelhead during the low-flow season under the alternatives considered, while recognizing the limitations and uncertainty of the IFIM approach.

The IFIM combined the hydraulic and habitat suitability criteria components to generate a habitat suitability index, often termed “weighted usable area”; in Normandeau (2019), the index is more accurately termed “area-weighted suitability.” Although the relationship between flow and habitat may be more complex than is captured in the IFIM, it is among several tools available for comparing alternatives. The IFIM study (Normandeau 2019) found that, for juveniles (> 6 centimeters fork length), habitat generally increases with increasing flows (Figure 3-6). Flows between 25 and 75 cfs produced maximum or near-maximum habitat for juveniles upstream of the Narrows, and higher flows produced a greater amount of habitat downstream of the Narrows. These flows producing maximum habitat in the Carmel River are much higher than would occur during summer in an unmanaged or historical condition and are higher than flows typically produced during summer when releases from LPR are managed to benefit steelhead. Juvenile rearing habitat declines rapidly as flows drop below 10 cfs and is of low abundance when flows are 5 cfs or lower.

For fry (< 6 centimeters fork length), habitat generally decreases with increasing flows, with maximum available habitat at flows around 5 cfs upstream of the Narrows. Higher flows (50 cfs) produced more habitat in the lower reach, likely due to the width of the channel and lower gradient of the river in this reach. For fry, habitat declines rapidly throughout all reaches evaluated using the IFIM at flows less than 3 cfs.

Each of the CRBHM scenarios described above was run through the IFIM in a time series analysis to predict rearing habitat duration for fry and juvenile steelhead (Normandeau 2021). The habitat duration graphs generated from the IFIM model outputs are displayed in Figure 3-7 and Figure 3-8. Because these graphs are based on synthetic hydrographs generated from the CRBHM, they are subject to accuracy limitations noted for the CRBHM. Juvenile habitat duration is displayed from July through September (Figure 3-7). In the Carmel River, steelhead fry rearing occurs primarily between April and June, although some fry-sized fish have been observed as late as July in some years. To display the effects of low-flow season on fry rearing, habitat duration is shown for the month of July only (Figure 3-8). These results and interpretation of these figures are discussed in Section 5.

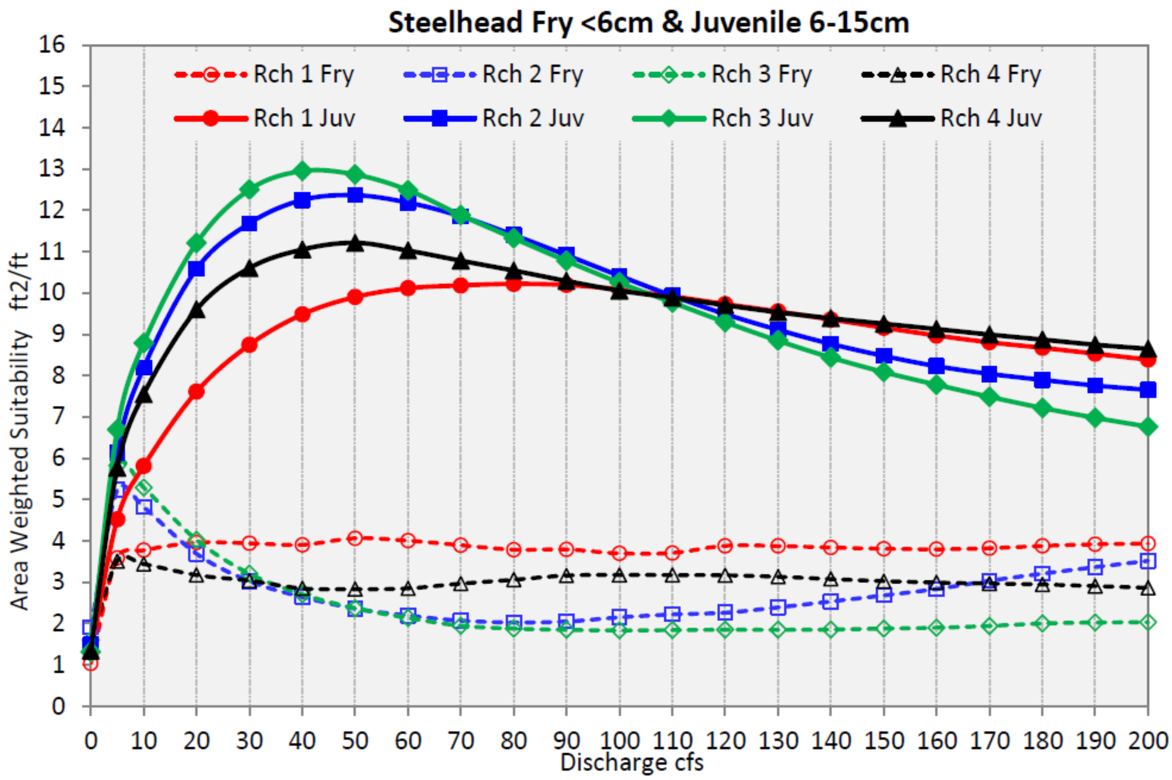

Figure 3-6 Area-Weighted Suitability Relationships for Fry and Juvenile Steelhead Rearing in the Carmel River

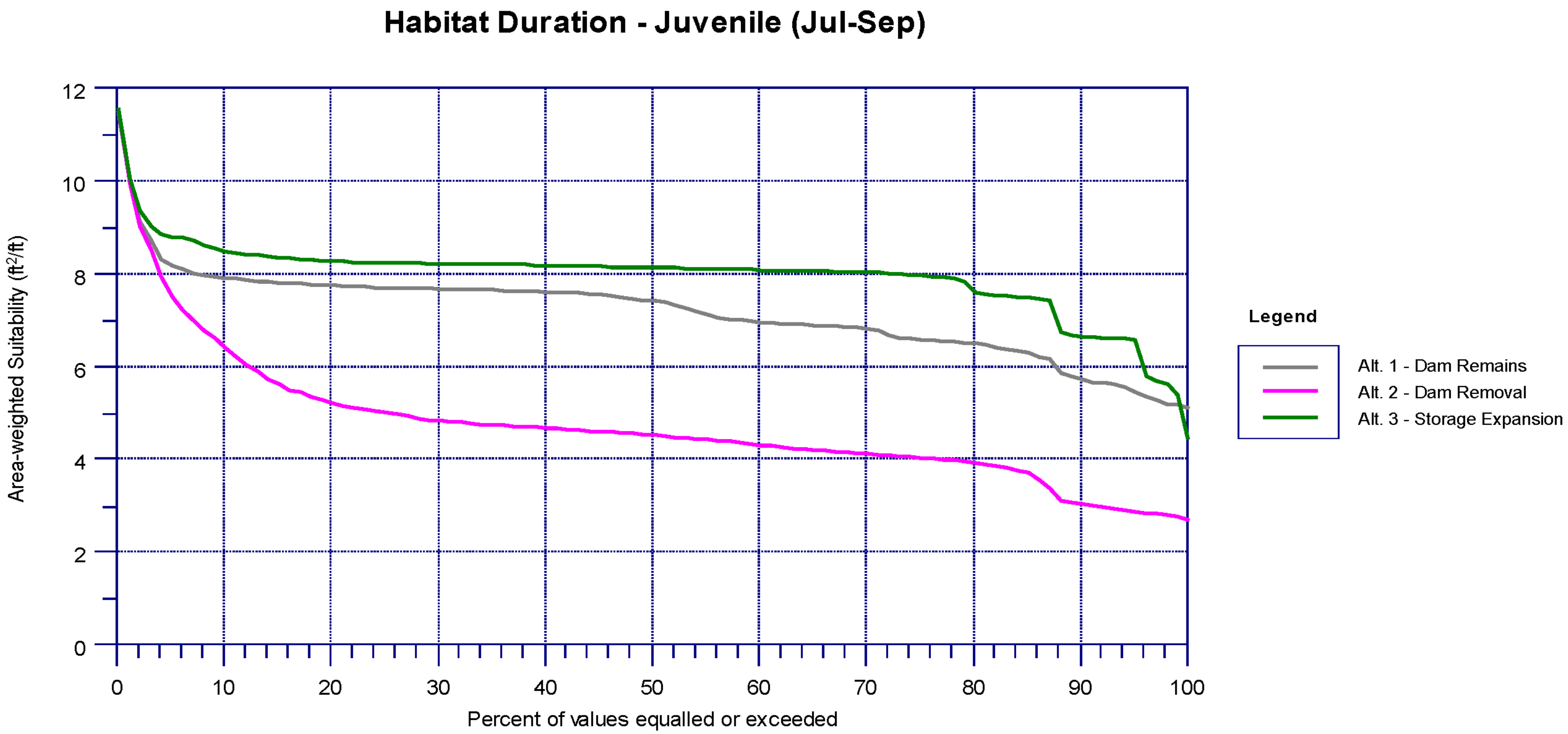

Figure 3-7 Habitat Duration Predicted by the IFIM Model for Juvenile Steelhead in the Carmel River (July–September), Based on CRBHM Predicted Flows

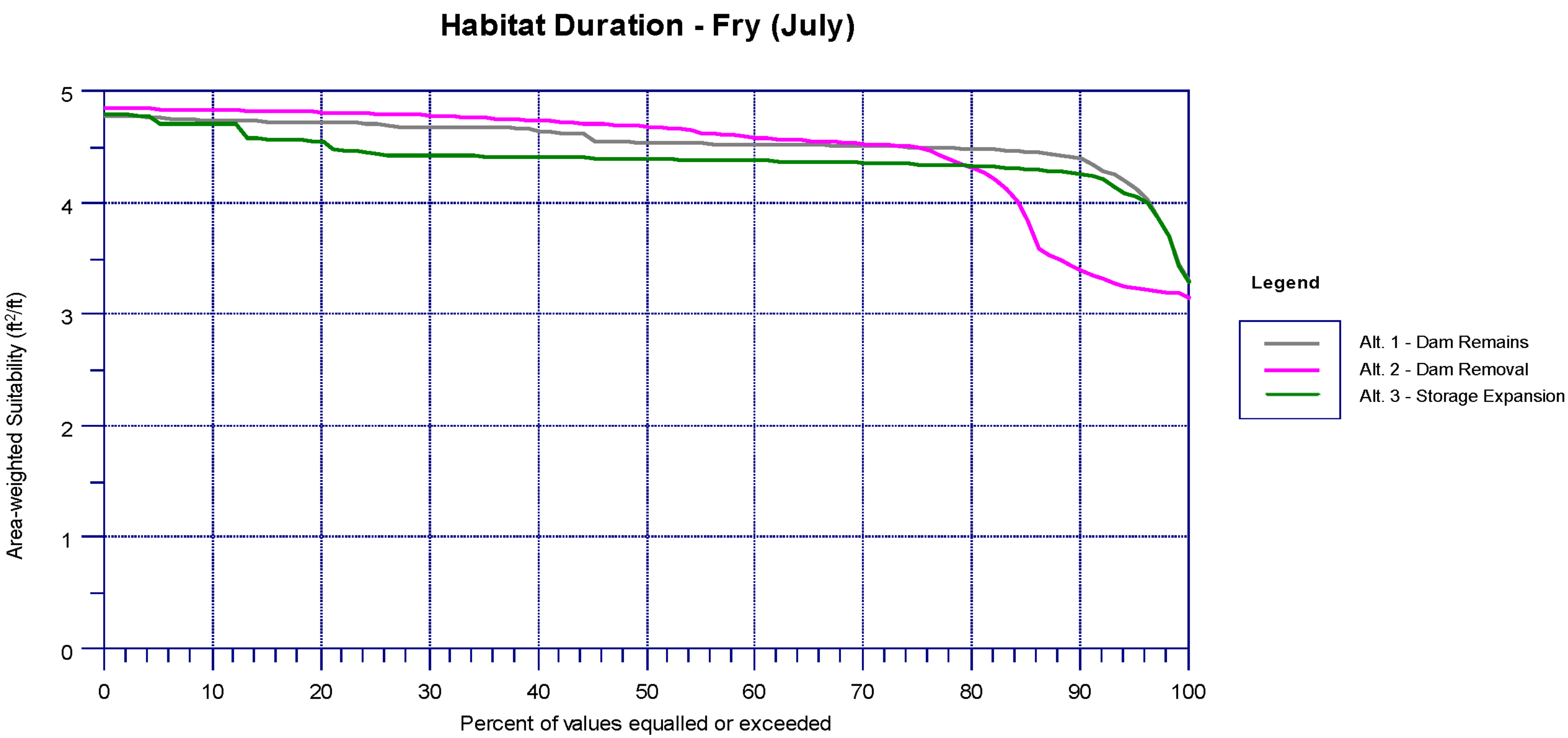

Figure 3-8 Habitat Duration Predicted by the IFIM Model for Fry Steelhead in the Carmel River (July), Based on CRBHM Predicted Flows

3.2 Fish Passage

Because fish passage concepts for LPD were developed and evaluated concurrently with the LP Alternatives Study, but under a separate scope of work (Section 1.3.4), this report relies on the concepts and evaluation described in the draft Fish Passage Feasibility Report for LPD (HDR et al. 2021). Like the LP Alternatives Study, a key premise of the Los Padres Fish Passage Study was collaboratively including the Los Padres TRC, the same group of stakeholders that includes the MPWMD, Cal-Am, NMFS, and CDFW that composed the TRC for the LP Alternatives Study. The TRC's involvement in this study included reviewing and commenting on consultant-prepared deliverables and participating in a series of TRC Meetings. Like the LP Alternatives Study, this input from the TRC was a critical part of the alternative selection process, and their input helped guide the development and refinement of the alternatives. Unlike the LP Alternatives Study, the fish passage study used a matrix to score and rank alternatives. Upon completion of the fish passage study there was a recommendation to retain two upstream fish passage options and two downstream fish passage options for further consideration.

Cal-Am would be required to implement upstream and downstream fish passage improvements if LPD were to remain in place (NMFS 2017). The fish passage options recommended for further consideration in HDR et al. 2021 are described in Section 5.2.3 and the analysis in this report assumes that the most compatible of the upstream and downstream fish passage options would later be combined with the preferred dam, reservoir, and sediment management alternative from the fish passage study. As described in Sections 4 and 5, Alternative 1 (Fish Passage, No Sediment Action), Alternative 3 (Storage Expansion and Dredging), and Alternative 5 (Recover Storage Capacity with Sluice Tunnel), all of which would retain LPD, assume implementation of fish passage improvements.

3.3 Probable Maximum Flood

The PMF is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a drainage area (FEMA 2003). The PMF will be a key driver for alternatives that modify LPD or spillway because the DSOD will require, as part of their approval, that the spillway and dam be improved to accommodate the revised PMF. Cal-Am is planning detailed geotechnical, structural, and condition assessment of the spillway. As the LP Alternatives Study progressed and the implications of the PMF were understood, Cal-Am's dam safety division indicated that any alternative that retains LPD over the long term should address the updated PMF.

Previous evaluations at LPD were based on a PMF calculated using methods described in NOAA's HMR 36 (which for LPD was calculated as 31,579 cfs [DSOD 1980b]). The current standard is based on the more conservative methods for calculating the PMF described in HMRs 58 and 59 (NOAA 1998, 1999). To understand the implications of the revised PMF for the dam, reservoir, and sediment management alternatives, AECOM calculated the PMF for LPD using the current standard. A detailed description of the methods used to calculate the revised PMF is provided in the Alternatives Development TM (Appendix F).

Calculation of the PMF first requires calculating the probable maximum precipitation (PMP), which is "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year" (NOAA 1998). The PMP can be estimated for two different types of storms: a General Storm and a Local Storm. For relatively small watersheds (< 500 square miles) the PMP for both types of storms are calculated, and the largest value is used. The PMP for the drainage area upstream of LPD (44.8 square miles) was determined using the calculation procedures from HMR 58 (NOAA 1998) and HMR 59 (NOAA 1999).

The PMP for the drainage area upstream of LPD was routed through the United States Army Corps of Engineers' Hydraulic Engineering Center Hydrologic Modeling System (HEC-HMS) hydrologic model (USACE 2021), which was developed for the San Clemente Dam Removal Project to determine the PMF (URS 2012). HEC-HMS was used because it is an industry standard for watershed hydrology. The HEC-HMS results indicate that the General Storm produces the maximum PMF of 66,443 cfs, compared to the HMR 36 PMF of 31,579 cfs (DSOD 1980b). Dam overtopping was excluded for this analysis because the peak water surface elevation without overtopping was used to help determine how high the dam should be raised, and the corresponding spillway modifications to pass the PMF.

The HEC-HMS results for the inflow and outflow of LPR for the General Storm and Local Storm are shown in Table 3-1. Based on the results, the revised PMF would result in overtopping of the existing dam embankment during the PMF event.

Table 3-1 HEC-HMS Results

Description	General Storm	Local Storm
Duration (hours)	72	6
Precipitation depth (inches)	44.34	4.97
Peak Stage (feet NAVD88)	1,071.2	1050.6
Peak inflow to LPR (cfs)	66,305	16,720
Peak outflow over LPD (cfs)	66,443	15,257

Notes:

cfs = cubic feet per second
LPD = Los Padres Dam
LPR = Los Padres Reservoir
NAVD88 = North American Vertical Datum of 1988

3.4 Flood Frequency

A flood frequency analysis was performed on the USGS Robles del Rio gauge data for water years 1956 through 2019 (n = 63) within the guidelines of Bulletin 17B (United States Interagency Advisory Committee on Water Data 1982; USGS 2011) using HEC SSP 2.1 (USACE 2016). A station weighted skew methodology was used in the analysis with a calculated station skew of -0.859, a regional skew of -0.469, and regional skew mean square error of 0.13. Calculated flood flows at the USGS Robles del Rio gauge are summarized in Table 3-2. The flow frequency plot is shown on Figure 3-9.

A flood frequency analysis was also performed for the MPWMD gauge location for water years 1958 through 2019, within the guidelines of Bulletin 17B (United States Interagency Advisory Committee on Water Data 1982; USGS 2011). MPWMD extended the period of record for the gauge location by estimating peak flows prior to 2001 based on water surface elevations recorded at the Los Padres dam and the spillway rating curve. A weighted skew methodology was used in the analysis with a calculated station skew of -0.8, a regional skew of -0.469, and regional skew mean square error of 0.13 (USGS 2011). Using this methodology, Los Padres dam is expected to contribute approximately 56 percent of the peak flows measured at the USGS Robles del Rio gauge.

A second analysis was also performed. The second analysis was a precipitation-weighted basin area reduction. The Carmel River contributing basin area above the USGS Robles del Rio gauge was calculated to be 193.4 square miles, while the contributing basin area above LPD was calculated to be 44.2 square miles. Therefore, the contributing basin area for LPD is 22.9 percent of the total contributing basin area of the USGS Robles del Rio gauge. Mean annual precipitation in the Los Padres basin is 39.1 inches per year versus 30.5 inches per year for the entire basin at the USGS Robles del Rio gauge. Using a precipitation-weighted basin area reduction, Los Padres dam is expected to contribute approximately 29.3 percent of the peak flows measured at the USGS Robles del Rio gauge.

Flood flow estimates below LPD are presented in Table 3-3. Instantaneous peak flows for both the USGS gauge and MPWMD gauge used in the Bulletin 17B analyses are provided on Figure 3-10.

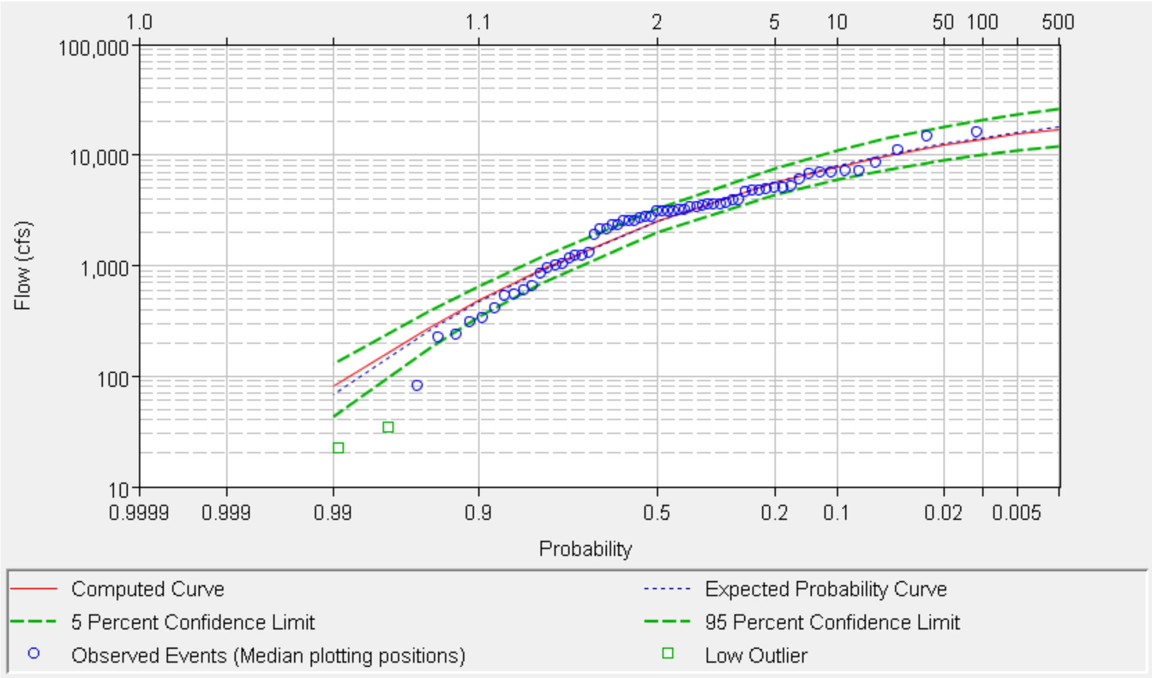

Figure 3-9 Flow Frequency for Carmel River at United States Geological Survey Robles del Rio Gauge No. 11143200

Table 3-2 Annual Peak Instantaneous Flows for Carmel River at USGS Gage No 11143200 (Water Year 1956 – 2019) using the Bulletin 17b Procedures

Recurrence Interval (years)	Annual Exceedance Probability	Peak Discharge (cfs)
2	50%	2,500
5	20%	5,600
10	10%	7,800
20	5%	9,800
50	2%	12,200
100	1%	13,800

Notes:

cfs = cubic feet per second
USGS = United States Geological Survey

Table 3-3 Estimated Annual Peak Instantaneous Flows for Carmel River at Los Padres Dam

Recurrence Interval (years)	Annual Exceedance Probability	Peak Discharge (cfs) Bulletin 17b	Peak Discharge (cfs) Basin Area Reduction
2	50%	1,600	750
5	20%	2,900	1,600
10	10%	3,800	2,300
20	5%	4,600	2,900
50	2%	5,700	3,600
100	1%	6,500	4,000

Note:

cfs = cubic feet per second

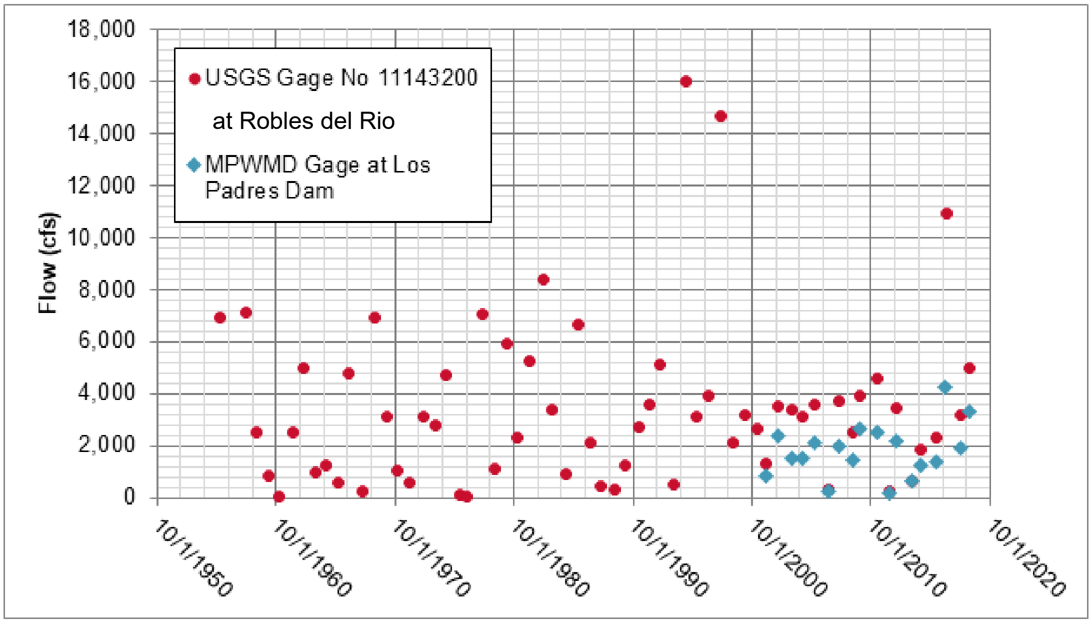

Figure 3-10 Annual Instantaneous Peak Flows for the Carmel River at USGS Gage No 11143200 and MPWMD Gage below Los Padres Dam

3.5 Flow Duration

An annual flow duration analysis was performed on the Los Padres gaging station. A summary of the annual exceedance flows based on mean daily flow data at the LPD gaging station is provided in Table 3-4. The exceedance flows statistically represent the flow equaled or exceeded a certain percentage of the time.

Table 3-4 Estimated Annual Exceedance Mean Daily Flows at Los Padres Gaging Station (October 1, 2001, to April 7, 2020)

Percent of Time Exceeded	Mean Daily Flow at Dam Site (cfs)
99.9%	2
99.0%	2
95.0%	3
90.0%	5
80.0%	7
70.0%	9
50.0%	15
40.0%	21
25.0%	47
15.0%	88
10.0%	144
5.0%	266
2.0%	526
1.0%	736
0.1%	1,722

Note:
cfs = cubic feet per second

3.6 Sediment Rating Curves

As described in Appendix D, available sediment transport data for bedload and suspended sediment were collected and used to update rating curves for locations along the Carmel River and its tributaries. Each rating curve was estimated from available sediment transport data sourced from the USGS Water-Data Reports (Markham et al. 1992; Markham et al. 1993; Ayres 1994; and Freeman et al. 1996), MPWMD field office data archives (MPWMD 1986), Curry and Kondolf (1983), and unpublished data collected by Balance Hydrologics for the San Clemente Dam Removal efforts (Balance Hydrologics 2001). Each rating curve was estimated using the best-fit power law when possible. When applicable, more representative rating curves were developed manually or with outliers not included.

Sediment availability and transport rates can vary considerably both temporally and spatially. Extreme “episodic” events, such as fires, landslides, or major flood events can introduce a large pulse of sediment and can temporarily increase the sediment transport rates. As a result, using the same rating curve for episodic and background chronic conditions is not typically applicable. Thus, separate rating curves are developed for both episodic and chronic conditions when the data is available. A sediment transport rating curve typically goes as a power law function: $Q_{sed} = aQ^b$ where a and b are the fit parameters corresponding to the intercept and slope, respectively, and Q_{sed} and Q are the sediment transport rate, typically in tons per day, and water discharge in cfs, respectively.

The relationship between episodic and chronic rating curves is typically well-defined. Rating curves tend to have the same b slope coefficient but have an a coefficient that is an order of magnitude larger than chronic rating curves. If data from only episodic or chronic conditions is available for rating curve development, we used this relationship to infer the other associated rating curve. In some cases, both episodic and chronic rating curves were not applicable and therefore not calculated, explained in more detail in Appendix D. All episodic and chronic rating curve equations developed for the Los Padres Alternatives Study are summarized in Table 3-5.

The Carmel River at Via Mallorca has the most abundant sediment transport dataset. The site has been a USGS streamflow gage since 1962 making this site an ideal location to collect paired sediment-flow measurements. Data has also been collected at Schulte Bridge, Robinson Canyon Road, and Robles del Rio. A considerable portion of the total sediment load in the Carmel River watershed comes from the tributaries. The hydrologic and sediment contribution from each tributary to the mainstem Carmel River varies, dependent upon the mean annual rainfall in the contributing watershed and the underlying geology and associated sediment production processes. For example, the underlying geology in the Tularcitos Creek watershed is largely sourced from the easily erodible Santa Margarita sandstone, which introduces an abundance of sand-sized sediments. Despite a low mean annual precipitation, the Tularcitos Creek watershed supplies a lot of sand considerably changing the sediment character downstream of the Tularcitos Creek confluence. Table 3-6 summarizes the differences in mean annual precipitation and geology in each of the main tributaries. Pine Creek, located to the south of San Clemente Creek, is another major tributary in the Carmel River watershed. Because access to Pine Creek is difficult, there is limited sediment transport and hydrologic data available and so rating curves were not developed. Graphs of the rating curves developed for the Los Padres Alternatives Study are presented in Section 2 of Appendix D.

Table 3-5 Rating Curve Coefficients for each Carmel River Mainstem and Tributary Site, for Bedload and Suspended Load, and for Chronic and Episodic Conditions, where Applicable

	Bedload				Suspended Sediment			
	Episodic		Chronic		Episodic		Chronic	
Station	Intercept *(a)*	Slope *(b)*	Intercept *(a)*	Slope *(b)*	Intercept *(a)*	Slope *(b)*	Intercept *(a)*	Slope *(b)*
Robles Del Rio	2.11E-04	2.44000	1.90E-07	2.85130	1.58E-04	2.17440	1.58E-05	2.17440
Robinson Canyon	2.94E-02	1.30672	2.94E-03	1.30672	4.89E-05	2.23137	4.89E-06	2.23137
Schulte Bridge	6.75E-02	1.33073	6.75E-03	1.33073	2.01E-10	4.45297	2.01E-11	4.45297
Via Mallorca	4.14E-01	1.21399	2.11E-01	1.16019	3.61E-04	2.32780	1.87E-05	2.50207
Cachagua Creek	1.20E-03	2.87070	1.20E-04	2.87070	5.36E-04	2.89365	5.36E-05	2.89365
San Clemente Creek	9.60E-02	1.25700	9.60E-03	1.25700	2.78E-04	3.24310	2.78E-05	3.24310
Tularcitos Creek[1]			1.47E-03/2.31E+00	3.64/0.87	7.46E-02	2.00416	7.46E-03	2.00416
Las Garzas Creek	-	-	8.87E-05	2.43342	-	-	1.39E-04	2.66786
Robinson Canyon Creek	1.03E+01	1.26490	1.03E+00	1.26490	3.03E-01	2.41096	3.03E-02	2.41096
Potrero Creek	3.03E-02	1.72378	-	-	2.07E-01	1.84796	-	-
Hitchcock Creek	5.93E-01	1.27000	5.93E-02	1.27000	1.15E-02	2.33000	1.15E-03	2.33000

Notes

1. The Tularcitos bedload rating curve is two-phase; with the first coeffiecients used for flows lower than 14.3 cfs, and second for flow greater than or equal to 14.3 cfs.

Table 3-6 Summary of Carmel River Watershed Major Tributaries; Mean Annual Precipitation, Watershed Size, and Geology

Tributary	Watershed Size	Mean Annual Precipitation[1]	Geology[2]
	(square miles)	*(inches)*	
Tularcitos Creek	56.3	21.5	Santa Margarita Sandstone, Miocene Marine clastic shale, sandstone, and conglomerate
Cachagua Creek	46.3	31.7	Mixed Miocene marine sandstone and Mesozoic granitic rocks
San Clemente Creek	15.6	37.4	Mesozoic granitic rocks, with some Mesozoic metasedimentary rocks
Las Garzas Creek	13.2	28.5	Mesozoic granitic rocks, with some Miocene unnamed sedimentary redbeds
Robinson Canyon Creek	5.4	22.2	Miocene unnamed sedimentary redbeds and marine sandstone
Potrero Canyon Creek	5.8	22.9	Miocene Monterey Formation shale, and Quaternary landslide and alluvial gravel, sand, and silt/clay
Hitchcock Canyon Creek	4.6	25.0	Mesozoic granitic rocks, primarily granodiorite, some Miocene marine rocks

Notes:

1. Estimated using Monterey County Isohyetal lines of average annual Rainfall in inches, published May 14, 2014, accessed April 30, 2018

2. Geologic information sourced from Geologic maps of various quadrangles, Dibblee, T. W., and Dibblee J. A., 2007, map scale 1:24,000

3.7 Sediment Transport Scenarios

Bedload supply and transport are vital to the creation and maintenance of functional aquatic habitat. Natural river dynamics include transportation of coarse sediment (e.g., sand, gravel, cobble, and boulder) downstream. Natural sediment pulses that result from heavy precipitation events are incorporated by stream and river processes into spawning beds, gravel bars, side channels, pools, riffles, and floodplains that provide habitat and support food chains of steelhead (and other aquatic species). These periodic inputs and movements of coarse sediment are necessary for the long-term maintenance of aquatic habitats. Steelhead evolved to depend on continued sediment delivery to provide substrate suitable for spawning and early rearing; and on access to floodplains that provide rearing habitat and velocity refugia during high winter flows.

Balance Hydrologics and UBC Geography (2019) (Appendix D) used a morphodynamic sediment transport model (BESMo) to assess the effects of sediment transport under different alternative and sediment management options included in the Los Padres Alternatives Study (Figure 3-11). Channel evolution modeling was completed to evaluate potential downstream effects related to sediment supply associated with four different potential future sediment management scenarios at LPD. Modeling was completed using the 1D BESMo model (Müller and Hassan 2018), a model developed and written by scientists at the University of British Columbia. BESMo was originally developed to investigate how bedload supply pulses to gravel-bed mountain streams evolve in time and space, through coupled bed elevation and bed surface sediment texture responses. The model was used to simulate erosion, deposition, and transport of sediment in the Carmel River downstream of LPD, including future conditions where sediment from LPR is transported into the Carmel River. The predicted flow and sediment concentrations leaving the reservoir were used as input into the BESMo model. The three BESMo scenarios considered in this report are:

- No Action Simulation: The No Action Simulation makes no change to the present operation or configuration of LPD or LPR, and as a result includes no bedload supply from the contributing watershed upstream of LPD to the downstream mainstem Carmel River. This scenario applies to the current Alternative 1 (Fish Passage, No Sediment Action) and Alternative 3 (Storage Expansion and Dredging), described in Sections 4.4 and 5, respectively.
- Uncontrolled Supply Simulation: In the Uncontrolled Supply Simulation, bedload sediment accumulated in LPR is rapidly transported to the downstream mainstem Carmel River according to sediment evacuation functions developed with data from similar types of previously completed projects. This scenario applies to Alternative 2 (Dam and Sediment Removal), assuming that all the accumulated bedload sediment is available for transport immediately following dam removal.
- Pulsed Supply Simulation: In the Pulsed Supply Simulation, sediment accumulated in LPR and the background historical supply is bypassed to the downstream mainstem Carmel River, according to the magnitude of individual flood events, through a sluice tunnel. This scenario applies to the current Alternative 5 (Recover Storage Capacity with Sluice Tunnel), described in Section 5.

To understand the effect of alternatives on steelhead habitat and stream morphology related to expected changes in sediment transport processes, changes to channel morphology were assessed based on model results. The evaluation, presented in Section 5, used analysis of the BESMo results (Appendix D), combined with knowledge of habitat requirements of steelhead, to assess how changes in bed elevation, substrate composition, and geomorphic processes would affect steelhead habitat (e.g., pool habitat, spawning gravel, floodplain connectivity, and winter refuge habitat).

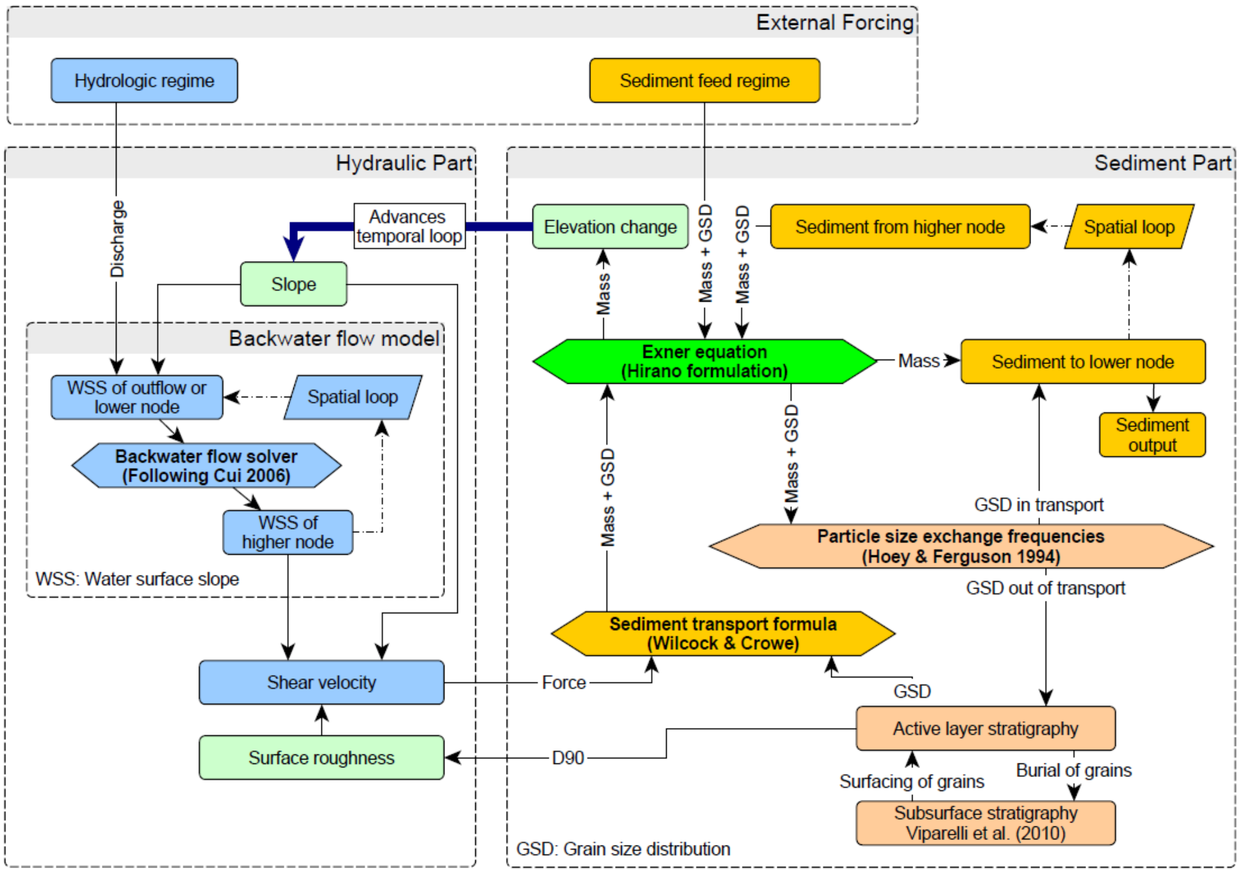

Figure 3-11 Main Components of the BESMo Sediment Transport and Profile Evolution Model

3.8 Suspended Sediment

Elevated suspended sediment concentrations may affect fish directly by changing their behavior, causing physiological stress, clogging or abrading the gills, and/or preventing fish from foraging efficiently. As the transported sand and fine sediment settles on the streambed, it can reduce the survival of incubating eggs and developing alevins in salmonid redds through reduced oxygenation of intergravel flow. Based on a review of the scientific literature, the most commonly observed effects of suspended sediment on salmonids include (1) avoidance of turbid waters in homing adult anadromous salmonids, (2) avoidance or alarm reactions by juvenile salmonids, (3) displacement of juvenile salmonids, (4) reduced feeding and growth, (5) physiological stress and respiratory impairment, (6) damage to gills, (7) reduced tolerance to disease and toxicants, (8) reduced survival, and (9) direct mortality (Newcombe and Jensen 1996).

Preliminary information on both concentration and duration of suspended sediment was developed initially in the Effects to Steelhead TM (Appendix E) and is used in the evaluation of the potential severity of suspended sediment effects on salmonids for the current Alternative 5, following the approach detailed by Newcombe and Jensen (1996). A sluice tunnel (see Alternative 5 in Section 5) could, if used to flush accumulated reservoir sediment, involve releasing large quantities of fine sediment (silt, organic matter, and fine sand) from the sediment accumulated in LPR into the Carmel River. Although the BESMo does not predict suspended sediment concentrations or durations, suspended sediment rating curves were developed concurrently with the BESMo (Section 3.6) and were used by AECOM to develop an approximation of potential suspended sediment concentrations downstream of LPD. A spreadsheet analysis of available flows and sediment rating curves was used to estimate potential suspended sediment concentrations and durations for use in evaluating the current Alternative 5 (Recover Storage Capacity with Sluice Tunnel). The methods used for this analysis are detailed in Section 2.2 of Appendix E and summarized below, and the results are discussed in the context of Alternative 5 in Section 4.4.2.

The suspended sediment rating curve for Robles del Rio for the episodic condition[8] (Table 2-1 and Figure 2-5 of Appendix D) was used to translate the flows in the sluice tunnel hydrograph into sediment transport in tons per day, and then into sediment concentrations in mg/L, to represent a sluicing condition. The resulting maximum suspended sediment concentration over the record was just under 1,300 mg/L, and occurrences within various concentration ranges are shown on Figure 3-12. These concentrations, because they are derived from suspended sediment data collected in the river, are more like background levels expected to be produced by the watershed; they do not describe the conditions that could occur during a sluicing event, where fine sediment is intentionally transported through the sluice tunnel.

Because a major sluicing event is expected to be able to discharge all or most of the fine sediment from the reservoir, the total suspended transport for individual storm events was compared to the total amount of sediment in Zone 1 of the reservoir. As described in Appendix E, the volume of accumulated fine sediment in Zone 1 of LPR is estimated to be approximately 197,000 tons. As a comparison, the largest event-based cumulative sediment transport based on the episodic rating curve was approximately 44,000 tons, over the period from February 6 to February 10, 1998, with flows ranging from 1,000 to 5,000 cfs. If a major sluicing event transported the contents of Zone 1, the sediment concentrations would be expected to increase significantly over the episodic background conditions.

The analysis then assumed that the largest storm event in the analysis record would transport all the sediment in Zone 1, and smaller events would transport less than the full amount of sediment in Zone 1. The largest storm event was selected based on the estimated cumulative sediment transport (the event of February 6 through 10, 1998), and the coefficient of the suspended sediment rating curve was adjusted so that the cumulative transport for the storm event equaled the total sediment weight in Zone 1. This resulted in a nearly 4.5-fold increase in suspended sediment transport. The resulting maximum suspended sediment concentration over the record was nearly 5,800 mg/L, and occurrences within various concentration ranges are shown on Figure 3-12. Figure 3-13 shows the suspended sediment concentrations over time during the winter of water year 1998, which includes the largest storm event.

This review of suspended sediment concentrations is based on a simplified simulation of sluicing events and how those would translate into sediment transport. The analysis did not include modeling sediment transport from the reservoir or in the river channel. If the sluice tunnel option is selected for further development, sediment transport modeling of the sluicing operation may be needed to better estimate the range of sediment concentration magnitudes and durations, and the potential changes to these over a series of operations and storm events, because it is possible that suspended sediment concentrations could be much higher.

As a comparison, the published sediment data for the Condit and Marmot dam removal projects were also reviewed. Condit Reservoir contained approximately 510 AF of silt and clay sediments (Wilcox et al. 2014), a quantity similar to that found at LPR, but Marmot Reservoir was said to contain zero silt and clay sediment (Major et al. 2012). Drawdown and flushing of Condit Reservoir through a tunnel produced sediment concentrations up to 850,000 mg/L to the White Salmon River downstream, consisting of silt, clay, and sand. Total sediment concentrations above 2,000 mg/L lasted about 4 weeks following dam breaching (Wilcox et al. 2014). Drawdown and flushing of Marmot Reservoir through an uncontrolled cofferdam breach produced a peak suspended sediment concentration of 49,000 mg/L initially to the Sandy River downstream, consisting primarily of silts and clays and transitioning primarily to sand within an hour. Suspended sediment concentrations were probably similar to those upstream of the reservoir within 2 months of dam breaching; at 7 months after breaching, this was confirmed to be the case (Major et al. 2012). Fish response to suspended sediment was not monitored in the White Salmon or Sandy Rivers.

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[8] Only data points supporting the fit of the episodic suspended sediment transport rating curve are shown on Figure 2-5 of Balance Hydrologics and UBC Geography (2019). Data points supporting the chronic suspended sediment transport rating curve are not shown on Figure 2-5, so the chronic rating curve was not used in this analysis.

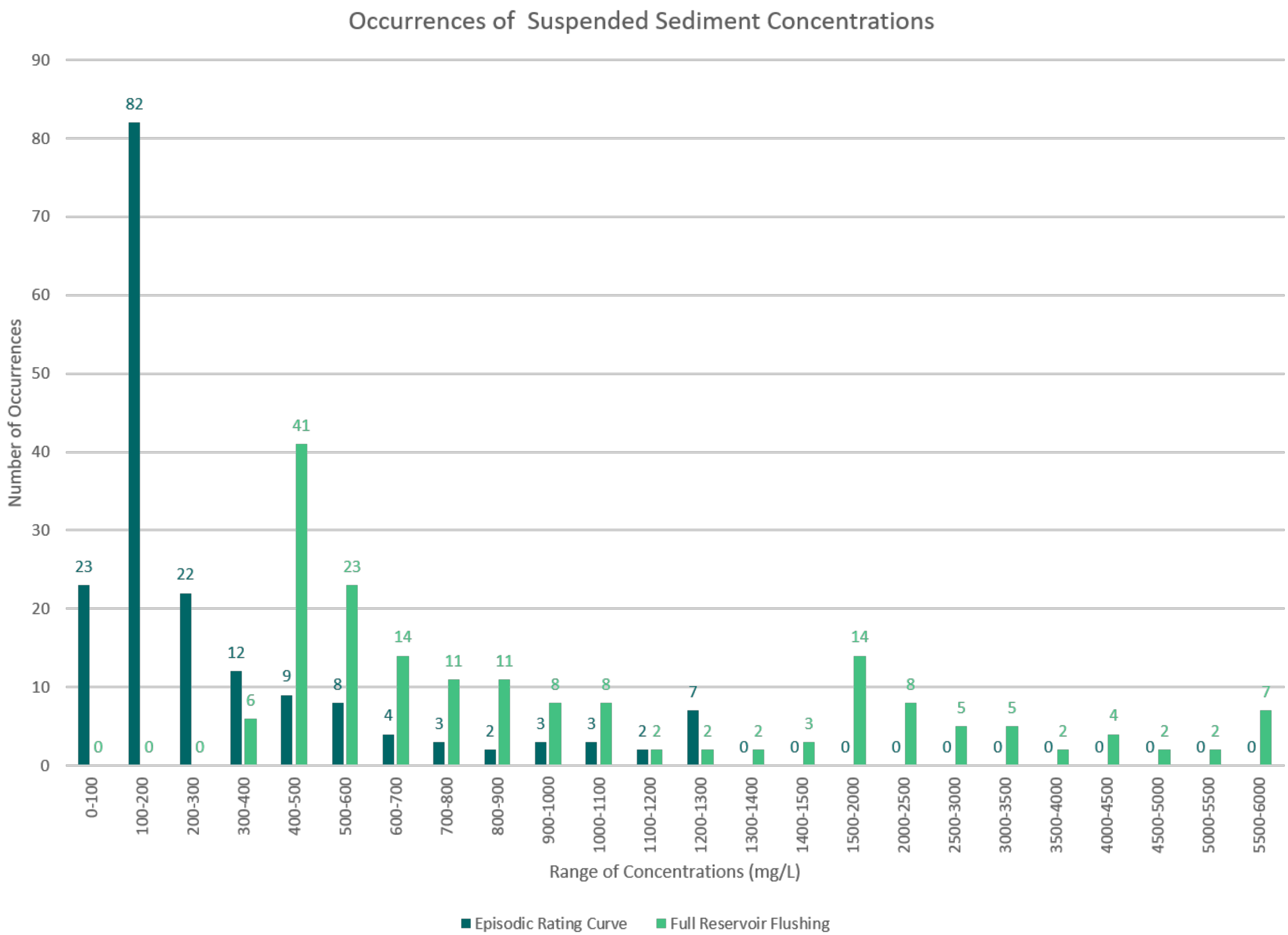

Figure 3-12 Occurrences of Suspended Sediment Concentrations

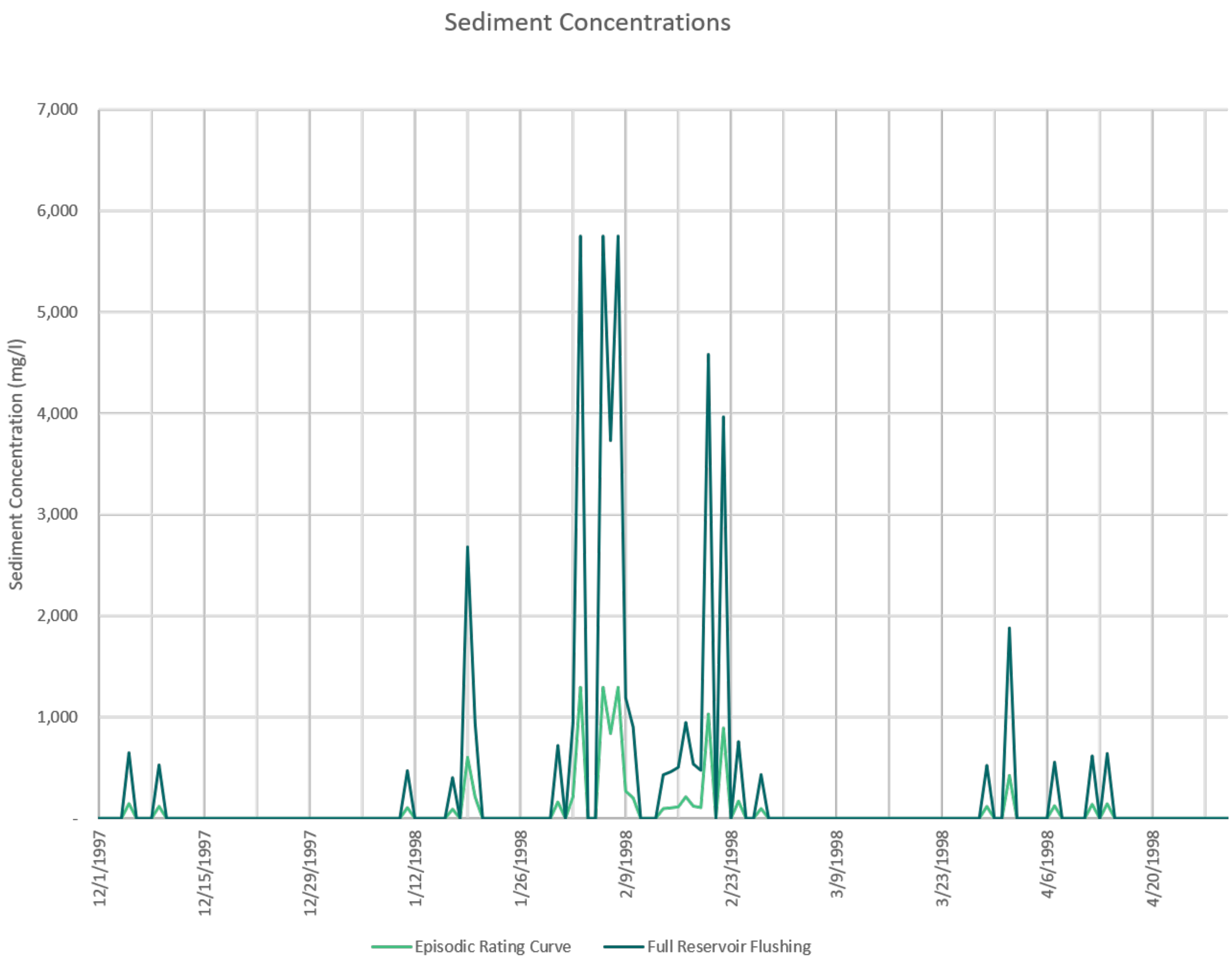

Figure 3-13 Sediment Concentrations During Winter of Water Year 1998

Studies of the Carmel River's response to the removal of San Clemente Dam (Harrison et al. 2018) found that prior to dam removal, turbidity in the river downstream of the dam increased to about 400 formazin nephelometric units (FNU) in response to modest flows of less than a 2-year return interval. For the water year during and immediately following dam removal, turbidity increased beyond the range of the instrument (above 1,600 FNU) during two events of similar size; in the second water year following dam removal, a series of flood events caused a hysteresis effect on turbidity over the duration of each event. Turbidity concentrations were higher during the rising limb of the hydrograph than during the falling limb, suggesting a lack of sediment delivery from the upper watershed during the later stages of the floods. Concentrations overall were lower during the last and largest event than during the preceding events of that second water year, also suggesting a generally sediment-supply-limited watershed. Harrison et al. (2018) posit that supply is limited due to the presence of LPD, which continues to trap sediment. These findings contrast with the results of a study that evaluated the relationship between flow and suspended sediment concentrations over some of the same 2017 storms, but on the San Lorenzo River. East et al. (2018) found that suspended sediment concentrations were generally higher on the falling limb of the storm hydrographs. Together, these studies suggest that, during storms, steelhead in the Carmel River downstream of LPD are currently exposed to suspended sediment concentrations that are lower than would naturally occur in the absence of LPD and LPR.

To conclude, the 1,300 mg/L peak concentration resulting from the episodic rating curve represents a typical high-turbidity event contributing to the reservoir from the watershed as background conditions. The 5,800 mg/L peak concentration resulting from the hypothetical discharge of all Zone 1 sediment represents a sediment release condition where a portion of the reservoir sediment leaves the reservoir in flows that are consistently high over several consecutive days. Based on literature review of previous dam removal projects that included sediment flushing, a true flushing event can put orders of magnitude more material in suspension than the estimates above, potentially resulting in peak concentrations of 49,000 mg/L and greater. The reviewed dam removal data showed high suspended sediment concentrations lasting for 1 to 2 months, but those conditions occurred because of continuous access to reservoir sediments afforded by long periods of high flow in the White Salmon and Sandy Rivers, which do not tend to occur on the Carmel River. The duration of high sediment concentrations would be limited by the operation of the sluice gate at Los Padres (see Alternative 5 in Section 5).

3.9 Suspended Sediment Effects on Steelhead

Based on the general predictions of suspended sediment concentration and durations, the results of Newcombe and Jensen (1996) were used to assess impacts of suspended sediment on steelhead. Newcombe and Jensen (1996) reviewed and synthesized 80 published reports of fish responses to suspended sediment in streams and estuaries, and established a set of equations to calculate severity of ill effect (SEV) indices (Table 3-7) for various species and life stages, based on the duration of exposure and concentration of suspended sediment present. The SEV provides a ranking of the effects of suspended sediment concentrations on salmonid species, as calculated by any of six equations that address various taxonomic groups of fishes, life stages of species within those groups, and particle sizes of suspended sediments. Newcombe and Jensen (1996) collected data on fish effects (on the SEV scale), suspended-sediment concentration (C, mg/L), and suspended-sediment exposure time (D, hr.) from a large number of papers dealing with many salmonid fishes at various life stages. The result of this approach is a life-stage-specific prediction of the SEVs on steelhead in Carmel River, based on the general predictions of suspended sediment concentrations and durations described above for sediment sluicing. This analysis was first presented in the Effects to Steelhead TM (Appendix E) and the results of the analysis for the current alternatives are presented in Section 5 of this report, under Effects to Steelhead, for each alternative.

Table 3-7 Scale of the Severity of Ill Effects Associated with Suspended Sediment

Category of Effect	Severity	Description
Nil effect	0	No behavioral effects
Behavioral effects	1	Alarm reaction
	2	Abandonment of cover
	3	Avoidance response
Sublethal effects	4	Short-term reduction in feeding rates Short-term reduction in feeding success
	5	Minor physiological stress: • Increase in rate of coughing • Increased respiration rate
	6	Moderate physiological stress
	7	Moderate habitat degradation Impaired homing
	8	Indications of major physiological stress: • Long-term reduction in feeding rate • Long-term reduction in feeding success • Poor condition
Lethal and paralethal effects	9	Reduced growth rate: • Delayed hatching • Reduced fish density
	10	Increased predation of affected fish; 0 to 20% mortality
	11	>20 to 40% mortality
	12	>40 to 60% mortality
	13	>60 to 80% mortality
	14	>80 to 100% mortality

Source: based on Newcombe and Jensen 1996

4. Alternatives Development

This section describes development of the LPD, LPR, and sediment management alternatives. Alternatives development was an iterative process that included developing concepts, presenting them to the TRC, and refining concepts based on TRC and stakeholder feedback, comments, and discussion. Technical memoranda and meetings used to present concepts and obtain feedback are listed in Section 1.2, and the TMs and meeting records are provided as appendices to this report under separate cover. The evaluation framework is described first, followed by a description of how the list of preliminary alternatives evolved into the two remaining feasible dam, reservoir, and sediment management alternatives described in Section 5.

4.1 Evaluation Framework

Based on the direction provided in the scope of work, a preliminary list of alternatives and evaluation criteria were presented for TRC review in the draft Study Preparation TM, discussed with the TRC at the first TRC meeting (TRC Meeting No. 1), revised based on discussion and written comments, and published in the final Study Preparation TM (Appendix A).

Initially the plan was to evaluate the alternatives using a grid analysis technique, or multi-criteria analysis tool (a matrix) with numerical scores and variable weighting across evaluation criteria (Appendix A), similar to the tool that was used in the Los Padres Fish Passage Study (HDR et al. 2021). However, the TRC decided that it preferred not to use a matrix to score and rank the dam and reservoir alternatives. A decision to abandon the evaluation matrix was discussed among AECOM, Cal-Am, and the MPWMD and communicated to the TRC via email on December 3, 2021.

Instead, the focus shifted gradually from selecting a preferred alternative to defining a range of feasible alternatives that could inform future discussion of a preferred alternative, as additional information becomes available. Advantages and disadvantages were discussed for each alternative and the previously identified evaluation criteria continued to be useful as guiding considerations (see Section 4.1.1) during alternatives refinement.

4.1.1 Guiding Considerations

Considerations for determining feasibility of an alternative include a combination of technical, geomorphic, and biological (e.g., steelhead) evaluations that provide information on the applicability of alternatives to the relevant issues. Technical feasibility is governed by engineering aspects, including the physical dam and reservoir characteristics, hydrology, water storage and release operations, and fluvial processes in the river. Steelhead responses to alternatives are influenced by flows and water quality, availability and characteristics of habitat, and migratory pathways. These factors were integrated into the LP Alternatives Study and assessed iteratively so that intermediate results from each analysis were used to refine and optimize alternatives throughout the study. Descriptions of these considerations, formerly the evaluation criteria, are provided in the Study Preparation TM (Appendix A).

Engineering

- What measures other than those primary to the alternative are needed to address dam stability to obtain DSOD approval?
- What are the cost and schedule implications of dam safety mitigation?
- What is the estimated construction cost?
- What is the estimated construction timeline?
- What is the estimated O&M cost?
- What is the area of permanent impacts?
- What is the area of temporary impacts?

Geomorphic

- Increase in Potential Flooding Near Developed Properties for an Event of Interest
- Sediment release greater than the natural load?
- Sediment Transport Prediction Certainty
- Sediment Management Adaptability

Biological

- Upstream Adult Steelhead Passage
- Downstream Adult Steelhead Passage
- Upstream Juvenile Steelhead Passage
- Downstream Juvenile Steelhead Passage
- Short-Term Effects on Steelhead Present During Sediment Release
- Proportion of Steelhead Affected by Short-Term Sediment Release
- Changes to Instream Pool Volume
- Changes in Spawning Habitat
- Changes in Floodplain Habitat Access
- Duration of Negative Habitat Effects
- Migration Period Flow Availability
- Rearing Period Flow Availability
- Spawning Period Flow Availability
- Spawning Habitat Availability
- Rearing Habitat Availability
- Quality of Rearing Habitat Upstream of LPD
- Ecosystem Connectivity
- Attraction, Passage, and Flows for Nontarget Species
- Quality of Water Passed Downstream

Water Supply

- Maximum Potential Water Yield at LPR
- LPR Storage Capacity
- Future LPR Storage Capacity
- Replacement Water Supply Needed?
- Reservoir Availability for Fire Response

Water Rights

- Need for Petition to Change Water Rights
- Effects on Cal-Am and MPWMD Water Rights
- Water Right Petition Process

Community Response

- Anticipated Community Objection

4.2 Evolution of Alternatives

The LP Alternatives Study was an iterative process throughout which concepts were presented, refined, and reformulated based on TRC and stakeholder review and discussion, and then presented again for further review. This section describes the evolution of the alternatives during the study, from a long and simple list of options to the list of two dam, reservoir, and sediment management alternatives described in Section 5. Throughout this section, information is provided to understand the alternatives that were eliminated from consideration and the reason(s) why. However, to avoid redundancy with less complete descriptions of those alternatives from previous TMs, detailed descriptions of the four alternatives retained into the draft final report are reserved for Sections 4.4 and 5. In these sections, the four dam, reservoir, and sediment management alternatives are presented with the most complete level of detail to which they were developed during the LP Alternatives Study. Additional description of alternatives eliminated, the process of reformulating alternatives, and supporting discussions can be found in the TMs and meeting records included by reference in this report as Appendix G under separate cover.

Table 4-1 provides a crosswalk of model scenarios and alternatives from previous works. The final list of alternatives is presented on the left, and the corresponding alternatives, scenarios, or combination thereof from each previous work that are most relevant to the current alternatives are listed in the subsequent columns to the right. The columns are organized, left to right, from most recent to oldest report or TM, so that the reader can trace the history of alternatives and model scenarios back through the history of the LP Alternatives Study. An earlier, more detailed version of the crosswalk is included with Appendix F.

4.2.1 Preliminary List of Alternatives

The preliminary list of alternatives presented below, initially based on the LP Alternatives Study scope of work and refined by the AECOM Team, was prepared for TRC review in the draft Study Preparation TM, discussed with the TRC at the first TRC meeting (TRC Meeting No. 1), revised based on discussion and written comments, and published in the final Study Preparation TM (Appendix A) along with the most relevant considerations for each.

- **No Sediment Management** focused on the effects of taking no action to manage the existing sediment accumulation in the reservoir or future sediment inputs. This alternative was intended to become the baseline for comparing alternatives.
- **Dam Removal** was to include sediment management and dam removal.
- **Recover Storage** was to include two sub-alternatives that involve removing sediment from LPR, but differed in the location where sediment would be disposed:
    - Recover reservoir storage capacity by dredging sediment and placing it on Cal-Am property downstream of LPD. This alternative was to involve reviewing a previous sediment disposal evaluation (MWH 2013) and evaluating whether the downstream sediment disposal site could be expanded to accommodate dredging the reservoir to its original capacity.
    - Recover reservoir storage capacity by dredging sediment and placing it off the Cal-Am property. This alternative was to describe dredging the reservoir to original capacity and transporting some or all reservoir sediment to an off-site disposal area. With this alternative, existing public roads in Cachagua Valley would not be used (i.e., Nason Road, Cachagua Road, and Tassajara Road); however, the concept of building a new road or conveyor system on private property was to be evaluated. This concept could be combined with placement of a portion of material on the Cal-Am property, and the remainder off site.
- **Storage Expansion** was to include four sub-alternatives that differed in the type and location of the upgraded dam or dams.
    - Expand reservoir storage with a rubber dam. This sub-alternative was to describe the use of a rubber dam (later described as pneumatic spillway gates, which is a more descriptive term for the same concept), which would increase the water surface elevation and associated reservoir storage. A rubber dam could be inflated or deflated to adjust the reservoir water surface elevation.
    - Perform a small dam raise at the existing dam. This sub-alternative was to describe an expansion of surface storage by raising the existing dam.
    - Construct a new dam downstream at the elevation of the existing dam (i.e., elevation = 1,042.9 feet NAVD88). This alternative was to describe an expansion of surface storage, with a new dam downstream.

Table 4-1 Summary of Alternatives and Model Scenarios from Past Work, as Relevant to Current Alternatives

Final Report (this document)	Alternatives Development TM (Appendix F)	Effects to Steelhead TM (Appendix E)	Fish Passage Feasibility Report (HDR et al. 2021)	IFIM Time Series (Normandeau 2019)	Basin Model Scenario (Appendix E)	BESMo (Appendix D)	Alternatives Descriptions TM (Appendix B)
Eliminated from Further Consideration – Alternative 1 (Fish Passage, No Sediment Action)	Alternative 1 (No Sediment Action)	Alternative 1	U1 or U8, and D1 or D8	Alternative 1	Current Los Padres	No Action	Alternative 1
Alternative 2 (Dam and Sediment Removal)	Alternative 2 (Dam and Sediment Removal)	Alternative 2	Volitional, no facilities	Alternative 2	Remove LPD	Closest to Historical Supply, but between that and Uncontrolled Supply	Alternative 2a
Alternative 3 (Storage Expansion and Dredging)	Alternative 3 (Storage Expansion and Dredging)	Alternative 4	U1 or U8, and D1 or D8	Alternative 4	LPR Expanded Storage	Closest to No Action, with possibility of one-time placement of coarse sediment below LPD	Alternatives 4b and 3a
Eliminated from Further Consideration – Alternative 4 (Recover Storage Capacity with Excavation)	Alternative 4 (Recover Storage Capacity with Excavation)	SM1 and SM2	U1 or U8, and D1 or D8	Not specifically addressed – between Current Los Padres and Los Padres Expanded Storage		Not specifically addressed – between No Action and Pulsed Supply	SM1 and SM2
Eliminated from Further Consideration – Alternative 5 (Recover Storage Capacity with Sluice Tunnel)	Alternative 5 (Recover Storage Capacity with Sluice Tunnel)	SM3	U1 or U8, and D1 or D8	Not specifically addressed – between Current Los Padres and Los Padres Expanded Storage		Pulsed Supply Simulation	SM3

Notes:

BESMo = University of British Columbia's one-dimensional morphodynamic sediment transport model
IFIM = Instream Flow Incremental Methodology
LPD = Los Padres Dam
LPR = Los Padres Reservoir
TM = Technical Memorandum

- Expand surface storage with a combination of two or three methods described above, an alternative that would have provided an opportunity to use the original reservoir to continue capturing sediment, allowing a lower reservoir to trap less in the near term.

- **Sediment Management Program**: A Sediment Management Program was considered to be relevant to alternatives involving retention or expansion of LPD and was to include evaluation of a long-term sediment management program. The evaluation was to describe levels of sediment management that could result in either maintaining the existing surface storage capacity or increasing surface storage over time up to the original reservoir capacity. In addition to reviewing options previously developed for dredging, this evaluation was to consider if there are additional feasible alternatives for removing material from the reservoir and transporting it to a disposal site. The evaluation was to consider periodic dredging and removal off site; periodic dredging and placement downstream of LPD, with the intent to allow the material to be captured and entrained by the river at high flows; constructing a sediment capture area in the reservoir; sluicing fine sediment during high flows; or constructing a bypass tunnel for incoming sediment. Other combinations could be evaluated.

4.2.2 Alternatives Descriptions

After the preliminary list of alternatives (Section 4.2.1) was refined through the TRC and stakeholder review process, it became the basis for the alternatives described in the Alternatives Descriptions TM (Appendix B), but not before the field investigation and analysis to quantify and characterize accumulated sediment in LPR (Section 2.4.1 and Sediment Characterization TM, Appendix C) was well underway. Beginning with the preliminary list (Section 4.2.1), the Alternatives Descriptions TM laid out high-level concepts that began to describe and illustrate the alternatives. The Alternatives Descriptions TM reformulated the Sediment Management Program, which was Alternative 5 in the Study Preparation TM (Appendix A), as four sediment management options that could be relevant to, or included with, multiple dam and reservoir alternatives. The dam and reservoir alternatives and sediment management options described in the Alternatives Descriptions TM are listed below.

Dam and Reservoir Alternatives from the Alternatives Descriptions TM

- No sediment management

- Dam removal
  - Full dam removal
  - Partial dam removal

- Restore reservoir capacity
  - Dredge and place on Cal-Am property
  - Dredge and place off Cal-Am property

- Storage expansion
  - Dam raise
  - Rubber dam
  - New dam downstream
  - Expand with combination

Sediment Management Options from the Alternatives Descriptions TM

- Periodic dredging to uplands
- Periodic dredging to floodplain
- Sediment sluicing through new tunnel
- Constructing a new bypass tunnel to transport sediment around the reservoir

4.2.3 Eliminated before Development

Through the process of describing the alternatives, in some cases the AECOM Team was able to identify fatal flaws and suggested eliminating unfavorable alternatives and began refining those that were more favorable. Following publication of the Alternatives Descriptions TM, through the TRC and stakeholder review process, including discussion at the second TRC meeting (TRC Meeting 2a) and written comments provided by the TRC, consensus was obtained on elimination of several alternatives. Based on the analysis in the Alternatives Descriptions TM, discussion at TRC Meeting 2a, and written comments provided on the Alternatives Descriptions TM, alternatives listed below were eliminated from further consideration.

- Dredge and place off Cal-Am property: The Alternatives Descriptions TM (Appendix B) reported that no reasonable off-site locations had been identified for sediment disposal. Based on those findings and subsequent discussion, the TRC and stakeholders agreed this should be removed from further consideration.
- Storage expansion – dam raise: Based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM, this was removed from consideration because, relative to other storage expansion options, it lacked flexibility, had higher anticipated construction costs, and greater environmental impacts.
- Storage expansion – new dam downstream: Based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM, this was removed from consideration due to anticipated high environmental impacts and construction costs.
- Storage expansion – expand with combination: This would have combined a new dam downstream with other options for storage expansion and was removed from consideration once the new dam downstream was eliminated.
- Constructing a new bypass tunnel to transport sediment around the reservoir: This was eliminated based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM due to anticipated high construction costs, high environmental impacts, and limited benefits.

Because these alternatives (or sub alternatives and sediment management options) were eliminated from further consideration, they were not developed to the same level of detail as alternatives that moved forward. Therefore, the descriptions of these alternatives are summarized in this section from the descriptions published in the Alternatives Descriptions TM, and these alternatives are not addressed further in this report. Alternatives carried forward are addressed in greater detail in subsequent sections of this report.

Dredge and Place off Cal-Am Property (Eliminated)

“Restore Reservoir Capacity by Dredging and Placing Off Cal-Am Property,” subsequently abbreviated as “Dredge & Place off Cal-Am Property,” was the concept presented in the Alternatives Descriptions TM that included dredging the reservoir to original capacity and transporting some or all reservoir sediment to an offsite disposal area (see Figure 4-1 for approximate limits of Cal-Am property). With this sub-alternative, existing public roads in Cachagua Valley would not be used (i.e., Nason Road, Cachagua Road, and Tassajara Road). Based on AECOM’s review of the area surrounding the reservoir using aerial photography conducted during preparation of the Alternatives Description TM, there are no practicable feasible locations for this sub-alternative. As noted above, based on those findings and subsequent discussion, the TRC and stakeholders agreed this concept should be removed from further consideration.

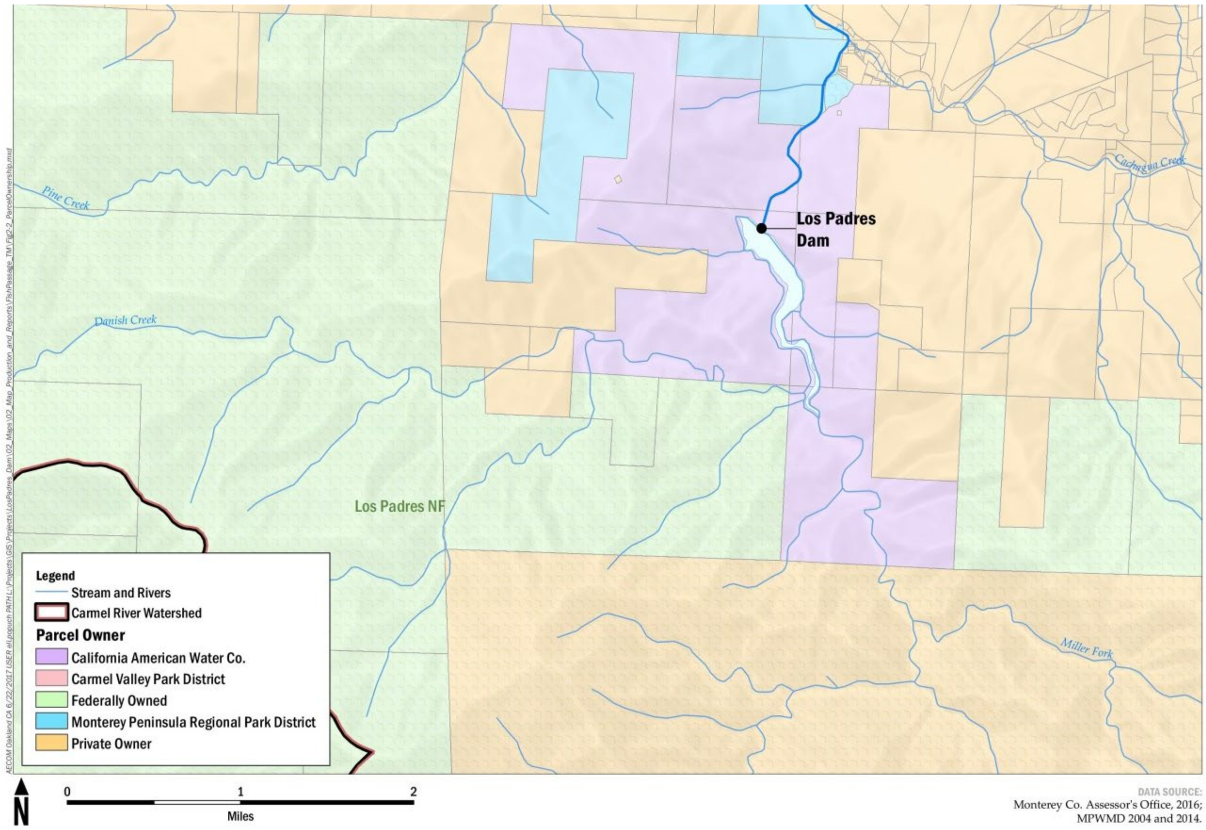

Figure 4-1 Approximate Location of California American Water Property

Source: Cal-Am and MPWMD 2016

Storage Expansion – Dam Raise (Eliminated)

"Expand with Dam Raise" was the concept presented in the Alternatives Descriptions TM (Appendix B) of expanding reservoir surface storage with a small dam raise at the existing dam. The maximum raise for the NMWS would be 9.6 feet, to El. 1,052.5 feet. This would increase the maximum storage capacity of the reservoir by 586 AF, from 1,601 AF to 2,187 AF. This would require raising the dam from the downstream side, modifying the spillway by raising the crest and the walls, and modifying portions of the outlet works. Construction of the dam raise would likely require two construction seasons, with the dam raise occurring during the first 6-month construction season and modifications to the spillway and outlet works being constructed during the following 6-month construction season. The relative cost of the dam raise concept was judged to be moderate but would require implementation of fish passage improvements that were not included in the cost comparison developed in the Alternatives Descriptions TM.

Major components of the dam raise concept would include the dam raise itself and replumbing the outlet works. The dam would be raised from the downstream side and would involve excavation at the downstream toe to expose bedrock, removal of the top approximately 40 feet of the dam to facilitate internal zoning, extension of the downstream blanket, a chimney filter, and extension of the top of the dam, as shown on Figure 4-2. Design for a dam raise would require stability analyses and seismic deformation analyses, and seepage analyses. These analyses would require a better understanding of the static and dynamic properties the dam, which would require drilling holes in the dam to obtain samples for laboratory analyses. There is a potential that deformation analyses could indicate the need for the upstream dam shell to be flattened.

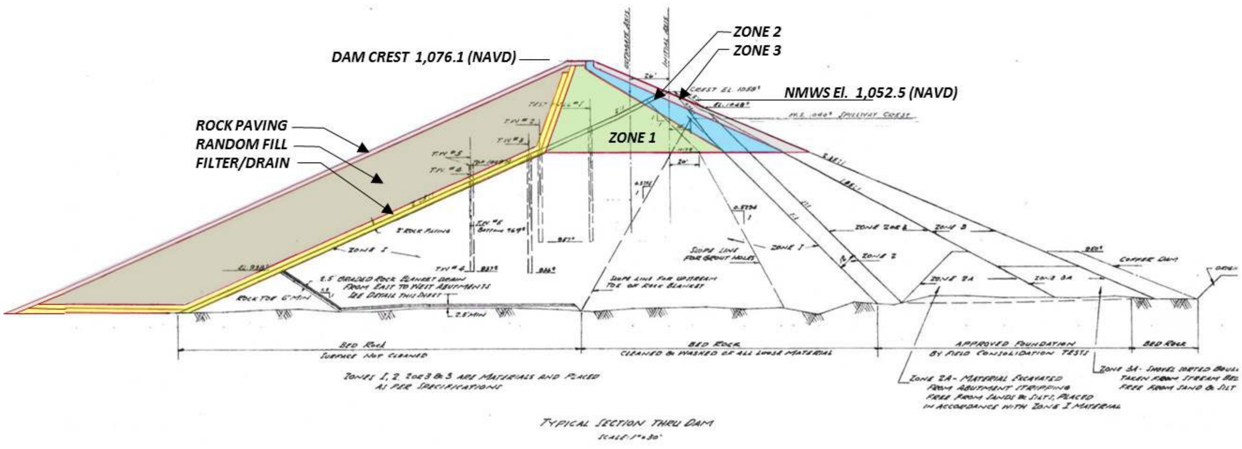

Figure 4-2 Dam Raise Section Concept

The current outlet works consists of a low-level outlet and a high-level outlet, but the low-level is the primary. The low-level outlet includes an upstream intake structure with a 30-inch hydraulically operated slide gate (invert El. 950.2 feet), an approximately 620-foot-long 30-inch-diameter steel conduit encased in reinforced concrete, and a downstream outlet works that divides into four outlet gates: a 30-inch butterfly valve, two 12-inch guard gate valves and regulating butterfly valves, and a 12-inch gate valve for habitat flow. The existing outlet structure for the low-level outlet is far enough downstream that it would not be affected by raising the dam. The upstream slide gate and hydraulic operating system would also not likely be affected by the dam raise (unless flattening of the upstream slope was determined to be needed); however, its ability to operate under the additional 12.5 feet of head at the raised NMWS would need to be confirmed. The high-level outlet would need to be modified to extend through the raise of the existing spillway crest and the combined outlet works would need to be reevaluated for meeting DSOD drawdown criteria.

As noted above, based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM, a dam raise was removed from consideration because, relative to other storage expansion options, it lacked flexibility, had higher anticipated construction costs, and greater environmental impacts.

Storage Expansion – New Dam Downstream (Eliminated)

"New Dam Downstream" was the concept presented in the Alternatives Descriptions TM of expanding surface storage by constructing a new dam downstream of the existing LPD. The location previously selected by The Mark Group (1995) for the New LPD (see Figure 4-3) would be best because of its narrow canyon width, requiring the least material to construct the new dam. Incompetent and weathered rock would need to be excavated for dam construction, with excavation depths for the right abutment, valley, and left abutment estimated to be 20 to 80 feet, 10 feet, and 20 to 70 feet, respectively. Most materials for an embankment dam would be sourced locally. Filter and drain materials would likely need to be imported or processed from the coarse sediment in the upper end of the reservoir. Aggregate materials for a roller-compacted concrete dam would be developed on site. Cement and flyash for the roller-compacted concrete dam would need to be imported. Three possible sizes were considered for the new dam downstream and a new, 203-foot-tall, embankment or roller-compacted concrete dam with crest El. 1,073 feet (NMWS 1,052.5 feet) and storage capacity of 7,529 AF were assumed for the Alternatives Development TM. The cost of a new dam, relative to other concepts considered, would be high to very high. Construction would require four construction seasons. As noted above, based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM, a new dam downstream was removed from consideration due to anticipated high environmental impacts and construction costs.

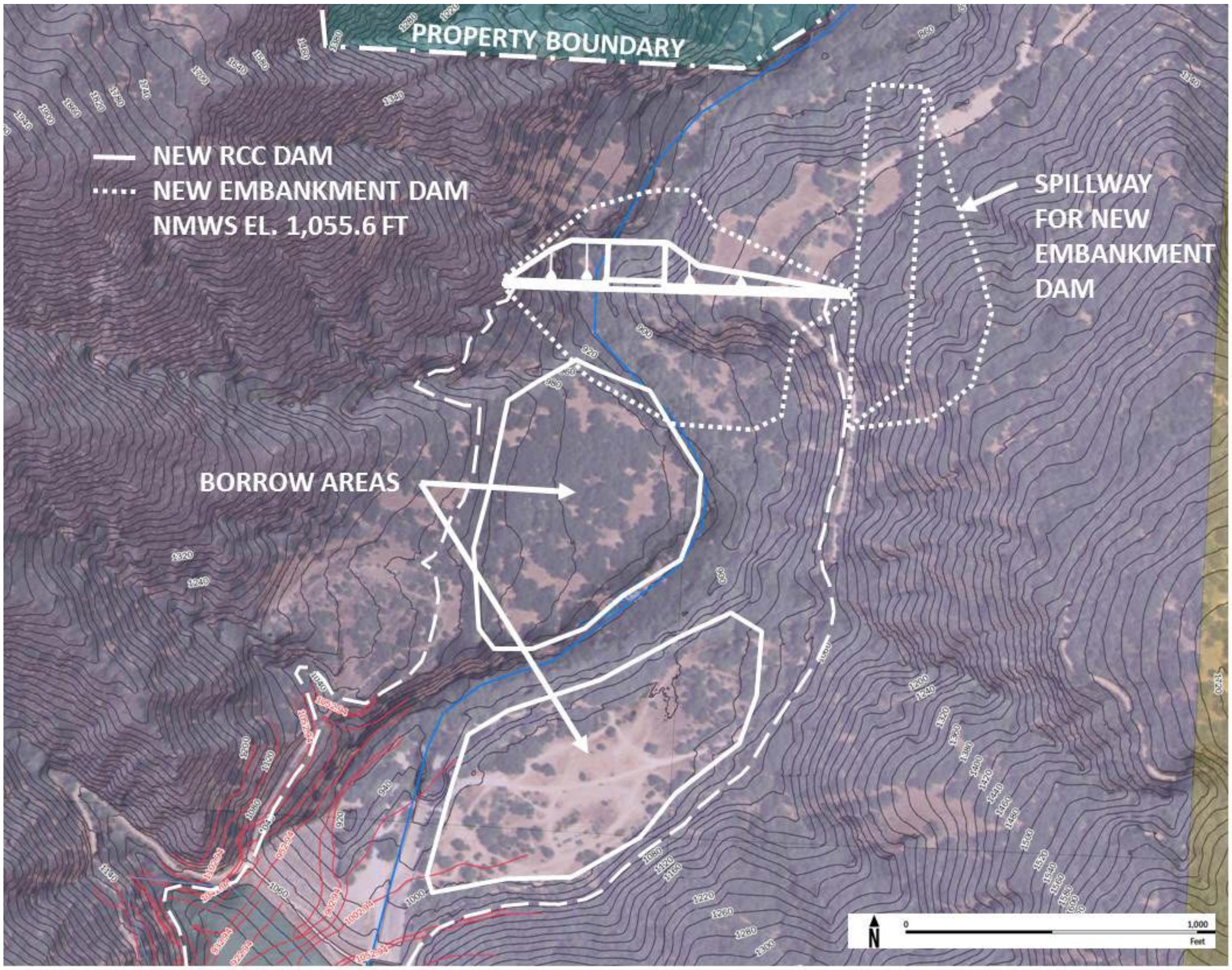

Figure 4-3 New Downstream Dam Concept Plan

Storage Expansion – Expand with Combination (Eliminated)

“Expand with Combination” was the concept presented in the Alternatives Descriptions TM of expanding surface storage with a combination of a new downstream dam and either a raise of LPD or placement of a rubber dam on the LPD spillway crest. This combination could provide an opportunity to use the original reservoir to continue capturing sediment, allowing a lower reservoir to trap less sediment. The new downstream dam would be restricted to a height that would not cause inundation of the invert of the LPD outlet structure (about El. 927.0 feet) during typical operations. Based on this restriction, the new downstream dam would be on the order of 45 feet high, with a maximum spillway crest elevation of about 920 feet, assuming 2 feet of freeboard between the LPD outlet invert and a reservoir level behind the new dam resulting from a 100-year event. The spillway crest would be at about El. 940 feet, to pass the HMR 58/59 PMF. The new dam would have a reservoir capacity of about 200 AF. The new dam would be constructed with RCC so that the majority of the dam crest could be used as a spillway crest, thereby avoiding construction of a separate spillway structure. The new dam would be at the same location and have similar construction methods as those described for “New Dam Downstream” concept. This concept would have combined a new dam downstream with other options for storage expansion and was removed from consideration once the new dam downstream was eliminated.

Bypass Tunnel to Transport Sediment Around the Reservoir (Eliminated)

Constructing a new bypass tunnel to transport sediment around the reservoir was the sediment management option described in the Alternatives Descriptions TM that would construct a 7,000-foot-long bypass tunnel from the upstream end of the reservoir, extending downstream past LPD (Figure 4-4). The intent of the bypass tunnel would be to convey sand and finer sediment past the reservoir during high-flow events. A settling basin just upstream of the intake would trap coarser sediment to prevent it from entering and potentially being trapped in the tunnel. Access to the intake location would be required for construction and for periodic removal of gravel, cobbles, and boulders from the settling basin. Access on the left side of the reservoir would include improving 3,200 lineal feet of existing unimproved road and construction of an additional 6,600 lineal feet of new road. Coarse sediment could be hauled to permanent disposal sites or to sites along the river downstream of LPD, where it could be mobilized back into the river system during high flows.

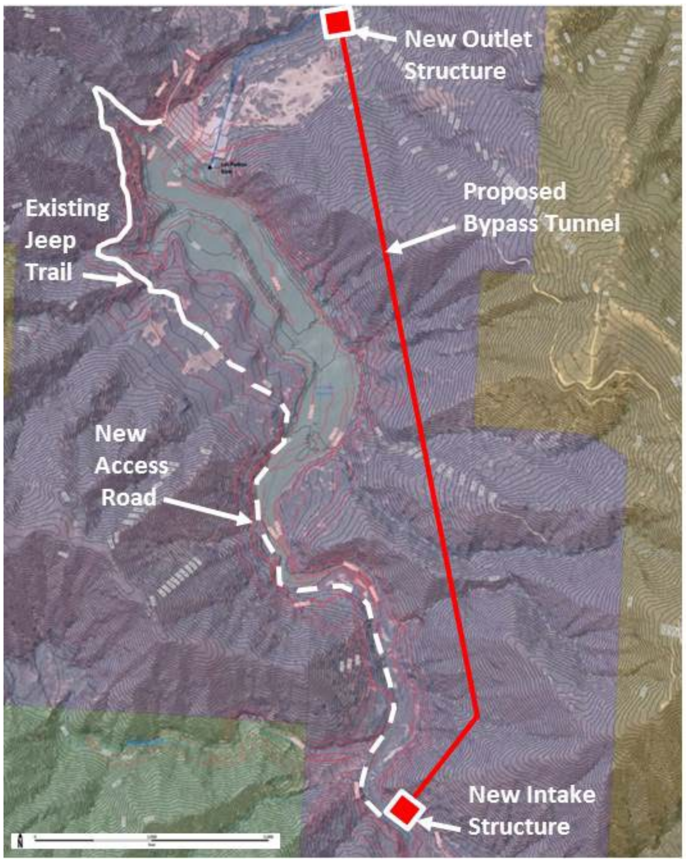

Figure 4-4 Bypass Tunnel Location

The size (13 to 16.5 feet wide) and length (7,000 feet) of tunnel that would be needed to convey sediment past the dam would be significant, potentially cost-prohibitive, and would be very high relative to other sediment management concepts presented in the Alternatives Descriptions TM. Periodic cleanout of the settling basin, on average every 5 years, would require reconditioning the access road and excavation and hauling of the coarse material to either permanent disposal sites or in-river disposal sites. Construction would require an estimated four construction seasons and would require cofferdams to separate the work from the active river channel. Rock would likely be excavated from the tunnel using drilling and blast methods, and would be hauled and placed in a permanent disposal sites. Following excavation, the tunnel would be lined with reinforced concrete. Assuming one third of the sediment might get past the bypass tunnel and settling basin, 125 AF to 260 AF of reservoir capacity might be lost during the 60-year project life. As noted above, this bypass tunnel concept was eliminated based on discussion at TRC Meeting 2a and subsequent written comments on the Alternatives Descriptions TM due to anticipated high construction costs, high environmental impacts, and limited benefits.

4.2.4 Alternatives Development

Based on review and discussion of the Alternatives Descriptions TM, prior to the third TRC meeting (TRC Meeting No. 2b), the preliminary list of alternatives (Section 4.2.1) had been reduced. Additionally, between when the Alternatives Descriptions TM was published in December 2017 and when the Alternatives Development TM was published in March 2022, the AECOM Team also completed the Sediment Characterization TM (Appendix C), sediment transport modeling and a Sediment Effects TM (Appendix D), and an analysis of the effects of the alternatives on steelhead (Appendix E). These studies of sediment and steelhead contributed to the Study participants' understanding of the sediment issue at LPD and how the alternatives under consideration may affect steelhead, and informed additional discussion of the alternatives leading up to preparation of the Alternatives Development TM. Alternatives that remained on the table and were discussed at TRC meeting 2b are listed below.

Dam and Reservoir Alternatives

- No sediment management
- Dam removal
  - Full dam removal
  - Partial dam removal
- Restore reservoir capacity
  - Dredge and place on Cal-Am property
- Storage expansion
  - Rubber dam

Sediment Management Options

- Periodic dredging to uplands
- Periodic dredging to floodplain
- Sediment sluicing through new tunnel

Based on discussion at the meeting and follow up correspondence among the TRC and study participants, additional refinements to this list of alternatives were made to help focus the alternatives development and analysis presented in the Alternatives Development TM. AECOM prepared a table that listed the actions for dam, reservoir, and sediment management that remained under consideration and identified a set of actions, based on the alternatives listed above, that encompassed all major actions under consideration. This table was shared with the TRC prior to proceeding with the Alternatives Development TM (Table 4-2).

Table 4-2 Reformulation of Five Alternatives that Include all Actions under Consideration after Technical Review Committee Meeting 2b

		Actions				
	Alternatives	Remove Dam	Dredge Fine Sediment	Sluice Tunnel	Excavate Coarse and Fine Sediment	Rubber Bladder Dam
1	No Sediment Action					
2	Dam Removal with Dredging	✓	✓			
3	Storage Expansion		✓		✓	✓
4	Recover Capacity with Excavation				✓	
5	Recover Capacity with Sluicing			✓		

Formulation of the alternatives as shown in Table 4-2 combined some actions within alternatives, but no actions were eliminated at this stage. Instead, actions were grouped to support the intent of each alternative in a manner that would allow for useful comparisons to be made among alternatives. This included combining Sediment Management Option 1 (periodic dredging to uplands) and Sediment Management Option 2 (periodic dredging to the floodplain) from the Alternatives Descriptions TM into a single sediment management approach that would involve dredging sediment and disposing of the sediment either in uplands or in the floodplain, to be managed adaptively, based on the type of sediment encountered (fine versus coarse), the immediate need for coarse sediment in the river, and the status of permanent, upland disposal sites. This approach had been discussed at the end of TRC Meeting 2b and it seemed more practical and likely than either option on its own.

Another decision made prior to publication of the Alternatives Development TM, but reflected in Table 4-2, included focusing on full dam removal with the acknowledgement that partial dam removal could be reintroduced as a value engineering option if dam removal was selected as the preferred alternative. Partial removal of the embankment dam would entail removal of the central portion of the embankment in profile, as shown in concept on Figure 4-5. In concept, the fill remaining on the left abutment (right side of Figure 4-5) would be accessible to Carmel River flood flows and would be entrained into the river when the flows in the river already have a high suspended sediment concentration. The fill remaining on the right abutment would not be accessible to river flow and would be stabilized by hydroseeding. Construction sequencing, duration, and sediment disposal would be similar to full dam removal but the spillway structure would be left in place, with the higher walls being demolished or trimmed to reduce health and safety risks to the public. The intake and outlet structures for the low-level outlet would be demolished and the 30-inch-diameter outlet conduit would be plugged at each end with concrete. Partial and full dam removal are expected to have similar benefits so maintaining both sub alternatives would not help differentiate dam removal from other alternatives. Because of the limited cost savings associated with partial dam removal and the disadvantage of leaving the spillway in the river canyon, a decision was made to focus on full dam removal at this stage of planning and analysis.

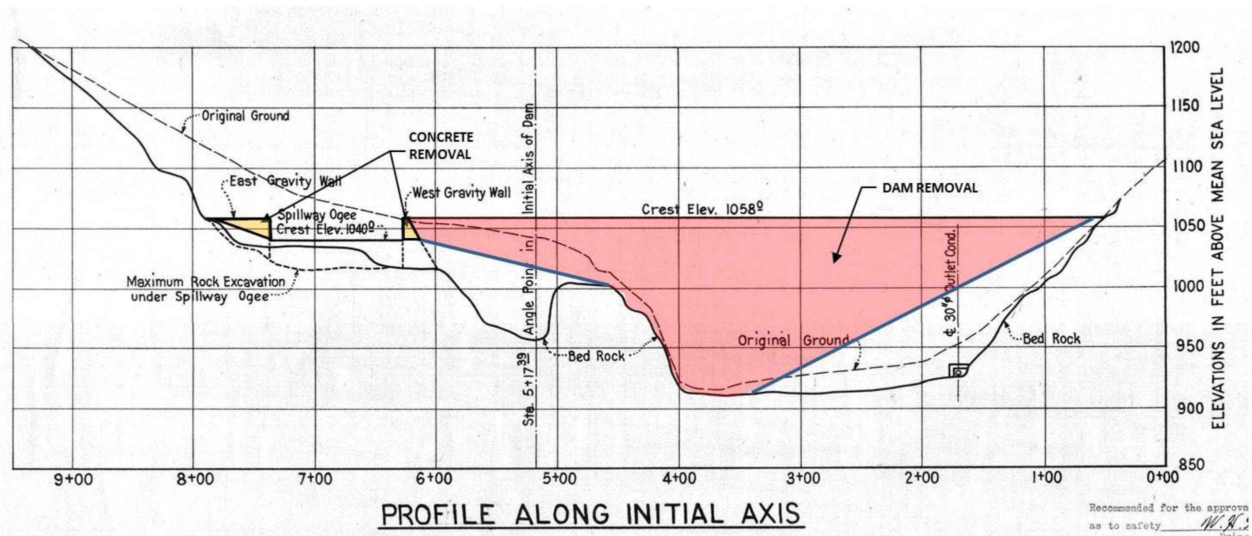

Figure 4-5 Alternative 2b Partial Dam Removal Profile

A third reformulation of alternatives that occurred between the Alternatives Descriptions and Alternatives Development TMs was combining actions to restore reservoir capacity with the storage expansion alternative (Table 4-2). It would be feasible to increase the height of LPD without also removing the accumulated sediment (or vice versa); however, if the goal of a project was to increase capacity of the reservoir, it seemed most likely that the accumulated sediment would also be removed as part of that project, and combining both actions would have the greatest benefit. Furthermore, the actions included in the reformulated storage expansion alternative were developed and described in a manner that would allow separating the storage increase from the sediment removal as individual actions, if desired, in the future. With the elimination and combination of various concepts as described throughout this section of this report, the five alternatives listed below were carried forward for further development and evaluation in the Alternatives Development TM.

Dam, Reservoir, and Sediment Management Alternatives from the Alternatives Development TM

- Alternative 1 – No Sediment Action
- Alternative 2 – Dam and Sediment Removal
- Alternative 3 – Storage Expansion and Dredging
- Alternative 4 – Recover Storage Capacity with Excavation
- Alternative 5 – Recover Storage Capacity with Sluice Tunnel

Like the alternatives from the Alternatives Descriptions TM listed in Section 4.2.2, alternatives eliminated from further consideration based on analysis in the Alternatives Development TM and subsequent feedback from the TRC are described in the following two sections, and the alternatives that will be considered further are presented in Section 5.

4.3 Eliminated after Development

Following the TRC's review of the Alternatives Development TM (Appendix F), discussion of the alternatives at TRC Meeting No. 3, and receipt of written comments on Appendix F, Alternative 4 (Recover Storage Capacity with Excavation) was eliminated from further consideration. Also eliminated from further consideration was an option that had previously been entertained, the option of using a sluice tunnel to remove sediment from LPR prior to dam removal. Alternative 4 and the sluice tunnel variation on dam removal are described in this section, including reasons why they are no longer being considered.

4.3.1 Alternative 4 (Recover Storage Capacity with Excavation)

Under Alternative 4, accumulated sediments would be periodically removed to maintain or recover reservoir storage capacity. Figure 4-6 shows an overview of Alternative 4 activities for periodic sediment removal to maintain or recover reservoir storage capacity. Alternative 4 was broken into two options: Alternative 4a, which assumed removal every 5 years on average; and Alternative 4b, which assumed removal every 10 years on average. Both options had the same removal approach (dredging, like Alternative 3 [Storage Expansion and Dredging], see Section 5) and shared the goal of removing the average annual sediment load, but differ in their frequency of recurrence and, therefore, removal volumes. Both options assume material placement at Disposal Sites B and C, with future dredging episodes potentially reaching far enough upstream to capture Zone 3 sediments for placement at Disposal Sites D and E.

In addition to other actions described in the Alternatives Development TM and summarized here, because the dam would remain in place, the fish passage improvements assumed for all dam-in alternatives and summarized from HDR et al. 2021 for Alternative 3 (Storage Expansion and Dredging) in Section 5.2.3 would also be implemented for Alternative 4.

After publication of the Alternatives Development TM, at the fourth TRC meeting (TRC Meeting No. 3) it was agreed (and confirmed upon receipt of written comments) that Alternative 4 would be eliminated. This alternative, summarized from the Alternatives Development TM in this section, was eliminated due to its limited advantages and highest cost relative to other alternatives. If Alternative 4 had moved forward, it would have needed to incorporate spillway and dam embankment improvements required to accommodate the updated PMF, as described later for Alternatives 1 and 5 in Section 4.4. This would have increased the cost by approximately $20.7 million.

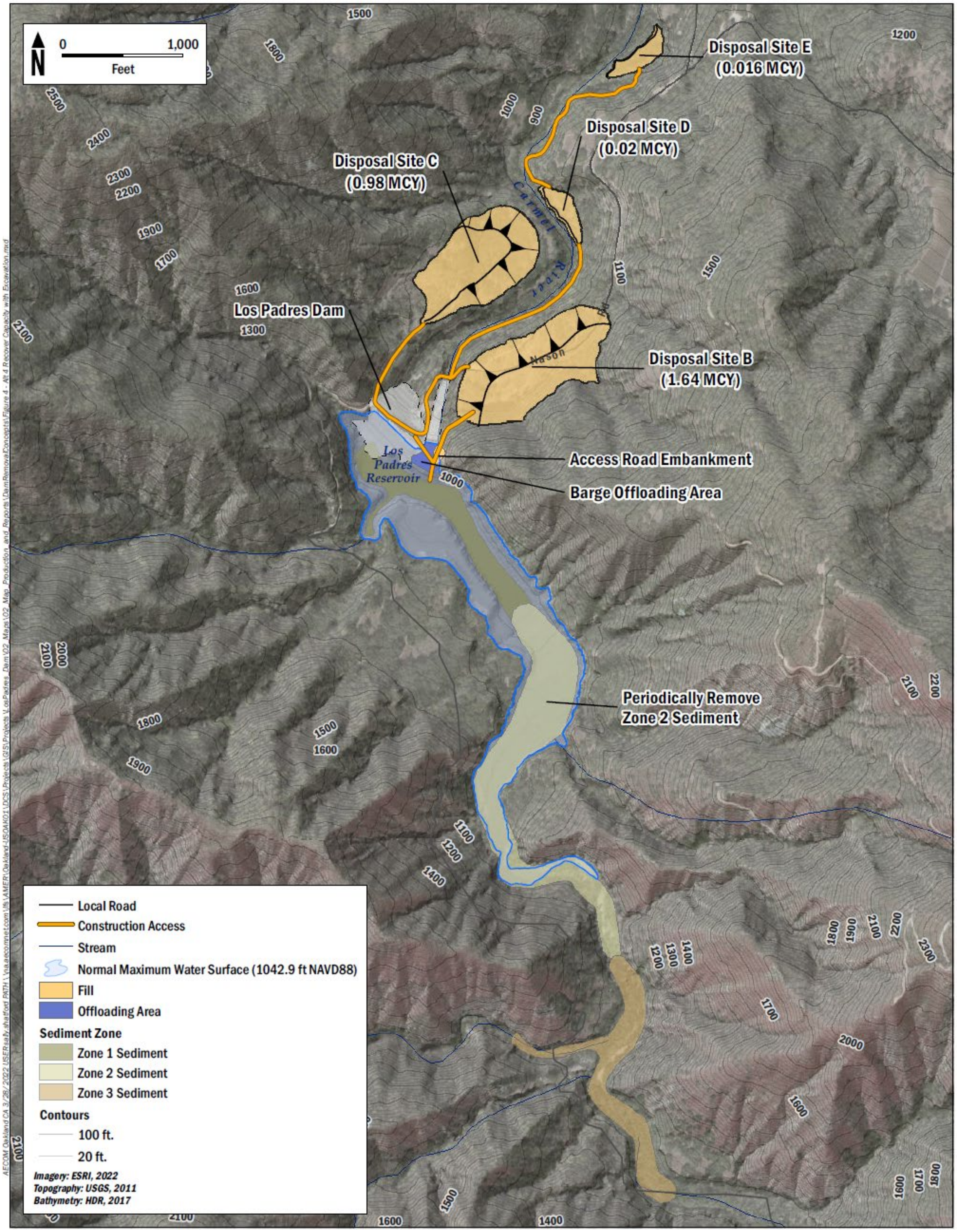

Figure 4-6 Alternative 4 (Recover Storage Capacity with Excavation)

Access Improvements

Access improvements required for Alternative 4 would be like those described in Section 5.2.2 for Alternative 3 (Storage Expansion and Dredging). This includes limited public roadway improvements (Section 5.1.2) and onsite improvements to accommodate construction equipment and access reservoir sediments and sediment disposal sites (Section 5.2.2).

Fish Passage Improvements

Two upstream and two downstream fish passage options were identified as preferred or warranting additional consideration (HDR et al. 2021). Those passage options are summarized in Section 5.2.3. As with other dam-in alternatives, if it had been selected, one upstream and one downstream fish passage option would have been adapted to Alternative 4. Additional detail and evaluation regarding fish passage at LPD are available in the draft Fish Passage Feasibility Report for LPD.

Sediment Removal

Sediment removal upstream of LPD is severely constrained by suitable access capable of supporting thousands of truck trips. Access via the “Jeep Trail” is no longer possible due to recent rockslides and the high potential for future rockslides along the steep, mountainous terrain. The steep slopes continue down to the accumulated sediments in the reservoir basin, preventing partial dewatering of the reservoir and construction of an access road around the lowest elevations of the reservoir basin.

Access to the upstream sediments must be gained either over water, or via an upstream access road and diversion system. Dewatering to the elevation required to construct an upstream access road may require a treatment system to meet discharge criteria. Also, building a road crossing on the approximately 400-foot-wide reservoir basin would require material sourced possibly near Disposal Site B, and would delay the time available for sediment removal. Neither of these complications align with a low-effort periodic removal of sediments from the reservoir. For these reasons, for this alternative, dredging of sediments using a barge-mounted excavator is preferred over dewatering and conventional excavation.

An estimated 18 AF (29,000 CY) of sediment is accumulated each year, reducing the reservoir storage by an estimated 16 AF each year. Alternative 4 assumes the removal of, on average, 90 AF (145,000 CY) every 5 years (Alternative 4a) or 180 AF (290,000 CY) every 10 years (Alternative 4b), by means of dredging to maintain reservoir storage capacity near the current level. Sediment zone volumes, disposal locations, and characterization for Alternative 4 are summarized in Table 4-3.

Table 4-3 Alternatives 4a and 4b Estimated Sediment Removal and Placement

Alternative	Area	Volume (AF)	Volume (CY)	Disposal Location	Characterization
Alternative 4a (5 years)	Zone 2	90	145,000	Site B and C	Predominantly silt and sand
Alternative 4b (10 years)	Zone 2	180	290,000	Site B and C	Predominantly silt and sand

Notes:
AF = acre-feet
CY = cubic yards
Source: Appendix C

The following timeline summarizes the anticipated sediment removal actions for Alternative 4 during a single construction year, with in-water construction work occurring from May 15 to October 15. Because the sediment removal work is not anticipated to take more than 1.5 to 3 months, there is available float in the 5-month in-water work window. Site mobilization and demobilization would occur before and after the sediment removal activities.

Construction Year 1:

Prior to May 15 (or later as schedule allows):

- Improve access roads as described in Section 5.1.2, with the exception of the access road on the reservoir sediments to the upstream extent of the project area because this alternative assumes that the reservoir will retain water during sediment removal.

- Clear and grub permanent sediment Disposal Sites B and C. Prepare the sites to receive material.

- Draw down the reservoir to elevation 1,025 feet to expose the offloading area on the natural terrace. Release of approximately 769 AF would take approximately 10 days, assuming minimum discharges from the restored low-level outlet (30 cfs) and siphon (average 12 cfs), as described in Section 5.1.3.

Beginning May 15 (or later as schedule allows):

- Create an approximately 20,000-square-foot offloading area adjacent to the spillway on the natural terrace near elevation 1,025 feet. Maintain the reservoir water level at elevation 1,025 feet, if possible, to offload material most efficiently from barges. Construct a lower shelf from which to offload as continued summer discharges lower the reservoir water surface elevation. See Section 5.2.6 for additional discussion on offloading area and lowered water level considerations.

- Assemble the flexi-floats and excavator on the barge to begin sediment removal.

- Construct in-water access routes to floodplain Disposal Sites D and E. Clear, grub, and prepare sites to receive material.

- Remove sediments using barge mounted excavator:
  - Alternative 4a: 145,000 CY (1.5 months)
  - Alternative 4b: 290,000 CY (3 months)

Alternative 4 would include periodic removal of the most accessible accumulated sediments in the reservoir, which are the Zone 2 sediments near the upstream extent of the reservoir. The reservoir water surface elevation would be lowered to approximately elevation 1,025 feet NAVD88 to allow for the offloading area to be positioned on the existing spillway terrace. A barge-mounted hydraulic excavator would excavate Zone 2 sandy sediments and deposit the materials in a secondary transport barge. The barges would be transported via work boat to the offloading area adjacent to the LPD spillway. There, a secondary land-based excavator would offload the barges onto articulating dump trucks that would haul the material to the downstream Disposal Sites B and C for conditioning and drying prior to permanent grading.

Figure 4-7 depicts the sediments to be removed from the reservoir. Substantial Zone 3 sediments begin appearing in the reservoir profile near Station 60+00, and the material excavated for Alternatives 4a and 4b extend no higher than approximately Station 50+00. Because the excavator must dig its access (including 10 feet of draft for full material barges), Zone 3 sediments are likely unreachable in the preliminary dredging episodes. Subsequent episodes may have more access to Zone 3 sediments, although sediment is anticipated to continue to deposit in the reservoir at the same rate of removal. If, however the newly accumulated material allows for more access to Zone 3 sediments, they may be excavated and placed at Disposal Sites D and E for mobilization downstream during large-flow events.

Hauling and Sediment Disposal

Excavated material would be hauled by articulated trucks and disposed of at Sites B and C. Subsequent episodes may allow for Zone 3 sediment to be sorted and placed at Sites D and E to support steelhead spawning areas and instream habitat downstream of the dam. Additional description of disposal sites, including access, consistent with the level to which this alternative was developed, are provided in the Alternatives Development TM (Appendix F).

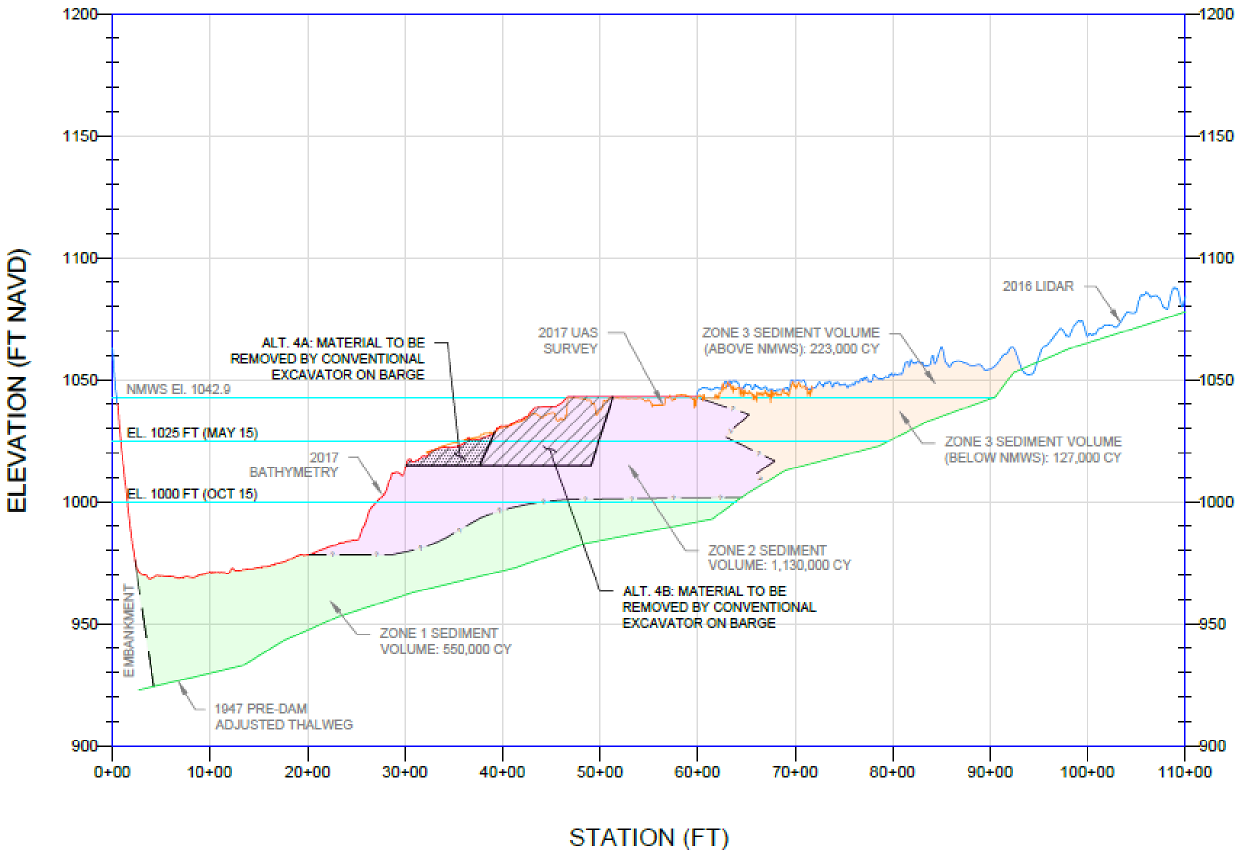

Figure 4-7 Material Dredging by Equipment Type and Water Level

Construction Cost

Higher unit costs associated with smaller volumes of sediment removal make Alternative 4a less cost effective over time compared to Alternative 4b. For that reason, the Alternatives Development TM presented an Opinion of Probable Construction Costs (OPCC) for Alternative 4b only. As described in more detail in the Alternatives Development TM (Appendix F), Section 6.5, a single bout of sediment removal could cost $13,760,000. A 50-year planning horizon for sediment removal was selected to calculate a total OPCC cost for sediment removal to compare with other alternative OPCCs. Assuming an annual escalation rate of 3 percent, the 50-year total (consisting of six separate sediment removal events) would be $195,700,000.

If Alternative 4 had moved forward, it would have needed to incorporate spillway and dam embankment improvements required to accommodate the updated PMF, as described later for Alternatives 1 and 5 in Section 4.4 and Alternative 3 in Section 5.2. This would have increased the construction cost by approximately $20.7 million. For this reason, and because it was eliminated earlier in the study, the OPCC developed for Alternative 4 is not directly comparable to costs presented in Section 6. To avoid a comparison of interim costs developed for the Alternatives Development TM and final costs presented in this report, refer to the Alternatives Development TM to compare costs between Alternative 4 and the four alternatives presented later in this report.

Operations and Maintenance

An operations plan would be developed during detailed design to outline required monitoring and procedures associated with timing of the recurring sediment removal events. Any monitoring stations and/or instrumentation associated with the operations plan would be built into the project design. However, implementation of the plan—which would include data collection and analysis, along with contracting/procurement and construction oversight—would increase the O&M responsibilities and budget at the site. Assuming one half-time employee for up to 2 months could increase the annual O&M budget by as much as $25,000, and that construction oversight costs for each recurring sediment removal project (assuming every 10 years) could add as much as $80,000 per 3-month sediment removal project, annual O&M costs associated with the upstream and downstream fish passage improvements could total as much as $782,000 (HDR et al. 2021).

Uncertainties

Key uncertainties associated with Alternative 4 at the time it was eliminated from further consideration included the following:

- Because this alternative extends into the future (relative to other alternatives, which include a single project and construction duration), a key uncertainty involves the rate of escalation, which can have a significant effect on future recurring sediment removal costs.
- Another key uncertainty involves potential effects of the dredging operation on adult and juvenile steelhead migration through the reservoir and into the upstream river channel. An assessment and adaptive management plan would be needed to coordinate the various activities and address associated uncertainties.
- As described in Section 5.1.9, conceptual or planning-level alternatives are uncertain by nature. Key assessments or investigations to help address uncertainties related to design and construction of this alternative are listed below:
    - A detailed assessment of temporary access that would be required within the river floodplain for equipment to clear, grub, and grade Disposal Sites D and E would be needed to understand potential impacts to habitat in this area.
    - Additional onsite geologic assessment and geotechnical investigation may be required during detailed design to confirm the extent of improvements required for the other temporary access roads proposed for sediment access and hauling.
    - A drying time test and correlated strength testing should be performed at later stages of design to better define sediment disposal site coverage times and reduce the risk of construction delays. Strength testing would also be used in stability analyses of the disposal sites to confirm the proposed disposal site slopes and allowable water content of the materials.

Advantages and Disadvantages

For a full list and discussion of advantages and disadvantages understood for Alternative 4 at the time this alternative was dismissed, see Section 6.8 in the Alternatives Development TM (Appendix F). Recurring sediment removal had notably higher costs than all other alternatives presented in the Alternatives Development TM, through 50 years, and did not offer unique benefits. Beyond 50 years, costs would continue to accumulate, due to repeated bouts of sediment removal, and rise, due to cost escalation, into the future. This alternative did not appear to be a cost-effective solution to long-term sediment management, relative to the other alternatives. It was eliminated from further consideration at TRC Meeting No. 3 without objection, a decision that was later supported by the TRC’s written comments on the TM.

4.3.2 Temporary Sluice Tunnel to Facilitate Sediment Flushing prior to Dam Removal

An alternative to dredging and excavation of accumulated reservoir sediments would be to construct a mechanism (such as the permanent sluice tunnel described for Alternative 5) that can be prepared in advance of project initiation and then operated during a major runoff event to evacuate sediment from the reservoir prior to initiating other aspects of the dam removal construction project. This approach is currently being considered for the Matilija Dam Removal Project in Ventura, California, the Searsville Dam Project in Santa Clara County, California, and the Klamath River Renewal Project in Klamath County, California.

In some cases, analysis has shown that this approach would greatly reduce the cost of sediment management during a specific dam removal project. However, every site is different and has its own considerations and constraints. Los Padres is an earthen dam while Matilija and Searsville are concrete dams, and the Klamath dams are utilizing existing tunnels to facilitate sediment mobilization. Earthen dams tend to be much wider than concrete dams, and the sluice tunnel conceptualized for Los Padres would be 900 feet long, while the tunnels through the concrete dam structures at Searsville and Matilija were closer to 40 to 50 feet in length. At the time when the decision was made to eliminate this sluice tunnel option for dam removal, the sluice tunnel (Alternative 5) OPCC was approximately $61 million while the cost of the proposed sediment excavation prior to dam removal was $53 million (Appendix F). In part due to its length, it may be that there is no real savings associated with constructing the sluice tunnel to remove sediment prior to dam removal at Los Padres. While there would be a savings if more sediment were left in place to move downstream after dam removal, that approach would not allow for a controlled release of sediment during high flows and instead the impacts could occur over a longer duration.

4.4 Eliminated after Draft Final Report

Following publication of the draft final report, review by the TRC, and receipt of written comments, several changes with direct bearing on the alternatives described in the draft final report came to be known to the LP Alternatives Study participants. These changes included the following:

- Input was received from the DSOD and Cal-Am's dam safety division, suggesting that additional dam safety improvements (and costs) to accommodate the updated PMF should be included with multiple alternatives.
- A manuscript was released by NMFS (Boughton and Ohms 2022), describing a quantitative analysis of the effects of streamflow on steelhead production in the Carmel River.
- Shifting stakeholder sentiment regarding the feasibility of Alternative 5 (Recover Storage Capacity with Sluice Tunnel) and how best to present Alternative 1 (Fish Passage, No Sediment Action).

Deemed too important not to address in the final report, an additional report iteration (this revised draft final report) and TRC Meeting No. 4 were added to the LP Alternatives Study scope of work (Section 1.2) to integrate the new information into the alternatives and their evaluation. AECOM updated the alternatives with the new information at a summary level, and AECOM and NMFS presented the new information to the TRC at Meeting No. 4. Based on comments received on previous works, including the draft final report, and based on discussion at the meeting, decisions were made to eliminate Alternative 1 (Fish Passage, No Sediment Action) and Alternative 5 (Recover Storage Capacity with Sluice Tunnel) from further consideration for long-term management of LPD and LPR.

Alternatives 1 (Fish Passage, No Sediment Action) and 5 (Recover Storage Capacity with Sluice Tunnel) are described in this section, including reasons why they are no longer being considered. They are presented with information and evaluation beyond that provided for Alternative 4 in Section 4.3, consistent with the level of information presented in the now superseded draft final report, at which time Alternative 4 had already been dismissed but Alternatives 1 and 5 were still being considered. An overview is provided for each alternative, followed by subsections describing key components of the alternative and general O&M considerations. Subsequent subsections for each alternative relate key findings from the Sediment Effects TM (Appendix D) and the Effects to Steelhead TM (Appendix E) to the alternative at the level of analysis that had been developed at the time it was dismissed. For each alternative, the last subsections summarize unresolved, alternative-specific uncertainties, advantages, and disadvantages identified during the LP Alternatives Study. Opinions regarding construction and O&M costs are presented in Section 6.

4.4.1 Alternative 1 – Fish Passage, No Sediment Action

Alternative 1 (Fish Passage, No Sediment Action) is based on a scenario in which LPD remains in place as under current conditions; no action is taken to manage the existing sediment accumulation in the reservoir, or future sediment inputs; and fish passage facilities are substantially improved or replaced per a standing agreement between Cal-Am, NMFS and the California State Coastal Conservancy. This alternative was created to serve as a no-action alternative for use in relative comparison with other action alternatives. At the outset of the LP Alternatives Study, it was envisioned that this alternative would be carried forward to the end of the study, along with at least one dam removal alternative and one reservoir expansion alternative. However, relatively early in the process, it became clear that no stakeholder wanted to see this alternative considered for implementation.

Although it was retained through the draft final report, a decision was made at TRC Meeting No. 4 to eliminate Alternative 1 from consideration as a feasible alternative for long-term management of LPD and LPR and move its presentation in the final report to Section 4. As noted in comments provided by Cal-Am on the Alternatives Development TM (Appendix F), Alternative 1 "…does not address the long-term impacts of sediment accumulation and loss of reservoir capacity…[and] should not be considered further." In their review of the same document, NMFS stated that Alternative 1 "…would not be beneficial in the long-term for either Cal-Am (declining water supply) or steelhead (declining water supply for releases, and quality)," and then pointed out during their review of the draft final report that "…fish passage facilities and infrastructure would lose their efficacy and result in poor water quality conditions..." Both NMFS and CDFW explicitly stated in their written comments on the draft final report that they do not consider Alternative 1 feasible. Additionally, based on dam safety input received from the DSOD and Cal-Am after publication of the draft final report, it was determined that Alternative 1 would need to include dam safety improvements (assumed to be spillway wall and dam embankment height raises; see Sections 5.2.4 and 5.2.5 for details) that previously had only been included with Alternative 3 (Storage Expansion and Dredging). This change was presented at TRC Meeting No. 4 and added substantial cost to the OPCC for Alternative 1.

It may take years or even decades to select, permit, and finance a preferred alternative, during which time the status quo is likely to continue (interim fish passage improvements without sediment management in the reservoir). This was discussed at various times during the LP Alternatives Study, including at TRC Meeting No. 4, as a potential reason to retain Alternative 1 among the feasible alternatives presented in Section 5 of the report. However, it was eventually agreed that with more than $100 million of dam safety and fish passage improvements and a presumed design life of at least 50 years, Alternative 1 does not reflect the status quo. Limited dam safety and fish passage improvements may be required at LPD over the short term, but no stakeholder advocated for spending this sum of money to implement changes at LPD that could be superseded by one of the favored alternatives presented in Section 5.

To clearly reflect the sentiments of stakeholders and avoid confusion regarding stakeholders' preference not to see Alternative 1 implemented as a long-term solution, Alternative 1 was eliminated from further consideration at TRC Meeting No. 4. It was then moved from Section 5, where it had previously been presented in the draft final report, to Section 4, with other alternatives that have been dismissed. Consistent with the initial intent of the LP Alternatives Study, Alternative 1 is presented here at the full level of detail to which it was developed during the study, so that the information is available should this alternative be needed as the basis of comparison in a future environmental document. Because costs for Alternative 1 were updated after review of the draft final report, and to support discussion at TRC Meeting No. 4, the OPCC for Alternative 1 is retained in Section 6. The estimate was updated to include dam safety and limited access improvements to address the PMF, and is current and comparable with the OPCCs presented for the feasible dam, reservoir, and sediment management alternatives presented in Section 5.

Overview

Under Alternative 1 (Fish Passage, No Sediment Action), no action is taken to manage the accumulated reservoir sediments or the incoming sediment. In addition, no action is taken to maintain or increase reservoir storage in any way. Given the average reservoir storage loss rate of 16 AFY and the remaining storage volume in 2017 of 1,601 AF (Section 2.4.1), it is estimated that the reservoir will be substantially filled with sediment by 2115 (although there is considerable uncertainty associated with this estimate). Figure 4-8 shows the dam and reservoir, with the approximate zones of current sediment deposition. Like other large reservoirs that have lost their storage capacity due to watershed sediment load, it is anticipated that some relatively insubstantial reservoir pool will remain directly upstream of the spillway due to hydraulic action occurring during storm events. As the reservoir continues to lose storage capacity over time, the flexibility to store and then release flows from the reservoir during the summer will decrease. Eventually, there will be little to no capability to augment summer flows with reservoir water.

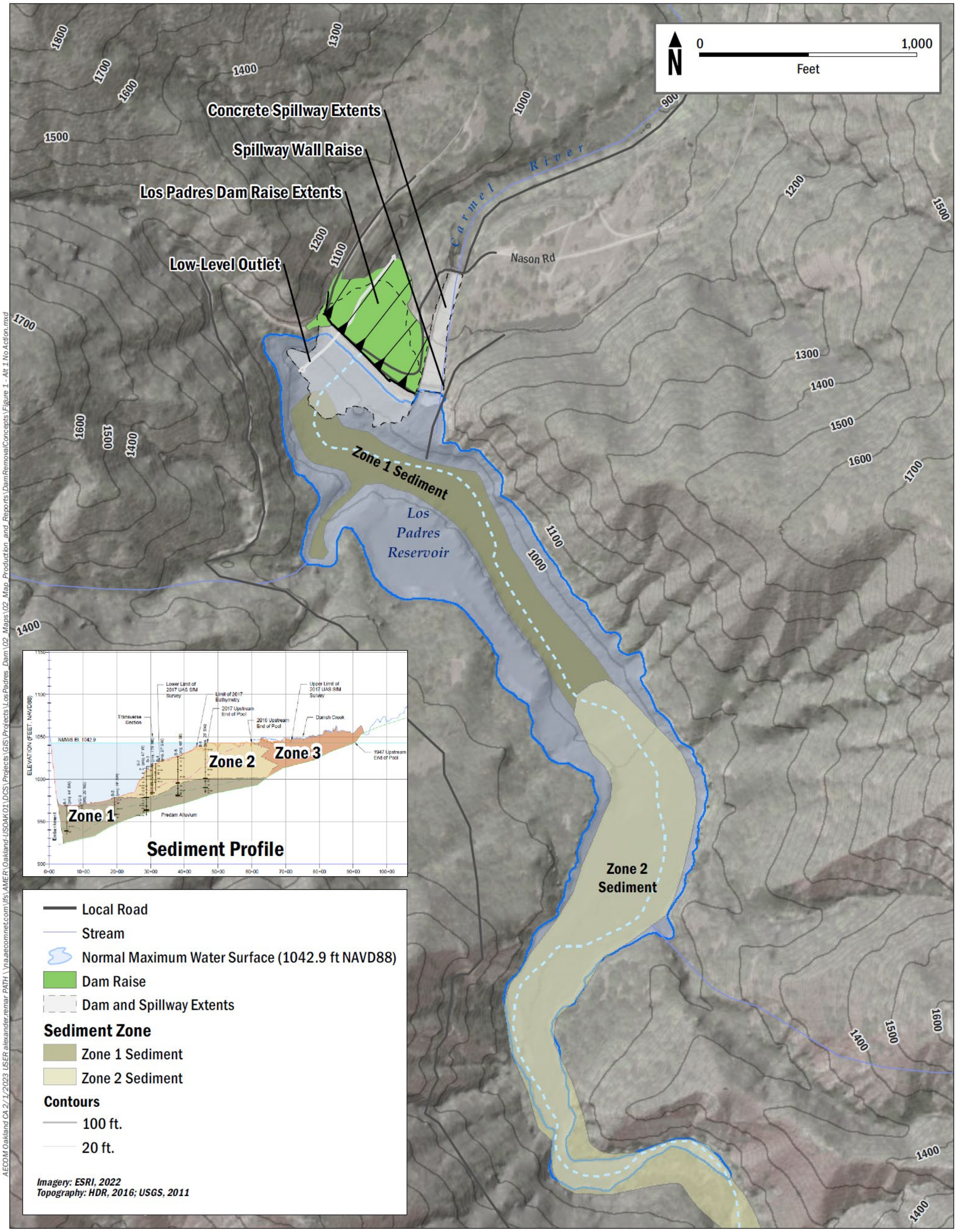

Figure 4-8 Alternative 1 (Fish Passage, No Sediment Action)

Alternative 1 (Fish Passage, No Sediment Action) includes fish passage improvements as conceptualized in the draft Fish Passage Feasibility Report for LPD (HDR et al. 2021), which are required by the existing MOA between Cal-Am, NMFS, and the California State Coastal Conservancy (NMFS 2017). In previous TMs and iterations of this final report, fish passage improvements were described in detail for Alternative 1 and back-referenced in later alternative descriptions. To provide a comprehensive description of Alternative 3 (Storage Expansion and Dredging) in Section 5 (because it remains under consideration, whereas Alternative 1 does not), the detailed description of fish passage improvements associated with dam-in alternatives in this final report is provided in Section 5.2.3, and a forward reference is provided here and in the Alternative 3 description below.

Because Alternative 1 would retain LPD, it would include spillway and dam embankment improvements similar to those described for Alternative 3 (Storage Expansion and Dredging) in Section 5.2. Construction of the dam safety improvements are assumed to require limited public road access improvements, similar to those described in Section 5.1.2. Dam safety and access improvements are noted below, but because Alternative 1 was eliminated before the dam safety improvements had been developed in detail specifically for this alternative, the detail is not provided in this section.

Access Improvements

To facilitate on-hauling of materials, limited public road access improvements would be required with Alternative 1. These improvements are described in more detail in Section 5.1.2.

Fish Passage Improvements

Two upstream and two downstream fish passage options were identified as preferred or warranting additional consideration (HDR et al. 2021). Those passage options are summarized in Section 5.2.3. As with other dam-in alternatives, if it had been selected, one upstream and one downstream fish passage option would have been adapted to Alternative 1. Additional detail and evaluation regarding fish passage at LPD are available in the draft Fish Passage Feasibility Report for LPD (HDR et al. 2021).

Spillway and Dam Embankment Improvements

The current concrete spillway does not accommodate the updated PMF, based on current standards. Improvements to the spillway and possibly the dam embankment would be necessary to convey the updated PMF. The current concept includes an increase in the dam embankment height to create the head necessary to convey the PMF through the existing spillway cross section. The existing spillway walls would also be raised to accommodate the increased flow. A more detailed description of the updated PMF calculation can be found in Section 3.3, and the dam and spillway improvements are described in more detail in Sections 5.2.4 and 5.2.5. Construction of the dam and spillway improvements is assumed to require limited public road access improvements, as detailed in Section 5.1.2.

Operations and Maintenance

A detailed description of operational protocols for fish passage and regulating outlet facilities is available in working draft form (HDR 2019). Current annual O&M at LPD includes the following (Cal-Am 2022):

- Daily oversight (except Sundays) for dam facility monitoring and reporting (4 hours per day, 7 days per week)
- Fish passage related oversight (5 months per year, 4 hours per day, 6 days per week)
- Behavior guidance system monitoring
- Road maintenance
- DSOD reporting
- Miscellaneous facility repairs

In accordance with the existing MOA between Cal-Am NMFS and the California State Coastal Conservancy (NMFS 2017), with Alternative 1 Cal-Am would be required to implement upstream and downstream fish passage improvements. Fish passage operations with implementation of Alternative 1 would increase relative to current operations. More complex passage equipment and more frequent operational demands results in greater uncertainty and risk due to the potential for improper operations or possible equipment failure (HDR et al. 2021). Additional entrance gates, auxiliary water systems, mechanical flow control weirs, complex maintenance requirements, and specialty skills required add to complexity, though operations might still be simple when these are automated. The number and cost of resources required to operate improved fish passage facilities is reflected in the level of effort used to derive order of magnitude O&M costs (Section 6).

Sediment Effects

The operation of dams can negatively affect sediment transport processes and the geomorphology of the affected drainages (NMFS 2011). Under Alternative 1, LPD would continue to prevent the transport of coarse sediment downstream of LPD through the Carmel River. Under existing conditions, bed elevations in the Carmel River downstream of LPD are degrading. Downstream of LPD, there is significant armoring of the streambed and incision into floodplain deposits along the lower 16-mile alluvial portion of Carmel Valley as a result of sediment retention at both LPD and the former site of the San Clemente Dam. Channel incision can result in the lowering of the groundwater table, reduced floodplain access, and decreased channel complexity (Bednarek 2001). A lack of bedload supply from upstream of LPD will cause the further incision of the Carmel River downstream of LPD through the lack of upstream gravel recruitment.

The BESMo model (Appendix D) predicts that under Alternative 1, the disruption in sediment transport would continue to affect all reaches in the Carmel River. BESMo predictions of change in channel bed elevation associated with Alternative 1 are shown in Figure 4-9. the top plot illustrates results for the wet hydrologic condition (where the first 10 years of the simulation were wet water years), the middle plot for the average condition, and the bottom plot for the dry condition. Each plot illustrates results for 100 simulations at three different simulation times: 10, 30 and 60 years. To highlight the most probable response trajectory for the simulations, the median response for the 100 simulations at each simulation time are shown as the thicker lines in the plots.

Pronounced effects would occur in the upstream portion of Reach 1, between LPD and Cachagua Creek. The simulations show that the low relative sediment supply downstream of LPD drives further channel bed degradation downstream to roughly the old San Clemente Dam location. BESMo predicts that the most significant spatial gradients in channel response are likely due to constructed channel conditions in the San Clemente Project Reach. Strong profile adjustments at this location are likely due to the constructed conditions; the reservoir deposit area is a location of channel bed erosion, with deposition predicted to occur between the new San Clemente Creek confluence and the former San Clemente Dam site. The reach from the former San Clemente Dam site to Tularcitos Creek is projected to have a wide range in the magnitude and spatial extent of aggradation and is highly dependent on hydrologic conditions. A general aggradation response of up to 5 feet is predicted to occur from Garzas Creek to the Narrows, followed by little to no change in deposition downstream to roughly the confluence of Robison Canyon Creek. Downstream of Robinson Canyon Creek, there is a consistent aggradation response of 2 to 5 feet relative to initial bed condition.

Under Alternative 1, the channel bed surface is projected to coarsen throughout the simulation reach, from LPD to the Pacific Ocean, despite the reintroduction of bedload supply from in between Los Padres and the former San Clemente Dam to downstream reaches. This simulation response highlights that the magnitude and gradation of the reintroduced bedload supply from the completed dam removal project is insufficient to limit general bed coarsening, which is substantial over much of the river.

Effects to Steelhead

This section summarizes potential effects to steelhead associated with Alternative 1, initially presented for an earlier formulation of alternatives in Appendix E. This section includes limited updates, including updates to incorporate results from NMFS’ Carmel River Steelhead Fishery Science Studies (Section 1.3.4) that were not available during preparation of Appendix E.

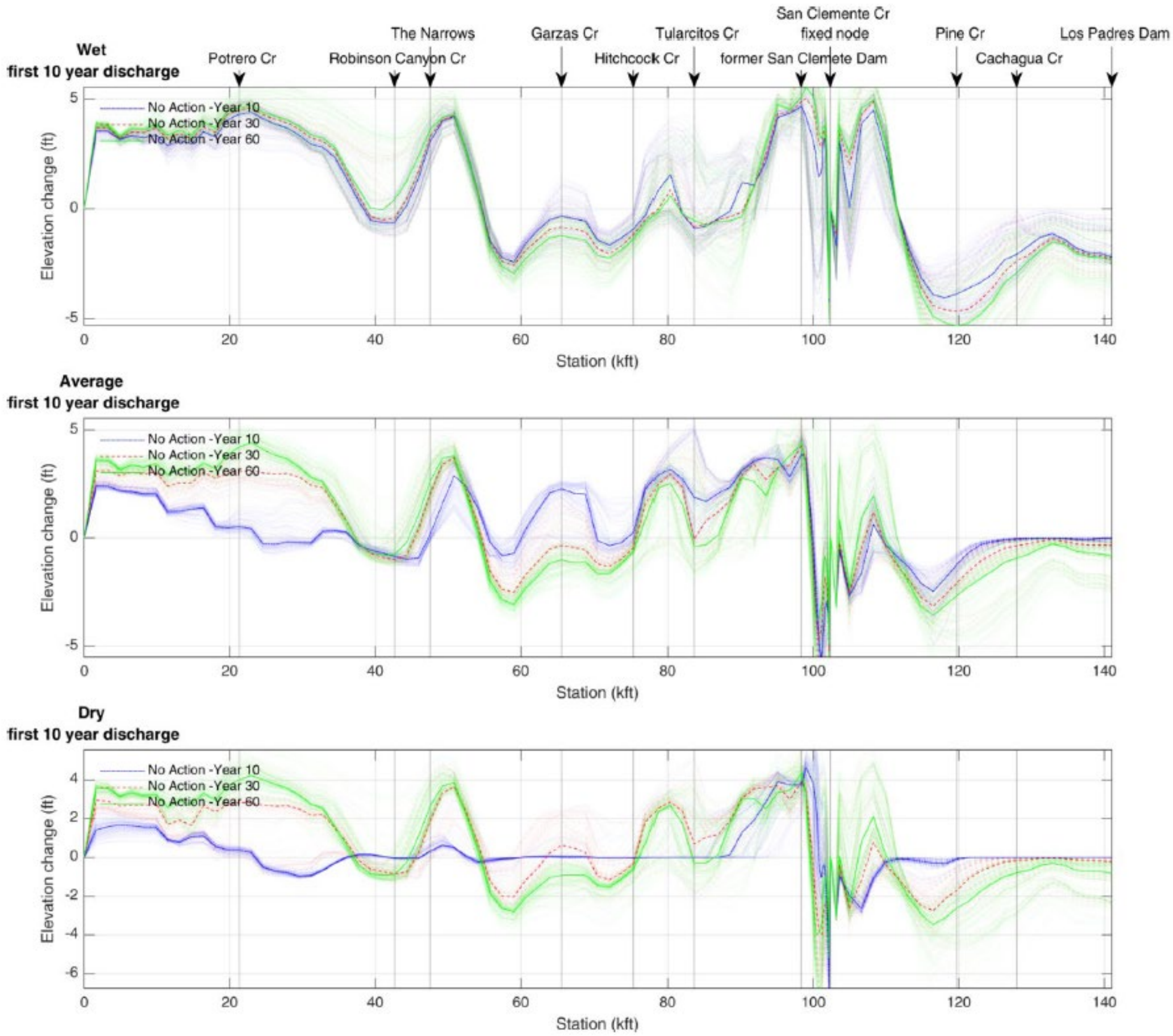

Figure 4-9 Change in Channel Bed Elevation Compared to the Initial Elevation Profile from 2017 Predicted by the BESMo for the No Action Simulation

Notes:

Top: high, middle: average, bottom: low cumulative discharge in the first 10 years.

The dark lines in each subplot signify the median condition at each node for each of the three time slices and the median for the Historical Supply Scenario at year 60; all other lines represent data from individual model runs.

The three solid lines in each subplot signify the median condition at each node for each of the three time slices; all other lines represent data from individual model runs.

Bedload Sediment Transport

Coarse sediment contributes to suitable spawning and rearing habitat for steelhead, so preventing coarse sediment from transporting downstream would continue to have a negative effect on steelhead spawning and rearing habitat downstream of LPD. Others studying sediment transport in the Carmel River have postulated that spawning gravel will continue to be a limiting factor for steelhead until LPD is removed (Smith et al. 2021). Overall, under Alternative 1, the channel bed surface from LPD to the Pacific Ocean would continue to coarsen, despite the reintroduction of bedload supply from the reach between the former San Clemente Dam and LPD. Steelhead spawning habitat suitability is strongly related to suitable spawning gravel. To mitigate the lack of bedload supply resulting from LPD, MPWMD has occasionally placed suitable spawning gravel in the Carmel River downstream of LPD, including 1,500 tons in 2014, 1,000 tons in 2019, and another 1,000 tons in 2021. In subsequent redd surveys conducted in 2019, 121 steelhead redds were observed in the newly placed spawning gravel between Schulte Road Bridge and LPD. The large number of redds observed in the newly placed spawning gravel suggest that the lack of gravel transport influences spawning habitat; when gravel augmentation does occur, steelhead readily spawn in the newly placed gravel. The bi-annual cost of gravel augmentation downstream of LPD, assuming 1,000 tons per event, is estimated by Cal-Am to be approximately $300,000 per event. Like other potential mitigation costs, this cost is not included in cost analyses presented in Section 6.

Adequate winter habitat is critical to steelhead populations, providing refuge from winter high-flow events (Solazzi et al. 2000). Steelhead prefer low-velocity pool habitats with large rocky substrate or woody debris for cover (Fontaine 1988; Hartman 1965; Raleigh et al. 1984; Swales et al. 1986). Large woody debris—in combination with other features, such as vegetated overhanging banks and interstitial spaces between cobbles and boulders—provide protection from high water velocities that can cause hazardous downstream displacement to less suitable habitat (Hartman 1965; Everest 1969; Bustard and Narver 1975; Grette 1985). Steelhead show less propensity than other species (e.g., coho salmon) for using off-channel slack-water habitats in winter, and a greater propensity for using in-channel cover such as that provided by woody debris—and, especially for age 0+ fish, the spaces between cobbles and boulder streambed substrates (Meyer and Griffith 1997; Finstad et al. 2007; Donaldson 2011). Such substrates have the advantage of being fairly common and usually immobile at all but the highest flows in higher gradient reaches. Although some wood may sink and remain in LPR, the ogee spillway at LPD is designed to be self-cleaning and frequently passes large wood. This and recruitment of wood up and down the Carmel River and its tributaries provides instream wood and associated habitat for steelhead. Steelhead in the Carmel River also depend on cobble and boulder substrate for velocity refugia.

As the channel continues to incise, bank erosion will continue, perpetuating a loss of channel complexity, including loss of instream refugia (meanders, pools, undercut banks, etc.), pool habitat, and suitable gravel substrate; and a continued loss of access to overbank habitat during winter high flows (NMFS 2011). Decreased connectivity of the channel to overbank habitat would continue to limit important steelhead winter rearing habitat and high-flow refugia during winter storm events. However, as the bed continues to coarsen to a cobble-boulder-dominated habitat, there will be an increase in cobble and boulder substrate, which can also provide refugia for juvenile steelhead during high winter flows (Huber et al. 2011).

Water Availability

Under Alternative 1, LPR would continue to be filled in with sediment, further reducing the storage capacity of the reservoir. During dry periods (normally from May through October), releases from LPR constitute most flow in the river downstream of LPD (Cal-Am and MPWMD 2016). The reduction in storage would incrementally reduce the ability to enhance summer rearing habitat for steelhead in the Carmel River downstream of LPD through flow releases. Based on the current reservoir storage and approximately 72 AF remaining within the reservoir below the proposed low-level invert elevation of 981.8 feet, an average release of 4.2 cfs can be made through the 6 months between April 15 and October 15 (not accounting for inflows into LPR summarized in Section 3.1.1). Over 60 years, the reservoir storage would be reduced by an estimated 960 AF, thereby reducing average releases between April 15 and October 15 to an estimated 1.6 cfs (not accounting for inflows into LPR summarized in Section 3.1.1) .

Under existing conditions, approximately 1.5 RM of habitat between Boronda Road and Robles del Rio Road, and up to 9 RMs of habitat downstream of the Narrows to the lagoon, are seasonally subjected to dewatering, depending on the magnitude of streamflow releases at LPD, seasonal air temperatures, and water demand (MPWMD 2018). MPWMD conducts annual fish rescues when these portions of the Carmel River and tributaries begin to dry back, beginning in the spring and extending into the summer. MPWMD has rescued an average of 14,598 steelhead in the Carmel River Basin each year since fish rescues began in 1989. Rescued steelhead are either released upstream of the Narrows or reared in captivity at the Sleepy Hollow Steelhead Rearing Facility. Under Alternative 1, fish rescues would continue in the Carmel Basin so long as portions of the Carmel River dry back. However, the steelhead rearing facility at Sleepy Hollow requires a minimum flow of 2 cfs in the Carmel River to operate. Over time, as the ability to store and release water under Alternative 1 is reduced, flow at Sleepy Hollow could drop below this threshold, especially in dry and critically dry years. Over time, this could impact the ability to operate the rearing facility when it is needed most.

In addition to being at risk of dry back, the lower reaches of the Carmel River apparently support the fastest observed growth of juvenile steelhead in the watershed; slower growth is observed in the tributaries and upper mainstem (Ohms and Boughton 2019; Arriaza et al. 2017). Ohms and Boughton (2019) found that juvenile steelhead in the Carmel River Watershed that are larger in their first year are more likely to become anadromous steelhead; smaller individuals are more likely to delay ocean migration for another year or become residents (Phillis et al. 2016; Satterthwaite et al. 2009; Hayes et al. 2008). Ohms and Boughton (2019) concluded that, therefore, supporting flows and suitable conditions, specifically in the lower Carmel River, are critical to maintaining anadromous steelhead production in the watershed.

The IFIM predicts that habitat suitability for fry is generally highest around 3 to 5 cfs, and for juveniles is generally around 30 to 40 cfs, although the flow at which habitat is predicted to be maximized varies with different locations in the Carmel River (Figure 3-6). However, flows that maximize habitat for juveniles would not be achieved under unimpaired conditions during the late summer dry period, consistent with central coast watersheds. For fry rearing, flows greater than 3 cfs are predicted to provide abundant rearing habitat (Figure 3-6), especially in Reaches 2 and 3. For juveniles, flows greater than 5 cfs are predicted to provide suitable habitat that would support survival through the late summer period, especially in pools with depths greater than 1.5 feet.

Stream flows under Alternative 1 from July through September are predicted to be similar to those under existing conditions. Based on the CRBHM flow exceedance figures (Figure 3-1 and Figure 3-2), during the summer, releases from LPD are predicted to provide flows for suitable fry rearing habitat (> 3 cfs) throughout most of the reach downstream of LPD—with the exception of the dry back that occurs in the lower Carmel River during some years (Figure 2-40). Based on the CRBHM model results, minimum flows to support juvenile rearing habitat (> 5 cfs) occur in the summer upstream of Reach 4 in most years (Figure 3-5). For example, at Highway 1, 3 cfs is predicted to be exceeded 72 percent of the time during all water years (Figure 3-1) and 50 percent during dry and critically dry years (Figure 3-2). Similarly, 5 cfs is predicted to be exceeded 50 percent of the time during all water years and 20 percent during dry and critically dry years at Highway 1.

Under Alternative 1, the Carmel River is predicted to typically be wetted (> 0.5 cfs) from LPD downstream to the lagoon (around 25 RMs) in the summer months (July through September) of normal water years (Figure 3-3). Flows of 3 cfs in the Carmel River are predicted to generally occur in the summer months of normal water years downstream of LPD to the lagoon (Figure 3-4). Additionally, flows of 5 cfs are predicted to occur in approximately 21 miles of the Carmel River in normal water years under Alternative 1 (Figure 3-5).

Wetted habitat under Alternative 1 would temporarily continue providing benefits to rearing steelhead by providing more habitat and increased connectivity of the watershed in comparison to a Carmel River without water storage and dry-season release. Based on recent modeling of the effects of flow on adult steelhead returns to the Carmel River watershed, flow-dependent returns could be higher or lower than a dam removal scenario, depending on whether infiltration in the lower valley is low or high (Boughton and Ohms 2022). If water infiltration in the lower valley is low, the model predicts that Alternative 1 (which would be similar to the historical baseline modeled in Boughton and Ohms 2022) would result in lower adult steelhead returns compared to dam removal. If water infiltration in the lower valley is high, the model predicts that Alternative 1 would result in slightly higher adult returns compared to dam removal. With high infiltration, the model predicts that increases in production in the upper watershed resulting from dam removal would be outweighed slightly by decreases in production in the lower watershed resulting from a smaller summer wetted area. However, the model used by Boughton and Ohms (2022) did not consider independent steelhead habitat variables other than flow and did not capture benefits of dam removal (e.g., improved passage through LPR, restoration of coarse sediment supply and natural thermal regime) that are unrelated to flow. Regardless of whether water infiltration in the lower valley is high or low, the flow model predicts that Alternative 1 would result in lower adult steelhead returns than reservoir dredging and storage expansion because storage expansion would increase the amount of water available for summer releases, increasing production by improving the quality and quantity of summer rearing habitat.

Although estuarine habitats are generally productive juvenile steelhead rearing locations (Hayes et al. 2008), striped bass (*Morone saxatilis*) have been documented in the estuary, sometimes in high abundance, and are known predators of juvenile steelhead (Ohms et al. 2021). Currently, during periods when the Carmel River is connected to the estuary, striped bass have been observed as far upstream as Tularcitos Creek. Alternative 1 could potentially result in increases to the distribution of striped bass by maintaining a relatively wetted connection to the estuary. The relative benefits of additional juvenile rearing habitat, in contrast with the potential for increased mortality risk associated with an increase in striped bass distribution, has not been evaluated. The ability of Alternative 1 to supplement dry season flows would be reduced over time as the reservoir continues to fill with sediment.

Water Temperature

Cal-Am intends to install a new low-level outlet in late-summer 2023 however, the general pattern of warming and reduced daily fluctuations in Reach 1 is anticipated to continue, as discussed in Section 2.6. In general, the effects of LPR on water temperature are most pronounced in Reach 1 and the upper portion of Reach 2 and dissipate downstream as other influences dominate. Under existing conditions, water temperatures by Reach 3 (far enough downstream that the temperature influence of LPR is muted, and upstream of the most frequent summer dry back) appear to provide adequate rearing temperatures for steelhead during all water year types (MPWMD 2018, 2019, 2020, 2021).

Warm water temperatures may affect steelhead growth in some reaches even in wet years. Water years 2019 and 2020 were characterized as extremely wet and normal, respectively; however, temperature data from continuous data loggers indicated water temperatures at some locations that were within potentially stressful ranges for steelhead in the summer months (MPWMD 2019, 2021). These warmer temperatures were especially apparent in Reach 1 directly downstream of LPD and near the location of the former San Clemente Dam in Reach 2 (Figure 1-1, where stream temperatures reached the suboptimal range for steelhead during summer months (MPWMD 2019, 2021). These suboptimal water temperatures are known to reduce growth rates in juvenile steelhead (Harvey et al. 2006) and/or displace fish to other sections of the river with cooler temperatures (MPWMD 2020). The exceptionally warm stream temperatures in the summer of 2020 were largely due to reliance on the LPD BGS for surface flows downstream of the dam and minimal use of the lower outlet, which had been clogged by rockslides. This set of circumstances may have been unique, but the general pattern of water released from LPR being warmer than inflow is expected to continue, and unpredictable operational issues could continue to periodically amplify this effect.

With the continued presence of LPD under Alternative 1, juvenile steelhead subject to suboptimal water temperatures would not have the option to migrate upstream to thermal refugia in the cool water documented upstream of LPR. Instead, they would be forced to migrate downstream to seek cold water refugia (e.g., part of Reach 2, Reach 3, and Reach 4), a resource that may diminish over time due to climate change. Additionally, juvenile fish moving downstream as far as Reach 4 to avoid warmer water temperatures have the potential to become stranded when the lower Carmel River dries back during the late spring through fall. Increased metabolic demands associated with elevated water temperatures would continue to result in poor growth and low survival of any steelhead occupying areas with suboptimal water temperatures in the Carmel River during the low-flow period from summer through fall.

Warmer water temperatures also support and provide a competitive advantage for aquatic invasive species (Rahel and Olden 2008). Striped bass are tolerant of warmer temperatures, up to 31°C (88°F) (NDEP 2016). Aquatic invasive species have been documented to prey on steelhead, and to compete for habitat and food resources (Carey et al. 2011; Thompson et al. 2012).

Releases from the proposed low-level outlet under Alternative 1 are initially anticipated to maintain water temperatures similar to existing conditions, although temperatures may increase over time due to climate change temperature increases; a shrinking reservoir pool; and additional, associated warming of stored water. Overall, water temperature conditions for steelhead would continue to sometimes be suboptimal, but not lethal.

Fish Passage

Under Alternative 1, upstream passage at LPD would continue to be operated as a managed fish passage facility. Based on the alternatives selected for further consideration in HDR et al. (2021), upstream fish passage could consist of either a technical fish ladder (Alternative U1) or a new trap-and-transport facility (Alternative U8).

A fish ladder would consist of an approximately 1,480 foot pool-and-weir type fish ladder comprising roughly 125 pools that would operate at flows ranging from 3 to 35 cfs (HDR et al. 2021). The fish ladder would provide volitional fish passage to upstream migrating adult steelhead, in which they would enter and navigate the ladder using their own swimming ability and behavioral cues, without human intervention. Although some juvenile steelhead might be able to use the ladder for upstream passage, the fish ladder would not be designed for juveniles and would generally be considered to block juvenile upstream passage for the purposes of this analysis.

Volitional fish passage is often safer than trap and transport or other nonvolitional fish passage alternatives, and more effective at passing salmonids upstream of barriers (Lusardi and Moyle 2017). Implementation of this fish passage alternative, in conjunction with Alternative 1, could improve adult upstream fish passage conditions at LPD over existing conditions and could make passage conditions at LPD safer and more effective than under existing conditions. Under existing conditions, upstream migrating adult steelhead have been observed holding in the plunge pool below LPD, indicating that current fish passage facilities could be causing a delay in migration (HDR et al. 2021). The modification of the plunge pool to guide fish into the fish ladder could decrease the amount of time it takes to pass LPD and reduce migration delays associated with the fish passage facilities under existing conditions.

Although a fish ladder at LPD would provide volitional passage to upstream migrating adult steelhead, fish ladders have been shown to have lower relative effectiveness when passing fish at high-head dams (with hydraulic differential greater than 100 feet from entrance to exit), such as LPD (HDR et al. 2021). The length and complexity of a fish ladder at LPD has the potential to increase passage times and increase the amount of energy that upstream migrating steelhead would exert over existing conditions, which could potentially result in reduced fitness while spawning. Current examples of fish ladders at these types of dams have shown relatively low success at passing fish. Accordingly, NMFS and CDFW recognize that the performance of fish ladders may have limitations and that managers should be cautious of over-emphasizing the importance of volitional passage at the expense of overall performance (i.e., safe and timely passage of fish upstream). Additionally, this and the other managed passage alternative (Alternative U8) described below would block or impede juvenile steelhead rearing downstream of LPD from accessing stream habitat above LPR.

The new trap-and-transport alternative (Alternative U8) would replace the existing trap-and-transport facility with a larger facility aimed at accommodating the future recovery levels of steelhead in the Carmel River (HDR et al. 2021). The overall function of the facility would be similar to those under existing conditions, where fish would be attracted to a fish ladder entrance, enter and ascend the fish ladder to a small pool, and then either pass or be lifted into a large holding gallery and into a transport flume. Fish would then be transferred from the transport flume, conveyed into a transport vehicle, transported upstream of LPD, and released into LPR. The new trap-and-transport facility would modify the plunge pool to improve the guidance and attraction to the fish ladder entrance implement a new fish ladder designed in compliance with NMFS design guidelines, and use increased attraction flows. These components would likely increase the effectiveness of the fish passage facilities over existing conditions.

Trap-and-transport fish passage facilities are nonvolitional and require human intervention to pass fish upstream of LPD. Additionally, there would be no potential for kelts to navigate the same facility downstream (whereas a fish ladder could be one of several components potentially providing downstream passage—for example, along with a collector and the spillway). This fish passage alternative would require fish to be held in a holding flume for up to 24 hours before being transported upstream, which delays migration and increases stress and the risk of disease (Lusardi and Moyle 2017). Stress induced from trap and transport has been shown to reduce disease resistance, swimming ability, and osmoregulatory ability, and can increase pre-spawn mortality (Maule et al. 1988 as cited in Lusardi and Moyle 2017).

Based on the preferred alternatives selected in HDR et al. (2021), downstream fish passage facilities included with Alternative 1 could consist of either a floating surface collector (FSC) (Alternative D1) or a spillway modification and the current FWC, with the addition of a 30 cfs attraction flow (Alternative D8). An FSC uses attraction flows and nets to guide downstream-migrating fish into a narrow channel that in turn guides fish into a collection inlet. Once in the collection inlet, downstream-migrating steelhead would remain in holding galleries until transferred to transport hoppers, barged to the dam crest, and then released into the tailwater pool through a water-to-water transfer down the existing smolt bypass pipe (HDR et al. 2021). The FSC in LPR would consist of full-depth guide nets and a floating barge, with attraction flows of up to 200 cfs; it would provide a barrier to inhibit passage of migrants downstream into the remainder of the reservoir. The FSC would be operated to coincide with the migration period of downstream-migrating steelhead and would operate 2 weeks past the end of the migration period to capture fish entering the reservoir.

The operation of the FSC and the attraction flows would alter the current water quality dynamics in LPR by causing mixing of the water column. Under existing conditions, LPR appears to be stratified in late spring and early summer; the mixing of the water column could destratify LPR, resulting in a reduction in the reservoir's temperature stratification during the early summer. Elimination of stratification would increase water temperatures in the deeper portions of LPR, reducing the ability of the reservoir to provide rearing habitat during the early summer. Mixing may increase temperatures downstream of LPD during the same period, prior to late summer when stratification typically dissipates, and potentially causing seasonal impacts to fry and juvenile rearing habitat downstream.

Stress from barge transportation of juvenile salmonids has been shown to increase predation levels after release, resulting in increased mortality (Lusardi and Moyle 2017). The presence of large piscivorous brown trout at the release location in the plunge pool below LPD could result in the predation of released juvenile steelhead.

Fish passage Alternative D8 involves a combination of actions, including modification to the existing spillway to provide safer and more effective downstream passage, and modifications to the existing FWC that would allow for attraction flows of 30 cfs. Modifications to the spillway would include a passage slot at the spillway crest to provide a larger opening for safer entrance and passage, and the implementation of an adjustable crest gate to control the depth and flow through the slot (HDR et al. 2021). Additional modifications to the spillway include a passage channel along the spillway, and modifications of the tailwater pool to improve safety during the transition from the spillway to the pool. Modifications to the FWC would improve the attraction to the entrance of the collector inlet. The existing FWC would be retrofitted to allow for up to 30 cfs of attraction flows and would route outmigrating steelhead directly to the existing smolt bypass pipe.

As with Alternative D1, fish passage Alternative D8 still requires the successful navigation of LPR by juvenile steelhead. Under existing conditions, Ohms et al. (2022) found that transit times of adults and juveniles in the reservoir were much slower than in the river and that 80 percent of monitored downstream-migrating juveniles were "lost" in the reservoir, most likely from mortality (e.g., predation or poor water quality); remaining resident in the reservoir; or simply not being subsequently detected at downstream PIT tag antennae. Brown trout have been documented in LPR and likely prey on *O. mykiss* in the reservoir. CDFW electro-fished upstream of LPR and observed brown trout up to 14 inches (Highland, pers. comm. 2017). A fish rescue and relocation effort conducted in the plunge pool below LPD captured 20 brown trout, five of which were larger than 20 inches (HDR et al. 2021). The capture of large brown trout downstream of LPR indicate they are likely using the reservoir and entering the lower watershed through the spillway. Brown trout are known predators of juvenile steelhead and likely account for a portion of the 80 percent of juvenile migrants lost in the reservoir reported in Ohms et al. (2022). For example, in Soda Springs Reservoir, a reservoir on the North Umpqua River that is similar in size to LPR, invasive brown trout were found to predate heavily on fry and juvenile salmonids moving through the reservoir (Stillwater Sciences 2019). Diet composition of larger brown trout (> 15 inches) contained primarily fish. This reservoir predation study found that brown trout had the greatest impact to migrating salmonids and consumed about half of juveniles produced upstream of the reservoir.

While some juvenile steelhead that enter LPR are likely lost to predation, there is evidence that a portion of juvenile steelhead in the upper watershed (above LPR) enter LPR in the spring and use it as a rearing habitat until the following winter, when they migrate out as smolts (MPWMD 2015a; Ohms et al. 2022). Ohms et al. (2022) documented 18 juvenile steelhead that entered LPR in 2019, remained in the reservoir for approximately 1 year (i.e., they were not detected moving upstream after entering the reservoir), and then were documented downstream of the reservoir in 2020. Additionally, LPR likely supports adfluvial steelhead, a life history in which steelhead migrate between stream and lake (reservoir) habitats to complete their life-history requirements (Leitwein et al. 2016). Juvenile steelhead rearing in LPR may encounter poor water quality conditions in the summer and fall, including high surface water temperatures and low DO levels at depths greater than 12 meters (Ohms and Boughton 2021). In addition, low summer inflows may prevent passage between the reservoir and the upper watershed. LPR may influence the migration patterns of juvenile steelhead in several ways, including but not limited to serving as a rearing area or as a temporary holding area for smolts and juvenile fish that migrate into the reservoir from upstream rearing habitat; acting as a physical or biological barrier to downstream migration due to some thermal or water quality condition that impedes transit; and/or acting as a refuge for predators that consume smaller fish attempting to pass through the reservoir.

There remains a high level of uncertainty related to the transit, residualization, predation, and mortality in LPR (HDR et al. 2021). Without fully understanding the effect of LPR on downstream-migrating juvenile steelhead, it is difficult to ascertain how the modifications to the existing facilities will affect the steelhead population.

Construction Effects

Although the focus of the LP Alternatives Study, when it comes to effects to steelhead, has been on the long-term changes that the alternatives would cause, this short section (and similar sections for each alternative) briefly outlines the major differences in construction effects among the alternatives for water availability, water temperature, and fish passage. For Alternative 1 (Fish Passage, No Sediment Action), because passage features and spillway and dam embankment improvements would be relatively near the surface of LPR, construction would not require accessing or manipulating reservoir sediment, and construction effects would be less severe than other alternatives. At the current level of analysis, it is assumed that the temporary construction effects on water availability, water temperature, and fish passage would be minimal.

Habitat Quantity

Alternative 1 would generally maintain steelhead habitat at the same locations it is present currently, with a gradual reduction in the ability to maintain dry-season releases from LPR; a gradual increase in water temperatures downstream of LPD due to a shrinking storage pool and, potentially, climate change; a gradual increase in the degree of channel incision downstream of LPD; and a gradual conversion of open water to stream habitat at the upstream end of the reservoir.

Summary

Alternative 1 (Fish Passage, No Sediment Action) would have minimal effects to water availability, water temperature, and fish passage during construction relative to other alternatives. Following construction, implementation would result in the continuation of dynamics similar to those that occur under existing conditions, with a gradual or episodic reduction in storage over time. In general, Alternative 1 would provide flows capable of providing rearing habitat for both fry and juvenile steelhead downstream of LPD during the dry season in normal water years. Summer releases from LPD create suboptimal (due to high water temperatures) rearing conditions for steelhead in the reach just downstream of LPD; other areas of the Carmel River consistently provide more favorable temperature regimes for rearing steelhead. Notably, Alternative 1 would continue to block upstream movement of juveniles, thus continuing to prevent access to thermal refugia in the watershed upstream of LPR. The frequent dry back that occurs in the lower 9 miles of the Carmel River would likely continue under Alternative 1, but to a lesser extent than would occur in the absence of LPR. Water availability would decrease as LPR continues to fill in with sediment, leading to increased dry back and a reduction in summer rearing habitat downstream of LPD over time.

In the absence of appropriate mitigation, Alternative 1 would result in the continued blockage of all of the sediment bedload and a portion of the suspended load, and thus incision of the channel downstream of LPD to the former San Clemente Reservoir area. This in turn would result in decreased habitat suitability for steelhead and further limit the quantity and quality of spawning habitat downstream of LPD in Reach 1 and a portion of Reach 2. Downstream of Reach 2, sediment transport and depositional rates are highly dependent on the recent reintroduction of bedload supply from the reach between the former San Clemente Dam and LPD.

Under Alternative 1, upstream passage facilities at LPD would consist of either a technical fish ladder or a new trap-and-transport facility. Both options would continue to provide upstream passage for adults and support the anadromous population. However, neither option favors juvenile upstream movement and, relative to full volitional passage, both options have potential to increase stress and migration delay for migrating adult steelhead.

Downstream passage facilities under Alternative 1 could consist of an FSC or a modification of the existing spillway and current FWC system. Both preferred downstream fish passage alternatives would result in nonvolitional fish passage, would continue to subject downstream-migrating juveniles to mortality in LPR, and would potentially favor resident and adfluvial over anadromous life histories. Although these options would be an improvement over existing conditions, dam removal is the only alternative that can provide complete volitional passage and provide safer and more effective migration.

Uncertainties

The biggest uncertainty associated with Alternative 1 is how quickly the remaining reservoir may fill with sediment, thereby impacting existing infrastructure, storage capacity, and potential summer releases. Although significant thought has been applied to understanding the change in reservoir capacity over time (Appendix C; CSUMB 2018) and developing average rates for sedimentation and storage loss, trends in hydrology and wildfire risk make it very difficult to accurately estimate when another large influx of sediment could significantly alter the remaining reservoir storage capacity. Nearly half of the accumulated sediment in LPR is estimated to have been deposited following heavy precipitation and flood events that occurred shortly after a major fire in the watershed, the Marble Cone Fire. It is estimated that the sequence of events that led to this extreme deposition have a recurrence interval of more than 1,000 years (MWH 2013). Although the climate may be changing to favor more extreme events, inclusion of this outlier event in the sedimentation rate used for planning in the LP Alternatives Study provides a conservative estimate of sedimentation rate that may account for future episodes of deposition.

Additional uncertainties associated with Alternative 1 include the following:

- The compatibility of the proposed fish passage improvements (HDR et al. 2021) with ongoing sediment deposition should be confirmed. Additionally, there is uncertainty regarding the future performance of the fish passage improvements. For example, the ability of downstream passage improvements to meet the 95 percent collection efficiency and 98 percent survival rate criteria noted in HDR et al. 2021 may be difficult, especially considering that in a recent study, only 20 percent of juveniles that entered the reservoir were later detected downstream of LPD (Ohms et al. 2022).
- The compatibility of the proposed fish passage improvements (HDR et al. 2021) with the embankment dam and spillway wall raise, detailed in Sections 5.2.3 and 5.2.4, should be confirmed. The dam safety improvements would not modulate the normal water surface elevation in the reservoir, and an initial review suggests that the footprint of the embankment and spillway modifications would not overlap the fish passage design components. Therefore, there is less potential for conflict than with Alternative 3 (Storage Expansion and Dredging, Section 5.2) or Alternative 5 (Recover Storage Capacity with Sluice Tunnel, Section 4.4.2).

- Once the reservoir fills and coarse sediment begins to pass over the spillway, it may result in additional deposition and increased flood risk downstream. Although it would be far into the future, mitigating flood risk in the lower Carmel River may eventually be a consideration, even without specific action to introduce bedload downstream of LPD.
- As discussed above, it is uncertain whether Cal-Am might lose a portion or all of their current water right at LPD as sediment continues to fill the reservoir. This has occurred in the past, but engagement with SWRCB on this topic is needed to determine how it might be handled in the future.
- There is a lack of adequate geologic and geotechnical baseline information, and the associated seismic assessment and stability analyses to support a detailed dam embankment raise design. In addition, all modifications would need to be designed using current standards and would require DSOD approval prior to their construction. It is possible that further analyses will indicate that other features of the dam will also require improvement, or that the currently envisioned improvements may need to be more extensive.

Advantages and Disadvantages

Advantages and disadvantages associated with Alternative 1 are discussed in the following paragraphs. Advantages and disadvantages are organized by the following categories: Local Impacts, Water Supply, Flooding, Geomorphology, Biological, Water Rights, and Regulatory.

Local Impacts (Traffic and Noise)

- **Disadvantage:** Impacts to local traffic and noise for Alternative 1 would be similar to other alternatives under which the dam would remain in place, but greater than Alternative 2, under which the dam would be removed. For all alternatives that leave the dam in place, it may be necessary to import between 2,500 and 3,300 loads of filter and drain material associated with the dam raise, if it is determined that those materials cannot be made on site. Associated equipment mobilization, material on-haul, and construction worker commuting would cause significant local traffic disruption. Similar to all alternatives, small improvements may be required along public roads (see Section 5.1.2) to accommodate construction traffic, which would cause additional disruption.

Water Supply

- **Disadvantage:** As LPR fills with sediment over time, reduced reservoir storage will limit Cal-Am’s ability to store water for any purpose in the future, including in support of surface flow and pumping in the lower river. This is a disadvantage relative to Alternative 3 (Storage Expansion and Dredging) and Alternative 5 (Recover Storage Capacity with Sluice Tunnel) but not relative to Alternative 2 (Dam and Sediment Removal).

Water Rights

- **Disadvantage:** Alternative 1 may result in a potential reduction in Cal-Am's water rights. Cal-Am's water rights have been reduced due to siltation in LPR in the past; under License 11866, Cal-Am was originally authorized to divert 3,030 AFY from the Carmel River to LPR, reduced to 2,179 AFY in 1995 (SWRCB Order WR 95-10), due to siltation in LPR. Therefore, it is possible that, as LPR continues to fill with sediment, the California SWRCB could reduce Cal-Am's current water right.

Geomorphology

- **Disadvantage:** Until LPR is full of accumulated sediment and transport of coarse sediment begins, LPD would continue to prevent the transport of coarse sediment downstream of LPD through the Carmel River, especially in the upstream section of Reach 1, between LPD and Cachagua Creek. Coarse sediment contributes to suitable spawning and rearing habitat for steelhead, so preventing coarse sediment from transporting downstream would continue to have a negative effect on downstream spawning habitat and limit other potential morphological benefits associated with large wood and instream and overbank habitat.

Flooding

- **Advantage:** Until LPR is full of accumulated sediment and transport of coarse sediment begins, LPD would continue to prevent the transport of coarse sediment downstream of LPD through the Carmel River. This would limit deposition near Cachagua, and may incrementally limit deposition in the lower 30,000 feet of the mainstem, which may reduce flooding in Cachagua and incrementally reduce flooding in the lower river, relative to other alternatives.

Biological

- **Advantage:** Initially, Alternative 1 would provide flows capable of providing rearing habitat for both fry and juvenile steelhead downstream of LPD during the dry season in normal water years. This benefit would diminish as the reservoir fills with sediment and the storage pool shrinks, affecting release volume and quality.

- **Advantage:** Relative to other Alternatives, construction effects to biological resources would be less severe.

- **Disadvantage:** As LPR fills with sediment over time, the ability to enhance summer rearing habitat and passage for steelhead in the Carmel River downstream of LPD through flow releases from LPR would be incrementally reduced. Based on the current reservoir storage and approximately 72 AF remaining within the reservoir below the proposed low-level invert elevation of 981.8 feet, an average release 4.2 cfs can be made through the 6 months between April 15 and October 15 (not accounting for inflows into LPR summarized in Section 3.1.1). Over 60 years, the reservoir storage would be reduced by an estimated 960 AF, thereby reducing average releases between April 15 and October 15 to an estimated 1.6 cfs (not accounting for inflows into LPR summarized in Section 3.1.1).

- **Disadvantage:** Implementation of fish passage improvements (HDR et al. 2021) would improve steelhead passage over existing conditions, but would be less beneficial to fish than the volitional passage provided in Alternative 2.

- **Disadvantage:** Upstream movement of juveniles would continue to be blocked, thus continuing to prevent access to thermal refugia in the watershed upstream of LPR.

- **Disadvantage:** Alternative 1 has the potential to continue causing stress and migration delay for migrating steelhead.

- **Disadvantage:** Provides suboptimal downstream juvenile passage through and mortality in LPR.

- **Disadvantage:** Provides a suboptimal water temperature regime in the summer months.

Regulatory

- **Disadvantage:** As LPR fills with sediment over time, the reduction in reservoir storage capacity would further limit Cal-Am's ability to release at least 5 cfs directly below LPD, as required by the SWRCB water rights permit. License 11866 requires release of 5 cfs at all times when water stored in the reservoir is adequate to maintain the release.[9] The ability to release 5 cfs would primarily be affected during summer months, when reservoir storage is at its minimum. Because the requirement is for release when water is being stored, it may not apply when storage is reduced and the reservoir is near empty.

- **Disadvantage:** As LPR fills with sediment over time, the reduction in reservoir storage capacity would eventually limit Cal-Am's ability to meet DSOD drawdown requirements via the low-level outlet works during an emergency. In addition, encroachment of sediment into the upper reservoir would also continue to reduce the capacity of the reservoir above the spillway crest, which may increase the water surface during the PMF.

[9] Originally, the 5 cfs release requirement at LPD was a settlement negotiated in 1948 between the California State Fish and Game Commission—which protested the application for water rights and asserted that a 10 cfs release was required—and the previous owner of LPD.

4.4.2 Alternative 5 – Recover Storage Capacity with Sluice Tunnel

Like Alternative 1 (Fish Passage, No Sediment Action), Alternative 5 (Recover Storage Capacity with Sluice Tunnel) remained under consideration through preparation of the draft final report and into TRC Meeting No. 4, but then was dismissed. Following review of the Alternatives Development TM (Appendix F), Cal-Am and MPWMD indicated that, due to uncertainty regarding its effectiveness in managing sediment and its frequency and severity of potential effects on steelhead, it was lower priority than other alternatives. CDFW and NMFS initially responded to Alternative 5 with questions about its operation and effects; however, after review of the draft final report, NMFS expressed doubt regarding the ability of avoidance, minimization, and mitigation measures to adequately address the adverse effects of sluicing associated with Alternative 5 on steelhead. Both NMFS and CDFW clearly stated in their written comments on the draft final report that they do not consider Alternative 5 to be feasible. Additionally, like Alternative 1, based on dam safety input received from the DSOD and Cal-Am after publication of the draft final report, it was determined that Alternative 5 would need to include dam safety improvements (assumed to be spillway wall and dam embankment height raises; see Sections 5.2.4 and 5.2.5 for details) that previously had only been included with Alternative 3 (Storage Expansion and Dredging). This change was presented at TRC Meeting No. 4 and added substantial cost to the OPCC for Alternative 5.

The now-superseded draft final report acknowledged that, relative to other alternatives, substantial analysis beyond that included in this report would be required to understand the effectiveness and effects of operating a sluice tunnel at LPD. Additional study of hydraulic, hydrologic, and sediment transport specific to Alternative 5 would be needed; furthermore, NMFS stated in comments on the Alternatives Development TM (Appendix F) that further evaluation should include a physical sluicing model, with sensitivity analysis of different hydrologic scenarios. During TRC Meeting No. 4, it was acknowledged that if Alternative 5 was retained for further consideration, it could substantively delay selection of a preferred alternative. It was further acknowledged that the additional analysis is not necessary if the alternative is not favored.

A decision was made at TRC Meeting No. 4 to eliminate Alternative 5 from further consideration for the following reasons:

- No stakeholder preferred Alternative 5.
- Two key regulatory agencies that would have to issue permits considered it infeasible.
- Retaining Alternative 5 could greatly increase the analysis and time required to arrive at a preferred alternative.

Alternative 5 is presented here at the full level of detail to which it was developed during the study. Because costs for Alternative 5 were updated after review of the draft final report to support discussion at TRC Meeting No. 4, the OPCC for Alternative 5 is retained in Section 6, includes dam safety improvements to address the PMF, and is current and comparable with the OPCCs presented for the feasible alternatives presented in Section 5.

Overview

Under Alternative 5, a sluice tunnel would be installed through the eastern abutment; it would be used to sluice sediment from the reservoir during wet water years (see Figure 4-10). A typical sluicing operation can be managed either to sluice accumulated reservoir sediment (sometimes referred to as flushing) or to simply pass high sediment-concentrated flow through the reservoir and prevent sediment accumulation. Sluicing and flushing are essentially the same action, although the terms may be used to subtly distinguish between the amount of accumulated sediment that would be affected. At LPR, because the sluice tunnel would normally be closed, there would always be some accumulated sediment transported when the gate was operated and the tunnel opened. Although some discussions have differentiated sluicing from flushing (e.g., Appendix F), this report does not intend for the two terms to have a conceptually different meaning and may instead indicate different points along a continuous gradient of sediment accumulation.

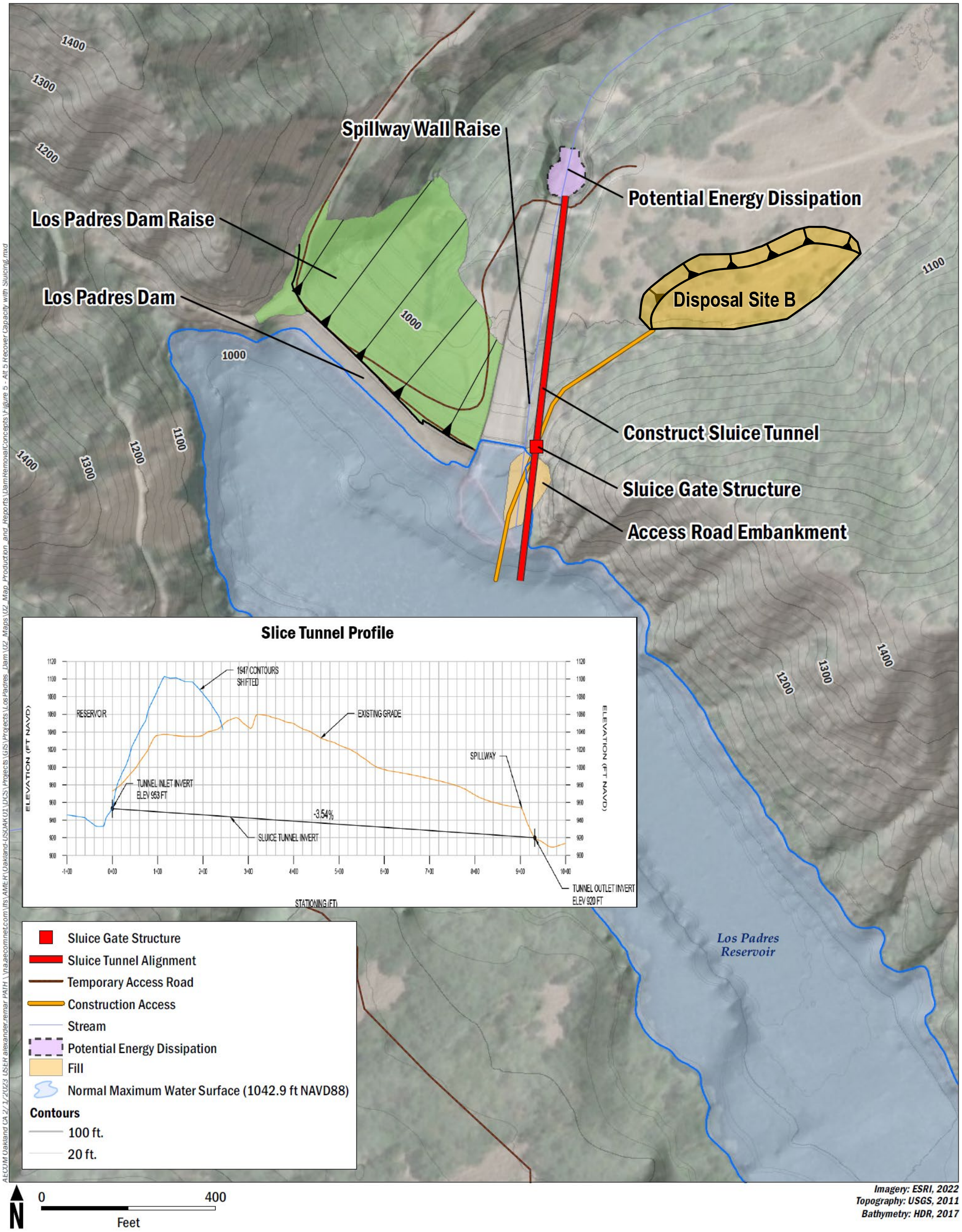

Figure 4-10 Overview of Alternative 5 (Recover Storage Capacity with Sluice Tunnel)

Conceptually, at LPR, a sluice tunnel would harness the scouring ability of flood flows to transport sediment from LPR to downstream of LPD at times when bedload and suspended sediment would naturally be moving throughout the Carmel River. This would involve lowering the reservoir for relatively short durations to allow high flows to pass through the reservoir area as run-of-the-river flows that would erode and flush a significant amount of the accumulated sediment downstream. It is the scouring force of the flood flow acting upon the substrate that moves the sediment, as opposed to the draining of the reservoir. The reservoir must be emptied of lentic water before significant volumes of sediment will move, and the sluice tunnel must be of adequate size to pass the flow in an open channel configuration so that the tunnel does not create a backwater in the reservoir.

The process generally would involve drawing down the reservoir immediately in advance of (or during) a storm event that is anticipated to produce peak flows greater than 1,000 cfs (less than a 2-year return interval flood), so that the storm flow would pass over and scour the accumulated sediment in the reservoir. The flood flow would create a head cut along its thalweg that would quickly perpetuate upstream from the sluice gate inlet and carve a channel through the accumulated sediment. As the channel migrates left and right it would scour a significant portion of the accumulated sediment and transport it through the sluice tunnel. Suspended sediment would largely stay in suspension and pass through the Carmel River to Monterey Bay and bedload would be deposited at varying rates and locations in the Carmel River, depending on the magnitude and duration of the flood flow.

Optimizing the sluicing operation would require additional hydrologic, hydraulic, and sediment transport analysis to confirm design and operational criteria and inform environmental permitting. Additional analysis will be required to develop more informed assumptions regarding the amount of sediment that will be transported at various flood flow rates, which will in turn inform the duration of sluicing and number of sluicing events that would be required to restore reservoir capacity. Once the majority of accumulated sediment is cleared from LPR, the sluice tunnel could be used less frequently or for shorter durations to periodically maintain storage capacity in LPR and coarse sediment transport to downstream. Operations would continue to be optimized through experience after construction. Although the frequency and duration of operation remains to be confirmed, there would be no requirement to sluice sediment every year and initial sediment evacuation could wait until an appropriate flood that would rapidly deplete accumulated reservoir sediment presented itself.

Fish passage would be interrupted during sluicing events, and fish in the reservoir would be transported downstream. Due to the physical conditions required to effectively scour the reservoir bed during flood flows and transport sediment through the sluice tunnel, there are no practicable methods to prevent fish in LPR at the time of sluicing from being entrained in the sluice tunnel; during sluicing events the entire reservoir pool would be converted to a turbid river. It is assumed that all fish in the reservoir during sluicing would be transported downstream in turbid flow, with potential for injury and mortality, along with future spawning gravels and large woody debris that also would be entrained in the sluice tunnel. Wood segments longer than the sluice tunnel is wide could potentially be caught at the entrance to the sluice tunnel, temporarily limiting its capacity until debris jams could be cleared. The impact to steelhead from sluicing (described below under Effects to Steelhead) could be reduced by timing the sluicing events to coincide with periods when they would have the least impact on fish.

In addition to actions described above, because the dam will remain in place, the spillway and dam embankment improvements discussed in Sections 5.2.4 and 5.2.5—and the fish passage improvements discussed in Section 5.2.3 for Alternative 3 (Storage Expansion and Dredging)—would also be implemented for Alternative 5. However, it should be noted that the fish passage improvements were developed based on existing conditions and infrastructure. The sluice tunnel improvements, in addition to the associated operations, outlined in this section for Alternative 5 may require changes in the fish passage improvement alternatives and associated costs.

A similar concept that is not included in this TM is a bypass tunnel that would transport incoming sediment around the dam and reservoir. This concept was removed from further consideration in response to input received at TRC Meeting 2a regarding the high impacts and costs compared to other concepts.

Access Improvements

All public road improvements described in Section 5.1.2 will also be required for Alternative 5, to facilitate material and equipment mobilization. In addition, local temporary access from the reservoir to Disposal Site B would be required to facilitate the hauling of tunnel debris for permanent disposal. The local access would involve a new quarter-mile access road from the work pad at the upstream tunnel entrance area along the eastern dam embankment (east of the spillway) to Disposal Site B.

Sediment Removal

There will be a limited volume (up to approximately 5,000 CY) of accumulated reservoir sediment removal (post-drawdown) needed to access the upstream end of the tunnel and construct an upstream work platform to facilitate tunneling operations. The sediment would be excavated in the dry, after sufficient reservoir drawdown and dewatering activities have been completed.

Sluice Tunnel

A sluice tunnel would be constructed to allow for river flow during storm events to mobilize accumulated reservoir sediments (while tunnel gates are open). Sediment mobilization could be maximized if reservoir drawdown was timed appropriately prior to or during a large storm event (Figure 4-11). Sluice tunnels have been used successfully to manage sediment accumulation at other dams (Kondolf et al. 2014), and a sluice tunnel is considered a feasible approach to managing sediment at LPD. However, additional analysis will be needed to support discussions with stakeholders to determine the specific goals for this alternative (e.g., removal of all accumulated sediment or maintenance of storage following mechanical removal of accumulated sediment), how long and how often the tunnel gates would be left open to facilitate sediment mobilization, and the resulting effects to steelhead in the Carmel River.

Figure 4-11 Photographs of the Spillway at LPD and the Downstream End of the Fish Bypass Pipe on January 8, 2017, at a Flow of Roughly 3,000 cfs

A straight tunnel alignment was selected along the eastern dam abutment, directly adjacent to the existing concrete spillway (see Sheet 9 in Attachment B). A straight alignment is preferred to a curved alignment (which would be required along the western abutment) due to the complexities and risks associated with drilling along a curve. In addition, although a geologic assessment along the tunnel alignment has not been completed at this time, previous geologic assessments by DSOD (1980a) and HDR et al. (2021) suggest that there is competent rock in this area.

Based on simple calculations of uniform flow through a horseshoe-shaped tunnel, tunnel sizes of 11.5 feet, 12.5 feet, 13.5 feet, and 14.5 feet would pass 5-year (2,900 cfs), 10-year (3,800 cfs), 20-year (4,600 cfs), and 50-year (5,700 cfs) storm events, respectively (see Table 3-3 in Section 3.4 for Estimated Annual Peak Instantaneous River Flows at LPD). The size of the sluice tunnel would ultimately be based on detailed hydrology, hydraulic, and sediment transport analyses specific to the tunnel completed as part of detailed design, but is assumed at 14 feet for this report.

A 14-foot-wide tunnel could pass up to the 20-year storm and would provide tremendous flexibility in terms of operating the sluice tunnel during large storm events, quickly clearing sediment from the reservoir, and then refilling the reservoir relatively quickly refilling after sluicing. However, further analysis during design may reveal that a smaller tunnel would be adequate at LPD, in which case the construction cost associated with the sluice tunnel could be reduced.

The sluice tunnel would require a gate, which could be closed after the sluicing duration is complete, allowing the reservoir to refill for the dry season. Minimum stream flow requirements could be met during refilling by using a new secondary pipe and valve to allow bypass flows around the sluice gate and tunnel. Once the reservoir water surface is above the invert of the low-level outlet, it could also be used to facilitate bypass flow releases. A vertical gate shaft/structure would be constructed at the location shown on Figure 4-10 to house the sluice gate, provide access for gate installation, and provide access for future gate maintenance. The tunnel would be sized large enough that most woody and other debris would pass through the tunnel during sluicing events, and access would be provided from one or both ends of the tunnel for inspection, maintenance, and so that any atypical debris jams could be removed.

For a scenario where sluicing would occur during a 10-year storm (peak flow of 3,800 cfs), if the gate were opened early on the rising limb of the storm hydrograph, and assuming an average incoming flow at that time of 200 cfs, a 14-foot tunnel could drain the full reservoir (containing 1,601 AF) in approximately 4 hours. If the gates were closed on the falling limb of the hydrograph, and assuming an average incoming flow rate of 200 cfs, the reservoir would require approximately 4 days to refill. This hypothetical sluicing event, leveraging the sediment transport capability of an entire 10-year flood, is expected to move a considerable volume of sediment. However, shorter duration sluicing events and at lower flows may also be used to manage accumulated sediment at LPR.

Assuming a minimum sluicing flow of 1,000 cfs, the sluicing tunnel could have been operated 11 of the 15 years from 2002 through 2016, based on data obtained from the MPWMD gauge downstream of the LPD. As shown on Figure 4-12, 6 of the 11 years had two or three events with peaks greater than 1,000 cfs. Operation of the sluicing tunnel would require forecasting of large storm events and protocols for opening the sluice gate, with respect to timing and rate of lowering of the reservoir.

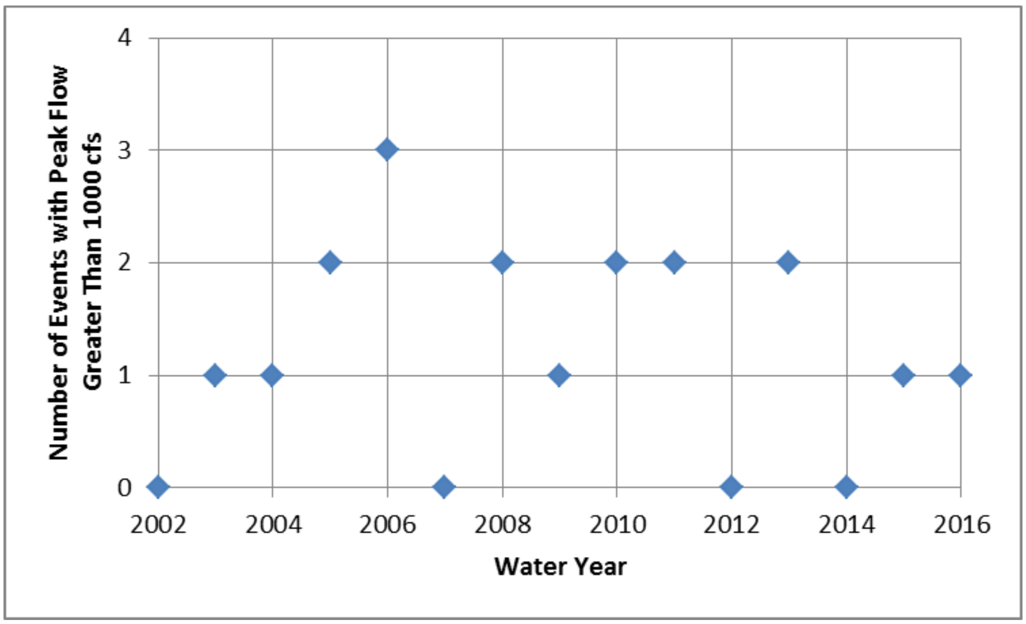

Figure 4-12 Flow Events Greater than 1,000 cfs at MPWMD Gauge below Los Padres Dam

If the majority of Zone 1 and Zone 2 sediment could be flushed over one or several large storm events (possibly over several years), the resulting reservoir capacity could reach up to 2,600 AF. At this storage capacity, refilling of the reservoir would require about 6.5 days, assuming average flows of 200 cfs. Once the volume of sediment in the reservoir has been depleted, less frequent or shorter sluicing events might maintain reservoir capacity, but additional analysis would be needed to refine expectations regarding sediment transport capacity of the sluice tunnel, its ability to reach sediment throughout the reservoir, and the frequency and duration of sluicing needed to initially deplete the accumulated sediment and then maintain capacity.

Excavation of the tunnel and shaft through granitic rock would likely use drilling and blast methods, with the excavated tunnel walls being temporarily supported by rock dowels. The reservoir would need to be completely lowered and a workpad constructed at the upstream end to accommodate the drilling equipment access. Drilling and blasting involves drilling the blast holes (see Figure 4-13), loading them with explosives, detonating the blast, ventilating to remove blast fumes, removing the blasted rock (mucking), scaling to remove loosened pieces of rock, and then lining the tunnel. Significant care would need to be taken to ensure that the blasts do not affect the existing spillway structure. This tunnel would likely be lined with reinforced concrete (see Figure 4-14).

Figure 4-13 Self-Drilling Multiple Boom Jumbo

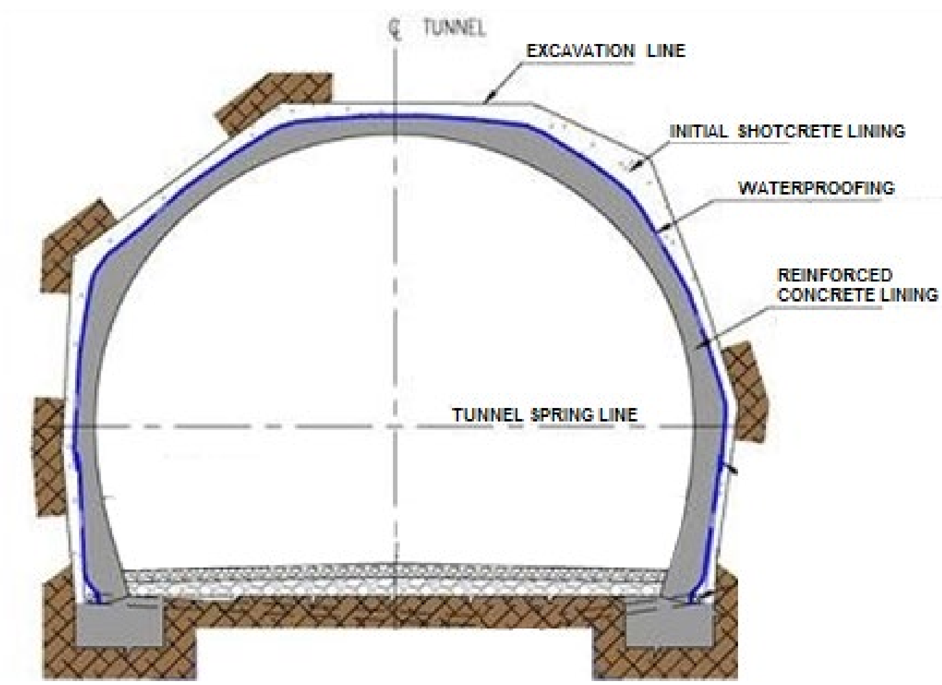

Figure 4-14 Concrete Tunnel Lining Schematic

Any tunneling activities will require a geotechnical investigation along the alignment of the proposed tunnel. Construction of the approximately 900-foot-long tunnel could occur over a 2-year construction period, with the first construction season being used to construct the sluice gate shaft and downstream portion of the tunnel. Completion of the upstream portion of the tunnel would occur during the dry season, when the reservoir could be emptied and Carmel River flows pumped around the dam. Although the diversion, dewatering, and treatment systems would function similarly to those described in Section 5.1.3, the diversion pipe and treatment system would be designed specifically for needs associated with the tunneling project.

Hauling and Material Disposal

The excavated sediment (described above under Sediment Removal) and tunneled rock (described above under Sluice Tunnel) would be hauled and disposed of at Disposal site B, as shown in Figure 4-10, using the local access improvements discussed above under Access Improvements.

Fish Passage Improvements

Two upstream and two downstream fish passage options were identified as preferred or warranting additional consideration (HDR et al. 2021). Those passage options are summarized in Section 5.2.3. As with other dam-in alternatives, if it had been selected, one upstream and one downstream fish passage option would have been adapted to Alternative 5. Additional detail and evaluation regarding fish passage at LPD are available in the draft Fish Passage Feasibility Report for LPD (HDR et al. 2021). Like cost information for the dam, reservoir, and sediment management alternatives, cost information for the fish passage options is summarized in Section 6.

Dam and Spillway Improvements

The current concrete spillway does not accommodate the updated PMF, based on current standards. Improvements to the spillway and possibly the dam embankment would be necessary to convey the PMF. The current concept includes an increase in the dam embankment height to create the head necessary to convey the PMF through the existing spillway cross section. The existing spillway walls would also be raised to accommodate the increased flow. A more detailed description of the updated PMF calculation can be found in Section 3.3, and the dam and spillway improvements are described in more detail in Sections 5.2.4 and 5.2.5.

There may be an opportunity to use the proposed sluice tunnel to convey some or all high flows, including the PMF, which could to some degree limit the need for the dam and spillway improvements discussed above. This function would be under the regulatory jurisdiction of the DSOD and could create conflict with requirements imposed by other regulatory agencies focused on protecting steelhead and other natural resources. Had this alternative been retained for further consideration, additional analysis and discussion with DSOD, and evaluation of operational scenarios, would have been required to confirm the merits of this approach.

Outfall

Based on AECOM field reconnaissance, it was determined that the plunge pool below the end of the spillway chute has exposed bedrock that has been sufficiently resistant to erosion (see Figure 4-15). However, an analysis should be completed in detailed design to confirm the need for any energy dissipation at this location, based on the sluice tunnel discharge and associated scour.

Figure 4-15 Proposed Sluice Tunnel Outfall Area

Operations and Maintenance

An operations plan would be developed during detailed design to outline required monitoring and procedures associated with timing of sluicing operations. The plan would consider specific objectives for sluicing activities, favorable timing of sluicing during the wet season, the duration of sluicing for favorable storm events, potential fish entrainment concerns, and other details that are beyond the current level of analysis. At another California site where sluicing is used to manage sediment accumulation behind a dam in a coastal steelhead stream (the Alameda Creek Diversion Dam), it was determined that early season storms, ideally before the upstream steelhead migration has begun, would provide the best opportunity for sluicing while minimizing effects on the steelhead population. These opportunities may be rare in the Carmel River, and sluicing events later in the season may have greater effect on the steelhead population. Additional hydraulic and sediment transport analysis would be required to determine the likely frequency, duration, and timing of sluicing events. Like Alternative 3 (Storage Expansion and Dredging), with increased storage, Alternative 5 would likely require development of a flow enhancement plan in coordination with NMFS and CDFW that addresses passage, attraction, and habitat enhancement flows, including connectivity with the lower Carmel River and the lagoon.

Any monitoring stations or instrumentation associated with the operations plan would be built into the project design. However, implementation of the plan—which would include data collection and analysis, along with gate operation (and likely monitoring of total suspended solids and/or turbidity of releases)—would increase the O&M responsibilities at the site.

More complex fish passage equipment and more frequent operational demands associated with fish passage improvements included in Alternative 5 would also increase the O&M effort relative to the current requirements.

Sediment Effects

Alternative 5 is the alternative that aims to restore sediment continuity while retaining LPD. Depending on how sluicing is managed, the amount of coarse sediment moving downstream would vary. In theory, with the large size of the sluice tunnel, high flows could eventually move accumulated coarse sediment through the reservoir and downstream of LPD. Any use of the sluice tunnel to mobilize accumulated sediment would result in a fine sediment release. In this report a sluice tunnel is assumed to have significant effect on fine and coarse accumulated sediment. The BESMo was used to evaluate geomorphic effects of mobilizing accumulated coarse sediment through a sluice tunnel under its Pulsed Supply scenario (Appendix D) and the fine sediment analysis is described in Section 3.8. This section summarizes results of both analyses, starting with fine, in the context of Alternative 5.

Fine Sediment

Use of the sluice tunnel would include sluicing accumulated fine sediment (silt, organic matter, and fine sand) during high-flow events. During the initial sluicing events, most sluiced sediment would be fine sediment from the lower reservoir. The increased fine sediment is expected to have little effect on the channel thalweg elevation downstream because fine sediment tends primarily to stay suspended throughout the river to the ocean. However, increased suspended sediment would have significant short-term effects on aquatic organisms, including steelhead.

Limited fine sediment transport analysis described in Section 3.8 concluded that the 1,300 mg/L peak concentration resulting from the episodic rating curve represents a typical high-turbidity event contributing to the reservoir from the watershed as background conditions. The 5,800 mg/L peak concentration resulting from the hypothetical discharge of all Zone 1 sediment represents a sediment release condition where a portion of the reservoir sediment leaves the reservoir in flows that are consistently high over a controlled period up to several consecutive days. Based on literature review of previous dam removal projects that included sediment sluicing, a true flushing event can put orders of magnitude more material in suspension than the estimates above, potentially resulting in peak concentrations greater than 49,000 mg/L. Although the reviewed dam removal data showed high suspended sediment concentrations lasting for 1 to 2 months, those conditions occurred because of continuous access to reservoir sediments resulting from long periods of high flow in the White Salmon and Sandy Rivers; these conditions do not tend to occur on the Carmel River. Additionally, the duration of high sediment concentrations would be limited by the operation of the sluice gate at LPD, which would operate within an assumed (for the sediment transport analysis) sluicing operational range of 500 to 5,000 cfs. Additional limitations could be developed to limit the timing, duration, or frequency of effects on steelhead, if appropriate.

Coarse Sediment

Coarse sediment effects associated with the sluice tunnel were modeled in the BESMo as the Pulsed Supply scenario (Appendix D). The sediment supply to reaches downstream of LPD in the Pulsed Supply scenario would causes up to 19 feet of aggradation just downstream of the Dam (Figure 4-16). The aggradation response at the dam lessens downstream, with little elevation change between Cachagua and Pine creeks, but increases up to an estimated 8 feet as the former San Clemente reservoir backwater zone and deposit is reached. Downstream of the former San Clemente Dam all three hydrologic conditions result in up to 9 feet of sediment deposition, which steadily decreases until Tularcitos Creek. After 60 years, the Pulsed Supply scenario does not show significant erosion or deposition within 10,000 feet upstream and downstream of Garzas Creek. Further downstream of this reach and up to the mouth of the river the Pulsed Supply simulation shows consistent deposition of 5 feet of sediment after 60 simulation years. Comparison of response across the three hydrologic conditions for the Pulsed Supply conditions suggests deposition is likely to occur independently of hydrology, given enough time for the channel to respond. Fining of the bed close to Los Padres reservoir is caused by the increased supply of relatively fine fractions. A more constant sediment feed from LPR is more effective in fining the bed downstream of LPD than a steeper, pulse-like rating curve, so the manner in which the sluice tunnel is operated could affect the outcome.

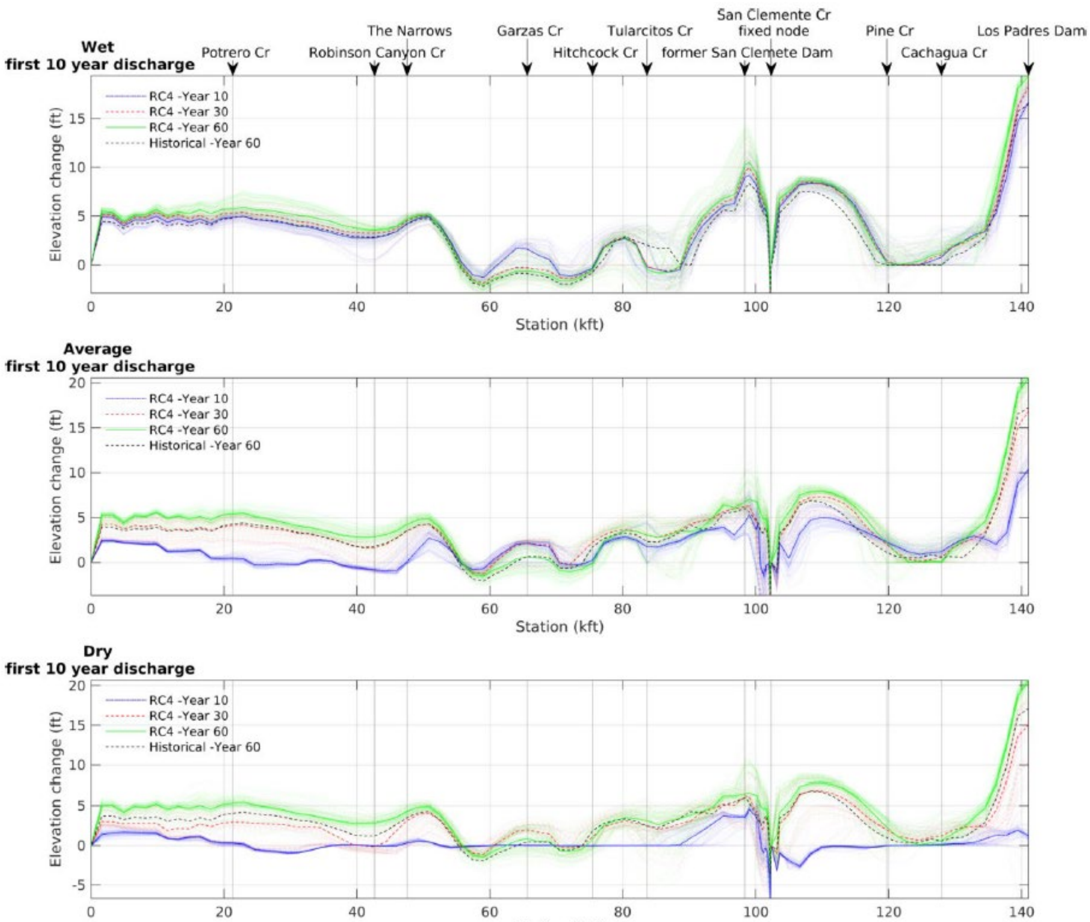

Figure 4-16 Change in Elevation Compared to the Initial Elevation Profile from 2017 for the Pulsed Supply Simulation

Notes:

Top: high, middle: average, bottom: low cumulative discharge in the first 10 years.

The dark lines in each subplot signify the median condition at each node for each of the three time slices and the median for the Historical Supply Scenario at year 60; all other lines represent data from individual model runs.

Effects to Steelhead

This section summarizes potential effects to steelhead associated with Alternative 5. Effects are partially drawn from analysis originally presented in Appendix E for an earlier formulation of alternatives. However, some effects are described differently because analysis in Appendix E assumes that the sluice tunnel would only transport fine sediment and this analysis assumes it would also transport coarse sediment. This section includes other, limited updates to the analysis presented in Appendix E, including the incorporation of results from NMFS' Carmel River Steelhead Fishery Science Studies (Section 1.3.4) that were not available during preparation of Appendix E.

Bedload Sediment Transport

If the sluice tunnel is used aggressively to transport coarse accumulated sediment and annual bedload from LPR to downstream, Alternative 5 could result in geomorphic changes that would benefit steelhead, over the long-term, like the benefits described for Alternative 2 (Dam Removal). Like Alternative 2, operation of the sluice tunnel could also result in short-term impacts due to deposition in rearing habitat. The timing of sluicing events would need to be carefully managed around steelhead presence in and use of the watershed. For example, sluicing with an early-season storm, prior to when adult steelhead have begun their spawning run up the Carmel River, would prevent coarse sediment from burying spawning redds or impacting the upstream migration. Although early-season high flows are rare, and therefore would only infrequently provide sluicing opportunities, additional hydraulic and sediment transport analysis would be needed to determine how effective such sluicing might be.

Fine Sediment Transport

Any use of the sluice tunnel would be expected to mobilize fine sediment and increase suspended sediment concentrations downstream. These effects would be most pronounced during initial sluicing events, due to the large quantity of accumulated fine sediment, or during the first sluicing event(s) following periods without sluicing. Short-term impacts related to increased suspended sediments include the reduced ability of steelhead to encounter prey, and injury or mortality during periods of increased suspended sediment concentrations. Additionally, as transported sand and fine sediment settles on the streambed, it can reduce the survival of incubating eggs and developing alevins in steelhead redds through reduced oxygenation of intergravel flow. Based on the large range of expected suspended sediment concentrations and the range of potential durations of increased suspended sediment concentrations, effects to steelhead would range from stressful to lethal. Suspended sediment concentrations would likely be greatest immediately downstream of LPD and would gradually decrease as sediment is diluted through tributary contributions to flow in the mainstem during periods of storm runoff.

As discussed in Section 3.9, using the general predictions of suspended sediment concentration and durations, the results of Newcombe and Jensen (1996) were used to conservatively assess impacts of suspended sediment on steelhead. Due to the flexibility in the management of a sluicing operation, we analyzed the effects of the predicted range of suspended sediment concentrations over a range of 2 to 5 days. In practice, much shorter sluicing events at very high flows may also mobilize considerable volumes of accumulated fine sediment. Further analysis would be required to confirm the rate of sediment evacuation that would occur at various flows, and therefore, the likely frequency and duration of sluicing events.

If suspended sediment concentrations resulting from sluicing were to remain at 5,800 mg/L over the course of 3 days, upstream migrating adults are predicted to experience an SEV of 10 during the migratory period (December through April) while active sluicing is occurring (Table 4-4). An SEV of 10 is associated with lethal and paralethal effects, with 0 to 20 percent mortality. This level of effect is anticipated to result in some mortality and delayed migration timing. If the sluicing event were to occur after spawning had occurred, incubating eggs and alevins are predicted to experience an SEV of 13, which is also associated with lethal and paralethal effects, resulting in >60 to 80 percent mortality. Fry and juvenile steelhead are predicted to experience an SEV of 10. This level of effect over the course of the sluicing event is anticipated to result in some mortality; increased risks of predation resulting from physiological stress, especially where nonnative piscivorous fish species (e.g., brown trout and striped bass) occur; and a reduction in the foraging ability of juvenile steelhead. If sluicing operations could be controlled to release 5,800 mg/L of sediment over a short duration (<12 hours), impacts to fry, juveniles, and adults would be sublethal. Impacts to the more sensitive incubating eggs would still be lethal.

Table 4-4 Summary of Predicted Newcombe and Jensen Severity Index and Anticipated Effects on Steelhead in the Carmel River Downstream of LPD during Sluicing Events Producing 5,800 mg/L of Suspended Sediment Concentrations for 3 Days

Life Stage	Total Exposure (hours)	Total CD (mg-hr/L)	SEV	Effects
Adult	72	417,600	10	0 to 20% mortality; increased predation; moderate to severe habitat degradation
Eggs and alevins			13	>60 to 80% mortality
Fry and juveniles			10	0 to 20% mortality; increased predation; moderate to severe habitat degradation

Notes:

CD = product of concentration and duration
LPD = Los Padres Dam
mg-hr/L = milligrams per hour per liter
mg/L = milligrams per liter
SEV = severity of ill effect

In the case of a sluicing event sending suspended sediment concentrations of up to 49,000 mg/L over the course of several days, steelhead in the Carmel River downstream of LPD would generally experience lethal effects. Upstream migrating adults are predicted to experience an SEV of 11 during the migratory period (December through April) while active sluicing is occurring (Table 4-5). An SEV of 11 is associated with lethal and paralethal effects, with >20 to 40 percent mortality expected. This level of effect is anticipated to result in adult mortality and delayed migration timing. Eggs and alevins are predicted to experience an SEV of 14, which is also associated with lethal and paralethal effects, resulting in >80 to 100 percent mortality. This level of mortality is anticipated to severely reduce successful hatching of redds and result in mortality of alevins, severely reducing successful recruitment of steelhead in affected reaches. Fry and juvenile steelhead are predicted to experience an SEV of 11, which would result in >20 to 40 percent mortality. This level of effect over the course of the sluicing event is anticipated to result in mortality; increased risks of predation, especially where nonnative piscivorous fish species (e.g., brown trout and striped bass) occur; and reduction in the foraging ability of juvenile steelhead, resulting in reduced growth rates. If sluicing operations could be controlled to release 49,000 mg/L of sediment over a short duration (<2 hours), impacts to fry, juveniles, and adults would be sublethal. Impacts to the more sensitive incubating eggs would still be lethal.

Table 4-5 Summary of Predicted Newcombe and Jensen Severity Index and Anticipated Effects on Steelhead in the Carmel River Downstream of LPD during Sluicing Events Producing 49,000 mg/L of Suspended Sediment Concentrations for 3 Days

Life Stage	Total Exposure (hours)	Total CD (mg-hr/L)	SEV	Effects
Adult	72	3,528,000	11	>20 to 40% mortality
Eggs and alevins			14	>80 to 100% mortality
Fry and juveniles			11	>20 to 40% mortality

Notes:

CD = product of concentration and duration
LPD = Los Padres Dam
mg-hr/L = milligrams per hour per liter
mg/L = milligrams per liter
SEV = severity of ill effect

As discussed in Section 3.8, the analysis conducted for suspended sediment concentrations was limited in its ability to provide specific magnitudes and durations of suspended sediment concentrations. Based on the outputs of this analysis, sluicing could result in increased mortality of steelhead downstream of LPD. Although sluicing events are anticipated to occur concurrently with winter storm events, they still could result in substantial effects to all life stages of steelhead—especially eggs and alevins, which would reduce the successful recruitment of steelhead in years that sluicing occurs. However, if sluicing operations were conducted for short (<24 hours) durations, coincident with winter high flows when all tributaries are typically accessible, steelhead may avoid the peak in concentrations by using refugia habitat in tributaries, side channels, or off-channel habitat. Several tributaries (e.g., Cachagua, Pine, San Clemente, Tularcitos, and Garzas Creeks) would presumably provide refugia from flushed sediment (Reference figure rearing habitat). Approximately 43 percent of the suitable steelhead rearing habitat in the Carmel River Watershed is estimated to be either in tributaries or upstream of LPD (Table 2-5). Therefore, a substantial portion of the rearing population would not be in the mainstem Carmel River during relatively brief reservoir drawdown and sediment release, and would therefore be unaffected by sluicing operations. Additional hydraulic and sediment transport analysis would be needed to determine the timing, duration, and frequency of sluicing events. However, the portion of the population that would avoid all impacts of sluicing would presumably recolonize the mainstem and support a strong recovery of the population, especially if sluicing operations were conducted infrequently (e.g., every 5 years or more). Additional hydrologic, hydraulic, and fine sediment transport analysis would allow for a narrowing of expectations regarding operation of the sluice tunnel, and therefore, its effects on steelhead.

Because many of the studies included in Newcombe and Jensen's (1996) analysis are laboratory studies, the results they describe may be a conservative estimate of the effects that may be experienced by steelhead exposed to elevated concentrations of fine sediment in the Carmel River. Under laboratory conditions, a fish would have no refuge from elevated suspended sediment concentrations. However, in a stream, fish may reduce their exposure to suspended sediment by seeking refuge in the mouths of tributaries with lower levels of suspended sediment, or where springs or other features provide inputs of water to the river and locally reduce suspended sediment concentrations. It is likely that steelhead in the wild would take advantage of these types of local variations in suspended sediment concentrations and, during extreme events, reduce their felt SEV from that predicted by the equations derived primarily from laboratory study. In this report, the effects of suspended sediment are described based strictly on the equations provided by Newcombe and Jensen (1996) and should be considered a conservative assessment of potential effects in that regard. This approach is useful for a general assessment of sediment released under a sluicing alternative, but a more site-specific and nuanced analysis may be appropriate when evaluating the potential effects of sluicing sediment on steelhead in the Carmel River.

Water Availability

Depending on the amount of sediment removed from LPR, Alternative 5 could result in increased reservoir storage, which would allow for an increase in summer flow releases. If sluicing were less effective or conducted less frequently, a lesser amount of reservoir storage would be recovered. Therefore, the benefits of increased water availability would fall somewhere between Alternative 1 (Fish Passage, No Sediment Action) and Alternative 3 (Storage Expansion and Dredging). For example, the extent of wetted channel during the dry season (Figure 3-3 through Figure 3-5) would at minimum be equal to the extents shown for Alternative 1 and would increase from there depending on how effective the sluice tunnel is and how aggressively it is used to recover storage capacity in LPR. Flow extents could increase over what is shown for Alternative 1, and unlike Alternative 1, could be maintained indefinitely with use of the sluice tunnel over time. However, the flow extents for Alternative 5 would never be as great as the extents shown for Alternative 3, which, with the spillway gates, includes storage beyond what could ever be achieved with the sluice tunnel alone. Similarly, the duration of flows over the dry season (Figure 3-1 and Figure 3-2) and the duration of juvenile and fry rearing habitat suitability (Figure 3-7 and Figure 3-8) would likely be intermediate to Alternatives 1 and 3. Like the flow extents, the curve lines for Alternative 5 would shift toward but never equal the predicted trends for Alternative 3 if the sluice tunnel is highly effective and/or used aggressively, and would remain closer to Alternative 1, as long as the sluice tunnel is periodically operated, if it is less effectively or used less frequently.

Recent modeling of the effects of flow on adult steelhead returns to the Carmel River watershed included the historical baseline and two reservoir dredging alternatives, but not a reservoir sluicing alternative (Boughton and Ohms 2022). Reservoir dredging resulted in a greater number of returning adults compared to the historical baseline. The magnitude of the effects of dredging on adult returns was impacted by the level of water infiltration in the lower valley, with low infiltration in the lower valley resulting in slightly higher increases in returning adults. Although a reservoir sluicing alternative was not modeled, it can be inferred that, because the effects of Alternative 5 on dry season flows would be somewhere between Alternatives 1 and 3, the effects of Alternative 5 on adult steelhead returns would also be somewhere between Alternatives 1 and 3 and would depend on the amount of material sluiced from the reservoir.

Water Temperature
Under Alternative 5, water temperature effects on steelhead would be similar to existing conditions and effects described for Alternative 1.

Fish Passage
Fish passage facilities under Alternative 5 would be like those described for Alternative 1 (Fish Passage, No Sediment Action) in more detail in Section 5.2.3. Effects to steelhead related to managed fish passage would be similar to those described for Alternative 1 in Section 4.4.1 under Effects to Steelhead. However, like the operational spillway gates that could complicate fish passage operations under Alternative 3 (Storage Expansion and Dredging), operation of the sluice tunnel included with Alternative 5 could affect fish passage operations. During the operation of the sluice tunnel, steelhead in LPR would become entrained in the tunnel and transported downstream of LPD. If entrained, adult steelhead migrating through the reservoir would fall back downstream; juveniles migrating or rearing in the reservoir could be transported downstream; and brown trout rearing in the reservoir could also be transported downstream. The overall effect of potential entrainment would depend on the seasonal timing, frequency, and duration of operation of the tunnel, as well as the risk of injury or mortality for those fish entrained.

Sluicing accumulated fine sediment from the lower reservoir could affect the topography and bathymetry in the transition between Zone 2 and Zone 3 sediments in LPR. However, this effect would be deeper in the reservoir and, depending on the stage of the reservoir during periods of steelhead migration, may not affect passage through a full LPR. Additionally, the bathymetry in this case would be shaped by the work done by fluvial processes (e.g., scour) as opposed to mechanical excavation, so would likely result in smoother transitions.

Construction Effects
Relative to other alternatives, effects to steelhead during construction of Alternative 5 would be more severe than Alternative 1 and less severe than Alternative 2 (Dam and Sediment Removal). Much of the construction would not require drawing down LPR or accessing accumulated sediment, but LPR would be drawn down and dewatered for one construction season (May 15 through October 15) to access the upstream end of the sluice tunnel. During that season, like Alternative 2, dry-season flow augmentation from LPR to the lower Carmel River would cease and fish passage would be interrupted, but temperatures would be closer to stream temperatures upstream of LPR than typical reservoir releases.

Habitat Quantity
Alternative 5 would generally maintain steelhead habitat at the same locations it is present currently, with potential to increase dry-season releases from LPR, reduce channel incision downstream of LPD, and improve spawning habitat quality through transport of coarse sediment to the Carmel River downstream of LPD. Depending on the effectiveness and frequency of operation of the sluice tunnel, some portion of stream channel immediately upstream of LPR, between the current reservoir pool and the original upstream extent of the pool (in 1947), could be reverted to reservoir pool. This is a reach of the Carmel River that was previously part of the reservoir pool but has been filled with accumulated sediment. Even if highly effective and operated aggressively, the sluice tunnel would not revert the channel upstream of the original reservoir pool to open water, so this effect would propagate upstream no further than an estimated 3,500 feet from the current pool and would end downstream of the gravels noted in Section 5.2.11.

Summary
During one construction season, Alternative 5 would eliminate dry-season flow augmentation from LPR to the lower Carmel River and interrupt fish passage but during that time temperatures would be closer to stream temperatures upstream of LPR than typical reservoir releases. Alternative 5 would result in effects to water availability intermediate to Alternative 1 (Fish Passage, No Sediment Action) and Alternative 3 (Storage Expansion and Dredging) and would affect water temperature like Alternative 1, essentially maintaining the existing water temperature regime downstream of LPR. Fish passage facilities would be like Alternative 1, but with operation potentially more complicated, and certainly disrupted during sluicing

events. As described above under Overview, there is no feasible way to exclude fish from the sluice tunnel while achieving the goal of sediment transport.

Depending on how sluicing is managed under Alternative 5, steelhead in the Carmel River downstream of LPD could experience significant levels of mortality resulting from increased suspended sediment concentrations. Based on the range of durations and concentrations assumed in this report, all life stages of steelhead would experience paralethal and lethal effects due to increased suspended sediment concentrations. This is expected to have a substantial effect on the steelhead population in the Carmel River and sluicing operations would need to be managed to reduce the risks. Sluicing could also result in reversion of a portion of the former reservoir pool that has been filled with sediment and is now functioning as stream habitat back to reservoir pool.

Due to the severity of effects to steelhead predicted by the limited fine sediment transport analysis, if Alternative 5 is selected for further development, additional hydraulic, hydrologic, and sediment transport modeling of the sluicing operations is recommended. This will increase confidence in the estimated range of sediment concentration magnitudes and durations, and the potential changes to these over a series of operations and storm events.

Uncertainties

Key uncertainties associated with Alternative 5 included the following:

- A significant uncertainty associated with Alternative 5 is the ability to permit the project, given the potential effect to all life stages of steelhead. Sluice tunnels are used effectively to manage sediment behind dams around the world (Kondolf et al. 2014) and in central California (e.g., the Alameda Creek Diversion Dam), but the effectiveness of a sluice tunnel depends on site-specific conditions that limit the ability to extrapolate the effectiveness at one site from observations at another. The BESMo model developed for the LP Alternatives Study predicts bedload movement from LPD to downstream but does not predict fine sediment transport or reservoir evacuation (Appendix D). Additional sediment evacuation and fine sediment transport analysis, beyond the scope of the LP Alternatives Study, would help guide expectations regarding the ability of the sluice tunnel conceptualized for LPD to access accumulated sediment away from its inlet; the frequency and duration of operation to move a given quantity of fine and coarse sediment; the resulting suspended sediment concentrations; and, therefore, impacts and benefits to steelhead. If some level of sluicing is acceptable to regulatory agencies, this information may be needed to confirm reasonable goals for sluice tunnel operation, as well as operational constraints, impacts, benefits, and design.
- Another uncertainty is whether DSOD would allow for reliance on the sluice tunnel to convey part or all the new HMR 58/59 PMF. If they did, and if that use of the spillway could be permitted with NMFS and CDFW, that could limit the need for a dam embankment and spillway wall raise, potentially reducing the OPCC presented in Section 6 by $20.7 million.
- Based on ongoing planning and design processes for several dam removal projects in California, depending on the amount of coarse sediment that would be transported to downstream of LPD, mitigation for the potentially increased flood risk could be required as part of the environmental compliance or regulatory approval process associated with installing and operating a sluice gate.
- As described in previous sections, conceptual or planning-level alternatives are uncertain by nature. Key assessments or investigations to help address uncertainties related to design and construction of this alternative are listed below:
    - There is uncertainty regarding the future performance of the fish passage improvements. For example, downstream passage improvements may be challenged to meet the 95 percent collection efficiency and 98 percent survival rate criteria noted in HDR et al. 2021, especially considering that in a recent study, only 20 percent of juveniles that entered the reservoir were later detected downstream of LPD (Ohms et al. 2022). Additionally, fish passage improvement alternatives (HDR et al. 2021) were developed based on existing conditions and infrastructure. The dam, spillway, and infrastructure improvements, in addition to the

associated operational changes, outlined in this section for Alternative 5 may require changes in the fish passage improvement alternatives and associated costs.

- An onsite geologic assessment and potentially a geotechnical investigation would be necessary to confirm construction and engineering details associated with the proposed tunnel, and the effects its construction might have on the existing spillway structure.

- An assessment of the potential effects of steelhead entrainment in the sluice tunnel would be needed to address this uncertainty in detailed design.

- Further study is needed to understand the frequency and duration required to flush varying volumes of accumulated sediment from the reservoir through operation of the sluice tunnel, and the resulting extent of mobilized sediments.

- An onsite geologic assessment and geotechnical investigation may be required during detailed design to confirm the extent of improvements required for the temporary access roads proposed for sediment access and hauling.

- Adequate geologic and geotechnical baseline information has not been gathered, nor have there been any associated seismic assessment and stability analyses to support a detailed dam embankment raise design. In addition, all modifications would need to be designed using current standards and would require DSOD approval prior to their construction. It is possible that further analyses will indicate that other features of the dam will also require improvement or that the currently envisioned improvements may need to be more extensive.

- An assessment to confirm embankment stability under rapid drawdown conditions would need to be completed during detailed design.

Advantages and Disadvantages

Advantages and disadvantages associated with Alternative 5 are discussed in this section, organized by the following categories: Local Impacts, Water Supply, Flooding, Geomorphology, Biological, Water Rights, and Regulatory.

Local Impacts (Traffic and Noise)

- **Disadvantage:** Impacts to local traffic and noise for Alternative 5 would be similar to other alternatives under which the dam would remain in place, but greater than Alternative 2, under which the dam would be removed. For all alternatives that leave the dam in place, it may be necessary to import between 2,500 and 3,300 loads of filter and drain material associated with the dam raise, if it is determined that those materials cannot be made on site. Associated equipment mobilization, material on-haul, and construction worker commuting would cause significant local traffic disruption. Similar to all alternatives, small improvements may be required along public roads (see Section 5.1.2) to accommodate construction traffic, which would cause additional disruption.

Water Supply

- **Advantage (sediment removal):** Removing a significant volume of the accumulated sediment through sluicing would increase storage above the current reservoir capacity, providing more flexibility for Cal-Am to store water for any purpose, including summer releases to enhance rearing habitat and passage.

- **Advantage:** Because sluicing could occur at any frequency, and indefinitely into the future, this alternative provides increased flexibility to provide reliable storage into the future; and to deal with significant watershed events, such as fires or rockslides, that could introduce a large sediment pulse into the river upstream of LPD.

Water Rights

- **Advantage:** Depending on how the sluicing operation is managed, Alternative 5 would either maintain the existing water rights agreements or could increase storage capacity, allowing Cal-Am to petition SWRCB to increase their water right associated with LPR.

Geomorphology

- **Advantage:** Depending on how sluicing is managed, the amount of coarse sediment moving downstream would vary. If the intent is to restore reservoir capacity, the sluicing could be managed to mobilize mostly fine sediments, thus limiting the amount of coarse sediment that would move into the reservoir and displace reservoir capacity. Although the Effects to Steelhead TM (Appendix E) suggests that coarse sediments will not be transported downstream and therefore not improve downstream aquatic habitat, management strategies may allow for coarse sediment transport downstream. Analysis in the Sediment Effects TM for the Pulsed Flow Simulation, which was intended to represent operation of a sluice gate, assumes that the annual load of coarse sediment is transferred downstream (Appendix D). If the sluice gate could be used to transport the accumulated coarse sediment and annual bedload to downstream of LPD, short-term impacts and long-term benefits associated with restoring bedload continuity would be like those described for Alternative 2 (Dam and Sediment Removal).

Flooding

- **Disadvantage:** Depending on how sluicing is managed, the release of accumulated reservoir sediment and subsequent return of the historic sediment load would increase deposition and associated flood risk throughout the downstream river relative to all other alternatives. However, the sluicing objective and frequency could be adaptively managed to affect the potential impact.

Biological

- **Advantage:** Would provide higher summer flows than Alternative 2 (Dam and Sediment Removal), flows capable of providing rearing habitat for both fry and juvenile steelhead downstream of LPD during the dry season in normal water years.

- **Advantage:** Depending on how sluicing is managed, Alternative 5 has the potential to increase spawning gravel availability downstream of LPD through transport of coarse sediment.

- **Advantage:** Construction effects (no dry-season flow augmentation and interrupted fish passage for one construction season) would be more severe than Alternative 1 bit less severe than Alternatives 2 and 3.

- **Disadvantage:** Depending on how sluicing is managed, steelhead in the Carmel River downstream of LPD could experience significant levels of mortality resulting from increased suspended sediment concentrations. Generally, under the assumed range of durations and concentrations evaluated in this report, all life stages of steelhead would experience paralethal and lethal effects from increased suspended sediment concentrations. This is expected to have a substantial effect on the steelhead population in the Carmel River, and sluicing operations would need to be managed to reduce the risks.

- **Disadvantage:** Through implementation of fish passage improvements, adult steelhead passage would be improved over existing conditions, but would be less beneficial to fish than the volitional passage provided in Alternative 2 (Dam and Sediment Removal). Additionally, operation of the sluice tunnel could conflict with, or at least would need to be closely coordinated with, fish passage operations. During the operation of the sluice tunnel, upstream fish passage would cease, and steelhead in LPR would become entrained in the tunnel and transported downstream of LPD. Although this could cause adult steelhead migrating through the reservoir to fall back downstream, timing of sluicing operations could reduce the potential for this effect.

- **Disadvantage:** Alternative 5 would continue to block upstream movement of juveniles, thus continuing to prevent access to thermal refugia in the watershed upstream of LPR.

- **Disadvantage:** Alternative 5 has the potential to continue causing stress and migration delay for migrating steelhead.

- **Disadvantage:** Alternative 5 provides suboptimal downstream juvenile passage through and mortality in LPR.
- **Disadvantage:** Alternative 5 provides a suboptimal water temperature regime in the summer months.
- **Disadvantage:** Depending on the amount of sediment transport achieved with the sluice tunnel, up to 3,500 feet of the former LPR pool currently filled with accumulated sediment could revert to reservoir pool, resulting in a potential loss of sub-optimal (due to effects of accumulated fine sediment and lack of sediment equilibrium) spawning and rearing habitat.

Regulatory

- **Disadvantage:** Alternative 5 could be difficult to permit, given the potential effects to all life stages of steelhead during episodes of elevated suspended sediment concentrations.
- **Disadvantage:** The project would likely be considered a modification of the existing LPD, thereby requiring DSOD design review and approval for construction.

5. Dam, Reservoir, and Sediment Management Alternatives

This section provides descriptions of each of the two LPD, reservoir, and sediment management alternatives that remain under consideration. Alternatives retain the numbering used in the Alternatives Development TM (Appendix F). Alternatives presented in this section include:

- Alternative 2 – Dam and Sediment Removal
- Alternative 3 – Storage Expansion and Dredging

An overview is provided for each alternative, followed by subsections describing key components of the alternative and general O&M considerations. Subsequent subsections for each alternative relate key findings from the Sediment Effects TM (Appendix D) and the Effects to Steelhead TM (Appendix E) to the alternative as it is currently understood. For each alternative, the last subsections summarize unresolved, alternative-specific uncertainties, advantages, and disadvantages identified during the LP Alternatives Study. Opinions regarding construction and O&M costs are presented in Section 6.

5.1 Alternative 2 – Dam and Sediment Removal

This section describes Alternative 2. Prior to dam removal, sediment would be removed from LPR using dry excavation techniques described in this section. Wet excavation methods, or dredging, described in Section 5.2.6 in association with Alternative 3 (Storage Expansion and Dredging) could be used in place of dry excavation if that was determined to be more desirable or cost-effective in the future.

5.1.1 Overview

Alternative 2 involves the removal of LPD after mechanical excavation of sediments (Zones 1 and 2) that would cause degraded water quality impacts downstream (during natural transport) if not removed prior to dam removal. Figure 5-1 shows an overview of Alternative 2 key components for dam and sediment removal.

To facilitate the demolition work, an upstream diversion structure and pipeline would be installed to allow for dewatering of the reservoir in the permitted in-water work window (approximately May 15 to October 15). A total of approximately 1,680,000 CY of sediment from Zones 1 and 2 would be excavated, in the dry, for permanent placement in onsite Disposal Sites A, B, and C. Zone 3 sediment (approximately 350,000 CY) would be left in place for future transport downstream. After Zone 1 and 2 sediment removal, the full dam would be removed down to the original river channel elevation. Excavated material from the dam would be disposed of in onsite Disposal Sites A, B, and C.

A similar concept presented in Appendix B that is not included in this report is a partial dam removal, which would have left a portion of the existing embankment and concrete spillway (outside of the river channel) in place. This concept did not move forward due to limited cost savings in comparison to a full dam removal and the disadvantage of leaving the concrete spillway in the river canyon (Section 4.2.4). In addition, offsite disposal locations were considered for accumulated sediment disposal, but removed from further consideration given a lack of reasonable locations (Section 4.2.3).

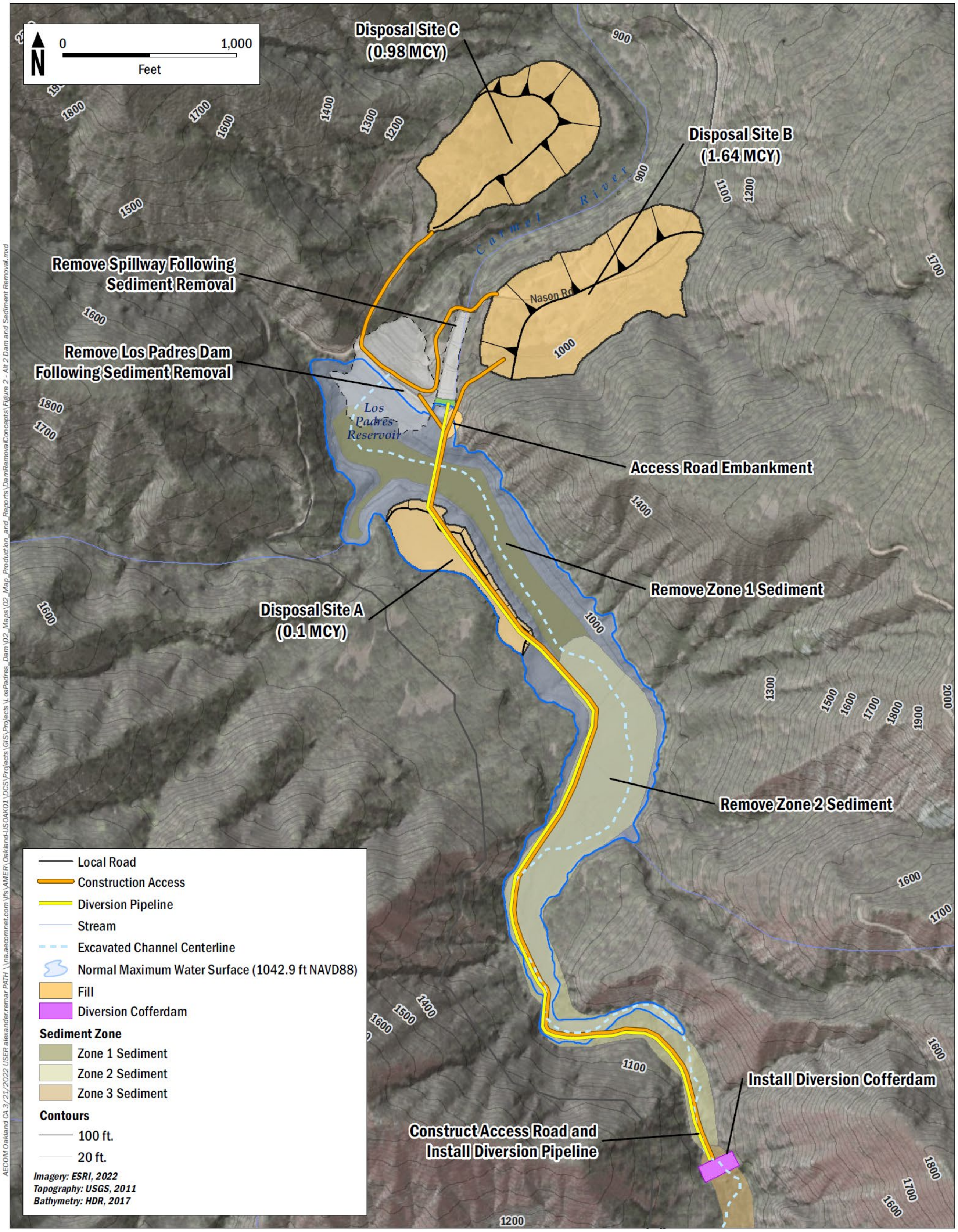

Figure 5-1 Overview of Alternative 2 (Dam and Sediment Removal)

5.1.2 Access Improvements

Construction equipment access to the project from Carmel Valley Road would be via Tassajara Road to Cachagua Road to Nason Road, as shown on Figure 5-2. Based on local input, our understanding is that tractor-trailers pulling lowboys have mobilized D8 bulldozers along this route using the existing roads and bridges. Based on an initial assessment, the following improvements would potentially be required for large-scale equipment mobilization and construction material delivery to the project site:

- Widen Tassajara Road and improve the shoulder just east of the intersection with Cachagua Road to accommodate construction traffic. The one-lane bridge on Tassajara Road also near the intersection of Cachagua Road would not require strength improvement.
- Widen Cachagua Road just west of the intersection with Tassajara Road to accommodate construction traffic.
- Strengthen Bridge #529 (a one-lane, load-restricted bridge on Cachagua Road) to handle construction equipment loads. Widen the curve west of Bridge #529 to 24 feet.
- Prune trees on Cachagua Road at Carmel Valley Road to improve sight distance.
- Erect a reduced speed limit sign north of Nason Road.

Vehicles hauling construction equipment or materials along this route would require traffic control in the form of pilot cars (and other measures required in the future contractor-provided, county-approved Traffic Control Plan, and other permits).

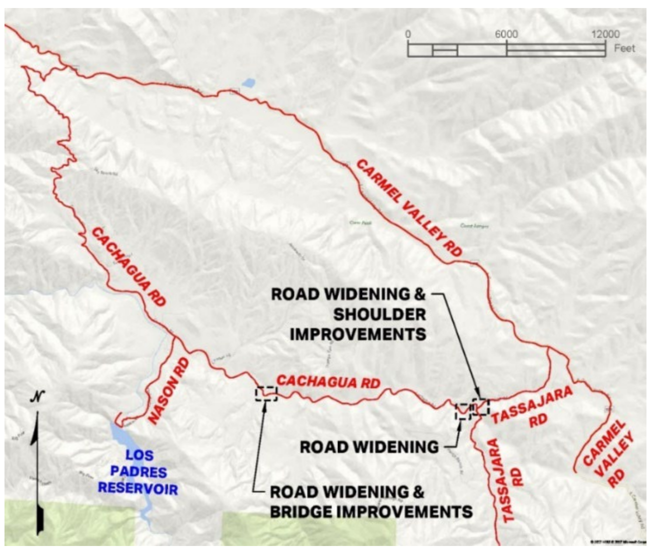

Figure 5-2 Location of Potential Public Road Improvements for Construction

In addition to the limited public road improvements, construction equipment access near the project site would require the following improvements, as depicted on Figure 5-1:

- **Disposal Site B Access:** Construct a new quarter-mile access road from the offloading area along the eastern dam embankment (east of the spillway) to Disposal Site B.
- **Reservoir Access:** Improve and widen the existing ramp between the dam crest and the reservoir.
- **Disposal Site C Access:** Widen the existing access road from the dam crest and extend it to Disposal Site C.
- **Spillway Bridge Access:** Replace the existing spillway bridge for construction vehicles.
- **Upstream Access:** At the beginning of each season of construction and after dewatering, construct an approximately 1.25-mile, 24-foot access route to the upstream extent of the project area over accumulated reservoir sediments and terraces. See Attachment B, Sheet 10, for the proposed road alignment.

5.1.3 Sediment Removal

To avoid degraded water quality impacts downstream associated with the release of fine sediments (clay and silt), Alternative 2 would require, at a minimum, removal of Zone 1 and 2 sediment prior to dam removal. The estimated 350,000 CY of sand and coarser materials in Zone 3 would be left in place to be transported through the reservoir area and downstream naturally following dam removal. The transition zone from sediment removal to remaining Zone 3 sediments may require some manipulation to provide adequate passage to the upstream river channel. In addition, it is likely that an adaptive management plan may be required to address temporary passage impediments that develop during the regulatory monitoring period in this area.

Sediment zone volumes for removal, disposal locations, and characterization for Alternative 2 are summarized in Table 5-1. Sediment removal volumes could potentially be reduced with design refinements if dam removal is selected for implementation. Refinements to consider include leaving sediment along the margins of the reservoir at elevations above the 100-year flood (while maintaining appropriate side slopes above that point), or constructing benches to be inundated at winter base flow elevations.

Table 5-1 Alternative 2 Estimated Sediment Removal and Placement

Area	Volume (AF)	Volume (CY)	Disposal Location	Characterization
Zone 1	340	550,000	Sites B and C	Clay/silt/fine sand
Zone 2	701	1,130,000	Sites B and C	Predominately silt and sand
Total Volume Removed	**1,041**	**1,680,000**		

Notes:
AF = acre-feet
CY = cubic yards
Characterization Source: Appendix C

Sediment removal upstream of LPD is severely constrained by access. Steep mountainous terrain with 2H:1V topographic slopes encompass the reservoir nearest the dam. Recent rockfall events in 2018, 2019, and 2020 eliminated the only vehicle access (“Jeep Trail”), which begins on the western dam abutment and travels southeast to the upstream reservoir reaches. Continued rockfall events are anticipated (Zinn Geology 2021); cutting a wide road across the lower slope could be expected to further destabilize upslope materials, possibly leading to more failures. For these reasons, access roads must be constructed if conventional excavation equipment (tracked or wheeled equipment) is to be used to remove accumulated sediments in the reservoir.

Because the production rate of conventional excavation equipment is nearly double that of a clamshell dredge on a barge, and 10 percent faster than a conventional excavator floating on a barge, Alternative 2 assumes dry excavation (with Carmel River diversion and dewatering of the reservoir). Dry excavation is most appropriate for Alternative 2 because the subsequent removal of the dam after sediment removal requires reservoir dewatering and temporary diversion as well. For comparison, Alternative 3 (Storage Expansion and Dredging) (Section 5.2) includes sediment removal with dredging equipment, so both reservoir sediment removal methods (dry and wet) are evaluated in this report.

The following timeline summarizes the anticipated actions for Alternative 2 during each construction year, with in-water construction work occurring from May 15 to October 15 of each year. Site mobilization and demobilization would occur just before and after the in-water work window to maximize sediment removal each construction season.

Construction Year 1

Prior to May 15:

- Begin drawdown of the reservoir using the restored low-level outlet with an inlet elevation of 981.8 feet (in accordance with the 60 percent design drawings [HDR 2022]), and the existing siphon. A discharge rating curve was not yet available for the low-level outlet, but it is assumed to controllably pass 30 to 70 cfs. Using the lower discharge of 30 cfs and an average siphon discharge of 12 cfs (down to elevation 1,013 feet), the reservoir could be dewatered to elevation 981.8 feet in 3 weeks.

- Conduct fish capture and relocation (to be conducted during every dewatering event).
- Improve access roads as described in Section 5.1.2, with the exception of in-water access on the reservoir sediments.
- Clear and grub permanent sediment Disposal Sites B and C. Prepare the sites to receive material.
- Construct a temporary dewatering treatment system to process turbid water in the last stages of reservoir dewatering (see Figure 5-3). The treated water will need to meet discharge criteria (typically not increasing turbidity by 10 to 20 percent in comparison to the reservoir inflow) prior to release into the Carmel River. The dewatering treatment system would be near Disposal Site B and the downstream end of the spillway, where sufficient space exists to accommodate a system similar to that used at the San Clemente Dam removal project. The system would consist of a lined treatment basin; turbine pump; pressurized sand filtration units with automatic backflush systems; flocculent injection pumps (to reduce turbidity); in-line influent and effluent flow and water quality meters; and a control unit.

Figure 5-3 Dewatering Treatment System and Basin, San Clemente Dam Removal, August 2015

Beginning May 15:

- Once the reservoir water level approaches elevation 980 feet, construct a displacement fill access road across the approximate 400 linear feet of soft reservoir sediments between the (pre-dam) natural terraces (approximate elevation 1,025 feet). The access road would cross from near the location of the pickup truck in Figure 5-4 to the opposite terrace (Attachment B, Sheet 10). For access road construction, use locally excavated material sourced from the treatment basin construction or Disposal Site B grading. Install culverts by trenching to encourage continued sediment draining to the reservoir bottom, or use the divided basins and dewatering trenches and sumps to enhance dewatering as is necessary to construct the access road. In the event of turbidity increase during road construction, turbidity curtains on the downstream side of the work area would limit turbidity transmission to the low-flow outlet. Additionally, a smaller temporary diversion dam or bladder dam with small diversion pipe could also be considered near the current Zone 1 and Zone 2 sediment intersection if turbidity does not meet discharge criteria and creek flows exceed the treatment system design flows.

Figure 5-4 Los Padres Dam Reservoir, Looking Southeast; Approximate Reservoir Elevation 1,014 feet NAVD88, November 5, 2013

- Continue access road construction along the western reservoir terrace to the upstream extent (Station 62+00) of sediment removal, using fill and crane mats where necessary.
- Construct a temporary diversion system for the Carmel River around the construction site (see Figure 5-5). Fish would be excluded from the diversion pipe and fish passage would not occur during the construction season while the diversion is in use.

Figure 5-5 San Clemente Dam Removal Upstream Diversion Structure and Diversion Pipe; Bottom Two Installation Photographs, October 2013; Top Operating Photograph, August 2015

- Install a temporary diversion structure near the upstream extent of work (Station 62+00), similar to that constructed during the San Clemente Dam Removal. The temporary structure would consist of a small earthen berm, driven steel sheet piles resting at grade, and a gated intake. If existing alluvial material prevents the use of sheetpiles, over-excavation or alternative cofferdam approaches will need to be considered. Every winter, the earthen berm would be excavated and stockpiled, and the gated intake removed. The sheet piles would remain in place, allowing winter flows to pass over the piles. The pre-dam alluvium is believed to reside approximately 20 to 30 feet below ground surface at this location, based on comparison of the adjusted 1947 pre-dam surface and 2017 UAS survey, and would be confirmed with geotechnical borings. The ground surface is approximately at elevation 1,050 feet, allowing for a potential 10-foot-tall dam crest to reside at an approximate elevation of 1,060 feet.
    - Install a diversion pipe from the diversion structure (crest elevation 1,060 feet) to the LPD spillway (elevation 1,043 feet), approximately 6,200 feet long (1.2 miles). The available elevation difference is likely sufficient to pass a 97 percent flow exceedance level of mean daily discharges, similar to the downstream San Clemente Dam Removal Project, which installed a 66-inch corrugated metal pipe to accommodate a 230 cfs flow for a May 15 construction start. An average daily flow frequency analysis is recommended for LPD.
    - The diversion pipe may be concrete-encased for rock fall protection; covered to limit water temperature increases if exposed to sunlight; and covered with sediment and secured with anchors to prevent floatation when inundated during winter months. The flow would be discharged to the spillway or into the downstream discharge pool with adequate erosion protection for summer diversions.

Construction Year 2

- Dewater the reservoir (1 month) and reroute river flows for the duration of in-water work.
    - As necessary in this year and the following construction years, install a system of wells, sumps, and trenches to support dewatering of the sediments. Dewatering the Zone 1 sediments will be difficult due to their low hydraulic conductivity and high moisture retention properties. A series of trenches will encourage water accumulation around dewatering sumps, allowing water to be pumped through the dewatering conveyance system. The dewatered fine-grained sediments will be moved and worked for moisture conditioning (discing or windrowing multiple times a day) at the disposal sites.
- Remove Zone 1 and 2 sediments (954,000 CY) (4 months).

Construction Year 3

- Dewater the reservoir (1 month) and reroute river flows for the duration of in-water work.
- Complete removal of Zone 1 and 2 sediments (726,000 CY) (3 months) (Figure 5-6).

Construction Year 4

- Dewater the reservoir (1 month) and reroute river flows for the duration of in-water work.
- Remove the LPD embankment (460,000 CY) (1.5 months) and associated features such as the spillway and low-level outlet (a portion of which is to be protected in place). See Section 5.1.5 for a description of dam removal.
- Construct channel grade-control and habitat restoration features.
- Remove the diversion structure, diversion pipe, and dewatering and treatment system components.

Figure 5-6 Sediment Excavation of Lower Reservoir Sediments, San Clemente Dam Removal, July 2014

Each year, site mobilization would include equipment and material delivery. Site demobilization each year would include diversion structure winterizing, disposal site hydroseeding, and best management practices. All heavy equipment will be moved off site at demobilization.

Although not included in Alternative 2, Zone 3 sediments could be included in the sediment removal volume, assuming the upstream diversion structure is installed near Station 69+00 instead of Station 62+00 to allow for removal of the sediments up to this station. Removing Zone 3 sediment would reduce the likelihood that deposition of stored sediment mobilized following dam removal would aggrade the stream channel and cause flooding. Moving the cofferdam upstream could increase the difficulty in using a sheetpile cofferdam, given the likely coarser substrate. There is a total of 350,000 CY of Zone 3 sediments, of which it is estimated that 200,000 CY could be removed during Construction Year 3 without impacting the schedule. The remaining 150,000 CY of Zone 3 sediments could be removed in Construction Year 4 while the LPD is removed.

The preceding sediment removal timeline is based on the following assumptions:

- Two 10-hour shifts per day, 7 days per week; production rates assume 1 day per week of downtime (e.g. maintenance, weather delays, or inefficiencies)
- 5-month construction season from May 15 to October 15
- 1-month dewatering each season from May 15 to June 15
- 4,500 CY/day per excavator; two excavators used
- An adequate number of trucks used to not cause delay time in loading and transporting
- An adequate number of dozers used at disposal sites to not cause delay time in grading or spreading material

There is a possibility that the contractor could incorporate an additional crew to increase production and decrease the overall construction duration.

5.1.4 Hauling and Sediment Disposal

Excavated material would be disposed of at the following three permanent disposal sites: Sites A, B, and C, as shown on Figure 5-1 and summarized in Table 5-2. Attachment B, Sheets 5 through 8, contain plan and cross section views of each proposed site. Prior to material placements, Disposal Sites B and C would be cleared of trees and vegetation and the topsoil stripped and stockpiled for reuse during site restoration. Site A resides on a terrace below the NMWS (where limited sediments have deposited), and therefore does not require clearing, grubbing, or significant sediment removal prior to use.

Table 5-2 Alternative 2 Disposal Sites A, B, and C

Location	Storage Capacity Cumulative Volume (CY)	Acreage (acres)	Maximum Fill Height (feet)	Proposed Finished Elevation (feet NAVD88)
Site A	107,000	5.1	30	1,042.9
Site B	1,640,000	16.8	120	1,100
Site C	980,000	14.1	120	1,080

Notes:

CY = cubic yards
NAVD88 = North American Vertical Datum of 1988

Because Alternative 2 includes reservoir dewatering, the excavated material will be relatively dry, with the exception of the fine-grained sediments. Zone 1 sediments will be moved and worked for moisture condition (discing or windrowing multiple times a day) at the disposal sites, but they will not delay the material acceptance rate of the disposal sites (the opposite is true in Alternative 3 [Storage Expansion and Dredging], where the disposal site capacity limits the rate of dredging).

Site A is a 5.1-acre site on a terrace on the western side of the reservoir (Figure 5-1, Attachment B, Sheet 6). Site A has a storage capacity of approximately 107,000 CY if filled to the NMWS elevation of 1,042.9 feet. The fill thickness in Site A would be about 30 feet. Because it would be inundated during the winter months, when the reservoir fills between construction seasons, Site A is only anticipated to be used for sediments from the dam embankment removal. Access to Site A would be along the dewatered reservoir sediments.

Sites B and C are downstream of the dam (Figure 5-1). Site B is a 16.8-acre site on a terrace on the eastern side of the canyon, and Site C is a 14.1-acre site on a terrace on the western side of the canyon (Attachment B, Sheet 7). Due to the high height of stockpiles B and C, an exploration and analysis program is recommended to assess the feasibility of the stockpiles. The exploration program would include investigation of the saturated and dried strengths of sediments (Zone 1, 2, and 3 materials). Samples of sediments would have a testing program performed that includes index testing, compaction testing, and strength testing of several samples of Zone 1, 2, and 3 materials. The strength developed from the strength testing is key in assessing the stability of the stockpiles.

In addition, an exploration of the foundation for the stockpiles would be performed. At the feasibility level, the exploration program would consist of at least one line of borings about every 500 feet with at least three to five borings per line. Borings would consist of mud-rotary drilling to rock with rock coring to a depth at least equal to the anticipated height of the stockpile. Samples collected from the borings would be tested for index and strength properties.

After completion of the exploration program, the stability of the proposed stockpiles would be assessed through slope stability calculations of the stockpile and foundation, as well as estimates of the potential seismic deformation for a design seismic event. While movement of the stockpiles after the design seismic event is likely acceptable, deformations should not be sufficient to cause a catastrophic failure of the stockpiles or cause the stockpiles to move so much that they block the Carmel River.

The slopes of the permanent disposal sites are anticipated to be between 2H:1V and 3H:1V and would be protected from erosion by hydroseeding (Attachment B, Sheets 6 and 7). The steeper slopes might require zoning of the disposal sites, with the coarser materials from Zone 2 being placed on the outside of the disposal site and finer materials from Zone 1 and 2 on the inside of the disposal site. Intermediate benches may also be needed, depending on slope heights.

Access to Site B would be along a new access road constructed from the spillway terrace (at an approximate elevation of 1,025 feet), adjacent to the eastern abutment of LPD and the spillway, and down to Disposal Site B at a grade similar to that of the existing road on the embankment dam. This road is necessary because the existing narrow road on the dam crest has a sharp turn, insufficient for the 25- to 30-foot radius required for turning of articulated trucks (Figure 5-7). The new eastern access road would eliminate the need for significant modifications to the dam embankment to allow for a sufficient turning radius, or a longer truck route requiring additional trucking times compounded over numerous years of construction.

Figure 5-7 Articulated Dump Truck, CAT 730

Access to Site C would be from the dam along an access road on the downstream west abutment. The access road would be widened and improved. With the current accumulated sediment estimates, there appears to be enough disposal site capacity (2.7 million CY) to accept all the accumulated sediment (1.9 million CY) if it were removed, as well as the dam embankment material (0.46 million CY – see Section 5.2.5).

5.1.5 Dam Removal

Dam removal would be completed in a single 5-month construction period (between May 15 and October 15). Phased removal of the embankment dam over multiple years is not feasible because it is not possible to safely convey flood flows past the dam without an active spillway.

Removal of the 148-foot-high LPD would require excavation of about 460,000 CY of zoned embankment (DSOD 2015b) for full removal, as shown conceptually in profile on Figure 5-8 and in plan and section on Sheets 1 and 2 in Attachment B. Approximately two-thirds of the excavated embankment materials would be relatively impervious materials that were primarily placed in the downstream portion of the dam. These materials, which were variously described in compaction tests during construction as “sandy soil,” “organic soil,” “sandy loam,” or “sandy organic soil” (Section 2.3.1), would be placed in permanent Disposal Sites B and C. The remaining embankment materials are sand, gravel, cobbles, and boulders that could be placed in Site A. The spillway would be removed in its entirety so as not to pose a health and safety risk to the public. Concrete debris generated during spillway demolition could be buried in the excavated materials at Sites B and C. The intake and outlet structures for the low-level outlet would be demolished, and the 30-inch-diameter outlet conduit would be abandoned by filling with controlled low-strength material or by plugging each end with concrete. The reinforced outlet conduit encasement would be abandoned in place because its removal could destabilize portions of the rock slope in which the encasement was built.

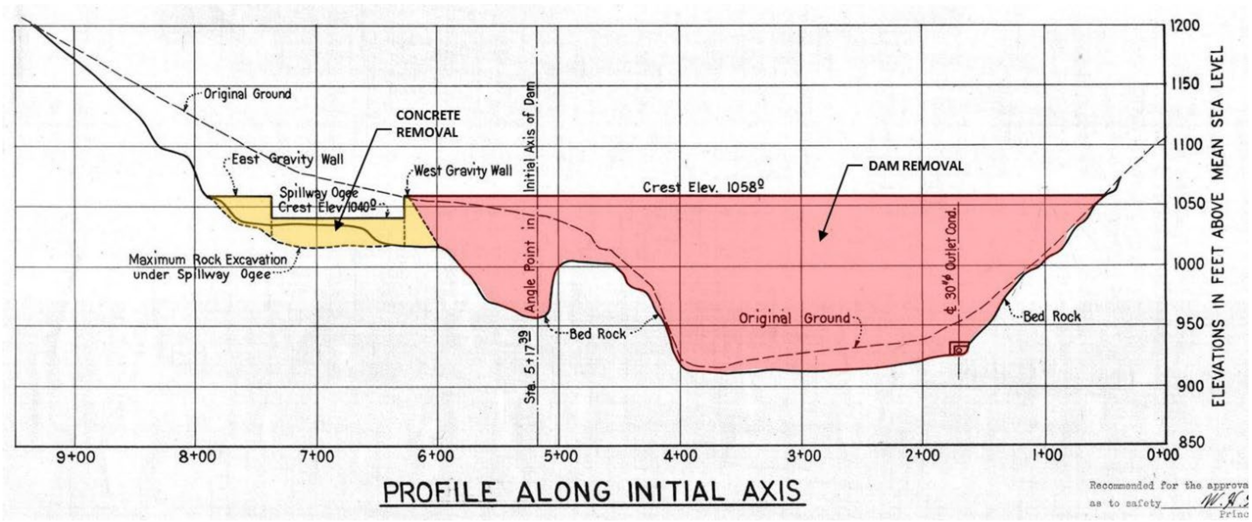

Figure 5-8 Alternative 2 Full Dam Removal Profile (NGVD29)

5.1.6 Operations and Maintenance

Although there would be some level of post-construction monitoring and reporting associated with regulatory permits (likely lasting up to 10 years), there would be no long-term O&M at the site. Post-construction activities associated with regulatory permits could involve maintenance activities related to fish passage, sediment stabilization, and habitat establishment.

5.1.7 Sediment Effects

Alternative 2 would be implemented after the fine sediment in Zones 1 and 2 of LPR is removed via excavation, as described above, or via dredging, so the primary sediment effects associated with Alternative 2 would be due to changes in coarse sediment supply. Alternative 2 would result in a significant increase in bedload sediment supply to downstream reaches, which could have substantial effects on steelhead habitat. With the removal of LPD, bed elevations along channel reaches downstream are generally expected to increase through sediment transport and deposition of primarily coarse sand, gravels, and cobbles (0.5 to 256 mm); this is the expected response because downstream reaches have received less sediment than that found under natural conditions since the dam was constructed. After dam removal, bed aggradation would begin with the first storms that generate runoff capable of mobilizing portions of the coarse sediment wedge in the reservoir. In general, the most rapid rates of aggradation occur with the first several storms following dam removal and taper off into the future years after these events. However, an aggradational signal in reaches most downstream of the dam would be delayed because it takes time for sediment to arrive at these reaches. Redistribution of gravel-sized coarse sediment to reaches downstream of LPD is expected to increase the amount of available steelhead habitat. Sediment supply in the former LPR would decrease rapidly following dam removal, depending on hydrologic conditions.

The BESMo (Appendix D) predicts that, under Alternative 2, roughly 22 feet of aggradation would occur just downstream of LPD following dam removal due to the reintroduction of sediment supply (Figure 5-9). Fining of the bed would occur close to LPR, resulting from the increased supply of relatively fine sediment. Aggradation response lessens downstream, but aggradation up to 9 feet is estimated to occur at the former San Clemente Reservoir backwater zone. Downstream of the former San Clemente Dam, the model predicts up to 13 feet of sediment deposition and a steady decrease in deposition occurring at Hitchcock Creek. Within 10,000 feet upstream and downstream of the Garzas Creek confluence, the model predicts 2 feet of erosion. Downstream of this zone of erosion, the model predicts relatively constant levels of aggradation of up to 5 feet. The model indicated that the redistribution of sediment downstream of LPD under Alternative 2 is likely to occur independently of hydrologic conditions.

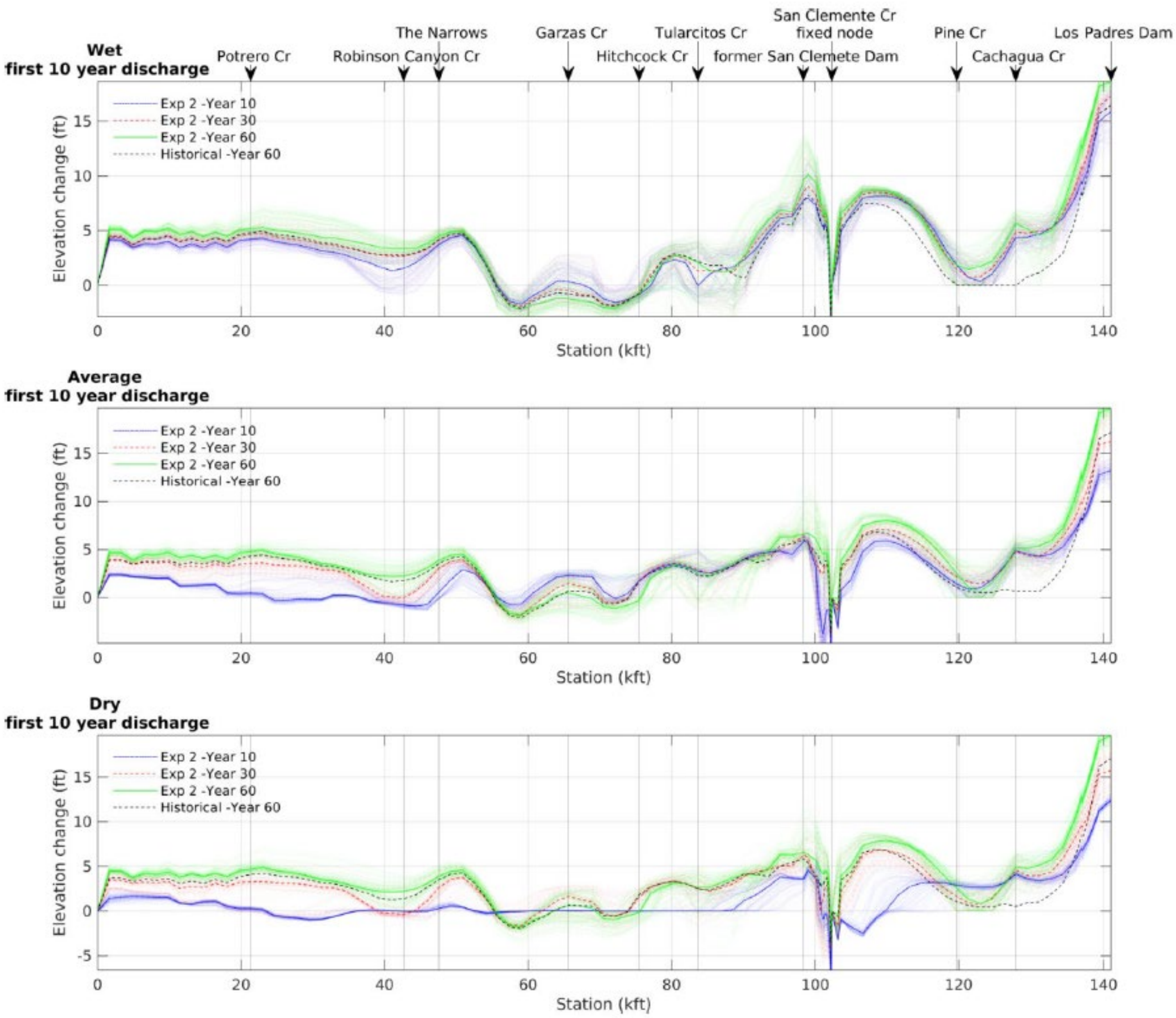

Figure 5-9 Change in Streambed Elevation Predicted for the BESMo Uncontrolled Supply Simulation

Notes:

Top: high, middle: average, bottom: low cumulative discharge in the first 10 years.

The dark lines in each subplot signify the median condition at each node for each of the three time slices and the median for the Historical Supply Scenario at year 60; all other lines represent data from individual model runs.

Under Alternative 2, the bed downstream of LPD is predicted to coarsen as a response to deposition and the resultant increase in bed slope. Only in the results for Year 10 of the dry hydrologic condition does the median grain size just below LPD decrease slightly from its existing size, later coarsening as shown in Years 30 and 60 (Appendix D). Resumption of the historical supply and the addition of accumulated sediment from LPR would prevent the further coarsening of the bed downstream of the former San Clemente Dam. An increase in upstream sediment supply would cause increased sediment mobility and bed mixing. The rapid supply of sediment downstream would alter the current dynamics of the river on a reach scale, including the loss of gravel bars, pools, and riffles; and would enhance sediment supply in low-velocity areas, the floodplain, and backwater areas (Pizzuto 2002). However, areas in the active channel that could temporarily be inundated by sands and small gravels would likely see fining within a relatively short period (i.e., a few years). Upstream of the former dam site, the channel would incise into the Zone 3 sediment upstream of LPD and rapidly redistribute this sediment downstream.

5.1.8 Effects to Steelhead

This section summarizes potential effects to steelhead associated with Alternative 2, initially presented for an earlier formulation of alternatives in Appendix E.

Bedload Sediment Transport

The redistribution of gravel-sized coarse sediment to reaches downstream of the dam and resumption of transport of the annual bedload would increase the quantity and quality of the available steelhead spawning habitat. Short-term impacts associated with Alternative 2 would include a reduction in pool habitat due to sediment deposition. This results in decreased rearing habitat, especially in the summer as pool depths become shallow due to decreased flows. After the removal of the San Clemente Dam, the primary geomorphic response downstream of the former dam was sediment deposition in pools and runs, with limited to no bed-elevation changes in riffles (NMFS 2018). Spawning gravel availability was increased near the former dam site; a loss in suitable spawning habitat occurred farther downstream of the dam, likely due to the transport of finer substrates (Ohms and Boughton 2019). However, in the medium to long term, restoration of annual sediment load would result in increased sediment supply and would benefit steelhead spawning habitat by introducing coarse-sized gravels to gravel-starved reaches downstream of the former dam. The effects of bedload deposition would last weeks or years, depending on the ability of subsequent erosive flows to scour or clean the substrate. For example, pools closest to the dam could be scoured out in 1 to 3 average years, whereas pools farther downstream could take several years to scour out, depending on hydrology. However, bedload supply and transport are vital to the creation and maintenance of functional aquatic habitat. Natural river dynamics include transportation of coarse sediment (e.g., sand, gravel, cobble, and boulder) downstream. The aggradation of the bed and increased sediment supply would increase channel complexity and overbank winter rearing habitat and velocity refugia access, resulting in increased habitat for all steelhead life stages.

Water Availability

During dry periods, releases from LPR typically constitute more than 50 percent and as much as 90 percent of the flow in the river downstream of LPD (Cal-Am and MPWMD 2016). More than 90 percent of the average annual precipitation in the watershed typically occurs between November and April, with the highest rainfall amounts occurring in January and February (Entrix 2008). Inflows to LPR are generally lower for the rest of the year, from May to October. Together, Figure 2-23 and Figure 2-24 show that for a little more than two-thirds of years between 1990 and 2021, inflow to LPR fell below 5 cfs during 1 or more months of the year.

Under Alternative 2, dry season flow releases from LPR would be eliminated and natural daily, seasonal, and annual flow variability would increase. Restoration of the hydrologic function of the Carmel River system under Alternative 2 is predicted to result in an overall decrease in flows during the dry season, and thus a substantial decrease in the quantity of steelhead habitat in the Carmel River downstream of LPD. Drying of the channel during summer months, which currently occurs most years in a portion of the Carmel River downstream of the Narrows (RM 8), is predicted to be extended across a greater length of stream and for a greater duration.

Summer streamflow downstream of LPD would be reduced with implementation of Alternative 2. Based on the CRBHM flow exceedance curves (Figure 3-1 and Figure 3-2), stream flows under Alternative 2 from July through September are predicted to be significantly less than those under other alternatives. During the summer, the absence of releases from LPD is predicted to significantly reduce flows capable of providing suitable fry rearing habitat (>3 cfs) throughout most of the Carmel River downstream of LPD—with most suitable habitat occurring in Reach 2 downstream of the confluence with Garzas Creek (Figure 1-1). Based on the CRBHM model results and IFIM habitat suitability predictions, flows most favorable for juvenile rearing habitat (> 5 cfs) are expected to be greatly reduced across all locations under Alternative 2 (Figure 3-5). At Highway 1, 3 cfs is predicted to be exceeded 12 percent of the time during all water years under Alternative 2 (Figure 3-1), and 4 percent during dry and critically dry years (Figure 3-2). Similarly, 5 cfs is predicted to be exceeded 8 percent of the time during all water years, and 2 percent during dry and critically dry years at Highway 1. This represents a 60 percent reduction in exceedance of 3 cfs during all water years, and a 42 percent decrease in exceedance of 5 cfs, when compared with Alternative 1. Overall, Alternative 2 is predicted to provide the shortest duration of suitable habitat for fry and juvenile steelhead downstream of LPD when compared to other alternatives (Figure 3-7 and Figure 3-8). Lower summer flows associated with Alternative 2 could affect operation of the steelhead-rearing facility at Sleepy Hollow, which requires a minimum flow of 2 cfs in the Carmel River to operate.

Based on the CRBHM flow extent figures (Figure 3-3 through Figure 3-5), under Alternative 2 during in normal water years, approximately 20 miles of the Carmel River downstream of LPD is projected to be wetted (> 0.5 cfs) in the summer, with a substantial increase in dry back predicted in the lower Carmel River (Figure 3-3). This is a 4.5-mile reduction in the predicted length of wetted habitat in the summer under Alternative 2 when compared with Alternative 1. Under Alternative 2, in the summer in normal water years, flows of 3 cfs are predicted to occur in approximately 7.5 miles of the Carmel River, a reduction of 17 miles when compared with Alternative 1 (Figure 3-4). Under Alternative 2, the CRBHM predicts that flows of 5 cfs in the summer of normal water years would not occur in the Carmel River, which is a reduction of 21 miles when compared with Alternative 1 (Figure 3-5).

Low summer flow has been associated with decreased survival of juvenile steelhead (Grantham et al. 2012; Hwan et al. 2017); as juvenile steelhead migrate to the ocean, low flows and high-water temperatures can directly impact downstream mortality and indirectly affect nearshore mortality (Ohms et al. 2021). Overall, the predicted reduction in flow would cause a significant reduction in available fry and juvenile rearing habitat. Additionally, the area prone to dry back is expected to extend farther upstream under Alternative 2 than under other alternatives.

Based on MPWMD-observed densities of steelhead reported in Ohms et al. (2021), the increased dry back could reduce habitat for more than 2,000 rearing steelhead in a normal water year in the lower Carmel River. Figure 2-42 shows the extent of seasonal and perennial rearing habitat, as well as barriers to steelhead migration, in the Carmel River watershed. MPWMD (Christensen, pers. comm. 2021) notes that several tributaries shown in Figure 2-42 as perennial rearing habitat are sometimes dry (or are intermittent) near their confluences with the mainstem Carmel River, including Robinson Canyon, San Clemente, Pine, and Danish Creeks, and maybe Miller Fork, but the map serves as a reasonable approximation of rearing habitat distribution in the watershed.

The lower reaches of the Carmel River support the fastest observed growth of juvenile steelhead, so a decrease in rearing habitat and an increase in dry back in the lower reach could reduce the production of anadromous steelhead in the Carmel River watershed (Ohms and Boughton 2019). Water infiltration in the lower valley would affect adult steelhead returns if LPD is removed; modeling of the effects of changes in streamflow predicted with LPD removal revealed that, if infiltration in the lower valley was low, steelhead returns were slightly higher compared to the historical baseline; and, if infiltration in the lower valley was high, steelhead returns were slightly lower than the historical baseline because production increase in the upper watershed would be outweighed slightly by a smaller wetted area and lower production in the lower watershed (Boughton and Ohms 2022). However, factors other than streamflow that influence steelhead production (e.g., stream temperature, ease of passage through LPR, and substrate composition) were not considered in the model.

Water Temperature

Alternative 2 would eliminate releases from LPR and restore a more natural thermal regime to the Carmel River. Under existing conditions, water temperatures upstream of LPR are generally cooler than locations in and downstream of LPR (MPWMD 2020). Regardless of any action taken at LPD, climate change will likely produce warmer natural stream temperatures, which could further affect rearing habitat downstream of LPD. With the removal of LPD, juvenile steelhead rearing in Reach 1 would have the opportunity to move upstream to locate thermal refugia, and water temperatures immediately downstream of LPD would be cooler than under existing conditions in the summer and fall months. The elimination of warm water releases from LPR would likely decrease water temperatures in downstream reaches; however, the area around the San Clemente Reroute Project is subject to suboptimal water temperatures under existing conditions, likely due to a lack of riparian vegetation. Temperatures in this reach may therefore remain suboptimal until the riparian cover matures (MPWMD 2019).

As discussed in Section 2.6, in some months (e.g., April), water temperatures consistently warm as water moves downstream from LPD, but in other months (e.g., September), water temperatures fluctuate as water moves downstream. Since the removal of San Clemente Dam, summer water temperatures downstream of the former dam site appear slightly cooler, and winter temperatures appear slightly warmer (MPWMD 2020). Similar trends may be observed below LPD following the implementation of Alternative 2 due to the elimination of releases from LPR.

The effects of the removal of LPD on water temperature would likely be most beneficial in the reach just downstream of LPD, where, under existing conditions, water temperatures are currently suboptimal for rearing steelhead. This reach would benefit from a more natural thermal regime, providing benefits to rearing steelhead by providing optimal water temperatures. Dam removal would also provide juvenile steelhead currently downstream of LPD access to the cold, perennial flow upstream of LPR providing an important cold-water refugia for fish that currently do not have access to upstream habitat. Although the removal of LPD would result in a more natural thermal regime in the Carmel River, resulting in cooler water temperatures in the reaches just downstream of LPD, and access to upstream cold-water refugia, the reduction in flow in the summer months would likely result in an overall decrease in rearing habitat downstream of LPD when compared with existing conditions.

Fish Passage

Alternative 2 would result in fully volitional upstream and downstream passage for all steelhead life stages, increasing the likelihood of successful passage to the upper and lower watershed. Under existing conditions, LPD currently impedes the upstream migration of adult steelhead and the downstream migration of juvenile steelhead from the upper watershed. Additionally, LPD completely blocks the upstream movement of juvenile steelhead to the upper watershed, preventing access to suitable rearing habitat, and especially to cool water that would offer thermal refugia during late summer and fall.

Based on a review of trap-and-haul programs, Lusardi and Moyle (2017) concluded that trap and haul can be a successful conservation strategy for anadromous salmonids, but the process can cause substantial levels of stress to steelhead, which can lead to increased pre- or post-spawn mortality of adult steelhead. Adult and juvenile fish have been observed using the spillway to migrate downstream, which has been shown to cause a migration delay in juveniles (Ohms et al. 2022) and presumably results in a greater occurrence of injury than under a no-dam condition (Boughton 2016). Compared with fish passage facilities and conditions under other alternatives, Alternative 2 would provide the safest and most effective fish passage opportunities for all life stages of steelhead in the Carmel River watershed.

Dam removal and restoration of the stream channel currently inundated by LPR would provide roughly 14.4 additional RMs of habitat for juvenile steelhead and resident *O. mykiss* whose access was blocked by LPD (Becker et al. 2010). The Carmel River upstream of LPR provides drought refugia to rearing steelhead. If steelhead were able to access this refugia habitat during drought years, it would increase the resiliency of the Carmel River steelhead population, especially during a warming climate. LPD currently interrupts the thermal regime of the Carmel River, resulting in suboptimal water temperatures downstream of the dam and a cold-water habitat upstream of LPR, which is inaccessible to steelhead rearing downstream of LPD. Willis et al. (2021) suggests that improving passage to juvenile salmonids or full dam removal are critical to reconnect species with the thermal regimes in which their life-history strategies originally evolved.

A wide distribution within a watershed is a critical element of steelhead population resiliency because it reduces the susceptibility of the population to catastrophic disturbance in one portion of the watershed (Lindley et al. 2007; Reeves et al. 1995). Currently, juvenile steelhead rearing downstream of LPD do not have access to habitat upstream of LPR. Instead, under present conditions, Carmel River downstream of LPD is subject to warming from LPR, in a pattern similar to many managed watersheds in California (Willis et al. 2021). Dam removal under Alternative 2 would increase the resiliency of the steelhead population in the watershed by increasing unimpeded volitional passage, especially for juveniles. LPR currently has deleterious effects on downstream-migrating juvenile steelhead, with a large proportion of downstream migrants “lost” while migrating through the reservoir (Boughton et al. 2020; Ohms et al. 2022). The removal of LPD would eliminate the reservoir and increase the likelihood of successful downstream passage of juvenile steelhead.

It is speculated that LPR likely supports a population of adfluvial steelhead, in which steelhead migrate between stream and lake (reservoir) habitats to complete their life-history requirements (CDFG 1995; Leitwein et al. 2016). The elimination of reservoir habitat would prohibit an adfluvial life-history strategy for the current population, and individuals would either exhibit a resident or anadromous life history. Based on PIT tag monitoring data to date (Ohms et al. 2022), the likely result would be an increase in anadromous smolt production from the upper watershed.

Construction Effects

Construction of Alternative 2 would require dewatering of LPR and bypassing inflow downstream of LPD through a diversion pipe for four construction seasons (May 15 through October 15). This would eliminate flow augmentation from LPR to the lower Carmel River, also one of the long-term effects of Alternative 2 described above. While there may be some risk of water temperatures increasing as streamflow passes through the diversion pipe, assuming this was addressed during design of the bypass, water released downstream of LPR would be closer to the temperature typical of reservoir inflows and would not be warmed during retention in LPR. Fish would be excluded from the bypass pipe and fish passage would not occur during the construction seasons.

Habitat Quantity

Although dam removal and elimination of water storage and dry-season release would reduce water availability, and therefore rearing habitat in the lower Carmel River (as described above), restoration of the portion of the Carmel River currently within the footprint of LPD and LPR would restore former steelhead habitat. Alternative 2 would include full restoration, either active or passive, of the Carmel River from downstream of LPD to the upstream-most extent of Zone 3 accumulated sediments. This includes the following stream restoration areas:

- Roughly 1,000 feet, from the confluence of the outlet channel (below LPD) and the Carmel River, upstream through the dam to the downstream extent of the reservoir pool.
- Roughly 4,500 feet of current reservoir pool (measured along the thalweg) that would be actively restored to stream channel.
- Roughly 4,500 feet of stream channel upstream of LPR that lies within the original reservoir footprint but is currently buried under accumulated sediment would be restored to its original grade following dam removal through a combination of active restoration (downstream 2,000 feet) and passive restoration (natural geomorphic processes; upstream 2,500 feet).

Based on these estimates, roughly 5,500 feet of steelhead habitat would be created and 4,500 feet improved through restoration of the LPD and LPR footprint. Upstream of LPR, the Carmel River flows perennially and has cold water year-round, based on monitoring data collected by MPWMD and presented in Section 2.6 as well as anecdotal observations. Restored habitat would provide spawning and year-round rearing habitat for steelhead. Restoration of the original elevation and grade of the channel upstream of the current pool, where it is currently buried under accumulated sediment, would likely bring the stream channel closer to groundwater and increase surface flow though this reach during the dry season (because surface flow tends to percolate down into accumulated sediments). In addition to the increase in habitat associated with this restoration, as discussed above, removal of LPD would open the restored habitat and the entire upper watershed to juvenile steelhead spawned elsewhere in the Carmel River watershed, where they would have reliable refuge from heat and drought.

Summary

During construction, Alternative 2 would eliminate dry-season flow augmentation from LPR to the lower Carmel River and interrupt fish passage, but temperatures would be closer to stream temperatures upstream of LPR than typical reservoir releases. Restoring natural sediment transport under Alternative 2 would result in an overall increase in the amount of suitable spawning gravel downstream of LPD when compared with Alternative 1. Alternative 2 would also have impacts to steelhead habitat, resulting from increased bedload movement from upstream of LPD in the short term, including the loss of pool habitat due to bedload deposition. However, this effect would be short-lived and, in the long term, Alternative 2 would increase channel complexity and limited overbank habitat connectivity, resulting in an increase in stream habitats that support steelhead fry and juvenile rearing.

Although instream habitat complexity would increase under Alternative 2, the loss of summer flow releases from LPR is predicted to result in a substantial decrease in flows capable of providing adequate rearing habitat for steelhead—and a substantial reduction in wetted stream, especially during dry years. Dry season diversions by riparian and appropriative water rights holders throughout the watershed likely reduce flow to the main stem that would otherwise provide summer rearing habitat.

Of all the project alternatives, Alternative 2 provides for the safest and most efficient steelhead upstream and downstream passage, providing fully volitional upstream and downstream passage for all life stages of steelhead. Adult upstream migration would be unimpeded by LPD and could result in the passage of more adult fish to the upper watershed when compared to other alternatives. Additionally, juvenile steelhead mortality currently presumed to occur under existing conditions in LPR would be significantly reduced after the removal of LPD. Juvenile downstream migrants would experience less predation and mortality than under the other alternatives, resulting in a potential increase in smolt production in the Carmel River, which would better support an anadromous life history.

Alternative 2 would also increase the amount of habitat for steelhead and resident *O. mykiss* through the restoration of roughly 10,000 feet of the Carmel River within the footprint of LPD, LPR, and accumulated sediment. Additionally, juvenile steelhead and resident *O. mykiss* rearing downstream of LPD would be provided year-round access to the restored habitat and the upper watershed, which currently provides suitable rearing habitat and optimal temperatures for rearing steelhead throughout the year.

5.1.9 Uncertainties

Key uncertainties associated with Alternative 2 include the following:

- Based on ongoing planning and design processes for other dam removal projects in California, mitigation for the potentially increased flood risk due to increased transport of bedload to the lower Carmel River could be required as part of the environmental compliance or regulatory approval process for dam removal.
- It is uncertain whether current water rights agreements can be renegotiated as part of dam removal. Currently, Cal-Am is required by SWRCB Order 95-10 to divert flow under all of its Carmel River water rights at the wells farthest downstream. When Order 95-10 is lifted, it is unknown how SWRCB will interpret Cal-Am's future water rights, what conditions might be placed on future rediversions of releases from storage, and what effect this will have on the water supply for the Monterey Peninsula. An MOA among Cal-Am, NMFS, and the California State Coastal Conservancy requires that Cal-Am obtain approval from SWRCB for a change in method and place of diversion under License 11866 prior to dam removal, such that Cal-Am's right to divert water is protected in the absence of LPD (NMFS 2017). Discussion with SWRCB is necessary to address this uncertainty and understand the process and timing of negotiations.
- Conceptual or planning-level alternatives are uncertain by nature, given the typical lack of sufficient design parameters and analysis available during the planning phase. Although this TM strives to address key uncertainties related to feasibility and cost, additional investigation, analysis, and design are needed to adequately address the uncertainty. Design and construction uncertainties are addressed to some extent in the OPCC estimates provided herein, through the use of design and construction contingencies (see Section 6). Key assessments or investigations to help address uncertainties related to design and construction of this alternative are listed below:
    - To confirm the approach provided herein, a detailed assessment must be completed of the public road improvements that may be required to accommodate construction traffic.
    - An assessment of potential passage issues at the transition zone between the proposed sediment removal and the remaining Zone 3 sediments is needed to reduce uncertainties associated with passage to the upstream river channel. An adaptive management plan will

likely be needed to address temporary passage impediments that may develop during the regulatory monitoring period in this area.

- Additional onsite geologic assessment and geotechnical investigation may be required during detailed design to confirm the extent of improvements required for the temporary onsite access roads proposed for sediment access and hauling.
- Additional onsite geologic assessment and geotechnical investigation may be necessary during detailed design to confirm final geometry and stability of the disposal site grading.
- Additional onsite geotechnical investigation will be required during detailed design to confirm the feasibility of using a sheetpile cofferdam for river diversion.
- Additional assessment of likely dewatering requirements, given the local geology and groundwater, should be completed during detailed design.
- This TM assumes a fairly proactive restoration, involving hydroseeding and planting for a variety of habitat types, along with associated irrigation. This approach should be discussed with appropriate regulatory agencies to see if a less proactive approach may be permittable.

5.1.10 Advantages and Disadvantages

Advantages and disadvantages associated with Alternative 2 are discussed in this section, organized by the following categories: Local Impacts, Water Supply, Flooding, Geomorphology, Biological, Water Rights, and Regulatory.

Local Impacts (Traffic and Noise)

- **Advantage:** Equipment mobilization, material on-haul, and construction worker commuting traffic for Alternative 2 would be less disruptive to local traffic than under Alternatives 1 (Fish Passage, No Sediment Action), 3 (Storage Expansion and Dredging), and 5 (Recover Storage Capacity with Sluice Tunnel) due to the fact that there is a relatively small amount of material that needs to be brought on site for Alternative 2, compared to the large volume of material required for the dam embankment raise associated with alternatives that leave the dam in place. Similar to all of the other alternatives, small improvements may be required along public roads (see Section 5.1.2) to accommodate construction traffic, which would cause additional disruption.

- **Advantage:** If Cal-Am prefers not to continue with ownership of the property surrounding LPD and LPR following dam removal, the adjacency of public land managed by the USFS and the Monterey Peninsula Regional Park District may favor conversion of the property to public ownership following dam removal. For example, Cal-Am has agreed to transfer the land at the former San Clemente Reservoir site to the United States Bureau of Land Management at some point in the future.

Water Supply

- **Disadvantage:** Due to the loss of storage associated with LPR, Cal-Am would lose the ability to store water at this facility for any purpose, including in support of surface flow and pumping in the lower river.

Water Rights

- **Disadvantage:** Alternative 2 may lead to the termination of Cal-Am's License 11866 and an amendment to several water rights orders (Orders WR 95 10, WR 2009 060, and WR 2016 0016). Cal-Am's current water right—allowing for diversion of 2,179 AFY to LPR and requiring that at least 5 cfs be released directly below LPD at all times during which water is being stored in the reservoir—could also be terminated. Discussions with SWRCB are needed to investigate the possibility of modifying the referenced agreements to relocate the legal point of diversion to downstream of LPR and maintain water rights.

Geomorphology

- **Advantage**: Restoring natural sediment transport under Alternative 2 would result in an overall increase in the amount of suitable spawning gravel downstream of LPD when compared with Alternatives 1 (No Sediment Action)(Fish Passage, No Sediment Action), 3 (Storage Expansion and Dredging), and 5 (Recover Storage Capacity with Sluice Tunnel). Although increases of spawning gravel have not been seen as a result of the removal of San Clemente Dam, Smith et al. (2021) suggested that this was likely due to the trapping capacity of LPD. Alternative 2 would also have impacts to steelhead habitat, resulting from increased bedload movement from upstream of LPD in the short term, including the loss of pool habitat due to bedload deposition. However, this effect would be short-lived; in the long term, Alternative 2 would increase channel complexity and limited overbank habitat connectivity, resulting in an increase in stream habitats that support steelhead fry and juvenile rearing.

Flooding

- **Disadvantage:** The return of the historic sediment load would increase deposition, and associated flood risk, throughout the downstream river relative to Alternatives 1 (Fish Passage, No Sediment Action) and 3 (Storage Expansion and Dredging). However, deposition would be slightly less pronounced than under Alternative 5 (Recover Storage Capacity with Sluice Tunnel) because Alternative 2 includes removal of sediment in Zones 1 and 2 prior to dam removal, while Alternative 5 sluices material from Zones 1 and 2 downstream. Once potential flood effects are fully understood, feasible mitigations (e.g., strategically placed flood walls or stream crossing retrofits) are likely available should they be needed.

- **Advantage:** The risk of a dam breach failure, and associated downstream flooding, would be eliminated via removal of the dam.

Biological

- **Advantage:** Alternative 2 provides for the safest and most efficient steelhead upstream and downstream passage, providing fully volitional upstream and downstream passage for all life stages of steelhead. Adult upstream migration would be unimpeded by LPD and could result in the passage of more adult fish to the upper watershed when compared to Alternatives 1 (Fish Passage, No Sediment Action), 3 (Storage Expansion and Dredging), and 5 (Recover Storage Capacity with Sluice Tunnel). Additionally, juvenile steelhead mortality currently presumed to occur under existing conditions in LPR would be significantly reduced after the removal of LPD. Juvenile downstream migrants would experience less predation and mortality than under the other project alternatives, resulting in a potential increase in smolt production in the Carmel River, which would better support an anadromous life history.

- **Advantage:** Alternative 2 would increase the amount of habitat for juvenile steelhead and resident *O. mykiss* rearing in the Carmel River through the restoration of approximately 10,000 feet of stream habitat in the footprint of LPR, LPD, and accumulated sediment. Additionally, juvenile steelhead and resident *O. mykiss* rearing downstream of LPD would be provided year-round access to the upper watershed, which currently provides suitable rearing habitat and optimal temperatures for rearing steelhead throughout the year.

- **Advantage:** Alternative 2 would restore a natural thermal regime to the Carmel River downstream of LPD.

- **Advantage:** The biological and geomorphic benefits described above would be maintained in perpetuity through natural processes and would not require the ongoing political will, capital, or labor associated with benefits conveyed via managed fish passage or managed sediment transport operations associated with dam-in alternatives.

- **Disadvantage:** Due to the loss of storage associated with LPR, Cal-Am would lose the ability to store water at this facility for any purpose, including summer releases to enhance rearing habitat and passage. This would result in a substantial decrease in flows capable of providing adequate rearing habitat for steelhead—and a substantial reduction in wetted stream, especially during dry years. This disadvantage would be partially offset by restored channel within the footprint of LPD and LPR, as described above, and could be further offset if Cal-Am developed alternative water supplies that allowed reduction of pumping beyond CDO requirements. However, water users on the Monterey Peninsula already pay among the highest rates in the nation (Food & Water Watch 2016). Alternative water supplies may currently be 40 times more expensive than Carmel River water (Christensen, pers. comm. 2022), and could continue to increase.

- **Disadvantage:** Construction effects (no dry-season flow augmentation and interrupted fish passage for four construction seasons) would be more severe than Alternative 1 and Alternative 5 but would be less severe than Alternative 3.

Regulatory

- **Advantage:** Current regulatory requirements associated with the dam would be renegotiated during the permitting process. Long-term regulatory involvement and oversight would be limited to post-construction monitoring and reporting, likely extending up to 10 years following construction. DSOD regulatory requirements would also be eliminated following dam removal.

5.2 Alternative 3 – Storage Expansion and Dredging

This section describes Alternative 3, which includes both dredging accumulated sediments to recover lost reservoir storage, and increasing the maximum storage at LPR by installing operable gates in the spillway to allow for a higher NMWS. Maximum storage would be achieved by implementing this alternative as described here, but either dredging or the spillway gates could be implemented alone, with smaller gains in reservoir storage. As discussed in Section 7.3, the TRC and stakeholders have not reached concurrence on whether to include the spillway gates in Alternative 3.

5.2.1 Overview

Under Alternative 3, storage capacity of LPR would be increased through a combination of the following:

1. The existing spillway would be modified by installing pneumatically actuated gates (also referred to as rubber bladder gates) on the existing spillway crest, adding 625 AF in reservoir storage.
2. To accommodate the updated HMR 58/59 PMF with the new spillway gates in the lowered position, the spillway walls and the embankment dam would be raised.
3. Removal of the majority of Zones 1 and 2 sediments, and partial removal of Zone 3 sediments, would be performed through wet dredging methods, allowing water to remain in the reservoir during sediment removal. Dredging would add 1,168 AF in reservoir storage (1,113 AF attributed to dredging below NMWS and 55 AF attributed to dredging above NMWS and below the new gated elevation of 1,052.5 feet). Dredged material would be disposed of at Sites B and C; coarser material from Zone 3 would be placed at Sites D and E, where it would be eroded over time and reenter the river system. Because there is more coarse material than there is space for at Sites D and E, there is sufficient coarser material volume to also supply the embankment dam raise, should the material meet the embankment fill specification.

Once construction is complete, the proposed spillway gates could be raised toward the end of the precipitation season, when the risk of large storms has passed but there is sufficient flow in the Carmel River that water could still be captured and stored for release later during the dry portion of the year.

Figure 5-10 shows an overview of Alternative 3 activities for installing the rubber bladder gates, raising the embankment dam, and removing the accessible sediment. Access to the accumulated sediment for removal would be via barge.

Because the dam would remain in place, spillway and dam embankment improvements are required to pass the updated PMF, and fish passage improvements are required to meet the existing MOA with NMFS and the California State Coastal Conservancy (see Section 1.3.3). However, the fish passage improvements were developed based on existing conditions and infrastructure. The dam, spillway, and infrastructure improvements, in addition to the associated operational changes, outlined in this section for Alternative 3 may require changes in the fish passage improvement alternatives and associated costs.

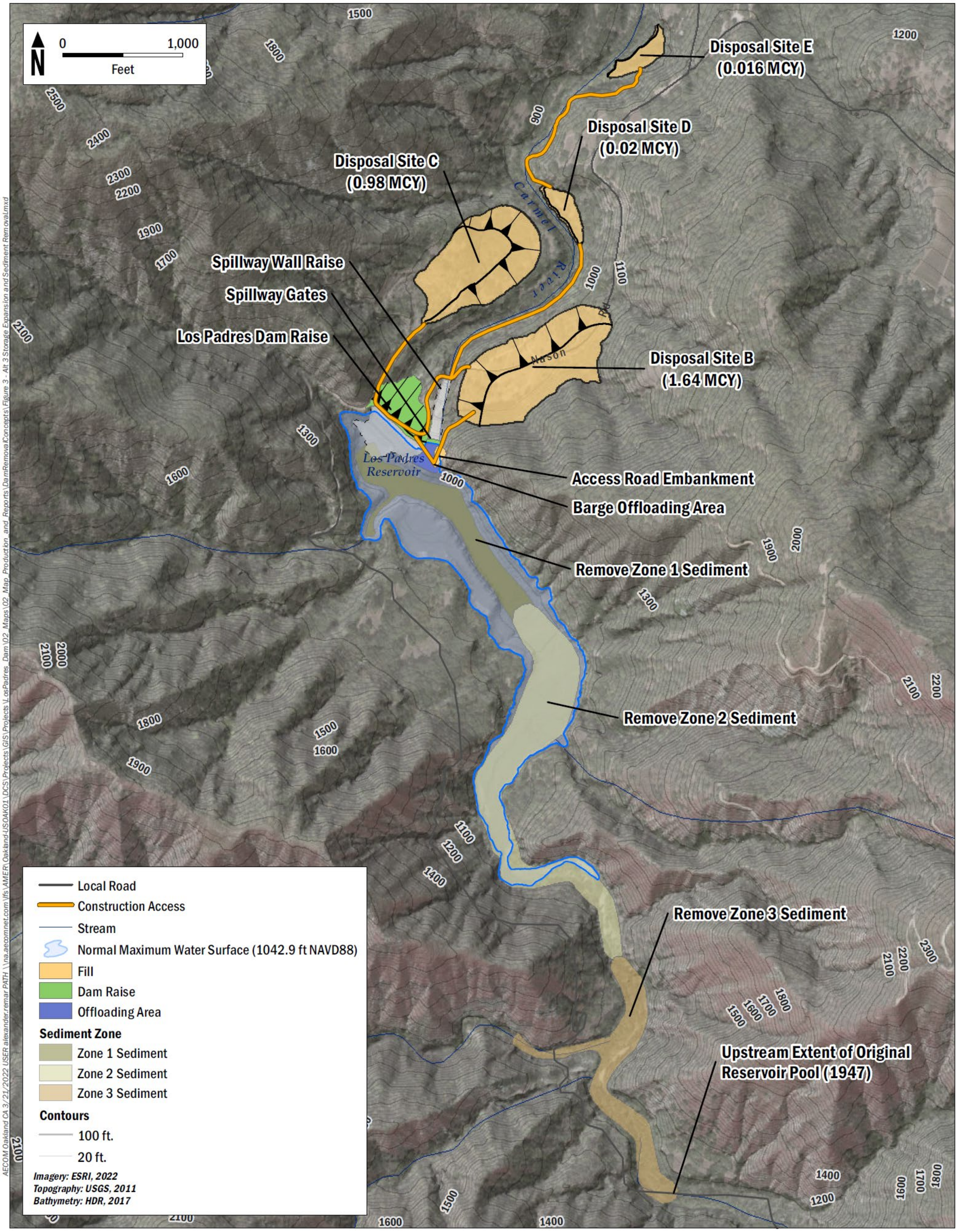

Figure 5-10 Overview of Alternative 3 (Storage Expansion and Dredging)

5.2.2 Access Improvements

All access improvements described in Section 5.1.2 for Alternative 2 (Dam and Sediment Removal), apply to Alternative 3, with the exception of the access road on the reservoir sediments to the upstream extent of the project area. Alternative 3 assumes that the reservoir will retain water during sediment removal, and the sediment will be accessed via barge. Development of an offloading area would use the existing terrace on the reservoir side of the spillway crest. Some grading and added base material may be required.

In addition, temporary access for sediment disposal at Sites D and E is proposed in the existing river floodplain for initial site clearing, grubbing, and grading to increase the flooding frequency and coarse sediment mobilization from these sites. Ideally, this temporary access would stay outside of critical habitat areas and would require limited grading or temporary gravel base. If the habitat impact of the temporary access roads outweighs the benefits of sediment mobilized from Sites D and E, material may alternatively be pushed off Nason road down toward the sites to mimic a natural debris slide, with the understanding that less frequent mobilizations may occur without initial grading.

5.2.3 Fish Passage Improvements

The fish passage improvements described below were conceptualized for LPD and LPR in their existing configuration (HDR et al. 2021), without the improvements associated with Alternative 3. Analysis presented in this report assumes that once a preferred alternative has been selected, if it retains LPD, one of the preferred upstream and downstream fish passage concepts developed previously will be adapted to that preferred alternative. Two upstream and two downstream fish passage options were identified as preferred or warranting additional consideration (HDR et al. 2021). Those passage options are summarized below. Additional detail and evaluation are available in the draft Fish Passage Feasibility Report for LPD. Like cost information for the dam, reservoir, and sediment management alternatives, cost information for the fish passage options is summarized in Section 6.

Upstream Passage

This section describes the two upstream fish passage options identified for further consideration (HDR et al. 2021). Both options would provide upstream passage for adult steelhead but would not provide upstream passage for juveniles. Upstream fish passage option U1, Technical Fish Ladder – Adult, consists of a concrete fish ladder traversing the right riverbank, adjacent to the spillway (Figure 5-11). The fish ladder would be cut into hard rock to avoid potential geotechnical issues associated with the left bank or modification of the earthen dam. Given the elevation difference between the reservoir and tailrace, the fish ladder would likely run parallel to the Carmel River and may require several directional changes to traverse the potential rise, while minimizing the footprint. The fish ladder would likely be a pool-and-weir type, with a central v-notch to operate at low flows (i.e., 3 through 30 cfs), if needed to conserve water releases from the reservoir and to accommodate targeted biological objectives and site-specific characteristics. A vertical slot baffled section of fish ladder would be present at the exit to accommodate the anticipated range of reservoir fluctuations that may be experienced during the period of adult migration.

Upstream fish passage option U8, Trap and Transport – Replace (Figure 5-12), replaces the existing trap-and-transport facility with a newer facility designed to contemporary standards, sized to accommodate the future recovery levels of steelhead in the Carmel River, and formulated using state-of-the-science project elements (HDR et al. 2021). In general, fish would be attracted to a fish ladder entrance; they would enter a short section of fish ladder that leads to a small transition pool; they may pass into or be lifted into a large holding gallery; they would pass over a false weir into a transport flume; and, ultimately, they would be conveyed into a holding tank or tanks until transferred into a transport vehicle and driven upstream to the reservoir.

Downstream Passage

This section describes the two downstream fish passage options identified for further consideration (HDR et al. 2021). Downstream fish passage option D1, FSC, includes implementation of a full-scale FSC with pumped attraction flow, a screened collection inlet, and the ability to collect out-migrating steelhead throughout a wider range of reservoir water surface elevations. The new FSC would float in the main body of the reservoir just upstream of the spillway forebay to take advantage of better orientation and depth in the reservoir (Figure 5-13). Full-depth guide nets would narrow the effective collection area in front of the FSC and guide fish to the collection inlet. The floating barge of the FSC would fluctuate vertically with changes in reservoir stage for an approximate range of 45 feet.

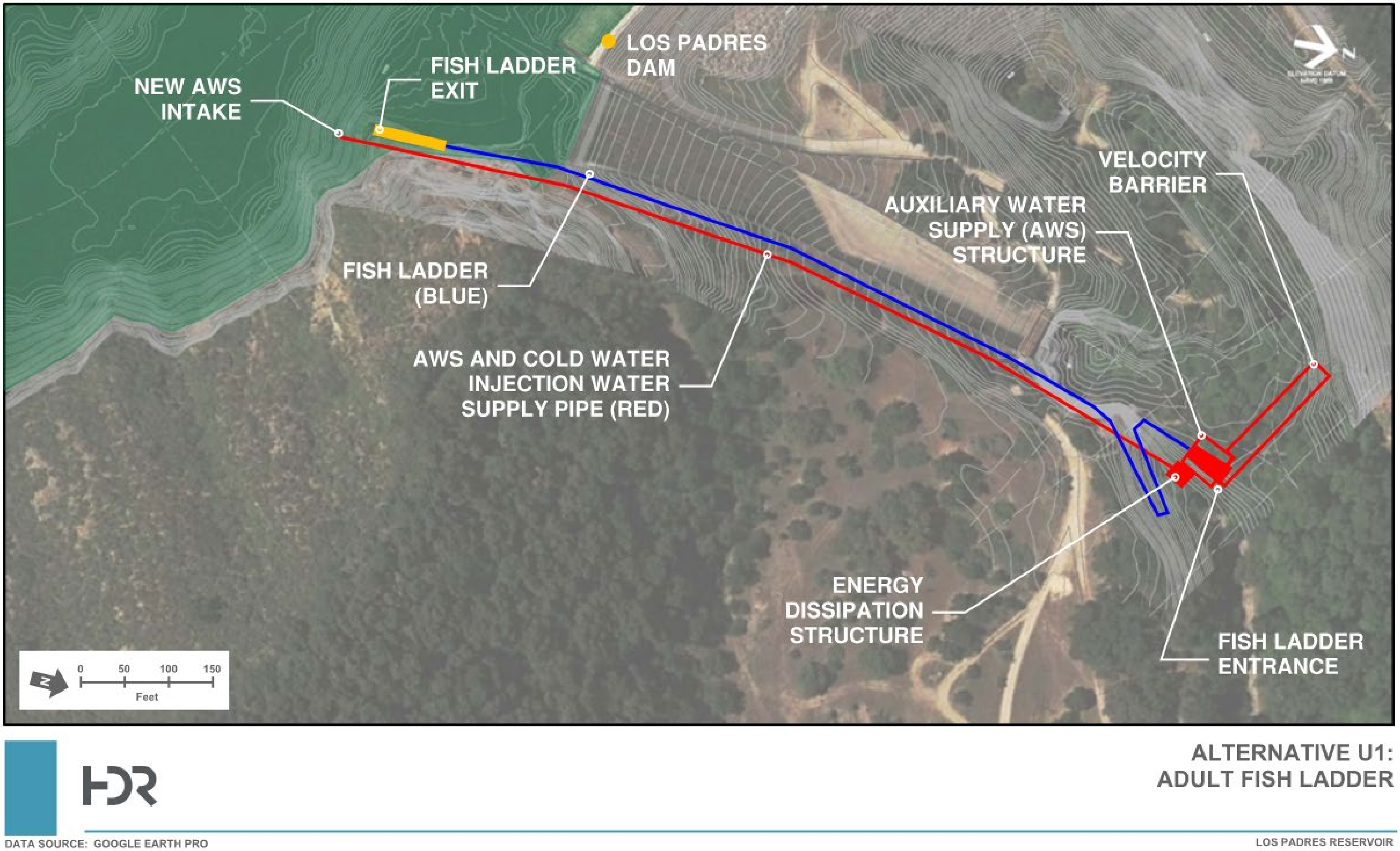

Figure 5-11 Upstream Fish Passage Option U1, Technical Fish Ladder – Adult (from HDR et al. 2021)

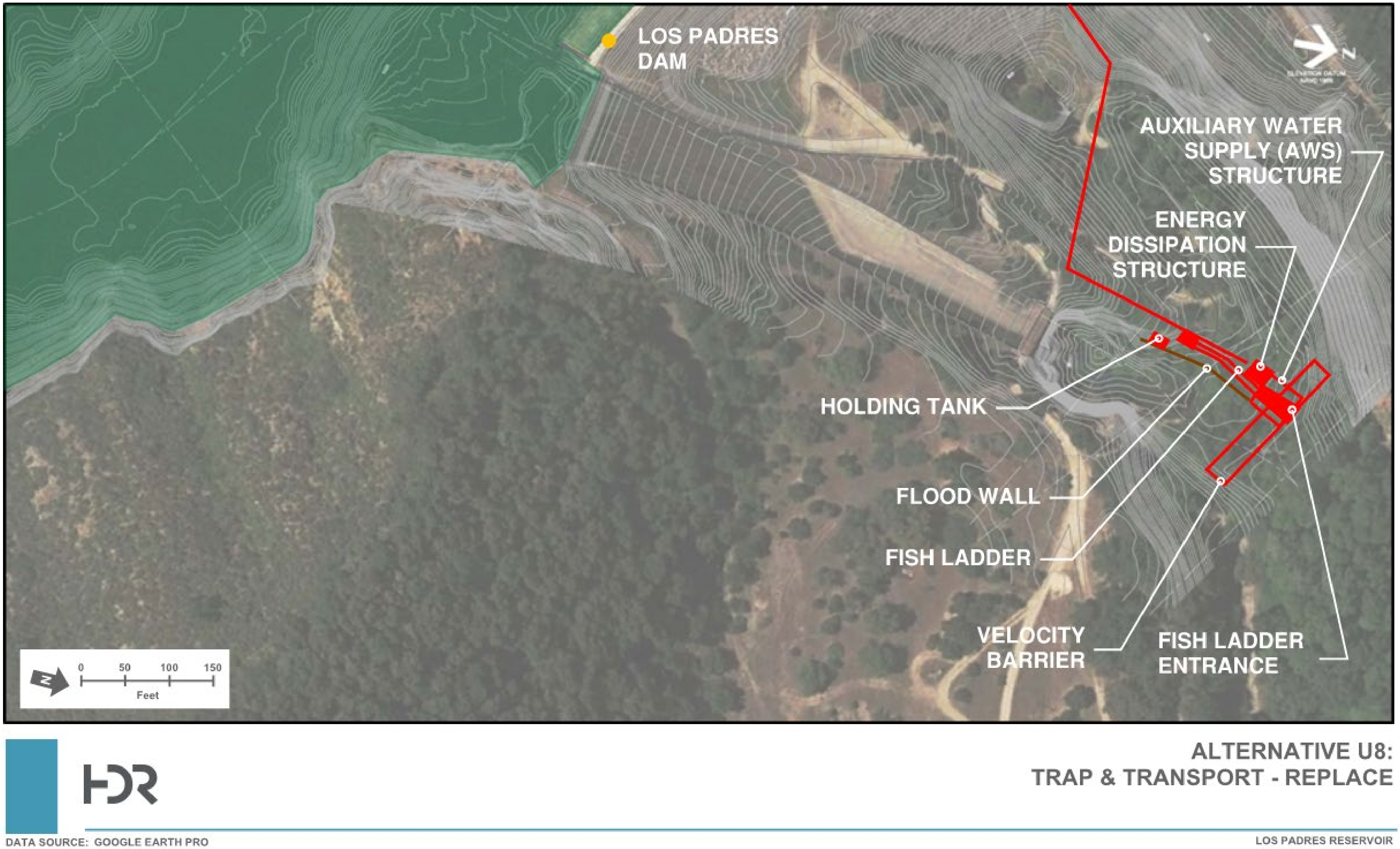

Figure 5-12 Upstream Fish Passage Option U8, Trap and Transport – Replace (from HDR et al. 2021)

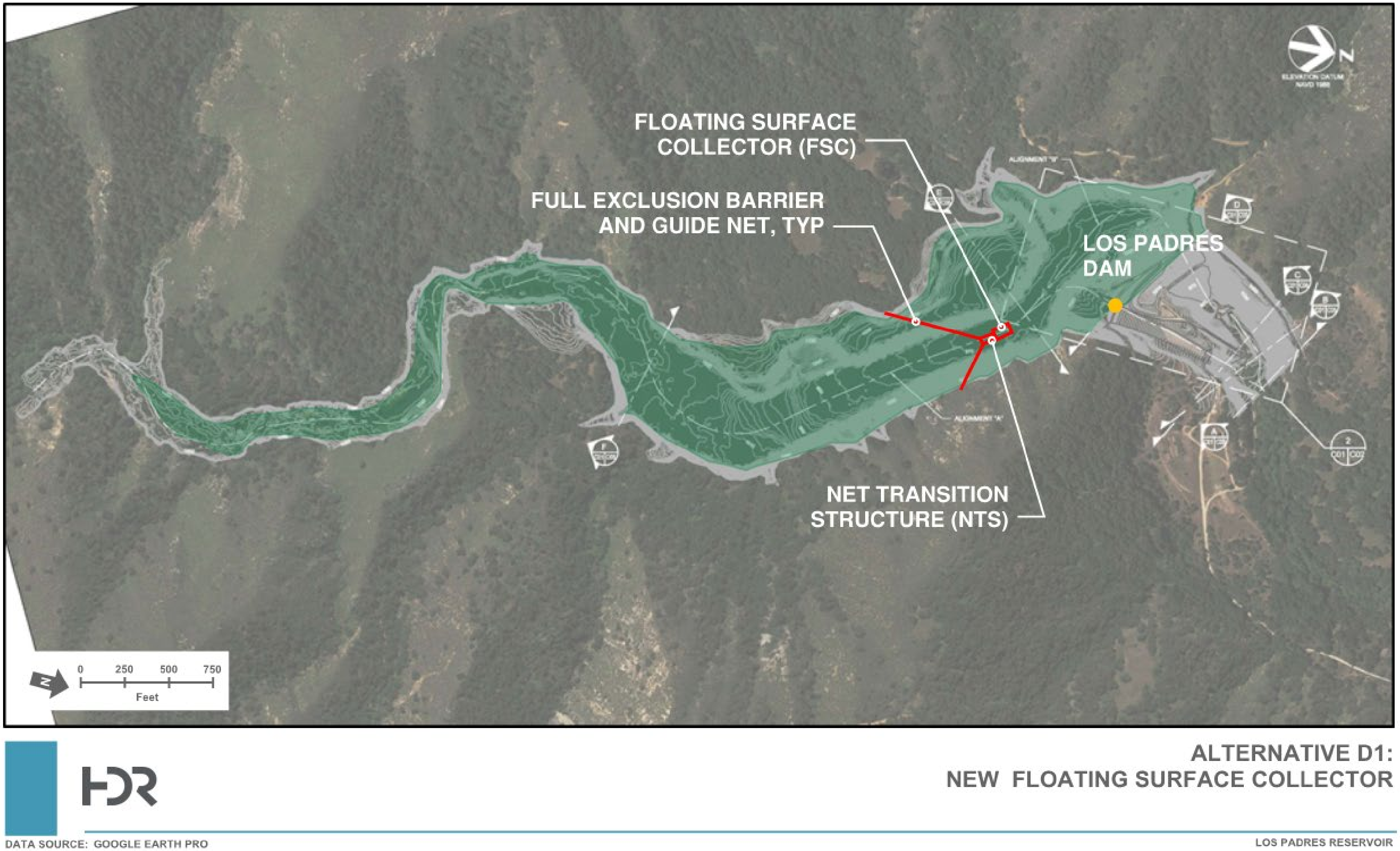

Figure 5-13 Downstream Fish Passage Option D1, FSC (from HDR et al. 2021)

Downstream fish passage option D8, Spillway Modification and Existing FWC with 30 cfs Attraction Flow, includes a passage slot that would be cut at the spillway crest to provide a larger opening for safe entrance and passage, with the implementation of an adjustable crest gate to control depth and flow through this slot (HDR et al. 2021). A passage channel would be constructed along the right wall of the spillway, providing safe passage to the existing tailwater pool. Modifications would also be made to the tailwater pool to improve safety during transition from the passage channel. In addition, the existing FWC would be modified to improve attraction to the entrance of the collector inlet. Improvements include additional floatation and modifications to the transition pool, with screens and a pumped flow array that could accommodate a pump-back rate up to 20 cfs. This would provide a total attraction flow of up to 30 cfs, and a targeted gravity bypass flow of 10 cfs.

5.2.4 Spillway Modifications

Pneumatically actuated spillway gates would be installed on the spillway crest to raise the NMWS elevation by 9.6 feet, to elevation 1,052.5 feet. This would increase the maximum storage capacity of the reservoir by 625 AF, from 1,601 AF to 2,226 AF. Additional storage capacity could be provided via sediment removal, as discussed in Section 5.1.7. The gates could be raised toward the end of the precipitation season when the inflow would still be adequate to allow downstream release concurrent with an increase in storage. The gates would be left up throughout the dry season, and lowered prior to any significant storm event. Views of an example pneumatically actuated spillway gate structure installed in the Nacimiento Dam concrete spillway are shown on Figure 5-14, Figure 5-15, and Figure 5-16. Installation of the gate structure would require modification of the existing concrete spillway to provide a flat concrete base on which to install the gates, and to maintain spillway capacity when the gates are lowered.

Figure 5-14 Pneumatically Actuated Spillway Gate at Nacimiento Dam (Construction – from Upstream Reservoir Side)

Figure 5-15 Pneumatically Actuated Spillway Gate at Nacimiento Dam (Construction – from Downstream Spillway Side)

Figure 5-16 Pneumatically Actuated Spillway Gate at Nacimiento Dam (Gates Down – Post-Construction)

To accommodate the proposed 9.6-foot-high spillway gate at LPD, a portion of the concrete ogee spillway crest would be removed and then reconstructed to provide a flat concrete base (see Figure 5-17 and Sheet 4 in Appendix B). Due to the dimensions of the gate panels, the spillway crest would also be extended approximately 12 feet into the reservoir. Similar to the existing spillway crest, the extended crest would be founded on bedrock. Care must be taken in the next phase of design to ensure that the overall width of the spillway crest does not change the spillway discharge coefficient (e.g., going from an ogee spillway to a broad-crested weir).

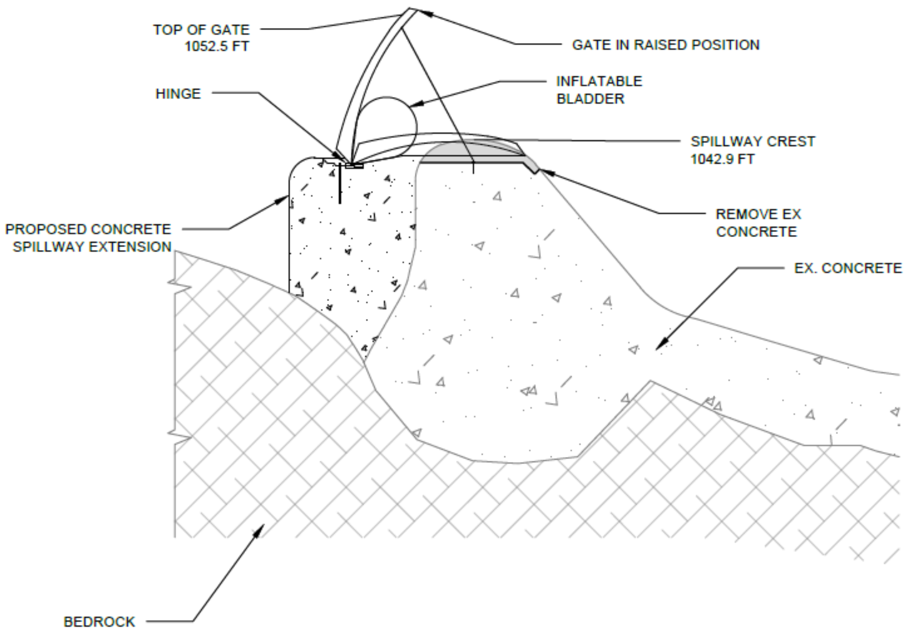

Figure 5-17 Spillway Modification Schematic

In addition, to accommodate the higher PMF from HMR 58/59 (Section 3.3), the spillway walls throughout the length of the spillway chute would be raised (Appendix B, Sheet 3).

Any spillway reconstruction and/or extension into the reservoir to accommodate the spillway gates would need to be founded on bedrock either directly or by piers. Excavations for spillway modifications placed directly on bedrock are likely to encounter areas of colluvium or debris slide material at the fishway foundation grade that would need to be over excavated to bedrock and built back up with concrete. Debris slides that would be impacted by excavation will need to be removed or stabilized for construction safety and to mitigate the potential risk of damage to proposed modifications. The slopes of required excavations in colluvium or bedrock, and any required stabilization, will need to be determined through a geotechnical investigation along the alignment of the proposed structures and analysis, using the data from the investigation.

Operational rules for the gates (when they can be raised, considering flood control, and what other circumstances would require lowering) and protection against vandalism would need to be addressed during detailed design to obtain DSOD approval.

Because the reservoir would be operated temporarily at a level greater than the NMWS, seepage and stability analyses—and likely seismic deformation analyses—would be required to demonstrate that minimum factors of safety are met under those conditions. The seepage analyses, stability analyses, and seismic deformation analyses are discussed in more detail in Section 5.2.12. It is possible that these analyses will indicate that other features of the dam will also require improvement (e.g., increasing the thickness of Zone 1 to the top of gate elevation and flattening the upstream slope) for Alternative 3 to be approved by DSOD.

5.2.5 Dam Embankment Raise

The spillway modification would trigger DSOD to require the PMF to be reevaluated using HMR 58/59, similar to what is described in Section 3.3. Based on the analyses summarized in Section 3.3, the updated PMF using HMR 58/59 is estimated at 66,443 cfs; the current HMR 36 PMF is 31,579 cfs (DSOD 2015b).

Based on an extrapolation of the current spillway rating curve, the HMR 58/59 PMF flood level would be about elevation 1,074.1 feet, 31.2 feet above the current spillway crest maximum elevation of 1,042.9 feet. Therefore, the raised dam crest would need to be elevation 1,042.9 feet plus 31.2 feet plus an assumed 1.5 feet of freeboard for wind-wave runup, which adds up to 1,075.6; a dam raise of approximately 14.7 feet. For the purposes of this TM, it is assumed that the design PMF would be that developed using HMR 58/59, and that the dam raise would be rounded up to 15 feet. The amount of freeboard required to pass the PMF could be reduced if the spillway crest were either widened or modified from its current straight ogee crest to a single-cycle labyrinth spillway crest. For the purposes of this TM, it is assumed that the spillway rating curve would stay the same as the existing curve. With the increased head created by the embankment raise and the associated spillway wall raise described in Section 5.2.4, LPD could pass the PMF without overtopping the embankment or spillway walls.

In the absence of any new geologic and geotechnical data related to dam stability, or any new analyses related to seismicity and related stability, the proposed top width of the raised dam is conceptually shown as widened to 50 feet, to reduce the risk of overall dam failure should the upstream dam face fail under seismic loading. A concept section of the dam raise is shown on Figure 5-18, and the plan view grading and conceptual cross section are shown on Sheets 1 and 2 in Attachment B.

The spillway walls at the crest would be raised to match the raised embankment crest. In addition, it was determined through HEC-RAS modeling that the spillway chute walls would need to be raised along the entire length of the spillway, as shown on Sheet 3 in Attachment B, to accommodate the higher PMF from HMR 58/59.

For this conceptual design, it is assumed that the dam would be raised from the downstream side. The foundation of the dam raise would require excavation at the downstream toe to expose bedrock. The downstream slope of the dam would be prepared by removing vegetation, and excavating and stockpiling the existing rock slope protection for reuse, to expose the Zone 1 embankment material. The top approximately 40 feet of the dam would be removed to facilitate internal zoning of the top of the dam raise, also requiring temporary lowering of the reservoir water surface elevation. The dam raise would include extension of the downstream blanket; a chimney filter between Zone dam 1 (likely silty sand [SM] to sandy silt [ML]) and the material used for the dam raise; and extension of dam Zones 1, 2, and 3 at the top of the dam raise, as shown on Figure 5-18 and on Sheets 1 and 2 in Attachment B. The chimney provides protection against uncontrolled piping and erosion of Zone 1, which could occur through cracks that could form during seismic deformation.

Dam Zone 1 material could come from alluvial fan deposits at the top of the terrace deposits that form the base of permanent Disposal Sites A, B, and C (The Mark Group 1995). Potential sources of dam Zone 2, Zone 3, and random fill materials are the coarse sediment in the upstream portion of the reservoir, and terrace gravels underlying the alluvial fan deposits in the terraces that form the base of permanent Disposal Sites A, B, and C. Should it turn out to meet the embankment fill specification, there is enough Zone 3 coarse material to meet the pertinent volume requirements for both the dam embankment and Disposal Sites D and E (see Section 5.2.8).

Filter and drain materials would likely need to be imported, but could potentially be processed from the coarse sediment in the upper end of the reservoir.

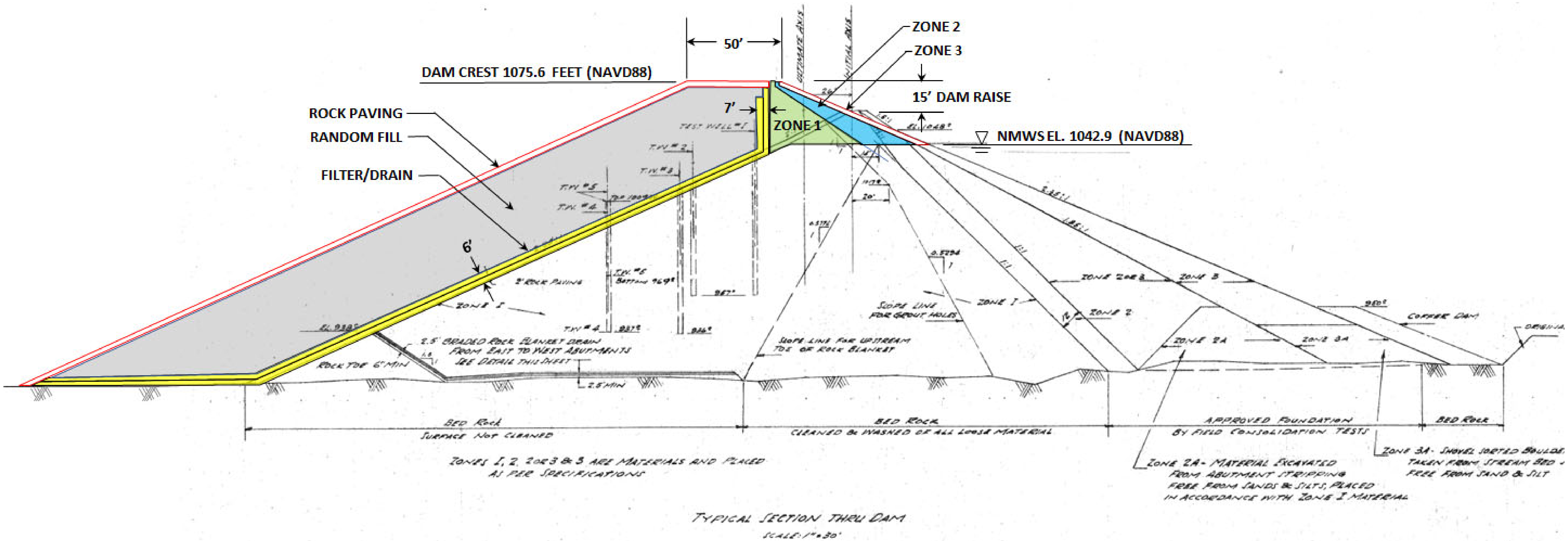

Figure 5-18 Dam Raise Schematic

5.2.6 Outlet Works

The current outlet works are described in Section 2.3, as is the proposed design to extend the low-level outlet.

The outlet structure for the low-level outlet is far enough downstream that it would not be affected by raising the dam; however, the concrete encasement may need to be extended. The proposed upstream low-level outlet intake, extension, and hydraulic operating system would also not likely be affected by the dam raise (unless flattening of the upstream slope was determined to be needed); however, the intake's ability to temporarily operate under the additional 9.6 feet of head associated with the raised NMWS would need to be confirmed, in addition to the ability to drain the expanded reservoir to meet DSOD standards.

Other outlet works such as the high-level outlet, siphon, and BGS/FWC will need to be evaluated to confirm their ability to operate under the additional 9.6 feet of head associated with the raised NMWS.

5.2.7 Sediment Removal

This alternative includes the removal of accumulated sediments with dredging methods while the reservoir remains partially full. A barge-mounted hydraulic excavator or clamshell bucket dredge would excavate the material and deposit it into a secondary materials transport barge. The barges would be transported via work boat to the offloading area adjacent to the LPD spillway. There, a secondary land-based excavator would offload the barges onto articulating dump trucks that would haul the finer material to the downstream Disposal Sites B and C for conditioning and drying prior to permanent grading. Coarser-grained material would be screened and rinsed (if necessary to meet particle-size specifications) then hauled directly and placed at Disposal Sites D and E for mobilization downstream during large-flow events. Should the coarser material meet the dam embankment fill specification, there is enough Zone 3 coarse material to supply both a dam embankment raise (see Section 5.2.5) and fill to capacity Disposal Sites D and E, with additional material to be disposed at Disposal Sites B or C.

Floating turbidity curtains or barriers would contain turbidity within the reservoir during mechanical dredging and prevent downstream transport of turbid water. Additional adaptive management measures (e.g., environmental buckets and material recovery restrictions) would be utilized to meet water quality discharge requirements, although material removal production rates would decrease with use of these measures.

All access to the sediments and sediment removal would be achieved through the use of floating equipment because road access is infeasible on the adjoining steep mountainous terrain due to recent rockslides (see discussion in Section 5.1.3). Sediment zone volumes, disposal locations, and characterizations for Alternative 3 are summarized in Table 5-3.

Table 5-3 Alternative 3 Estimated Sediment Removal and Placement

Area	Volume (AF)	Volume (CY)	Disposal Location	Characterization
Zone 1	340	550,000	Site B and C	Organics, clay/silt/fine sand
Zone 2	701	1,130,000	Site B and C	Predominately silt and sand
Zone 3 (Below NMWS)	72*	115,700*	Site B, C, D and E	Sand and coarser materials
Zone 3 (Above NMWS)	55**	89,300**	Site B, C, D and E	
Total Volume Removed	**1,168**	**1,885,000**		

Notes:

* Approximately 7 AF (11,400 CY) would not be feasible to excavate due to shallow drafts for floating equipment.
** Approximately 83 AF (133,600 CY) would not be feasible to excavate due to shallow drafts for floating equipment.

AF = acre-feet
CY = cubic yards
NAVD88 = North American Vertical Datum of 1988
NMWS = normal maximum water surface (at spillway crest maximum elevation of 1,042.9 feet NAVD88)

Characterization Source: Appendix C

As described in the timelines below, the reservoir water level would be drawn down to elevation 1,025 feet to access the offloading area. Roughly based on historical reservoir levels (Figure 2-14) (which include prescribed releases, evaporation, and inflows), the water surface is anticipated to drop approximately 5 feet per month, resulting in an elevation of 1,000 feet by October 15. Lowering the reservoir to gain access to the offloading area will likely impact low-flow releases and temperatures (both within the reservoir and downstream) during sediment removal activities. These impacts could potentially be mitigated through raising the offloading area, however, this would require identification of a material borrow source, a geotechnical investigation and stability analyses to confirm the existing terrace could withstand the additional fill, and, most importantly, would lower the sediment removal production rate (and increase construction duration) since a less efficient clamshell dredge (relative to conventional excavator) would be required to reach the deeper sediments.

Figure 5-19 summarizes which equipment would remove the sediments based on station. Over the course of multiple construction years, it is anticipated that a conventional excavator on a flexi-float barge will be able to excavate all of Zone 2, the majority of Zone 3, and about 30 percent of Zone 1 sediments above elevation 980 feet (because the excavator has a working depth of 20 feet below the lowest water surface elevation of elevation 1,000 feet). Sediments between elevation 980 feet and the original grade of elevation 920 feet would be removed with a barge-mounted clamshell dredge.

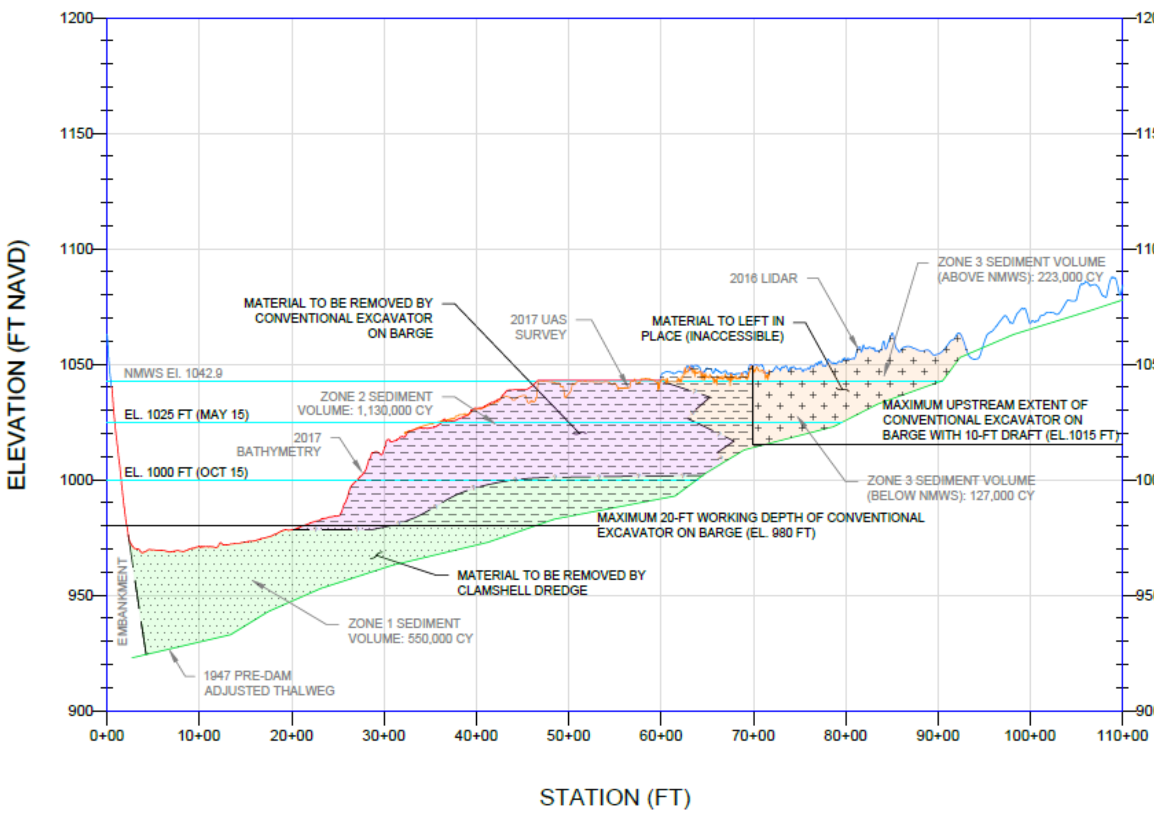

Figure 5-19 Material Dredging by Equipment Type and Water Level

The barge-mounted excavator would dig its access into the upstream Zone 2 sediments, sequenced over multiple years to safely remove the material that will slough and fall into the working zone of the excavator as it progresses upstream. Near Station 80+00, the maximum water level (elevation 1,025 feet) intersects the original streambed profile. Excavation would cease at that point, leaving approximately 17 percent of the Zone 3 sediments (60,000 CY) upstream of Station 80+00, including all of the sediment accumulated at the mouth of Danish Creek.

The following timeline summarizes the anticipated sediment removal actions for Alternative 3 during each construction year, with in-channel construction work occurring from May 15 to October 15 of each year. Site mobilization and demobilization would occur just before and after the permitted in-water work window to allow for maximum sediment removal each construction season.

Construction Year 1:

Prior to May 15:

- Improve access roads as described in Section 5.2.2.
- Clear and grub permanent sediment Disposal Sites B and C. Prepare the sites to receive material.
- Draw down the reservoir to elevation 1,025 feet to expose the offloading area on the natural terrace. Release of approximately 769 AF would take approximately 10 days, assuming minimum discharges from the restored low-level outlet (30 cfs) and siphon (avg. 12 cfs), as described in Section 5.1.3.

Beginning May 15:

- Create an approximately 20,000-square-foot offloading area adjacent to the spillway on the natural terrace near elevation 1,025 feet. Maintain the reservoir water level at elevation 1,025 feet, if possible, to offload material most efficiently from barges. Construct a lower shelf from which to offload as continued summer discharges lower the reservoir water surface elevation.
- Assemble the flexi-floats and excavator on the barge to begin sediment removal.
- Remove Zone 2 and 3 sediments (540,000 CY) by barge-mounted excavator (5 months).
- Construct in-channel access routes to floodplain Disposal Sites D and E. Clear and grub and prepare sites to receive material.

Construction Year 2:

- Assemble the flexi-floats and excavator on the barge to begin sediment removal. Lower the reservoir to elevation 1,025 feet and recreate the offloading area as necessary.
- Remove Zone 2 and 3 sediments (540,000 CY) by barge-mounted excavator (5 months).

Construction Year 3:

- Assemble the flexi-floats and excavator on the barge to begin sediment removal. Lower the reservoir to elevation 1,025 feet and recreate the offloading area as necessary.
- Complete removal of Zone 1, 2, and 3 sediments (370,000 CY) by barge-mounted excavator (3 months).
- Disassemble and reconfigure the flexi-floats for the clamshell dredge (0.5 months).
- Remove Zone 1 and 2 sediments (122,000 CY) by clamshell dredge (1.5 months).

Construction Year 4:

- Assemble the flexi-floats and clamshell dredge to begin sediment removal. Lower the reservoir to elevation 1,025 feet and recreate the offloading area as necessary.
- Complete removal of Zone 1 and 2 sediments (313,000 CY) by clamshell dredge (4 months).

The speed of sediment removal depends on the water depth in which the sediments reside and the capacity of the disposal sites to allow sufficient material drying time (discussed in Section 5.2.8). Table 5-4 summarizes the working depths and daily production rates for a traditional excavator, such as a CAT 336, mounted on a barge (Figure 5-20) and clamshell dredge (Figure 5-21) for use in Alternative 3. A clamshell dredge and traditional excavator mounted on a barge could use a bucket larger (3 CY) than that of a long-reach excavator (likely limited to 1 CY). Because the long-reach excavator would therefore have a lower production rate, it was subsequently eliminated from consideration.

Table 5-4 Equipment Capabilities

Equipment	Daily Production (CY/day)	Working Depth (feet)
Conventional excavator on barge (Alternative 3 [Storage Expansion and Dredging])	4,050	≤ 20
Clamshell dredge (Alternative 3 [Storage Expansion and Dredging])	2,600	> 50
For Comparison:		
Dry excavation (Alternative 2 [Dam and Sediment Removal)])	4,500	N/A
Long-reach excavator on barge (not used)	1,350	≤ 50

Note:
CY = cubic yards

Figure 5-20 Conventional Excavator on Flexi-Float Barge

Figure 5-21 Clamshell Bucket Dredging

The daily production rates listed in Table 5-4, as well as the overall sediment removal timeline, are based on the following assumptions:

- Two 12-hour shifts per day: 7 days per week (production rates assume 1 day per week of downtime (e.g., maintenance, weather delays, and inefficiencies)
- Five-month construction season from May 15 to October 15
- Equipment (not used concurrently due to disposal site limitations):
  - 4,050 CY/day per conventional excavator on a barge
  - 2,600 CY/day per clamshell dredge
- Adequate number of material barges, work boats, offloading excavator, and trucks used to not cause delay time in loading and transporting
- Adequate number of dozers used at disposal sites to not cause delay time in grading or spreading material
- Contractor manages excavation around reservoir stage to optimize removal limitations of each dredge in the zoned sediments

5.2.8 Hauling and Sediment Disposal

Excavated material would be hauled by articulated trucks and disposed of at the permanent Disposal Sites B, C, D, and E, as shown on Figure 5-10 and summarized in Table 5-5. Attachment B, Sheets 5 through 8, contain plan and profile views of each proposed site. Refer to Section 5.1.4 for descriptions of Sites B and C. All of the material excavated for this alternative could be disposed of at Sites B and C, with the option of placing a relatively small portion of the coarser material at Sites D and E for subsequent erosion during large flow events.

Table 5-5 Alternative 3 Disposal Sites A, B, C, D, and E

Location	Storage Capacity Cumulative Volume (CY)	Acreage (acres)	Maximum Fill Height (feet)	Proposed Finished Elevation (feet NAVD88)
Site B	1,640,000	16.8	120	1,100
Site C	980,000	14.1	120	1,080
Site D	20,000	1.8	20	905
Site E	16,000	1.8	15	870

Notes:

CY = cubic yards
NAVD88 = North American Vertical Datum of 1988

Disposal Site B and C Coverage Time Constraints

A land-based excavator will offload the material from the barge onto trucks for hauling to Sites B and C, where the material will require conditioning and drying prior to permanent grading. Zone 1 sediments will require the longest time to dry due to their low hydraulic conductivity and high moisture retention properties. These fine-grained sediments will be moved and worked for moisture conditioning (discing or windrowing multiple times a day) as they dry.

All materials would be dried to a water content no more than 5 to 10 percent above the optimum water content (in accordance with ASTM D1557) prior to placement of the next lift of material. Based on the anticipated material gradations, water content, and weather during construction, drying times could vary from 5 to 7 days for Zone 1 and 2, and from 3 to 5 days for Zone 3. Overall, a drying time of 5 to 7 days is targeted at this stage of design.

Disposal Sites B and C are on hillslopes. When constructed with side slopes between 2H:1V and 3H:1V with fill heights of 120 feet, the effective area (i.e., footprint available to receive material at one time) ranges between 25 percent and 55 percent of the total acreage covered. Table 5-6 summarizes the effective areas of Sites B and C when broken into three 40-foot incremental fill heights. Dividing the effective area by the anticipated daily fill area for each dredge scenario (conventional excavator, clamshell, or both) results in the number of days the effective area will be covered with a drying 2-foot lift (i.e., coverage time). As described above, a coverage/drying time of at least 5 to 7 days is recommended at this stage of design.

Table 5-6 Disposal Site B and C Coverage Times

<table>
<tr><th>Site</th><th>Fill Height (feet)</th><th>Incremental Volume (CY)</th><th>Effective Area (square feet)</th><th>Excavator Coverage Time (days)</th><th>Clamshell Coverage Time (days)</th><th>Excavator and Clamshell Coverage Time (days)</th></tr>
<tr><td>B</td><td>40</td><td>460,000</td><td>310,500</td><td rowspan="2">5.7 + 2.5 = 8.2</td><td rowspan="2">8.8 + 3.8 = 12.6</td><td rowspan="2">3.5 + 1.5 = 5</td></tr>
<tr><td>C</td><td>40</td><td>200,000</td><td>135,000</td></tr>
<tr><td>B</td><td>80</td><td>600,000</td><td>405,000</td><td rowspan="2">7.4 + 4.4 = 11.8</td><td rowspan="2">11.5 + 6.9 = 18.4</td><td rowspan="2">4.5 + 2.7 = 7.2</td></tr>
<tr><td>C</td><td>80</td><td>360,000</td><td>243,000</td></tr>
<tr><td>B</td><td>120</td><td>580,000</td><td>391,500</td><td rowspan="2">7.2 + 5.2 = 12.4</td><td rowspan="2">11.2 + 8.1 = 19.3</td><td rowspan="2">4.4 + 3.2 = 7.6</td></tr>
<tr><td>C</td><td>120</td><td>420,000</td><td>283,500</td></tr>
</table>

Notes:
Excavator Coverage Time assumes an excavator daily fill of 54,675 square feet for a 2-foot lift.
Clamshell Coverage Time assumes a clamshell daily fill of 35,100 square feet for a 2-foot lift.
Excavator and Clamshell Coverage Time assumes a daily fill of 89,775 square feet for a 2-foot lift.
Green = beyond 5 to 7-day design coverage time
Grey = near 5 to 7-day design coverage time
CY = cubic yards

Table 5-6 shows the time estimated to dry sediment for placement in 2-foot lifts at Disposal Sites B and C, at three potential fill heights and with various equipment. The equations in the time columns represent the sum of the time required to dry one lift of sediment at Site B plus the time required to dry one lift of sediment at Site C, using a single type or both types of equipment. As shown in Table 5-6, Sites B and C combined have sufficient capacity for one conventional excavator on a barge to work continuously with 8 to 12 days of coverage time, and one clamshell with 13 to 19 days of coverage time. When both these dredges are operated simultaneously, however, the coverage time approaches the limit of 5 to 7 days. An added level of operational complexity and potentially costly shutdowns arise when two dredges are excavating different material types for disposal at two different sites (with constrained access). For these reasons, Alternative 3 assumes that only one dredge (conventional excavator or clamshell) would be in operation at any given time.

A drying time test and correlated strength testing should be performed at later stages of design to better define coverage times and reduce the risk of construction delays. Strength testing would also be used in stability analyses of the disposal sites to confirm the proposed slopes and allowable water content of the materials.

Disposal Sites D and E

Disposal Sites D and E are downstream of LPD, at elevations where coarse-grained sediment (Zone 3) could be accessed and mobilized during large-flow events. Site D is a 1.8-acre area that has a capacity of about 20,000 CY at a top elevation of 905 feet. Site E is a 1.8-acre area that has a capacity of about 16,000 CY at a top elevation of 870 feet. Preliminary analysis of these disposal sites indicates that 10-year to 20-year flood flows could mobilize sediments placed at Sites D and E (Appendix B), thereby introducing coarser sediment back into the downstream river system. Some grading and removal of the existing armor of boulders would make more of the areas accessible to storm flows, possibly allowing 5-year flood flows to access the area.

Both Disposal Sites D and E would be cleared of trees prior to use. Because sand and finer material is included with Zone 3 material (Table 2-4), sorting may be needed if sediment placed in Sites D and E would include the typical minimum particle size for steelhead spawning of 0.1 inch. Material may be screened and rinsed (as necessary and with proper turbidity best management practices) prior to placement to meet desired particle sizes for these sites. Sites D and E would be accessed on a new road constructed in the river floodplain due to steep slopes between the sites and Nason Road above. Ideally, this temporary access would stay outside of critical habitat areas and would require limited grading or temporary gravel base. See additional discussion in Section 5.2.12.

Another option for transporting and placing coarse material in Disposal Sites D and E may involve the use of a sluice pipe from stockpiles near the dam (in the material processing area associated with Disposal Site B). This approach could reduce the impacts associated with vehicular access through the stream channel. As part of the Lower Yuba River Gravel Augmentation Project, the United States Army Corps of Engineers (USACE 2013) determined that up to 5,000 tons of gravel could be transported from stockpiles approximately 2,000 linear feet from the final placement location in the river channel and floodplain using an 8-inch sluice pipe. The sluicing process was estimated to require between 2 and 3 cfs, and the overall average slope of the sluice pipe was approximately 18 percent. Additional information is needed to determine the effectiveness of the sluicing operation at the Lower Yuba River Project, and to confirm the feasibility of this option for Los Padres.

5.2.9 Operations and Maintenance

An operations plan would be developed during detailed design to outline the required monitoring and procedures associated with timing of the gate operation and associated flow releases in the summer. The gates would be raised toward the end of the precipitation season, and would ideally be timed to take advantage of the spring flows to decrease the duration required to fill the additional storage provided by the spillway gates. Flows from April through June can range between 10 and 20 cfs. Assuming a constant inflow of reservoir discharge of 5 cfs and inflow of 10 to 20 cfs, it would take approximately 3 to 9 weeks to fill the additional storage (625 AF) provided by the spillway gates. Any alternative that increases water storage in LPR would likely require development of a flow enhancement plan in coordination with NMFS and CDFW that addresses passage, attraction, and habitat enhancement flows, including connectivity with the lower Carmel River and the lagoon.

Monitoring stations and instrumentation associated with the operations plan would be built into the project design. However, implementation of the plan—which would include data collection and analysis, along with gate and valve operation—would increase the O&M responsibilities and budget at the site.

More complex fish passage equipment and more frequent operational demands associated with fish passage improvements included in Alternative 3 would also increase the O&M effort relative to the current requirements, as described in Section 4.4.1 for Alternative 1 (Fish Passage, No Sediment Action).

5.2.10 Sediment Effects

Sediment effects for Alternative 3 would be similar to those described for Alternative 1 in Section 4.4.1, with little suspended sediment effect and continued incision of the channel downstream of LPD. This impact may be reduced by the introduction of coarse sediments into the system through placement in Disposal Sites D and E.

5.2.11 Effects to Steelhead

This section summarizes potential effects to steelhead associated with Alternative 3, initially presented for an earlier formulation of alternatives in Appendix E.

Bedload Sediment Transport

Effects to steelhead due to changes in sediment transport for Alternative 3 would be similar to those described for Alternative 1 (Fish Passage, No Sediment Action) in Section 4.4.1. However, the ongoing impact of interrupted coarse sediment supply may be reduced by the introduction of coarse sediments into the system through placement of dredged sediment in Disposal Sites D and E.

Water Availability

Given the small capacity of the LPR, Alternative 3 would not have a significant impact on instream flows during the precipitation season. However, the additional total 1,793 AF of storage would allow additional average releases of 5.0 cfs (9.8 AF per day) during the 6-month dry season period (not accounting for inflows into LPR summarized in Section 3.1.1). Increasing the reservoir capacity would also create new water right allocations and would presumably allow for additional pumping in the Carmel River Basin above the 3,376 AFY CDO limit. Increased summer flow releases would increase both the quality and quantity of summer rearing habitat for steelhead downstream of LPD by increasing flows through existing rearing habitat and by wetting portions of the channel that currently dry out in summer months.

Based on the CRBHM model results, stream flows from July through September under Alternative 3 are predicted to be greater than under any other dam, reservoir, and sediment management alternative. During the summer, the increased flow releases from LPD would significantly increase suitable fry and juvenile rearing habitat throughout the Carmel River downstream of LPD. Alternative 3 is predicted by the IFIM to provide a greater duration of suitable habitat for fry and juvenile steelhead than Alternative 1, while providing a substantially greater duration of suitable habitat than Alternative 2 (Figure 3-7 and Figure 3-8). Based on the CRBHM output, minimum flows predicted by the IFIM to support juvenile rearing habitat (> 5 cfs) are expected to be met more than 90 percent of the time during the dry season downstream of LPD and near the location of the former San Clemente Dam in Reach 2 (Figure 1-1, in both average and dry and critically dry water years. The CRBHM flow exceedance curves indicate that at Highway 1 (Figure 1-1), in the summer, 3 cfs is predicted to be exceeded 90 percent of the time in all water years (Figure 3-1) and 58 percent of the time in dry and critically dry years (Figure 3-2). Similarly, 5 cfs is predicted to be exceeded at Highway 1 82 percent of the time in all water years (Figure 3-1) and 48 percent of the time in dry and critically dry years (Figure 3-2). The increase in water during the dry season would likely reduce the amount of dry back currently experienced in the lower Carmel River. This would result in increased rearing habitat availability for steelhead in the lower watershed, which supports the fastest observed growth of juvenile steelhead in the watershed (Boughton and Ohms 2018).

Under existing conditions, up to 9 miles of habitat in the lower Carmel River are seasonally subjected to dewatering—depending on the magnitude of streamflow releases at LPD, seasonal air temperatures, and water demand. Water availability under Alternative 3 would be the greatest out of all alternatives. Under Alternative 3, in normal water years, the Carmel River is predicted to be wetted (> 0.5 cfs) from LPD downstream to the lagoon in the summer months (Figure 3-3). This increase in wetted habitat would reduce dry back associated with the summer months in dry years and provide the maximum amount of wetted habitat downstream of LPD when compared with other alternatives. Based on the CRBHM flow predictions shown in the figures, under Alternative 3, flows of 5 cfs would occur in summer months of normal water years throughout the Carmel River, from LPD downstream to the lagoon (Figure 3-5). This increase in wetted habitat and increased flows during the dry season would benefit the quantity and quality of existing steelhead rearing habitat. Boughton and Ohms (2022) modeled the historical baseline flow and five alternative flow scenarios, and found that dredging LPR to expand its storage capacity yielded higher adult steelhead returns compared to the historical baseline, even if water infiltration in the lower valley was high. By increasing available rearing habitat in the lower Carmel River, Alternative 3 has the potential to boost juvenile steelhead production in the Carmel River watershed compared to existing conditions, and would provide the greatest amount of wetted habitat downstream of LPD when compared to other dam and reservoir alternatives.

Water Temperature

Alternative 3 is not likely to increase cold water storage in LPR, and the temperature of released water is anticipated to be similar to existing conditions, as described for Alternative 1 above. Over time, if climate change were to increase stream temperatures in the Carmel River, the value of rearing habitat in the lower Carmel River could decrease relative to colder reaches upstream of LPR.

Fish Passage

Effects of Alternative 3 on steelhead upstream and downstream passage would be similar to those described under Alternative 1 (Fish Passage, No Sediment Action), but for two reasons this alternative is considered slightly less favorable for fish passage than Alternative 1. Under existing conditions, HDR et al. (2021) identified LPR as having an influence on the migration patterns of juvenile steelhead, including acting as a physical or biological barrier to downstream migration due to some thermal or water quality condition that impedes transit. Alternative 3 would result in a larger, deeper reservoir, which has the potential to further impede the successful migration of juvenile steelhead, depending on when the spillway gates are raised to take advantage of the additional storage. Brown trout predation in LPR could be a significant cause of mortality for juvenile steelhead, and an increase in the size of the reservoir has the potential to increase the population size of brown trout, thus increasing the risk of predation of juvenile steelhead. The increase in reservoir size would increase transit time, which could further decrease anadromous production and increase the risk of predation, injury, or mortality (Ohms et al. 2022; HDR et al. 2021).

A second consideration that may result in fish passage under Alternative 3 being less favorable than Alternative 1 is related to the need to coordinate design and operation of the spillway gates with fish passage facilities. While it is assumed that one of the upstream and downstream passage options would be adapted to the preferred dam, reservoir, and sediment management alternative, spillway gates may conflict with improved passage through the spillway and operation of the gates could affect design or operation of a fish ladder due to modification of the maximum water surface elevation in LPR. Additional design coordination is needed to confirm how the fish passage options would be adapted to this alternative. While it is probably safe to assume that integration of improved fish passage with Alternative 3 is feasible, addition of spillway gates to LPD could make fish passage design and operation more complicated.

Construction Effects

For four construction seasons (May 15 through October 15) Alternative 3 would require drawing down LPR to elevation 1,025 feet, beginning the dry season with reduced water storage. This would limit the volume of water available for dry season release, thereby reducing the flow augmentation in the lower Carmel River to somewhere between the flow extents shown for Alternative 1 (Fish Passage, No Sediment Action) and Alternative 2 (Dam and Sediment Removal) (Figure 3-3 through Figure 3-5. With a smaller reservoir, water temperatures at the reservoir outlet would be warmer than existing conditions and warmer than water temperatures described for Alternative 1. Effects of warmer temperatures below LPD could impact rearing steelhead as well as water temperatures at the Sleepy Hollow rearing facility, which could be particularly important to the steelhead population during construction years. These effects would need to be evaluated further if this alternative is selected. Fish passage would also be affected during the construction season, with an interruption to downstream migration because the water surface elevation would be too low to operate the existing downstream passage facilities.

Habitat Quantity

As described above under “Water Availability,” the extent of usable steelhead rearing habitat would increase under Alternative 3 due to increased storage and summer releases. Alternative 3 could also affect steelhead spawning habitat immediately upstream of the reservoir. Field biologists have noted spawning-sized gravels immediately upstream of the original head of LPR, raising the question of whether *O. mykiss* redds in this reach could be inundated if spillway gates are raised to increase storage (Ohms and Hamilton, pers. comm. 2021). Gravels reportedly begin near the location of the original, 1947 head of reservoir (prior to sediment accumulation that reduced the upstream extent of the reservoir pool) roughly at station 90 and continue upstream for about 3,000 feet of the Carmel River channel, roughly to station 120 in Figure 5-22. AECOM (2018) characterized deposition at the upstream end of the reservoir, above the high reservoir pool elevation, but downstream of this location. Relatively coarse sediment deposition upstream of a reservoir is not uncommon, due to reductions in water velocities during flood conditions as a stream approaches a reservoir; some of these deposits probably formed because of the reservoir. *O. mykiss* spawning has been observed in this reach, and spawning has frequently been observed farther upstream in smaller gravel patches in boulder-dominant reaches (Ohms and Hamilton, pers. comm. 2021).

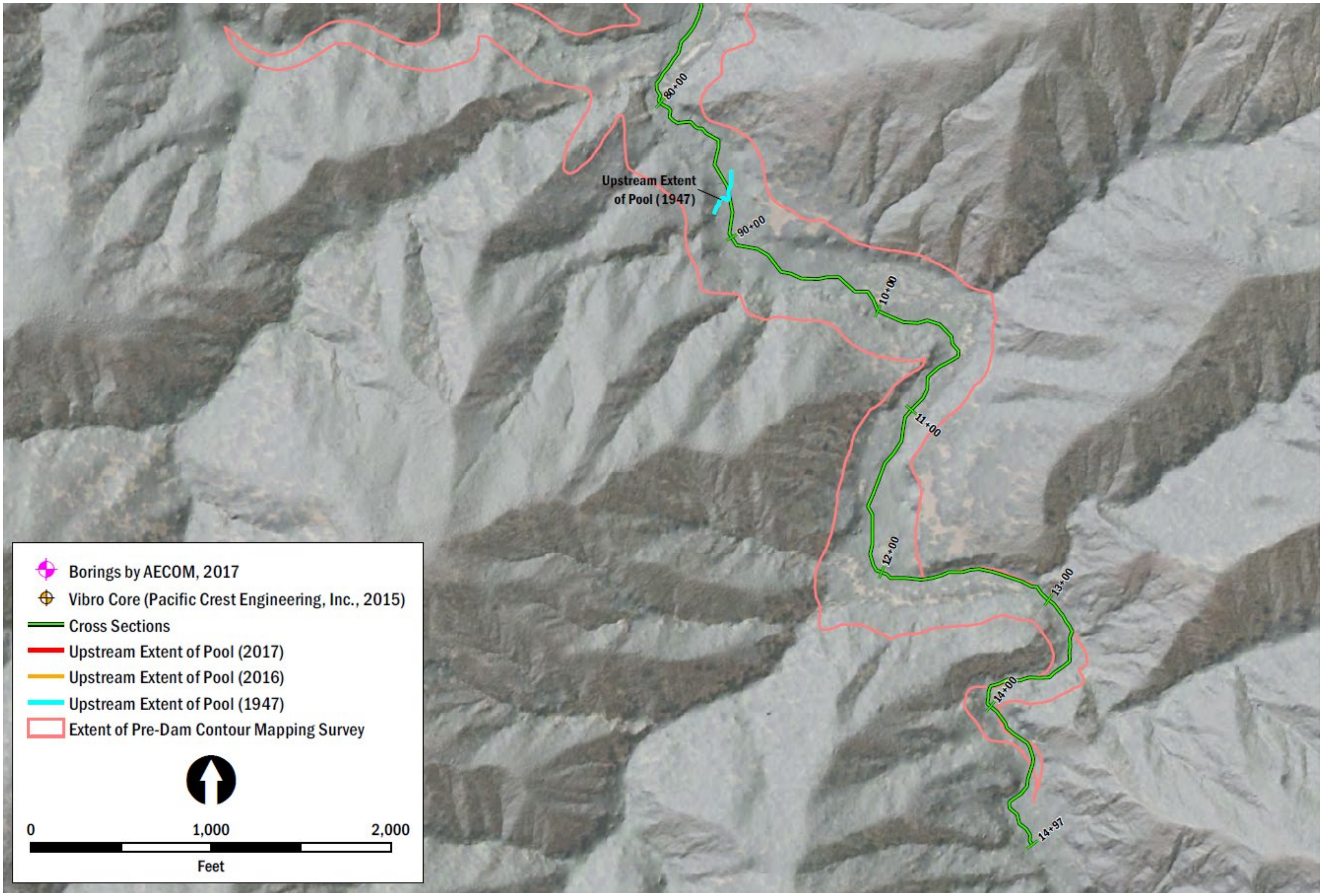

Figure 5-22 Excerpt of Figure 1 from Sediment Characterization TM, Showing Area of Gravel Deposition (Roughly between Station 90 and Station 12)

Source: AECOM 2018

AECOM evaluated whether the location would be inundated during operation of the spillway gates and concluded that it would not. Because excavation of accumulated sediment using barge-mounted equipment is limited by the depth required to float the barge (see Section 5.2.6 and Figure 5-19), removal of Zone 3 sediment would stop at roughly station 70, downstream of the original 1947 pool extent (Figure 2-21). Upstream of this point, accumulated sediment would remain in place, including sediment that has deposited upstream of the original pool extent and increased the elevation of the stream's thalweg and banks upstream of the reservoir. Raising the spillway gates would raise the water surface elevation to approximately 1,052.5 feet NAVD88 and would extend the reservoir pool upstream to roughly station 80, downstream of the location noted for its gravels. Raising the spillway gates would inundate roughly 3,500 feet of stream habitat upstream of the current reservoir pool, but roughly 2,500 feet of that habitat would have been returned to reservoir pool via sediment removal included with this Alternative 3. This would leave the lowermost 1,000 feet of the Carmel River upstream of the new LPR pool subject to inundation annually when the spillway gates are raised. Based on the way the stream evolves through episodes of sediment deposition upstream of the pool, this habitat contains finer substrate and is less developed than the habitat noted upstream for its spawning-sized gravels. A similar effect would occur on approximately the lowermost 100 feet of Danish Creek, which converges with the Carmel River upstream of the current reservoir pool but downstream of the 1947 reservoir pool. Although a detailed operations plan would be developed during subsequent design phases, it is currently assumed that the spillway gates would be raised during the latter portion of the wet season, reducing potential for conflict between the spillway gates and potential spawning habitat upstream of LPR.

Summary

During construction, Alternative 3 would have a negative effect on the dry season extent of wetted channel downstream of LPR, the temperature of water released from LPR, and downstream fish passage. After construction, Alternative 3 result in the continuation of similar dynamics that occur under existing conditions and under Alternative 1 regarding bedload and fish passage conditions. In general, Alternative 3 would provide the highest summer flows capable of providing adequate rearing habitat for both fry and juvenile steelhead downstream of LPD throughout the dry season, in comparison to existing conditions and other dam, reservoir, and sediment management alternatives. The frequent dry back that occurs in the lower 9 miles of the Carmel River is predicted to not occur in normal water years under Alternative 3, due to the increase in summer flow releases from LPD.

Alternative 3 would result in the continued blockage of sediment transport and thus incision of the channel downstream of LPD, resulting in decreased habitat suitability for steelhead, and would continue to limit the quantity and quality of spawning habitat downstream of LPD. This impact may be reduced by the introduction of coarse sediments into the system through placement in Disposal Sites D and E.

Like Alternative 1, under Alternative 3, upstream passage facilities at LPD would consist of either a technical fish ladder or a new trap-and-transport facility. Additional design and operation effort could be required for fish passage to coordinate with the spillway gate. Both options would continue to provide upstream passage for adults and support the anadromous population. However, neither option favors juvenile upstream passage; relative to full volitional passage, both options have potential to increase stress and migration delay for migrating steelhead.

Downstream passage facilities under Alternative 3 could consist of an FSC or a modification of the existing spillway and current FWC system. Both preferred fish passage alternatives would result in nonvolitional fish passage, would continue to subject downstream-migrating juveniles to mortality in LPR, and may favor resident and adfluvial over anadromous life histories. Although these options would be an improvement over existing conditions, complete volitional passage (i.e., dam removal) would provide safer migration.

Alternative 3 would provide the greatest benefits to rearing steelhead downstream of LPD in the summer months when compared to existing conditions and other dam, reservoir, and sediment management alternatives. However, up to 3,500 feet of the former reservoir pool, now functioning as stream habitat, could be affected by dredging (2,500 feet) and inundation during gate operation (1,000 feet).

5.2.12 Uncertainties

The primary uncertainty associated with Alternative 3 pertains to the lack of adequate geologic and geotechnical baseline information, and the associated seismic assessment and stability analyses to support a detailed dam embankment raise design. In addition, all modifications would need to be designed using current standards and would require DSOD approval prior to their construction.

Because the reservoir would be operated temporarily at a level greater than the current NMWS, seepage and stability analyses would be required to demonstrate that minimum factors of safety are met. The most recent seismic stability analysis was performed for LPD by DSOD in 1981 (DSOD 1981). The 1981 seismic stability analysis was based on a seismic hazard analyses for the dam that considered three major active faults: the San Gregorio-Hosgri fault, the San Andreas fault, and the Rinconada fault (DSOD 1980a). Based on the seismic hazard evaluation, the San Gregorio-Hosgri fault was determined to be the controlling fault, with a Maximum Credible Earthquake of M7.5 and a peak ground acceleration of 0.4g. Based on the current understanding of the seismic hazards around LPD, the Monterey Bay-Tularcitos Fault Zone should also be considered an earthquake source. The Monterey Bay-Tularcitos Fault Zone, being much closer to the dam than the San Gregorio-Hosgri fault, will likely result in higher peak ground accelerations than were assumed in the 1981 analysis.

Ground motions developed based on the revised seismic hazard analysis should be used for liquefaction triggering analyses of the granular dam Zones 2 and 3 in the upstream shell; seismic deformation of both the upstream and downstream shells; and analyses for potential for cracking of Zone 1 during seismic shaking where it overlies the foundation ridge at the right abutment, which could lead to seepage and potential piping from the downstream slope of the embankment. Seepage analyses, static stability analyses, and seismic stability analyses would require a better understanding of the static and dynamic properties of the dam Zone 1 (impervious embankment) and dam Zone 2 (free-draining upstream zone). Obtaining these properties would require drilling multiple holes in the dam to obtain samples for laboratory analyses, including gradation, Atterberg Limits, and shear strength. In addition, downhole geophysics would likely be needed for dynamic properties of the Zone 1 material. Given the relatively steep upstream slope (2.35H:1V), there is a potential that deformation analyses could indicate the need for the upstream shell to be flattened. It is also possible that the analyses may indicate a similar finding for the downstream slope.

It is possible that the analyses will indicate that other features of the dam will also require improvement (e.g., increasing the thickness of Zone 1 to the top of gate elevation and flattening the upstream slope) for Alternative 3 to be approved by DSOD.

Conceptual or planning-level alternatives are uncertain by nature. Key assessments or investigations to help address uncertainties related to design and construction of this alternative are listed below:

- A detailed assessment of temporary access that would be required within the river floodplain for equipment to reach Disposal Sites D and E is needed to assess potential impact to habitat in this area.
- There is uncertainty regarding the future performance of the fish passage improvements. For example, downstream passage improvements may be challenged to meet the 95 percent collection efficiency and 98 percent survival rate criteria noted in HDR et al. 2021, especially considering that in a recent study, only 20 percent of juveniles that entered the reservoir were later detected downstream of LPD (Ohms et al. 2022). The dam, spillway, and infrastructure improvements, in addition to the associated operations, outlined in this section for Alternative 3 may require changes in the fish passage improvement alternatives and associated costs.
- A detailed assessment of the public road improvements that may be required to accommodate construction traffic needs to be completed to confirm the approach provided herein.
- Additional onsite geologic assessment and geotechnical investigation may be necessary during detailed design to confirm the extent of improvements required for the onsite temporary access roads proposed for sediment access and hauling.

- Additional onsite geologic assessment and geotechnical investigation may be necessary during detailed design to confirm final geometry and stability of the disposal site grading.
- Additional assessment of likely dewatering requirements, given the local geology and groundwater, should be completed during detailed design.
- Additional analyses of historical Carmel River flows should be conducted to determine how frequently river flows at the end of the precipitation season are sufficient to close the spillway gates and use the additional storage capacity.
- A drying time test and correlated strength testing should be performed at later stages of design to better define sediment disposal site coverage times and reduce the risk of construction delays. Strength testing would also be used in stability analyses of the disposal sites to confirm slopes of the proposed disposal site and the allowable water content of the materials.

5.2.13 Advantages and Disadvantages

Advantages and disadvantages associated with Alternative 3 are discussed in this section, organized by the following categories: Local Impacts, Water Supply, Flooding, Geomorphology, Biological, Water Rights, and Regulatory.

Local Impacts

- **Disadvantage:** Impacts to local traffic and noise for Alternative 3 would be similar to other alternatives under which the dam would remain in place, but greater than Alternative 2, under which the dam would be removed. For all alternatives that leave the dam in place, it may be necessary to import between 2,500 and 3,300 loads of filter and drain material associated with the dam raise, if it is determined that those materials cannot be made on site. Associated equipment mobilization, material on-haul, and construction worker commuting would cause significant local traffic disruption. Similar to all alternatives, small improvements may be required along public roads (see Section 5.1.2) to accommodate construction traffic, which would cause additional disruption.

Water Supply

- **Advantage (spillway gates):** Raising the maximum storage pool by 9.6 feet with a pneumatically actuated spillway gate would add 625 AF of storage to the current reservoir capacity during the dry season, providing more flexibility for Cal-Am to store water for any purpose, including supplementing summer streamflow to potentially support additional pumping in the lower Carmel River during the dry season. The additional 625 AF of storage would allow additional average releases of 1.7 cfs (3.4 AF per day) over a 6-month period.
- **Advantage (sediment removal):** Removing the majority of the accumulated sediment would add an additional 1,113 AF of storage to the current reservoir capacity, providing more flexibility for Cal-Am to store water for any purpose. When the spillway gates are up, sediment removal above the NMWS results in an additional 55 AF of gained capacity, totaling 1,168 AF. The additional 1,168 AF of storage would allow additional average releases of 3.3 cfs (6.4 AF per day) over a 6-month period.
- **Advantage:** Assuming the sedimentation rates described in Section 2.4.1, following project implementation, approximately 100 years would pass before the reservoir capacity would be reduced to its current capacity of 1,601 AF.

Water Rights

- **Advantage:** Because the gates would only be raised toward the end of the precipitation season, Alternative 3 would not significantly impact instream flows during the precipitation season and would therefore not substantially affect Cal-Am's and MPWMD's water diversions associated with Permits 21330, 20808A, and 20808C.

- **Advantage:** Alternative 3 would increase the capacity of LPR, and Cal-Am could petition SWRCB to increase their water right associated with LPR.

Geomorphology

- **Disadvantage:** Alternative 3 would result in the continued incision of the channel downstream of LPD, resulting in decreased habitat complexity and a continued lack of access to overbank habitat. The lack of continued upstream gravel recruitment would continue to limit the quantity and quality of spawning habitat downstream of LPD. This in turn would continue to have a negative effect on downstream spawning habitat, and limit other potential morphological benefits associated with instream and overbank habitat. This impact may be reduced by the introduction of coarse sediments into the system through placement in Disposal Sites D and E.

Flooding

- **Advantage:** Other than the coarse sediment placed in Disposal Sites D and E, LPD would continue to prevent the transport of future coarse sediment to downstream and through the Carmel River, thereby limiting deposition compared to other alternatives that either release accumulated sediment rapidly (Alternative 5 [Recover Storage Capacity with Sluice Tunnel]) or immediately return the system to the historic annual sediment load (Alternative 2 – [Dam and Sediment Removal]). There is still a long-term trend toward sediment deposition; it is just less pronounced for those alternatives that keep the dam in place and do not release additional sediments above the current load.

Biological

- **Advantage:** Storage expansion through gate installation and sediment removal would not result in any changes to the downstream channel geometry from the current condition. It would, however, allow for a greater quantity of water for dry season release. This would increase the amount of fry and juvenile rearing habitat in the lower Carmel River, and would reduce the amount of dry back that occurs under existing conditions relative to other alternatives. As noted above under Water Supply, average flow releases over a 6-month period could increase by 1.7 cfs due to the additional storage related to gate installation, and another 3.3 cfs due to the additional storage related to the sediment removal. Although the benefits of additional flow would be reduced immediately below LPD by channel incision, the IFIM habitat duration and CRBHM flow extent analyses indicate that additional storage and release would benefit rearing habitat in the lower Carmel River.
- **Disadvantage:** Through implementation of fish passage improvements, adult steelhead passage would be improved over existing conditions, but would be less beneficial to fish than the volitional passage provided in Alternative 2 (Dam and Sediment Removal).
- **Disadvantage:** Downstream passage could be affected by increasing the reservoir water surface elevation during the latter portion of the juvenile out-migration season. Increasing the water surface elevation could interfere with the existing BGS and/or proposed fish passage improvements described in HDR et al. (2021).
- **Disadvantage:** If the river dries up during the dry season, filling of a larger reservoir in the rainy season could lengthen the time it takes for the river to fully connect to the lagoon. This impact could be offset somewhat by the ability to release flow during the dry season, which would contribute to aquifer recharge.
- **Disadvantage:** Alternative 3 would continue to block upstream movement of juveniles, thus continuing to prevent access to thermal refugia in the watershed upstream of LPR.
- **Disadvantage:** Alternative 3 has the potential to continue causing stress and migration delay for migrating steelhead.
- **Disadvantage:** Alternative 3 provides suboptimal downstream juvenile passage through and mortality in LPR.

- **Disadvantage:** Alternative 3 provides a suboptimal water temperature regime in the summer months.

- **Disadvantage:** Dredging could convert 2,500 feet of the former LPR pool currently filled with accumulated sediment back to reservoir pool, resulting in a potential loss of developing spawning and rearing habitat. Another 1,000 feet of the Carmel River upstream, plus approximately 100 feet of Danish Creek, could be subject to inundation when the spillway gates are raised.

- **Disadvantage:** Construction effects (no dry-season flow augmentation, interrupted fish passage, and increased temperature of releases for four construction seasons) would be more severe than any other alternative.

Regulatory

- **Advantage:** The increase in reservoir storage capacity would further Cal-Am's ability to release at least 5 cfs directly below LPD, as required by the SWRCB water rights permit. Release of 5 cfs at all times during which water is being stored in the reservoir is a requirement of License 11866. This is an advantage relative to Alternative 1 (Fish Passage, No Sediment Action) but not relative to Alternative 2 because dam removal would eliminate the flow release requirement.

- **Disadvantage:** Although the passage efficiency, collection efficiency, and survival of a future fish passage project are unknown, based on review of similar projects and site-specific conditions, it may not be feasible to meet the 95 percent collection efficiency and the 98 percent survival rate criteria noted in HDR et al. 2021. Inability to meet agency fish passage criteria would likely result in additional regulatory oversight.

6. Cost Opinions for Alternatives

This section describes the anticipated construction, O&M, and implementation costs for Alternatives 1 (Fish Passage, No Sediment Action), 2 (Dam and Sediment Removal), 3 (Storage Expansion and Dredging), and 5 (Recover Storage Capacity with Sluice Tunnel), the alternatives that remained under consideration through publication of the LP Alternatives Study Draft Final Report. Although Alternatives 1 and 5 have not been recommended for further consideration, cost information for them, consistent with the level of design and cost detail presented for the alternatives in this section, was developed prior to their elimination. Therefore, cost information for Alternatives 1 and 5 is retained in this section. The basis and methods of the cost information are presented first, followed by a summary of opinions regarding cost for each alternative. Detailed cost information is provided in Attachment C, and an additional comparison of costs between the two feasible alternatives described in Section 5 is provided in Section 7.1.

6.1 Basis for Cost Development

The methods used to develop the opinions of anticipated construction, O&M, and implementation costs are described below. The resulting opinions of cost are provided in Section 6.2.

6.1.1 Capital Costs (Opinion of Probable Construction Costs)

The engineer's opinion of costs associated with construction includes assessment of the procurement of materials and the time, labor, and equipment required to install, erect, and construct each of the alternative components to the intended initial operational condition. The anticipated construction costs are included herein as OPCCs; OPCCs express an opinion of costs, generated by the study engineers and based on information available at the time the TM was prepared.

The following assumptions were used as a common framework during OPCC development for each alternative:

- OPCCs are developed in conformance with AACE International Recommended Practice No. 18R-97, Class 5 Cost Opinions, with a range of accuracy based on 0 to 10 percent project definition and a +50 percent to -25 percent range of accuracy.
- Mobilization and general requirements are expressed as a percentage of the OPCC subtotal (10 percent each).
- Contractor general conditions, bonds, and overhead and profit are expressed as a percentage of the OPCC subtotal (10 percent, 3 percent, and 15 percent, respectively).
- State taxes are assumed to be 7.25 percent, as applied to material and equipment.
- Each OPCC includes a 50 percent contingency to account for undefined design and construction items.
- All OPCCs are presented in 2022 US dollars and are not escalated (unless otherwise noted for longer-term recurring activities).
- Individual cost items, details, and quantities for each concept alternative are developed using concept-level illustrations, details from OPCCs prepared for other like projects, RSMeans cost databases, and parametric comparison to other like facilities already constructed and in operation.

6.1.2 Operations and Maintenance Costs

Current annual O&M costs associated with the operation of LPD are estimated by AECOM at approximately $430,000 (Cal-Am 2022); these costs would continue in the future. O&M cost estimates assume the following activities:

- daily oversight for dam facility monitoring and reporting (4 hours per day, 7 days per week);
- oversight related to fish passage (5 months per year, 4 hours per day, 6 days per week);

- behavior guidance system monitoring;
- staff fuel costs;
- road maintenance;
- DSOD reporting; and
- miscellaneous facility repairs.

The engineer's opinions on future additional O&M costs associated with the proposed alternatives were based on our understanding of existing O&M activities and costs at LPD, in addition to a projection of additional activities associated with newly constructed improvements and facilities. For alternatives where the dam remains in place, future O&M estimates associated with proposed fish passage improvements were taken from HDR et al. (2021).

The following assumptions are used to develop anticipated O&M costs for each alternative:

- Costs are generated for a single operational season, although the duration of any given activity will vary based on the purpose and need.
- It is assumed that daily travel to the site will be required for all alternatives, similar to what is currently required given the remoteness of the project area.
- Labor costs are assumed at an hourly rate of $125 per hour, based on discussions with Cal-Am.

6.1.3 Implementation Costs

Implementation costs account for administration, studies, engineering, permitting, and construction management efforts required prior to and during construction of each alternative. For the purposes of this study, implementation costs are calculated based upon a percentage of the base OPCC presented in Section 6.2.

Implementation costs do not account for or include right-of-way acquisition, temporary construction easements, utility fees, or additional planning studies required prior to design.

Percentages of base OPCC used to estimate project implementation costs are as follows:

- Owner's Administration – 8 percent
- Engineering and Design – 12 percent
- Permitting – 3 percent
- Contracting and Procurement – 4 percent
- Owner's Construction Management – 8 percent

6.2 Cost Summary

This section summarizes the results of the various costs analyses described in Section 6.1.

6.2.1 Capital Costs (Opinion of Probable Construction Costs)

Table 6-1 summarizes the OPCC for Alternative 1 (Fish Passage, No Sediment Action). In accordance with the existing MOA between Cal-Am, NMFS, and the California State Coastal Conservancy (NMFS 2017), Cal-Am would be required to implement upstream and downstream fish passage improvements if LPD were to remain in place. Because the fish passage improvement cost was taken from a separate document (HDR et al. 2021), the associated cost is added as a separate line item No. 5. Approximately 21 percent of the cost for this alternative involves the spillway and dam embankment improvements; the remaining 79 percent of costs are associated with fish passage improvements.

Table 6-2 summarizes the OPCC for Alternative 2 (Dam and Sediment Removal). Approximately 58 percent of the cost for Alternative 2 (Dam and Sediment Removal) involves the removal and disposal of more than 1.68 million CY of accumulated reservoir sediment (including reservoir dewatering and diversion in the site preparation line item); the remaining 42 percent of costs are associated with dam removal and reservoir restoration. This calculation considers applicable portions of mobilization/ demobilization and site preparation.

Table 6-1 Alternative 1 (Fish Passage, No Sediment Action) Opinion of Probable Construction Costs Summary

Line Item #	Line Item	Description	Estimate
1	Mobilization/demobilization	Percentage of spillway/dam construction activities (10%)	$1,034,000
2	Site preparation	Access improvements	$550,000
3	Spillway Improvement	Raise spillway walls to accommodate updated PMF	$1,050,000
4	Dam Embankment Improvement	Raise dam embankment to accommodate updated PMF	$8,740,000
		Subtotal	**$11,380,000**
		General Conditions (10%)	$1,140,000
		Bond (3%)	$350,000
		General Contractor's Overhead and Profit (15%)	$1,710,000
		Total Spillway/Dam Construction Cost	**$14,580,000**
		Contingency (50%)	$7,290,000
		Spillway/Dam Total with Contingency	**$21,870,000**
5		**Total Fish Passage Improvement Cost (HDR et al. 2021)**	**$82,100,000**
		Total Construction Cost with Contingency	**$103,970,000**
		Low Side of Class 5 Estimate Range (-30%)	$72,780,000
		High Side of Class 5 Estimate Range (+50%)	$155,960,000

Notes:
Line item totals are rounded up to the nearest ten thousand, and subsequent calculations are rounded to the nearest ten thousand.
PMF = probable maximum flood

Table 6-2 Alternative 2 (Dam and Sediment Removal) Opinion of Probable Construction Costs Summary

Line Item #	Line Item	Description	Estimate
1	Mobilization/demobilization	Percentage of construction activities (10%)	$4,490,000
2	Site preparation	Clearing and grubbing, work pads, access improvements, new access through reservoir, dewatering and diversion	$5,820,000
3	Dam removal	Demolition of dam, spillway, and outlet works; hauling and placement of concrete and embankment materials in disposal	$9.660,000
4	Reservoir restoration	Restoration of former reservoir area with native vegetation	$7,270,000
5	Sediment removal	Sediment removal (1.7 million CY) in the dry, hauling and placement at disposal sites	$22,070,000
		Subtotal	**$49,310,000**
		General Conditions (10%)	$4,940,000
		Bond (3%)	$1,480,000
		General Contractor's Overhead and Profit (15%)	$7,400,000
		Total Construction Cost	**$63,130,000**
		Contingency (50%)	$31,570,000
		Total with Contingency	**$94,700,000**
		Low Side of Class 5 Estimate Range (-30%)	$66,290,000
		High Side of Class 5 Estimate Range (+50%)	$142,050,000

Notes:
Line item totals are rounded up to the nearest ten thousand, and subsequent calculations are rounded to the nearest ten thousand.
CY = cubic yards

Table 6-3 summarizes the OPCC for Alternative 3 (Storage Expansion and Dredging). Because the fish passage improvement cost was taken from a separate document (HDR et al. 2021), the associated cost is added as a separate line item No. 6. Approximately 67 percent of the construction cost for Alternative 3 (Storage Expansion and Dredging) involves the removal and disposal of more than 1.9 million CY of accumulated sediment. This calculation considers applicable portions of mobilization, demobilization, and site preparation.

Table 6-4 summarizes the OPCC for Alternatives 5 (Recover Storage Capacity with Sluice Tunnel). Because the fish passage improvement cost was taken from a separate document (HDR et al. 2021), the associated cost is added as a separate line item No. 6.

Table 6-3 Alternative 3 (Storage Expansion and Dredging) Opinion of Probable Construction Costs Summary

Line Item #	Line Item	Description	Estimate
1	Mobilization/demobilization	Percentage of construction activities (10%)	$4,800,000
2	Site preparation	Clearing and grubbing, work pads, and access improvements	$3,130,000
3	Spillway modifications and gate installation	Spillway crest modification, wall raise, and gate and control system installation	$4,100,000
4	Dam embankment raise	Embankment raise, filter/drain, and surface rock painting	$8,740,000
5	Sediment removal	Sediment removal (1.9 million CY) in the wet, hauling and placement at disposal sites	$31,970,000
		Subtotal	**$52,740,000**
		General Conditions (10%)	$5,280,000
		Bond (3%)	$1,590,000
		General Contractor’s Overhead and Profit (15%)	$7,920,000
		Total Storage Expansion/Dredging Construction Cost	**$67,530,000**
		Contingency (50%)	$33,770,000
		Storage Expansion/Dredging Total with Contingency	**$101,300,000**
6		Total Fish Passage Improvement Cost (HDR et al. 2021)	$82,100,000
		Total with Contingency	**$183,400,000**
		Low Side of Class 5 Estimate Range (-30%)	$128,380,000
		High Side of Class 5 Estimate Range (+50%)	$275,100,000

Notes:

Line item totals are rounded up to the nearest ten thousand, and subsequent calculations are rounded to the nearest ten thousand.

CY = cubic yards

Table 6-4 Alternative 5 (Recover Storage Capacity with Sluice Tunnel) Opinion of Probable Construction Costs Summary

Line Item #	Line Item	Description	Estimate
1	Mobilization/demobilization	Percentage of construction activities (10%)	$3,870,000
2	Site preparation	Clearing and grubbing, work pads, and access improvements	$880,000
3	Construct sluice tunnel	Sediment excavation, tunneling, material disposal, tunnel lining, gate structure, and intake/outfall portals	$27,830,000
4	Dam and Spillway Improvements	Dam and Spillway Improvements	$9,790,000
5	Site restoration	Removal of temporary access and hydroseed disposal area	$110,000
		Subtotal	**$42,480,000**
		General Conditions (10%)	$4,250,000
		Bond (3%)	$1,280,000
		General Contractor's Overhead and Profit (15%)	$6,380,000
		Total Sluice Tunnel Construction Cost	**$54,390,000**
		Contingency (50%)	$27,200,000
		Sluice Tunnel Total with Contingency	**$81,590,000**
6		Total Fish Passage Improvement Cost (HDR et al. 2021)	$82,100,000
		Total with Contingency	**$163,690,000**
		Low Side of Class 5 Estimate Range (-30%)	$114,583,000
		High Side of Class 5 Estimate Range (+50%)	$245,535,000

Notes:
Line item totals are rounded up to the nearest ten thousand, and subsequent calculations are rounded to the nearest ten thousand.

6.2.2 Operations and Maintenance Costs

For Alternative 1 (Fish Passage, No Sediment Action), in accordance with the existing MOA between Cal-Am, NMFS, and the California State Coastal Conservancy (NMFS 2017), Cal-Am would be required to implement upstream and downstream fish passage improvements if LPD were to remain in place. Spillway and dam embankment improvements are also included, although it is not anticipated that these would significantly increase annual O&M. Annual O&M costs associated with the fish passage improvements could range from $389,000 to $782,000 (HDR et al. 2021).

For Alternative 2 (Dam and Sediment Removal), although there would be some level of post-construction monitoring and reporting associated with regulatory permits (likely lasting up to 10 years), there would be no long-term O&M at the site. Post-construction activities associated with regulatory permits could involve maintenance activities related to fish passage, sediment stabilization, and habitat establishment.

For Alternative 3 (Storage Expansion and Dredging), an operations plan would be developed during detailed design to outline the required monitoring and procedures associated with timing of the gate operation and associated flow releases in the summer. Monitoring stations and instrumentation associated with the operations plan would be built into the project design. However, implementation of the plan—which would include data collection and analysis, along with gate and valve operation—would increase the O&M responsibilities and budget at the site. It is assumed that a half-time employee for up to 4 months could increase the annual O&M budget by as much as $50,000. In addition, Alternative 3 would involve annual O&M costs associated with the upstream and downstream fish passage improvements could total as much as $782,000 (HDR et al. 2021).

For Alternative 5, an operations plan would be developed during detailed design to outline required monitoring and procedures associated with timing of sluicing operations. Any monitoring stations or instrumentation associated with the operations plan would be built into the project design. However, implementation of the plan—which would include data collection and analysis, along with gate operation (and likely monitoring of total suspended solids and/or turbidity of releases)—would increase the O&M responsibilities and budget at the site. It is assumed that a half-time employee for up to 4 months could increase the annual O&M budget by as much as $50,000. In addition, Alternative 5 would involve annual O&M costs associated with the upstream and downstream fish passage improvements could total as much as $782,000 (HDR et al. 2021).

Table 6-5 summarizes the total anticipated future annual O&M estimates for each alternative.

Table 6-5 Additional Operations and Maintenance Estimate Summary

Alt. #	Alternative Name	Description	Future Dam O&M Estimate	Future Fish Passage O&M Estimate	Future Annual O&M Estimate
1	Fish Passage, No Sediment Action	Existing dam and fish passage improvement O&M	$333,000	$782,000	$1,115,000
2	Dam and Sediment Removal	None	-	-	-
3	Storage Expansion and Dredging	Dam and spillway gates monitoring and maintenance; Fish passage improvement O&M	$382,000	$782,000	$1,165,000
5	Recover Storage Capacity with Sluice Tunnel	Dam and tunnel gates monitoring and maintenance; Fish passage improvement O&M	$382,000	$782,000	$1,165,000

Notes:

Line item totals are rounded up to the nearest thousand, and subsequent calculations are rounded to the nearest thousand.

O&M = Operations and Maintenance

6.2.3 Implementation Costs

Table 6-6 summarizes the various implementation costs associated with each alternative.

Table 6-6 Implementation Cost Summary

Alt. #	Alternative Name	Owner's Admin (8%)	Engineering and Design (12%)	Permitting (3%)	Contracting and Procurement (4%)	Construction Management (8%)	Total (35%)
1	Fish Passage, No Sediment Action	$8,317,600	$12,477,000	$3,120,000	$4,159,000	$8,318,000	$36,391,600
2	Dam and Sediment Removal	$7,574,000	$11,361,000	$2,841,000	$3,787,000	$7,574,000	$33,137,000
3	Storage Expansion and Dredging	$14,669,000	$22,004,000	$5,501,000	$7,335,000	$14,669,000	$64,178,000
5	Recover Storage Capacity with Sluice Tunnel	$13,096,000	$19,643,000	$4,911,000	$6,548,000	$13,096,000	$57,294,000

Notes:

Line item totals are rounded up to the nearest thousand, and subsequent calculations are rounded to the nearest thousand.

7. Discussion

This section presents a comparison of key considerations for the two alternatives that remain under consideration and are presented in Section 5; highlights outstanding uncertainties that have been identified as important to selecting a preferred dam, reservoir, and sediment management alternative; documents recommendations and preferences of the TRC and stakeholders; and concludes with a short synthesis of findings and discussion of next steps.

7.1 Alternatives Comparison

This section compares costs, sustainability, geomorphic effects and flood risk, effects to water supply and water rights, and effects to steelhead for the alternatives presented in Section 5. In addition to the discussion in the following subsections, Table 7-1 summarizes advantages and disadvantages for each of the two feasible alternatives, relative to each other. These advantages and disadvantages are described in Sections 4 and 5 relative to the group of four alternatives that were carried into the draft final report. However, this section focuses only on the two alternatives that remain under consideration at the conclusion of the LP Alternatives Study.

7.1.1 Cost

Table 7-2 summarizes the estimates of OPCC and O&M for each alternative that remains under consideration, breaking down the OPCC into “non-sediment removal,” “sediment removal,” and “fish passage” categories, to show what is driving the total cost for each alternative. The OPCC for Alternative 3 (Storage Expansion and Dredging) is nearly twice the OPCC for Alternative 2 (Dam and Sediment Removal). Alternative 3’s removal of sediment in the wet appears to be more expensive ($38/CY) than mechanical sediment removal ($31/CY) in the dry (Alternative 2), so the cost could potentially be decreased somewhat by adapting the dry excavation method of sediment removal described for Alternative 2 to Alternative 3. Alternative 3 also includes more than $1 million in annual O&M costs; whereas, because facilities requiring operations and maintenance would be removed, Alternative 2 has no long-term O&M costs. As described previously, the fish passage construction costs brought forward from HDR et al. 2021 assume the most expensive of two upstream and two downstream passage options proposed for further consideration, because fish passage design has not yet been coordinated with Alternative 3 (Storage Expansion and Dredging). Although it is possible that the cost of some passage options would increase when adapted to Alternative 3, other, less expensive upstream and downstream fish passage options presented in HDR et al. 2021 have also been selected for further consideration.

If trap and transport was selected for upstream passage, changes resulting from design coordination may not result in any cost increase. If a fish ladder was paired with Alternative 3 (Storage Expansion and Dredging), the cost increase may be correlated to the total anticipated range of water surface conditions that would occur during the months that passage is required. The fish ladder exit is far more complex, with wider ranges of reservoir fluctuation. However, if the anticipated reservoir fluctuation during the period of adult upstream migration is near the range established in the fish passage report, then increase in cost of the fish ladder, following design coordination, may be less. There would also be a cost impact to downstream fish passage, but again it would depend on the technology (e.g., there may be no change for a new FSC, and the use of the existing FWC may be infeasible). Due to uncertainty regarding changes to the fish passage options and their costs, fish passage costs in Table 7-2 are unmodified from HDR et al. 2021, pending design coordination.

Table 7-1 Comparison of Advantages and Disadvantages Between Two Feasible Alternatives that Remain under Consideration

No.	Alternative Name	Advantages and Disadvantages: Cost	Local Impacts	Water Supply/ Water Rights	Geomorph-ology	Flooding	Biological	Regulatory
2	Dam and Sediment Removal	+ • OPCC of $95 million, roughly half that of Alternative 3 • No long-term O&M costs	+ • Four construction seasons, but less impact than Alternative 3	- • Reservoir storage lost • May lead to loss of water rights or need for expensive replacement water, pending negotiation with SWRCB	+ • Increase in suitable spawning gravel, channel complexity, and overbank habitat connectivity	- • Restores downstream deposition and increases flood risk, especially near Cachagua, incrementally downstream	+ • Fully volitional upstream and downstream passage for all life stages of steelhead • Increased steelhead habitat in former dam and reservoir area • Restored natural thermal regime and access to temperature refugia • Biological benefits maintained into perpetuity without intervention • No flow augmentation and interrupted passage for four construction seasons (but slightly less impact than Alternative 3) - • No ability to release summer flows, potentially mitigated by restored habitat in dam and reservoir footprint	+ • Limited short-term regulatory involvement and oversight
3	Storage Expansion and Dredging	- • $183 million OPCC ($101 million + $82 million of passage improvements) • Over $1 million O&M costs annually into perpetuity	- • Higher impact due to filter/drain material on-hauling	+ • Highest increase in storage and summer flow releases • Cal-Am could petition SWRCB to increase water right	- • Prevents the transport of coarse sediment and associated benefits, could be partially mitigated with use of disposal Sites D and E	+ • No significant change from current conditions • Significantly increases the duration before dam fills in and coarse sediment moves downstream (increasing flood risk)	- • Adult passage improvements less beneficial than volitional passage; spillway gates may negatively affect fish passage • Continues to block upstream juvenile passage and provide suboptimal downstream juvenile passage • Continued stress and migration delay for migrating steelhead • Provides a suboptimal water temperature regime • Would impact 3,500 feet of stream habitat developing in accumulated sediment in former reservoir pool • Most severe construction effects (no flow augmentation, interrupted passage, and increased temperature of releases for four construction seasons) + • Provides greatest increase in summer rearing flows downstream of LPD	- • Ongoing, heavy regulatory involvement over the long term by multiple agencies

Notes:

+ Advantage
- Disadvantage

Cal-Am = California American Water
LPD = Los Padres Dam
O&M = operations and maintenance
OPCC = Opinion of Probable Construction Costs
SWRCB = State Water Resources Control Board

Table 7-2 Costs Comparison for Remaining Alternatives

Alt. No.	Alternative Name	Alternative OPCC: Non-sediment OPCC	Alternative OPCC: Sediment Removal OPCC	Alternative OPCC: Fish Passage OPCC	Total OPCC	Annual O&M Cost
2	Dam and Sediment Removal	$41,910,000	$52,760,000	—	$94,700,000	-
3	Storage Expansion and Dredging	$30,430,000	$70,830,000	$82,100,000[1]	$183,360,000	$1,165,000

Notes:

Totals are rounded up to the nearest ten thousand.

[1] Fish Passage OPCC assumes the most expensive of the upstream and downstream passage options from HDR et al. 2021. Lesser cost options may also be suitable, and the cost of any option could increase after adaptation to Alternative 3.

OPCC = Opinion of Probable Construction Costs

7.1.2 Sustainability

Although there are several different lenses through which one could evaluate sustainability of the alternatives, one way to look at sustainability is to consider the duration of the sediment management benefits associated with each alternative. Another lens through which sustainability can be viewed is to consider the amount of labor, materials, and fuels that are required to implement each alternative, a surrogate for greenhouse gas emissions or environmental footprint associated with construction (or sediment removal), often reflected in the capital cost. Alternatives that rely on manual processes for sediment removal or that affect accumulated sediment for a shorter duration are considered less sustainable than alternatives that rely on natural processes to manage sediment or affect sediment accumulation over a longer duration. Table 7-3 lists the remaining alternatives in the order of their perceived sustainability when viewed through these lenses, along with the portion of the OPCC associated only with sediment removal.

Table 7-3 Cost and Duration of Sediment Management for Remaining Alternatives

Alternative No.	Alternative Name	Sustainability Rank	Sediment Removal OPCC[1]	Duration of Sediment Benefit
2	Dam and Sediment Removal	1	$52,760,000	Forever
3	Storage Expansion and Dredging	3	$70,830,000	≈100 Years

Notes:

[1] Excludes fish passage and non-sediment removal costs

OPCC = Opinion of Probable Construction Costs

Alternative 2 (Dam and Sediment Removal) is considered more sustainable than Alternative 3 (Storage Expansion and Dredging) (Table 7-3). Alternative 2 has the lowest sediment management cost. Once the dam is removed, natural sediment transport would be restored and sediment would be managed through natural processes into perpetuity, without O&M costs or the need to implement sediment management projects at LPR in the future. With Alternative 3, depending on patterns of fire, flood, and sediment deposition, it is estimated that it would be 100 years after construction before the reservoir storage would be reduced back to the amount of storage present in 2017. This resets the clock on sediment accumulation but over time sediment accumulation would again become problematic and another major action would be required to address it.

One could apply a similar thought process to the sustainability of fish passage and conclude that Alternative 2, the only alternative without engineered fish passage construction and associated O&M costs, is the most sustainable. Alternative 3 includes non-volitional, managed fish passage. In fact, all the benefits to steelhead associated with Alternative 3, including fish passage, sediment transport, and flow augmentation depend on managers maintaining the will and funding to continue operation of these features year after year, where funding may be contingent on the willingness of the public to support such programs. The biological and geomorphic benefits associated with dam removal, including fully volitional fish passage for all life stages of steelhead, would be maintained in perpetuity through natural processes and would not require the ongoing political will, capital, or labor associated with benefits conveyed via managed fish passage or sediment management operations included with dam-in alternatives. In that sense, and because dam removal is essentially permanent, the benefits associated with Alternative 2, as well as elimination of dry-season flow augmentation at LPD, are most likely to endure of all the considered alternatives.

7.1.3 Geomorphic Effects and Flood Risk

Chapter 5 of Appendix D compares results of the various sediment transport scenarios modeled using the BESMo for the wet hydrologic condition. Figure 7-1 shows the median and 25th to 75th percentile range of predicted channel bed elevation changes over time for Alternative 1 in green, Alternative 2 in grey, and Alternative 5 in purple (pink represents the Historical Supply simulation, which is described in Appendix D). Alternative 3 would likely be closest to the No Action simulation results (in green) because the one-time placement of coarse sediment in Disposal Sites D and E is not expected to have the same impact on channel bed elevations over the duration of the simulations as the restoration of a pulsed or continuous bedload supply. There is no BESMo scenario to represent the one-time placement of coarse sediment that could be included with Alternative 3. Predicted increases in channel bed elevation suggest locations where flooding may worsen. Although the BESMo is not a flood model, the channel bed elevations predicted by BESMo could inform flood modeling if used to evaluate the flood risk of the alternatives.

Upstream of the former San Clemente Dam, the primary response to resumption of Los Padres (and upstream) sediment supply is net deposition (Figure 7-1). Deposition is greatest just downstream of LPD, ranging from 16 to 19 feet with the Uncontrolled simulation (representing Alternative 2, Dam and Sediment Removal) projecting the most deposition. The projected magnitude of deposition just downstream of LPD with restoration of bedload transport is plausible because topographic data local to LPD suggests about 20 feet of net bed elevation decline since LPD was constructed in 1949. It is thus expected that Alternative 2 would lead to recovery of local average channel bed elevations. This could have implications for flooding in the community of Cachagua, which saw 100 to 150 residences damaged in March 1995 during the largest flood of record out of 60 years of data (Section 2.8). In contrast, the No [sediment] Action simulation projects several feet of further bed erosion until the profile approaches the former San Clemente reservoir pool. Depending on how much coarse sediment is recovered during dredging and placed in floodplain disposal sites, the response curve predicted for Alternative 3 may shift slightly from that associated with the No Action simulation, in the direction of (but not likely approaching) the increased supply simulations associated with Alternatives 2. A detailed evaluation of flood effects would require flood modeling not included in the scope of the LP Alternatives Study; however, based on evaluations completed for other dam removal projects, once potential flood effects are fully understood, feasible mitigations (e.g., strategically placed flood walls, stream crossing retrofits) are likely available should they be needed.

Around the former San Clemente Dam site, predicted trends in deposition and erosion are influenced by specific aspects of the channel related to construction of the dam removal and Carmel River reroute. The magnitude of projected deposition, and the downstream advance of deposition beyond the former dam site, act to smooth out abrupt profile changes and facilitate bedload transport rates which converge to similar magnitudes across locations of profile change.

Around Tularcitos Creek, the multiple simulations show a range of results that suggest the projected average bed elevations are sensitive to the sequence of future floods. Appendix D suggests that the response near Tularcitos Creek is conditioned by the magnitude of bedload deposition at the former San Clemente Dam during the first 10 projection years, coupled with the particular and associated downstream advance of coarse grain size fractions. Field-based monitoring of bed elevation and bed surface texture response upstream of Tularcitos Creek may provide the data needed to make informed decisions regarding likely trajectory of responses there, an important location near the upstream end of Carmel Valley Village (Figure 1-1). Carmel Valley Village is somewhat more flood prone than Cachagua and typically sees flooding begin when river flows approach a 10-year event (Section 2.3.2). During the 1995 event-of-record, 80 residences in Robles del Rio were damaged.

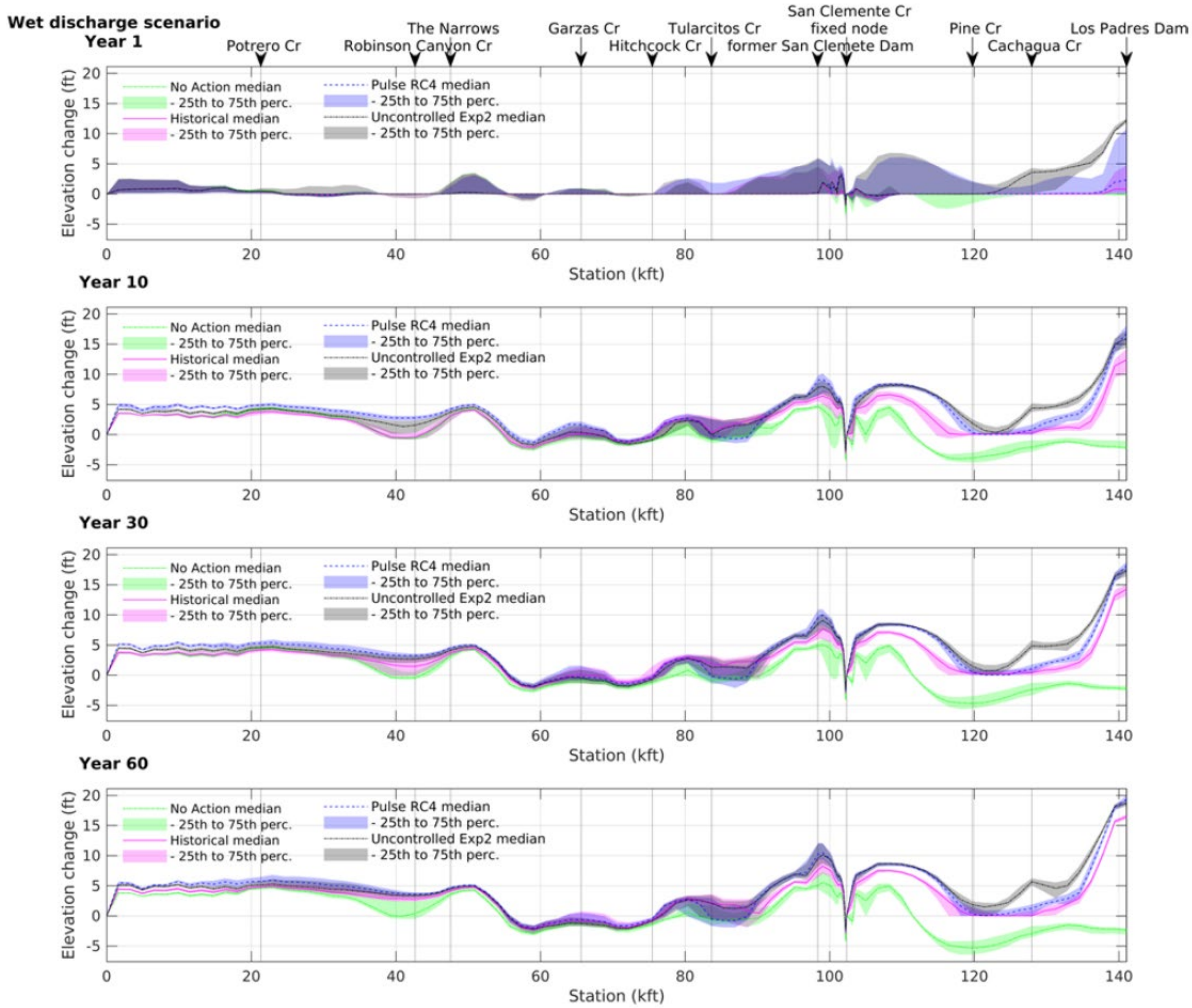

Figure 7-1 Comparison of Projected Bed Elevation Change from the 2017 Initial Profile for Four Sediment Supply Simulations

Notes:

Green (No Action Simulation) corresponds to Alternative 1 (Fish Passage, No Sediment Action) and is the closest representation of Alternative 3 (Storage Expansion and Dredging); grey (Uncontrolled Supply Simulation) corresponds to Alternative 2 (Dam and Sediment Removal); and purple (Pulsed Supply Simulation) to Alternative 5 (Recover Storage with Sluice Tunnel).

Shaded regions capture the 25th to 75th percentile responses across the 100 simulations for the wet condition. Results are shown for simulation years 1, 10, 30, and 60.

Through Carmel Valley Village, downstream of Hitchcock Creek and as far downstream as a bit beyond Garza Creek (station 60,000 feet), simulations associated with dam removal are projected to yield bed elevation changes which generally fluctuate around no net change to average bed elevation (Figure 7-1). This suggests that this roughly 15,000 feet of mainstem Carmel River is indicated by an existing bedload transport capacity that can accommodate upstream supply increases across most of the grain size classes, and flood risk may be less sensitive to actions at LPD.

This relatively high transport capacity changes and lessens moving toward The Narrows (Figure 1-1). Approaching The Narrows, all simulations, including the No Action simulation, which does not increase bedload sediment transport, project roughly 5 feet of deposition by year 10, and this magnitude of deposition holds out through year 60 of the simulations (Figure 7-1). At The Narrows the channel is more laterally confined, so bed elevation is the primary response to increased bedload supplies. Just downstream of The Narrows, the No Action simulation predicts between 0 and 3 feet of net deposition, whereas the simulations that introduce bedload supply from above LPD (including that representing Alternative 2) converge to an approximate net deposition magnitude of 4 feet.

Regardless of whether bedload sediment transport is restored at LPD, all simulations evolve to between 4 and 6 feet of net deposition in the lower-most 35,000 feet of the Carmel River at year 60 (Figure 7-1). A similar pattern is predicted under the average and dry hydrologic conditions, although the predicted aggradation is significantly delayed compared to the wet conditions (Appendix D). This suggests that flood prone properties in the lower river will continue to see the likelihood of flood damage increase regardless of any action taken at LPD, and that various actions at LPD would have only an incremental effect on that outcome.

The No Action simulation results in projected bed elevation responses associated with coarsening of the bed surface relative to initial conditions (Appendix D). Coarsening is most pronounced under the No Action simulation and decreases for the additional sediment supplied from the Los Padres reservoir storage and upper contributing watershed. This outcome suggests that the gravel and coarser bedload content from the watershed area upstream of the former San Clemente Dam is large relative to the fractional content of bedload supplies along the lower mainstem and is therefore important in setting the ultimate texture of the riverbed surface. Furthermore, the bedload supply sourced from the Los Padres reservoir storage and the upstream contributing watershed is important in terms of moderating the overall coarsening response. Additional figures and discussion describing changes in channel bed grain size of the alternatives (in the context of BESMo model scenarios) are provided in Appendix D.

7.1.4 Water Supply and Water Rights

Water rights at LPD are linked to the amount of storage in the reservoir and have been reduced once as storage in the reservoir has declined. A summary of water rights in the Carmel River and associated with LPR is provided in Section 1.3.3. Care has been taken, in coordination with the TRC and stakeholders, to describe water rights as accurately as possible. However, due to minor differences in interpretation and the absence of SWRCB from the process to date, further clarification may occur after preparation of this report. With an associated water right of 3,030 AF,[10] LPR is a large portion of Cal-Am's solely owned water rights in the Carmel River watershed and an important component of the municipal water supply. It is assumed that changes in storage at LPR would affect water rights. Table 7-4 shows the changes in water storage and dry-season release (assuming no inflow to LPR) estimated for each alternative.

Table 7-4 Comparison of Changes in Storage Capacity and Summer Release with No Inflow to LPR Estimated for Remaining Alternatives

No.	Alternative Name	Change in Storage	Change in Dry-Season (6 months) Release
2	Dam and Sediment Removal	- 1,601 AF	- 4.2 cfs (-8.4 AF/day)[1]
3	Storage Expansion and Dredging	+ 1,113 AF with dredging + 625 AF with gates + 55 AF with both[2] + 1,793 AF total	+ 3.1 cfs (+6.1 AF/day) with dredging + 1.7 cfs (+3.4 AF/day) with gates + 0.2 cfs (+0.3 AF/day) with both[2] + 5.0 cfs (+9.8 AF/day) total

Notes:

1 Assumes approximately 72 AF remain within the reservoir below the proposed low-level invert elevation of 981.8 feet.

2 Storage and release gained from removing material above the NMWS and closing the gates.

AF = acre-feet
cfs = cubic feet per second
LPR = Los Padres Reservoir
NMWS = normal maximum water surface

Alternative 3 (Storage Expansion and Dredging) would result in a substantial increase in storage capacity and dry-season release at LPR. Consistent with the corresponding CRBHM scenario (Section 3.1.1), it is

10 Cal-Am's right under License 11866 has a face value of 3,030 AFY. Although a figure of 2,179 AFY was determined by SWRCB as the amount available under the License in 1995 due to siltation, that lower number may be relevant only for the purposes of determining compliance with the CDO. Similarly, the 60 AFY figure assumed by SWRCB for Cal-Am's riparian rights also may only be relevant for the purposes of compliance with the CDO; riparian water rights are generally not quantified.

assumed that with Alternative 3, Cal-Am would negotiate an increase in water rights to reflect additional storage capacity. Water stored and released at LPR would provide instream, environmental flows before being recaptured at wells in the lower Carmel River. The CRBHM scenarios assume that most of the water recovered in the lower river would be pumped during the wet season, with minimal pumping (100 AF per month) in the dry season as is needed to maintain the Begonia Iron Treatment Removal Plant. The remainder (>600 AF per month) would be pumped December through May. Currently, pumping during the dry season tends to be greater than 100 AF per month, with June through November pumping in 2022 ranging from 223 AF to 370 AF per month (MPWMD 2023).

Alternative 2 (Dam and Sediment Removal) would result in immediate loss of all storage and dry season release from LPR. Under that scenario, municipal water supply would benefit if Cal-Am and SWRCB were able to agree to retain water rights associated with LPR. According to an existing MOA, dam removal is conditioned upon Cal-Am obtaining approval from SWRCB for a change in method and place of diversion under License 11866, such that Cal-Am's right to divert water is protected in the absence of LPD (NMFS 2017). While this is stated in the MOA, SWRCB is not party to the MOA.

Another aspect of dam removal that has been raised, relative to water availability, is the potential impact of dam removal on regional wildfire suppression activities. As described in Section 2.4.2, water from LPR is sometimes used for wildfire suppression but does not appear to make up a large portion of the total volume of water used to fight wildfires in the region. Although a detailed evaluation of impacts to fire suppression is beyond the scope of the LP Alternatives Study, based on evaluations completed for other California dam removal projects and given alternative water sources available regionally, it seems with additional evaluation and planning removal of LPD could be accomplished with an acceptable effect on fire suppression activities. Additional analysis would be required during environmental review if Alternative 2 is selected for development, but impacts to fire suppression activities are not likely to drive selection of a preferred alternative.

7.1.5 Steelhead

The *South-Central California Coast Steelhead Recovery Plan* (NMFS 2013b) prioritizes "…solutions that emphasize resilience in the face of projected climate change to ensure a sustainable future for both human communities and steelhead," as a necessary component of the recovery of the S-CCC steelhead population. Table 7-5 provides a summary and visual overview of the effects to steelhead for the two remaining alternatives for the primary factors considered in the analysis in this report. In general, the alternatives evaluated in this report benefit steelhead in the Carmel River by either restoring natural processes to the river or through the continued augmentation of summer flows and improving engineered fish passage facilities. Dam removal stands out as having multiple, strong benefits for steelhead but comes at the cost of losing the ability to augment summer rearing habitat with flow releases downstream of LPD. It is difficult to know exactly how the steelhead population would respond to a loss of wetted channel in the lower river, where production is currently highest, offset by the ecosystem restoration that comes with dam removal, including improved spawning habitat downstream of LPD, volitional passage for all life stages without the temperature and predation effects of LPR, and restoration of roughly 10,000 feet of stream channel through the footprint of LPD, LPR, and accumulated sediment. Boughton and Ohms (2022) have shed some light on the anticipated steelhead population response to potential changes in streamflow, but the effect of changes among other habitat parameters on the Carmel River steelhead population associated with the alternatives under consideration have not been modeled. Considering the multiple benefits associated with Alternative 2, inclusion of other habitat parameters (e.g., temperature or spawning substrate) in a population model could reveal advantages of Alternative 2 not captured in Boughton and Ohms 2022. Furthermore, if climate change were to lead to warmer stream temperatures in the Carmel River, the benefit of additional wetted habitat downstream of LPD (where temperatures are higher than upstream of LPR) could be less than currently predicted.

Table 7-5 Comparison of Long-Term Effects to Steelhead for the Remaining Alternatives

	Sediment Transport	Water Availability	Water Temperature	Fish Passage	Habitat Quantity
Alternative 2 Dam and Sediment Removal	+ Natural sediment transport, increased habitat complexity and increased spawning habitat	- Less wetted summer rearing habitat	+ Restores natural thermal regime, provides access to thermal refugia	+ Volitional upstream and downstream passage for all life stages; no reservoir migration	+ Restoration of 10,000 feet of river, access to summer refugia upstream of LPR
Alternative 3 Storage Expansion and Dredging	- Potential for one-time introduction of coarse sediment with temporary benefit	+ More wetted summer rearing habitat	- Suboptimal temperature regime, continued blockage of thermal refugia	- Managed passage, design coordination needed; no upstream juvenile passage; migration through reservoir	- Summer coldwater refugia upstream of LPR inaccessible; impacts to 3,500 feet of upstream habitat with dredging and gate operation

Notes:

+ (green) = better, - (salmon) = worse

LPR = Los Padres Reservoir

Germane to NMFS' stated goal above is the access to cold and perennial stream habitat upstream of LPD that dam removal would afford juvenile steelhead rearing in the Carmel River, a valuable resource in the face of climate change. Adults would also have improved access to upstream habitat, where the federal wilderness protects the watershed and development is nonexistent. Although the Carmel River has been managed for many years to maximize production downstream of LPD, other coastal steelhead streams in northern and central California have alluvial reaches downstream of their canyon reaches that historically flowed intermittently during the dry season (Grossinger et al. 2008; Stanford et al. 2013). Steelhead have evolved opportunistically to take advantage of a wide variety of habitat conditions (Moyle et al. 2008; NMFS 2013b). Removal of LPR would eliminate releases to downstream but also would eliminate loss of juveniles spawned upstream that must transit through the reservoir (Ohms et al. 2022). With the restoration of geomorphic processes and the thermal regime in the lower river, new and restored habitat through the LPD and LPR reach, and improved access to 14.4 miles (Becker et al. 2010) of cold, perennial, protected habitat in the upper watershed, production rates at various locations in the watershed would shift. From Boughton and Ohms (2022), we can conclude that, when considering streamflow alone, both dam removal and increasing storage in LPR may benefit the Carmel River's steelhead population; but in the case of dam removal, the benefit would be greatest with reduced groundwater extraction along the Carmel River during the dry season. The effect of climate change on stream temperatures in the Carmel River has not been studied in detail but could influence the quality of summer rearing habitat over time, potentially increasing the value of the coldest habitat or decreasing the value of the warmest habitat. Theoretically, this could increase the importance of upstream habitat relative to downstream, potentially increasing the production benefits predicted for Alternative 2 and decreasing the production benefits predicted for Alternative 3.

At other locations where sediment transport processes and volitional fish passage were restored, steelhead recolonization occurred rapidly. Examples include the restoration of fish passage following fish ladder installation at Landsburg Dam on the Cedar River, Washington (Kiffney et al. 2009), and following removal of Condit Dam on the White Salmon River, Washington (Allen et al. 2016). Steelhead recolonization of habitat upstream of Condit Dam was notable, with steelhead spawning observed in upper basin tributaries within 5 years of dam removal. However, fish passage (existing facilities) and limited sediment transport (gravel augmentation mentioned in Section 4.4.1) occur now at LPD and will occur to some degree under all alternatives evaluated.

When considering the long-term future of LPD, Carmel River steelhead are faced with a tradeoff. Modeling of the effects of streamflow, or water availability, on steelhead production predicted that “the gain in adult production from reconnecting the upper watershed was approximately equal and opposite to the loss of adult production due to lower summer flows without the dam,” (Boughton and Ohms 2022). However, this prediction considers only water availability and no other benefits of dam removal, such as improved habitat dynamics and sediment regimes. Alternative 2 (Dam and Sediment Removal) would restore habitat and natural processes and eliminate impacts on passage between the upper and lower watershed, but it would also eliminate the ability to augment dry season flows downstream of LPD (Table 7-5). Alternative 3 (Storage Expansion and Dredging) benefits steelhead by maintaining higher flows in the lower Carmel River but would perpetuate many of the ongoing impacts to the steelhead population associated with the existing dam and reservoir. If dam removal increased production from above LPD as predicted by Boughton and Ohms (2022), and if those steelhead spawned in the upper watershed accumulated other benefits not addressed in the production model as they moved downstream because they are rearing in habitat restored or improved due to dam removal, then, theoretically, steelhead production under Alternative 2 may be higher than the model predicts. Considering the population’s sensitivity to spring low-flow and infiltration in the lower river (Boughton and Ohms 2022), managing the Carmel River’s water resources to minimize infiltration downstream of the Narrows during the dry season would benefit steelhead in the Carmel River regardless of the action taken at LPD. If a quantitative comparison of tradeoffs among non-flow habitat parameters (e.g., temperature, spawning gravel availability, and total miles of available habitat) is needed to determine which alternative would have the greatest benefit for steelhead, then additional modeling and analysis may be needed. However, either increasing storage and dry-season flow augmentation or dam removal combined with careful management of dry season infiltration in the lower river would likely improve conditions for Carmel River steelhead.

7.2 Outstanding Uncertainties

As noted previously, conceptual, or planning-level alternatives are uncertain by nature, given the typical lack of sufficient design parameters and analysis available during the planning phase. Assessments or investigations to help address uncertainties related to design and construction are addressed for each alternative in Sections 4 and 5. This section focuses on the two remaining alternatives and the uncertainties that are most relevant to selecting between them. If a decision cannot be made regarding a preferred alternative based on the information presented in this report, then some of these uncertainties may need additional study before the long-term future of LPD and LPR can be decided.

The LP Alternatives Study was initiated, in part, because LPR is filling with sediment. As it fills with sediment the reservoir will stop providing benefits but some of its adverse effects will persist (e.g., impacts to steelhead migration). It therefore befits stakeholders to take decisive action before sediment accumulation further diminishes the reservoir’s benefits. Although this report estimates that it will be roughly 100 years before LPR is filled with sediment, that estimate is highly uncertain due to the episodic nature of sediment deposition, and possibly conservative with the inclusion of the 590 AF of sediment deposition following the Marble Cone Fire (a sequence of events estimated to have a 1,000-year recurrence interval [Section 4.4.1]).

Alternative 2 (Dam and Sediment Removal) would benefit from resolution of lingering questions surrounding water rights, steelhead population response, and flood effects. Now that feasible alternatives for LPD and LPR have been defined and their effects explored, it would be timely to engage SWRCB and confirm that removal of LPD would not result in forfeit of the water right associated with LPR, conferred by License 11866. The water right associated with LPR is important to the Monterey Peninsula municipal water supply. NMFS, the MPWMD, and Cal-Am acknowledge that approval from SWRCB for a change in method and place of diversion will be required prior to dam removal (NMFS 2017).

The LP Alternatives Study has described the types of effects that steelhead would experience with Alternative 2, and a flow-based model has been used to quantify the likely effects of changes in streamflow on the steelhead population. However, existing information has not allowed for a quantitative comparison of the habitat upstream of LPR (which would become more accessible) with habitat changes that would occur downstream with restoration, reduced summer flows, and increased bedload transport.

Additionally, temperature may have an important effect on habitat quality and population dynamics in the Carmel River, an effect that could become more important if climate change results in warmer stream temperatures; that effect also has not been quantified. Therefore, attempts to predict the overall steelhead population response to any alternative are incomplete. If additional quantitative comparison is required beyond the flow-based model developed by NMFS (Boughton and Ohms 2022), detailed habitat surveys—particularly upstream of LPD—and inclusion of additional habitat parameters in the model may move stakeholders closer to a preferred alternative.

Flood effects would likely require more detailed analysis during the environmental review process for Alternative 2. Based on the BESMo results, there may be greater flood impacts to Cachagua with Alternative 2 than with other alternatives. Development of a flood model that predicts inundation depths and frequencies based on the bed elevation adjustments predicted by the BESMo would provide a quantitative comparison of flood effects and would help identify possible downstream actions to affect flooding, and associated costs.

Routine geotechnical investigation of the sediment disposal sites will inform their design and acceptable capacities, but the investigations are not likely to differentiate Alternative 2 from Alternative 3 (Storage Expansion and Dredging). Evaluation of cultural resources was not part of the LP Alternatives Study scope of work, but incidentally, MPWMD holds documentation of potentially significant Native American cultural resources roughly 0.4 mile north (downstream) of LPD that could affect use of some disposal sites. Significantly reduced disposal site capacity could require reductions in sediment removal volumes assumed in Alternatives 2 and 3, or identification of an alternate disposal location. Further study to confirm the location of and potential for impact to cultural sites should be completed before undertaking design of sediment disposal Sites C, D, and E.

In the context of LPD in its existing configuration, multiple fish passage options are feasible and worthy of further consideration (HDR et al. 2021); however, in the context of LPD with spillway gates (Alternative 3), the compatibility, risks, and benefits of the passage options have not been fully evaluated. Because Alternative 3 includes water surface elevation modulations in LPR and could affect fish passage operations, additional design coordination and analyses of effects to fish passage operations would progress this alternative. With only 20 percent of juveniles that entered LPR later detected downstream of the dam (Ohms et al. 2022), it may not be possible for improved fish passage facilities to meet the 95 percent collection efficiency and 98 percent survival criteria noted for downstream passage in HDR et al. 2021, even with the dam and reservoir in their existing configuration.

Considering the substantial effects of LPR on fish passage and migration, relatively little is known about how juvenile steelhead use LPR. At the start of the LP Alternatives Study the only information available was from MPWMD's limited trapping studies in the 1990s (MPWMD 2015b). NMFS' recent investigation added considerably to our knowledge of steelhead use of the reservoir (Ohms et al. 2022), but due to the relatively short duration of that study it was not able to determine the proportion of juveniles lost in LPR (i.e., those that moved downstream into LPR and were not later detected upstream or downstream in Carmel River) that were rearing for an extended period in LPR, that were lost to predation, or that moved downstream but were not detected by the PIT tag antennas. Whether to guide selection of the most favorable fish passage options or to inform anticipated operation of spillway gates, the following additional study of Carmel River steelhead could yield valuable information:

- Life history of juvenile steelhead upstream of LPD, including downstream migration timing, reservoir rearing, residualization, survival, and behavior
- Adult migration delay downstream of LPD
- Relationship of population productivity dynamics to non-flow habitat parameters (including available spawning and rearing habitat and stream temperature) of the Carmel River and tributaries upstream and downstream of LPD

7.3 Technical Review Committee and Stakeholder Recommendations

The LP Alternatives Study was a collaborative process during which TRC and stakeholder input was provided frequently and incorporated throughout alternatives development and analysis. Questions and concerns were typically addressed by study participants through a combination of technical analysis, professional experience, local knowledge, reference information, and communication. Study participants were generally able to reach mutually agreeable decision points and conclusions, such that many of the recommendations of the TRC are reflected throughout this report. The purpose of this section is to document TRC and stakeholder recommendations and preferences that may not be reflected in the general report content.

At conclusion of the LP Alternatives Study, CDFW indicated that it prefers Alternative 2 (Dam and Sediment Removal) for steelhead and other native aquatic species benefits, and other stakeholders agreed that only Alternatives 2 and 3 (Storage Expansion and Dredging) should be considered further for the long-term future of LPD and LPR. Although impacts to fire suppression may not drive selection of a preferred alternative (Section 7.1.4), Cal-Am would like to study the impacts of dam removal on regional fire suppression activities prior to selecting a preferred alternative.

CDFW's preference for Alternative 2 was qualified by the following comments provided on the Revised Draft Final Report on April 8, 2023:

- Comment No. 2: *CDFW believes that Alternative 2 (dam removal) is the preferred alternative for steelhead and other native aquatic species benefits. The coastal location of the Carmel River offers buffering against temperature changes associated with climate but there is uncertainty what stream conditions will be like in 50 years and that the more productive reaches could potentially shift to the upper watershed. That said, there is also uncertainty of rainfall patterns with climate change, thus reservoir storage and releases could be considered beneficial by keeping the lower Carmel River [that Boughton and Ohms (2022) deemed the most productive for steelhead growth under current conditions] wetted for steelhead during years when it may typically go dry.*
- Comment No. 9: *CDFW considers Alternative 3 to potentially not be feasible since it is unlikely to meet typical through reservoir survival performance standards (75 to 80 percent), given existing data showing through reservoir survival rates of 20 percent. Inability to meet typical through reservoir survival performance standards would likely result in additional regulatory oversight, including the need to change to a Carmel River collector. Based on HDR et al. 2021, a Carmel River collector may not be feasible due to hillslope stability, loss of access, and inability to provide reliable access and service power improvements necessary for both construction and operation.*
- Comment No. 19: *CDFW believes that Alternatives 3 (Dam and Sediment Removal) and 4 (Recover Capacity with Excavation) should both remain on the table for consideration as long as the in-reservoir survival is improved (only 20 percent under existing conditions while 75 to 80 percent survival is the typical standard) and that the reservoir is operated to release flows to keep fish in good condition per Fish and Game Code 5937 (flows targeted for steelhead in- and out-migration as well as rearing flows that improve growth and survival per the dynamics described in Boughton and Ohms [2022]).*

Notably, Comment No. 19 suggests further consideration of Alternative 4 (Recover Storage Capacity with Excavation). Alternative 4 was dismissed unanimously by all LP Alternatives Study participants, including CDFW, after publication of the Alternatives Development TM, at the fourth TRC meeting (TRC Meeting No. 3), and that decision was subsequently confirmed via written comments. Although eliminated earlier in the LP Alternatives Study due to its limited advantages and highest cost relative to other alternatives, Comment No. 19 suggests that CDFW may wish to revisit Alternative 4.

Alternative 3 (Storage Expansion and Dredging) currently includes both dredging to restore reservoir capacity and installation of operable spillway gates to increase the NMWS of LPR. Either action alone would have benefits, and Cal-Am may prefer not to include the spillway gates. NMFS and the MPWMD have indicated with written comment that if LPD remains, they would like to see it provide maximum water storage and release benefits. However, considering the dam was designed and built in 1949, addition of spillway gates would require a comprehensive analysis of the existing dam to current standards by DSOD and therefore could trigger major structural improvements to the existing dam. Some of these improvements are captured in the description and cost associated with Alternative 3, but there could be others. Cal-Am would like to avoid such a comprehensive analysis and potential overhaul of the structure, and initially recommended that the spillway gates be removed from Alternative 3. Upon further discussion, because the spillway gates could still be removed later, Cal-Am agreed with the decision to retain the gates in this final report.

Stakeholders and the TRC noted several other preferences or specific information needs relevant to Alternatives 2 and 3. Cal-Am would like geotechnical investigation of the sediment disposal sites completed to confirm their ability to receive accumulated sediment as described for Alternatives 2 and 3, as well as further analysis of the risks and benefits associated with the various fish passage options associated with Alternative 3. NMFS would like to see the CRBHM updated with recent data (2016-2022) and rerun to reflect the final alternatives. NMFS would also like to see the CRBHM (with updated data 2016-2022) rerun for a dam removal scenario with no Cal-Am pumping in the low flow season.

Many of CDFW's final comments on the LP Alternatives Study were related to temperature, particularly stream temperatures considering climate change. Although potential changes in Carmel River water temperature due to climate change have not been quantified, CDFW posits that warming due to climate change could increase the population-level benefits of Alternative 2, relative to Alternative 3, by increasing the importance of habitat upstream versus downstream of LPD. CDFW hypothesized that consideration of other habitat parameters (i.e., water temperature as affected by climate change) would reduce and potentially eliminate Alternative 3's advantage of more wetted summer rearing habitat downstream of LPD. In CDFW's own words, from Comment No. 1 on the Revised Draft Final Report:

> *We understand that inclusion of water temperature modeling (and thus the effects on quantity/ quality of steelhead habitat downstream of Los Padres Dam) relative to climate change wasn't included in the scope of this project. Because steelhead life history in the future will be affected by climate change (and also because CEQA will require this kind of analysis anyway), we recommend doing this evaluation proactively to determine the potential magnitude of effects on steelhead habitat as there is the potential for the ecotone in the Central Coast to be much different in 50 years (e.g. similar to that currently in Southern CA?) thus the water management alternatives may have different relative effects on steelhead populations. Where possible, it would be helpful to build these temperature models (as well as models of changed rainfall patterns given the alternatives and the effects on streamflow) into the fish population modeling scenarios developed by Boughton and Ohms (2022), which didn't include future temperature scenarios.*

Although CDFW has already suggested a preferred alternative, additional quantification of current and future temperature effects on steelhead habitat and population dynamics in the watershed could help all stakeholders understand this aspect of and potential differentiator among alternatives.

7.4 Conclusion and Next Steps

All the alternatives presented in this report are conceptual and may change or be refined as design development and facility and biological goals and objectives are advanced. The focus of the LP Alternatives Study has been developing feasible alternatives for the long-term future of LPD and LPR that address the accumulation of sediment in the reservoir while balancing water management, dam safety, and steelhead recovery considerations. A second primary focus has been to understand and compare the effects of favorable alternatives on resources that are likely to drive selection of a preferred alternative. As a preferred alternative is selected and developed further, additional effects analysis will be necessary in the context of environmental compliance and permitting. Any of the alternatives described in this report may require measures to avoid, minimize, or mitigate adverse effects in compliance with the federal ESA, California Environmental Quality Act, California Fish and Game Code, and other environmental regulations, as appropriate.

The LP Alternatives Study has defined two feasible alternatives for managing sediment at LPR, one of which would remove the dam and reservoir (Alternative 2) and one of which would modify and retain the dam and reservoir (Alternative 3). A primary tradeoff for steelhead between these two alternatives is the benefit of habitat restoration and unimpeded passage at LPD and LPR (Alternative 2, Dam and Sediment Removal) versus the benefit of augmented summer rearing flows in the lower river (Alternative 3, Storage Expansion and Dredging). Dam removal would require modification of the water right associated with LPR to maintain that portion of the municipal water supply. Other water management changes that allow for reduced groundwater extraction along the Carmel River during the dry season would amplify the restorative potential of dam removal but would also have benefits regardless of action at LPD. Aggradation between LPD and the confluence with Cachagua Creek that would occur following dam removal would benefit ecosystem processes and steelhead, but potential flood effects on the community of Cachagua require additional study so that they can be addressed prior to dam removal, as appropriate.

When considering the need for additional information to select a preferred alternative, it should be recognized that time spent deliberating comes at the cost of additional sediment accumulation, reduced water storage and release, and a threatened population of S-CCC steelhead that may require action at LPD to recover. Studies that will be needed to design, permit, or operate a preferred alternative should be distinguished from studies needed to further differentiate Alternatives 2 and 3 and select a preferred alternative.

Dam removal is the less-expensive, nature-based solution for LPD. In many cases, dam removal can have broad ranging benefits to ecosystem function and salmonid conservation (Quiñones et al. 2015). The exact population or ecosystem response to dam removal may be difficult to predict, in part because many dam removal projects have been poorly monitored (Bellmore et al. 2017). If dam removal is preferred, additional study could focus on specific design and permitting questions with more focus than studies that seek to continue evaluation of both alternatives. In that case, the following investigations could move forward:

- Engage SWRCB and initiate water rights negotiations: Relevant parties should seek to make current water extraction practices under License 11866 permanent (i.e., SWRCB Order 95-10 requiring withdrawing water at the most downstream wells). Additionally, lowering winter instream flow requirements to allow additional winter diversions to storage in the Seaside Groundwater Basin could further reduce summer demand on Carmel River water. Alternative water supply management approaches that reduce groundwater extraction along the Carmel River would have benefits with or without dam removal. Even if Alternative 3 remains under consideration, separating the water rights issue from the dam and fish passage infrastructure issue would allow stakeholders to focus on the question of the environmental benefit of leaving the dam in place versus removing it.

- Investigate geotechnical conditions and cultural resources around the proposed sediment disposal sites: If there are any constraints on use of the sediment disposal sites identified in Section 5, especially Sites B and C, they would best be resolved early in the design process. Because impacts to sensitive Native American resources via sediment disposal may require design modification, that constraint also should be evaluated early.

- Proceed with flood modeling: Flood modeling will be required to determine the magnitude of potential flood effects suggested by the BESMo results. This modeling could leverage the adjustments in channel bed elevation and grain size predicted by the BESMo to predict flood depths and recurrence intervals at areas of concern. Should additional project elements be needed to affect flooding, that could increase the cost associated with dam removal or other alternatives that transport coarse sediment downstream.

Relative to dam removal, Alternative 3 maintains conditions closer to the existing at LPD and LPR, while improving engineered fish passage and considerably increasing storage. Alternative 3 benefits water supply and water availability for steelhead, relative to the existing condition, although the persistence of benefits that rely on suitable water temperatures in the lower river have not been confirmed in the face of climate change. If a dam-in solution is preferred, or if stakeholders continue considering both Alternatives 2 and 3, then the following investigations could be considered high priority:

- Conduct geotechnical and cultural resources investigations at the proposed disposal sites: Like dam removal, Alternative 3 is also dependent on disposal sites and any constraints on their use should be identified prior to further design.
- Conduct additional design coordination with fish passage improvements: If Alternative 3 remains under consideration, the conceptual designs and operational frameworks developed in the separate fish passage and dam, reservoir, and sediment management studies should be reconciled to confirm compatibility and the best fit between the fish passage options and Alternative 3. Adjustments to design concepts, operational framework, or the relevant OPCCs may be required and could shift stakeholder preferences if costs or benefits would be different from those described in this report.
- Confirm dam safety analysis and design requirements with the DSOD: Limited dam safety improvements to address current DSOD criteria are included with Alternative 3 (Storage Expansion and Dredging). If DSOD would require analysis or improvements beyond those assumed in Section 5, that could significantly affect the cost of dam-in alternatives and therefore, stakeholder perception regarding a preferred alternative.
- Additional analysis of stream temperatures, including the effects of climate change, may further differentiate alternatives or allow stakeholders to identify a preferred alternative more confidently.

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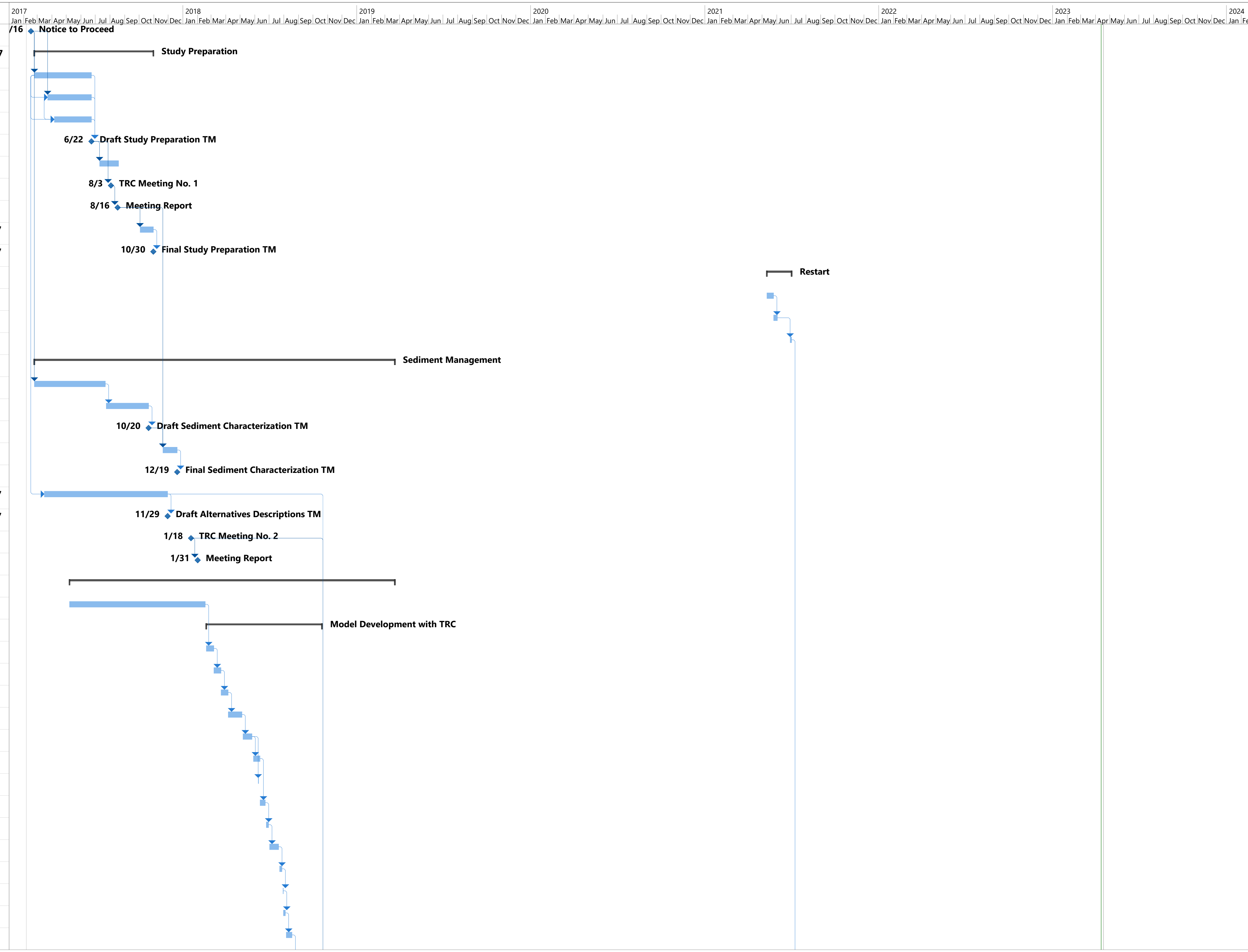
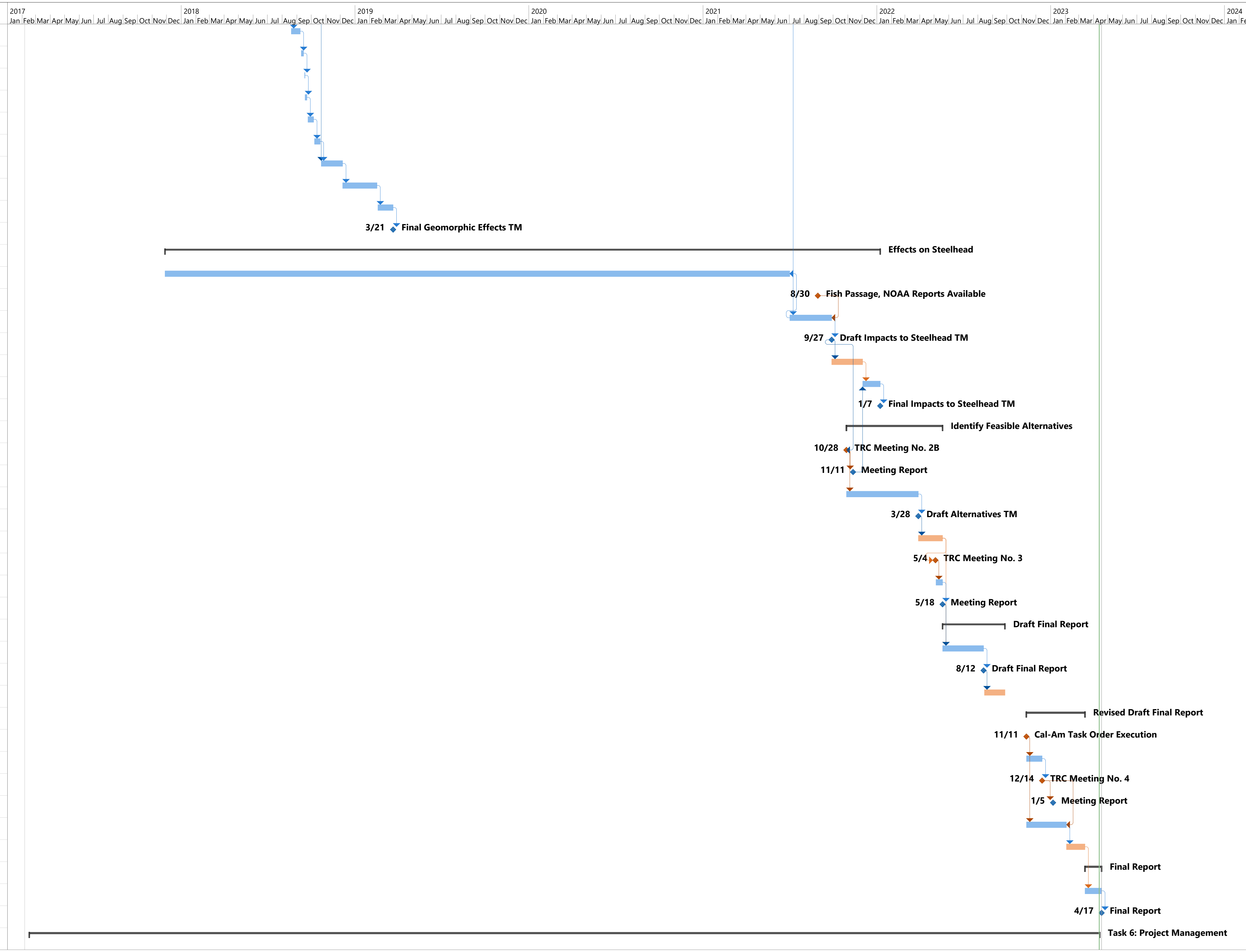
Attachment A
LP Alternatives Study Schedule

ID	Task Name	Duration	Start	Finish
1	Notice to Proceed	0 days	Thu 2/16/17	Thu 2/16/17
2	**Study Preparation**	**175 days**	**Thu 2/23/17**	**Mon 10/30/17**
3	Task 1-1: Compile Background Inform	85 days	Thu 2/23/17	Thu 6/22/17
4	Task 1-2: Prepare Evaluation Criteria	65 days	Thu 3/23/17	Thu 6/22/17
5	Task 1-3: Identify Critical Data Gaps	55 days	Thu 4/6/17	Thu 6/22/17
6	Draft Study Preparation TM	0 days	Thu 6/22/17	Thu 6/22/17
7	Task 1-4: TRC Meeting No. 1	30 days	Mon 7/10/17	Fri 8/18/17
8	TRC Meeting No. 1	0 days	Thu 8/3/17	Thu 8/3/17
9	Meeting Report	0 days	Wed 8/16/17	Wed 8/16/17
10	Revise Study Preparation TM	20 days	Tue 10/3/17	Mon 10/30/17
11	Final Study Preparation TM	0 days	Mon 10/30/17	Mon 10/30/17
12	**Restart**	**37 days**	**Tue 5/11/21**	**Thu 7/1/21**
13	Review Previous Study Reports	10 days	Tue 5/11/21	Mon 5/24/21
14	Plan Internal Workshop	5 days	Tue 5/25/21	Tue 6/1/21
15	Restart Workshop	3 days	Tue 6/29/21	Thu 7/1/21
16	**Sediment Management**	**525 days**	**Thu 2/23/17**	**Thu 3/21/19**
17	Task 2-1: Obtain Reservoir Sediment S	105 days	Thu 2/23/17	Fri 7/21/17
18	Prepare Draft Sediment Characterizat	64 days	Mon 7/24/17	Fri 10/20/17
19	Draft Sediment Characterization TM	0 days	Fri 10/20/17	Fri 10/20/17
20	Revise Sediment Characterization TM	20 days	Mon 11/20/17	Tue 12/19/17
21	Final Sediment Characterization TM	0 days	Tue 12/19/17	Tue 12/19/17
22	Task 2-2: Describe Alternatives	180 days	Thu 3/16/17	Wed 11/29/17
23	Draft Alternatives Descriptions TM	0 days	Wed 11/29/17	Wed 11/29/17
24	TRC Meeting No. 2	0 days	Thu 1/18/18	Thu 1/18/18
25	Meeting Report	0 days	Wed 1/31/18	Wed 1/31/18
26	**Task 2-3 Geomorphic Effects of Chan**	**473 days**	**Mon 5/8/17**	**Thu 3/21/19**
27	Preliminary Model Development	198 days	Mon 5/8/17	Fri 2/16/18
28	**Model Development with TRC**	**172 days**	**Mon 2/19/18**	**Fri 10/19/18**
29	No Action Simulation Plan (TM 1)	12 days	Mon 2/19/18	Tue 3/6/18
30	TRC Review TM 1	11 days	Wed 3/7/18	Wed 3/21/18
31	BESMo/San Clemente Comparison (	11 days	Thu 3/22/18	Thu 4/5/18
32	TRC Review TM 2 & Comment Resol	21 days	Fri 4/6/18	Fri 5/4/18
33	No Action Results & Historical Suppl	15 days	Mon 5/7/18	Fri 5/25/18
34	TRC Review TM 3 & Comment	10 days	Tue 5/29/18	Mon 6/11/18
35	TM 3 Conference Call w/TRC	1 day	Fri 6/8/18	Fri 6/8/18
36	TM 3 Comment Resolution	9 days	Tue 6/12/18	Fri 6/22/18
37	TM 3 Follow-up Conference Call w/	5 days	Mon 6/25/18	Fri 6/29/18
38	Historical Supply Results & Pulsing P	14 days	Mon 7/2/18	Fri 7/20/18
39	TRC Review TM 4	5 days	Mon 7/23/18	Fri 7/27/18
40	TM 4 Conference Call w/TRC	1 day	Mon 7/30/18	Mon 7/30/18
41	TRC Comments on TM 4	4 days	Tue 7/31/18	Fri 8/3/18
42	TM 4 Comment Resolution	10 days	Mon 8/6/18	Fri 8/17/18

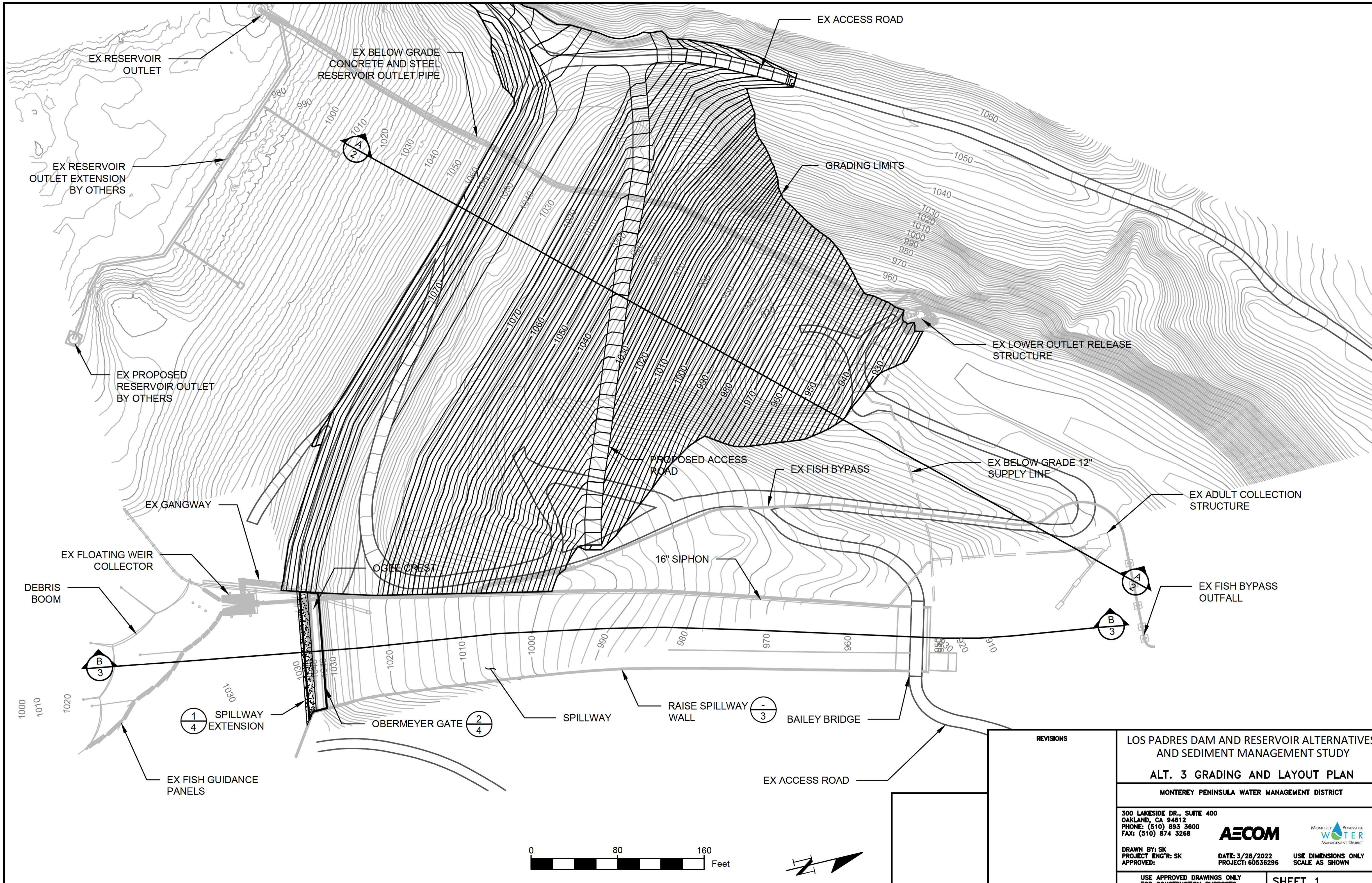


Date: Thu 4/13/23 | AECOM Task | AECOM Milestone | Summary | External Tasks | External Milestone

ID	Task Name	Duration	Start	Finish
43	Pulsing Results & Worst Case Plan (1	14 days	Mon 8/20/18	Fri 9/7/18
44	TRC Review TM 5	5 days	Mon 9/10/18	Fri 9/14/18
45	TM 5 Conference Call w/TRC	1 day	Mon 9/17/18	Mon 9/17/18
46	TRC Comments on TM 5	4 days	Tue 9/18/18	Fri 9/21/18
47	TM 5 Comment Resolution	10 days	Mon 9/24/18	Fri 10/5/18
48	Worst Case Simulation	10 days	Mon 10/8/18	Fri 10/19/18
49	Draft Geomorphic Effects TM	31 days	Mon 10/22/18	Wed 12/5/18
50	TRC Review Geomorphic Effects TM	48 days	Thu 12/6/18	Fri 2/15/19
51	Revise Geomorphic Effects TM	24 days	Mon 2/18/19	Thu 3/21/19
52	Final Geomorphic Effects TM	0 days	Thu 3/21/19	Thu 3/21/19
53	**Effects on Steelhead**	**1049 days**	**Tue 11/28/17**	**Fri 1/7/22**
54	Preliminary Analysis	923 days	Tue 11/28/17	Fri 7/2/21
55	Fish Passage, NOAA Reports Available	0 days	Mon 8/30/21	Mon 8/30/21
56	Prepare Draft Steelhead TM	60 days	Fri 7/2/21	Mon 9/27/21
57	Draft Impacts to Steelhead TM	0 days	Mon 9/27/21	Mon 9/27/21
58	TRC Review of Draft Steelhead TM	44 days	Tue 9/28/21	Wed 12/1/21
59	Revise Impacts to Steelhead TM	22 days	Thu 12/2/21	Fri 1/7/22
60	Final Impacts to Steelhead TM	0 days	Fri 1/7/22	Fri 1/7/22
61	**Identify Feasible Alternatives**	**134 days**	**Thu 10/28/21**	**Wed 5/18/22**
62	TRC Meeting No. 2B	0 days	Thu 10/28/21	Thu 10/28/21
63	Meeting Report	0 days	Thu 11/11/21	Thu 11/11/21
64	Task 4-2: Alternatives Development	97 days	Fri 10/29/21	Mon 3/28/22
65	Draft Alternatives TM	0 days	Mon 3/28/22	Mon 3/28/22
66	TRC Review Alternatives TM	37 days	Tue 3/29/22	Wed 5/18/22
67	TRC Meeting No. 3	0 days	Wed 5/4/22	Wed 5/4/22
68	Prepare Meeting Report	10 days	Thu 5/5/22	Wed 5/18/22
69	Meeting Report	0 days	Wed 5/18/22	Wed 5/18/22
70	**Draft Final Report**	**90 days**	**Thu 5/19/22**	**Mon 9/26/22**
71	Prepare Draft Final Report	60 days	Thu 5/19/22	Fri 8/12/22
72	Draft Final Report	0 days	Fri 8/12/22	Fri 8/12/22
73	TRC Review of Draft Final Report	30 days	Mon 8/15/22	Mon 9/26/22
74	**Revised Draft Final Report**	**76 days**	**Fri 11/11/22**	**Mon 3/13/23**
75	Cal-Am Task Order Execution	0 days	Fri 11/11/22	Fri 11/11/22
76	TRC Meeting Preparation	20 days	Fri 11/11/22	Tue 12/13/22
77	TRC Meeting No. 4	0 days	Wed 12/14/22	Wed 12/14/22
78	Meeting Report	0 days	Thu 1/5/23	Thu 1/5/23
79	Prepare Revised Draft Final Report	50 days	Fri 11/11/22	Thu 2/2/23
80	TRC Review Report	26 days	Fri 2/3/23	Mon 3/13/23
81	**Final Report**	**25 days**	**Tue 3/14/23**	**Mon 4/17/23**
82	Prepare Final Report	25 days	Tue 3/14/23	Mon 4/17/23
83	Final Report	0 days	Mon 4/17/23	Mon 4/17/23
84	**Task 6: Project Management**	**1560 days**	**Thu 2/16/17**	**Thu 4/13/23**



Attachment B
Drawings



REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

ALT. 3 GRADING AND LAYOUT PLAN

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

AECOM

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

DRAWN BY: SK
PROJECT ENG'R: SK
APPROVED:

DATE: 3/28/2022
PROJECT: 60536296

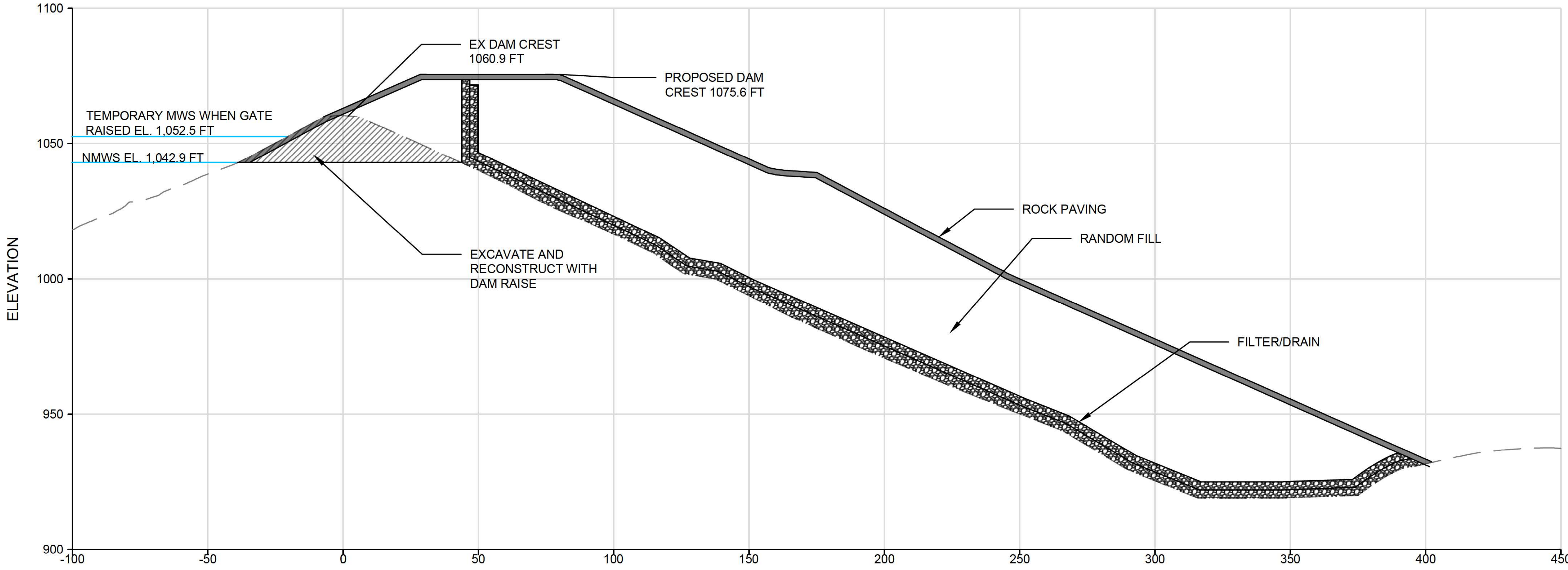
USE DIMENSIONS ONLY
SCALE AS SHOWN

USE APPROVED DRAWINGS ONLY FOR CONSTRUCTION PURPOSES

SHEET 1

PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:
1. BASE CONTOURS GENERATED USING ASSISTED PHOTOGRAMMETRIC METHODS BY HJW GEOSPACIAL, INC., OAKLAND, CA. DATED NOVEMBER 24, 2010
2. ACCURACY OF CONTOURS MAY DEVIATED FROM ACCEPTED STAMDARDS IN AREAS OF DENSE VEGETATION
3. HORIZONTAL COORDINATES ARE IN REFERENCE TO CALIFORNIA STATE PLANE, ZONE IV, NAD 1983
4. VERTICAL ELEVATIONS ARE IN REFERENCE TO NAVD88



A/1 TYPICAL DAM SECTION

0 40 80 Feet

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

ALT. 3 TYPICAL DAM RAISE SECTION

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

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OAKLAND, CA 94612
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FAX: (510) 874 3268

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Monterey Peninsula WATER Management District

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SHEET 2

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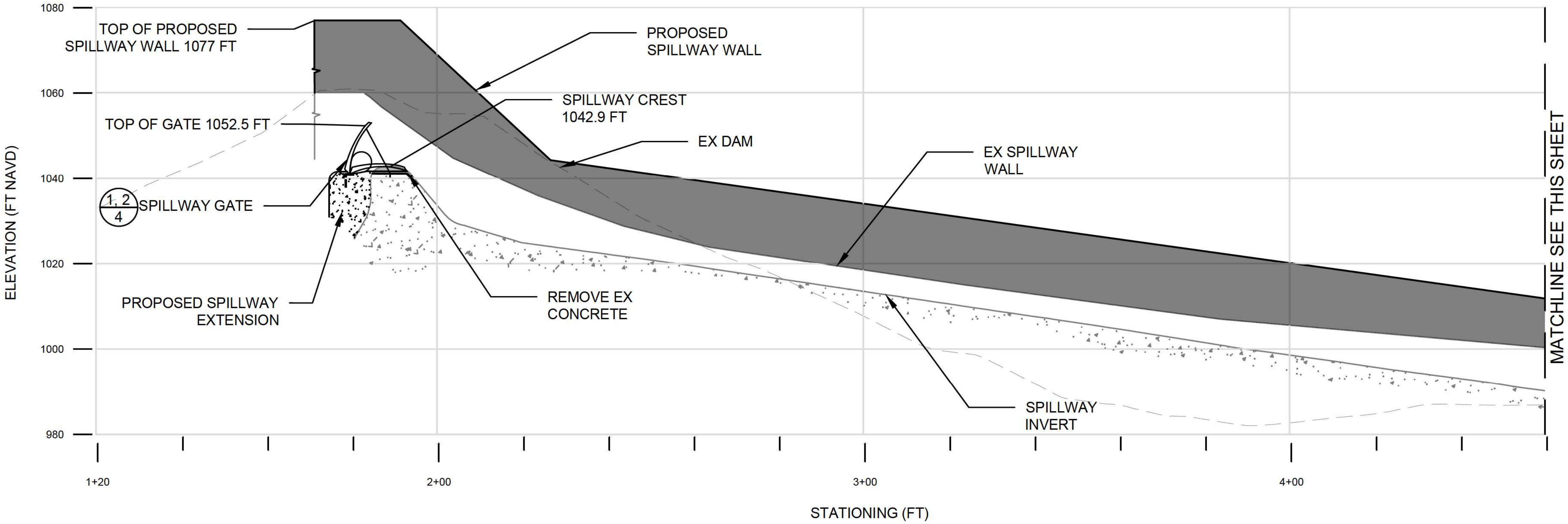

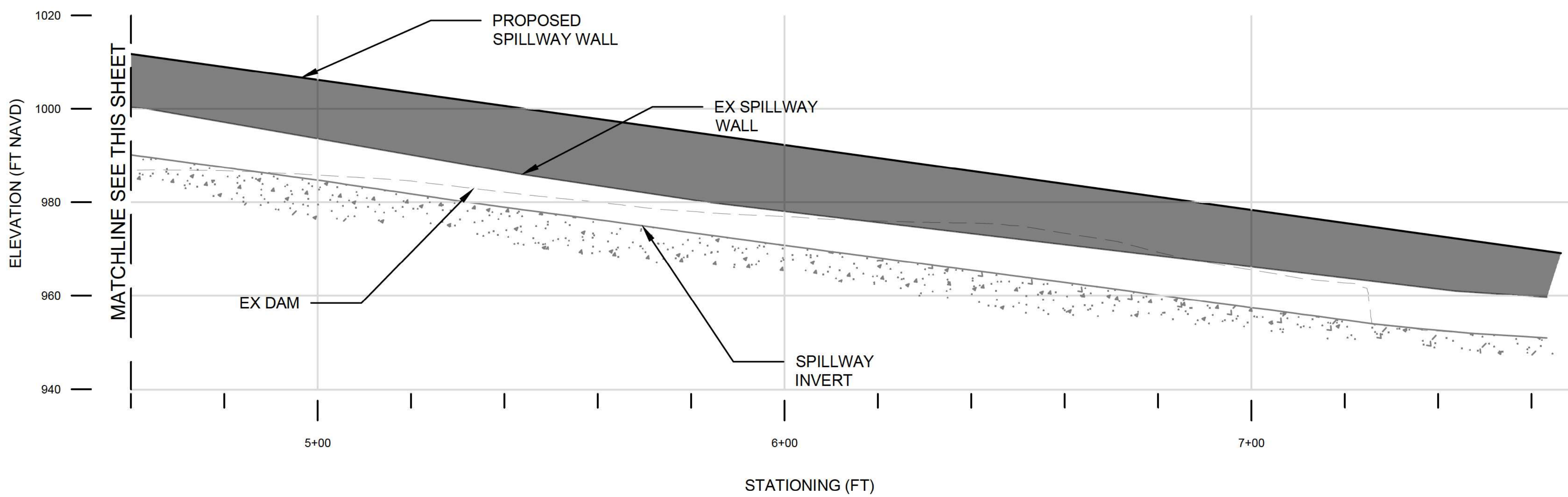

B
1
SPILLWAY PROFILE

0 30 60
Feet

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

ALT. 3 CONCRETE SPILLWAY PROFILE

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

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OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

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Monterey Peninsula WATER Management District

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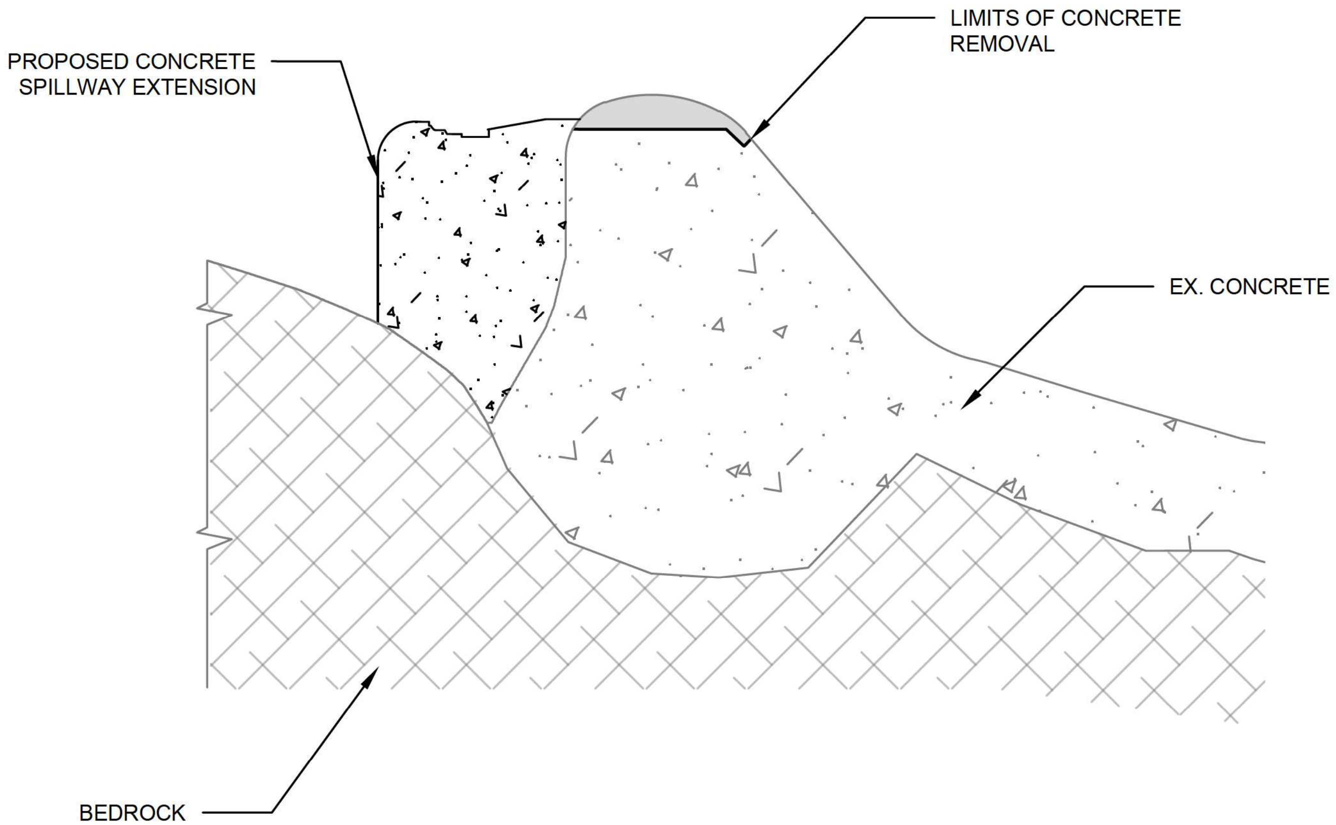
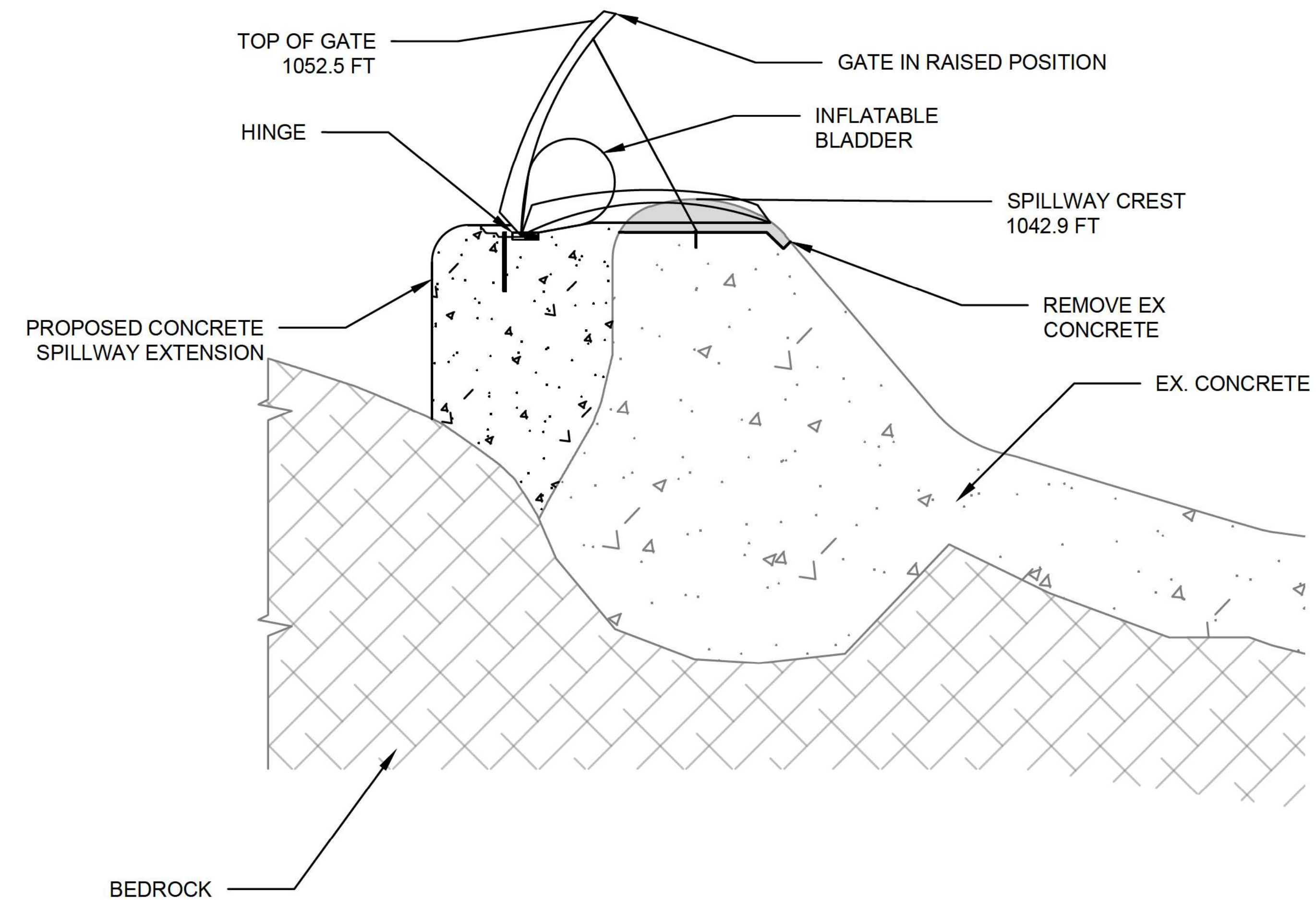
SHEET 3

PRELIMINARY — NOT FOR CONSTRUCTION



1 / 1, 3 SPILLWAY MODIFICATION SECTION

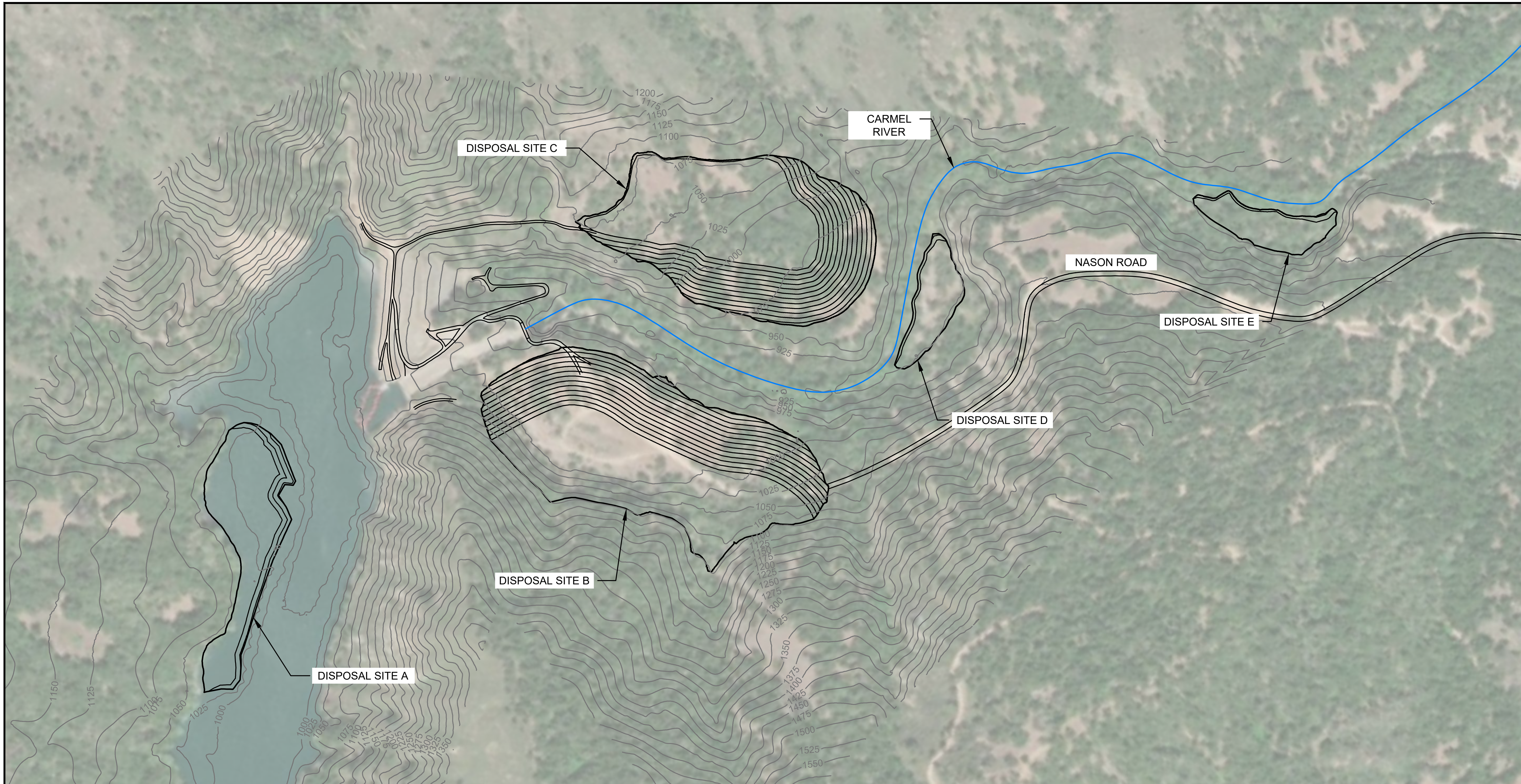


2 / 1, 3 SPILLWAY GATE

0 10 20 Feet

REVISIONS	LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY ALT. 3 SPILLWAY DETAILS
	MONTEREY PENINSULA WATER MANAGEMENT DISTRICT
	300 LAKESIDE DR., SUITE 400 OAKLAND, CA 94612 PHONE: (510) 893 3600 FAX: (510) 874 3268 AECOM Monterey Peninsula Water Management District DRAWN BY: SK PROJECT ENG'R: SK APPROVED: DATE: 3/28/2022 PROJECT: 60536296 USE DIMENSIONS ONLY SCALE AS SHOWN
	USE APPROVED DRAWINGS ONLY FOR CONSTRUCTION PURPOSES · SHEET 4

PRELIMINARY — NOT FOR CONSTRUCTION



NOTES:
1. ALTERNATIVE 2 ASSUMES USE OF DISPOSAL SITES A, B, AND C
2. ALTERNATIVE 3 ASSUMES USE OF DISPOSAL SITES B, C, D, AND E
3. ALTERNATIVE 4 ASSUMES USE OF DISPOSAL SITES B, C, D, AND/OR E

0 400 800 Feet

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

DISPOSAL SITES OVERVIEW

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
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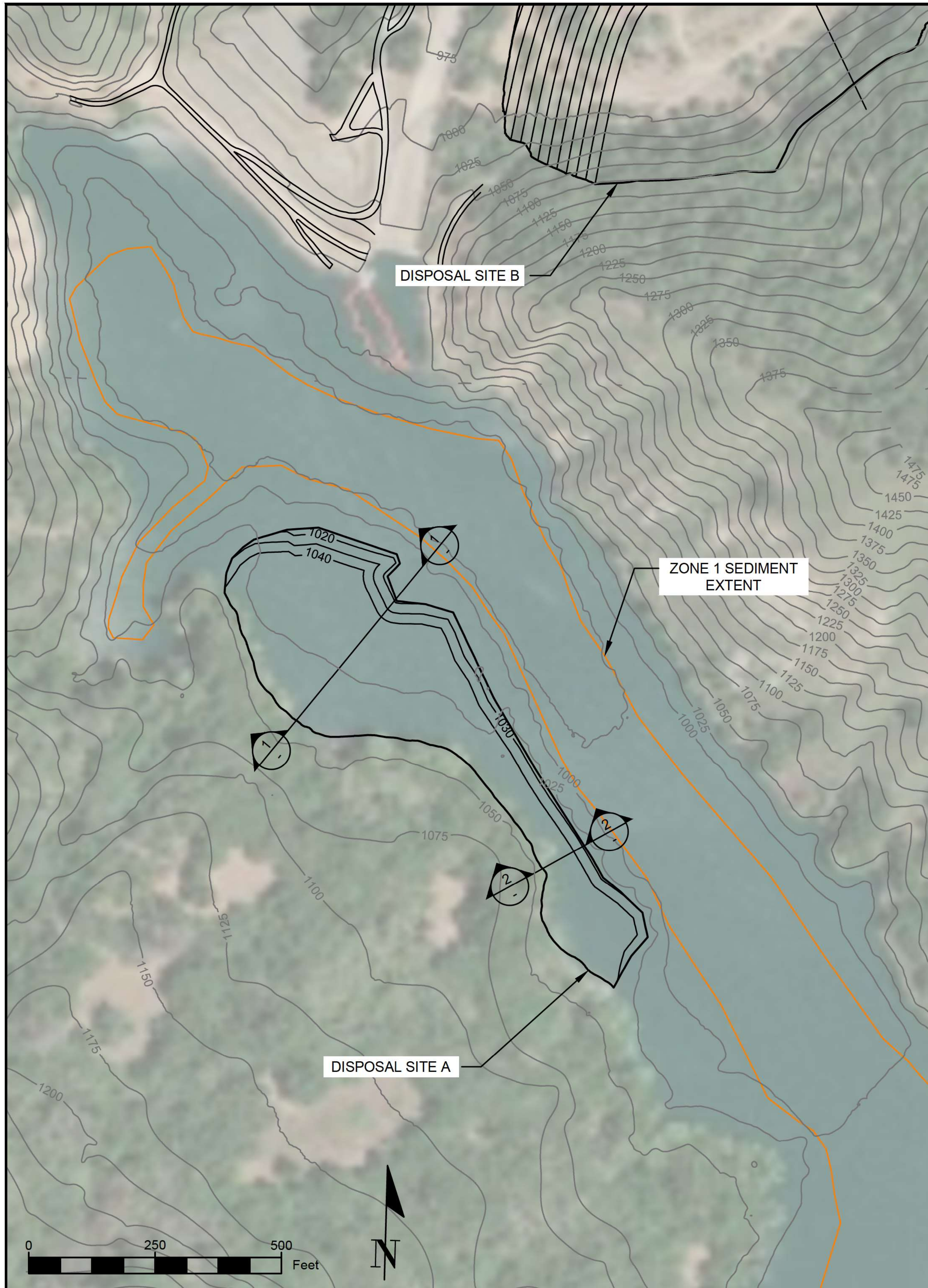
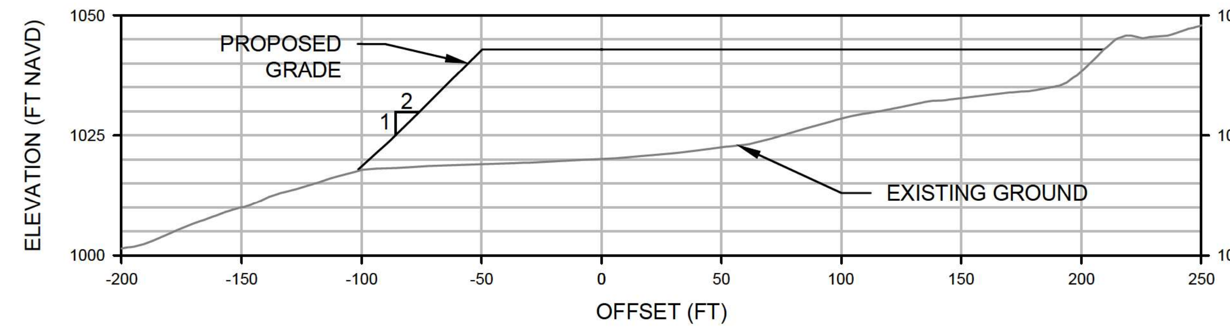
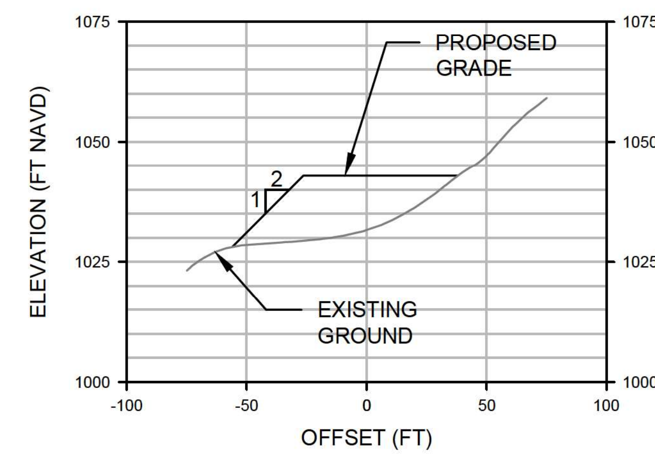
SHEET 5

PRELIMINARY – NOT FOR CONSTRUCTION





1 - SITE A SECTION



2 - SITE A SECTION

NOTES:

1. ALTERNATIVE 2 ASSUMES USE OF DISPOSAL SITES A, B, AND C

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

DISPOSAL SITE A

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

AECOM

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

DRAWN BY: SK
PROJECT ENG'R: SK
APPROVED:

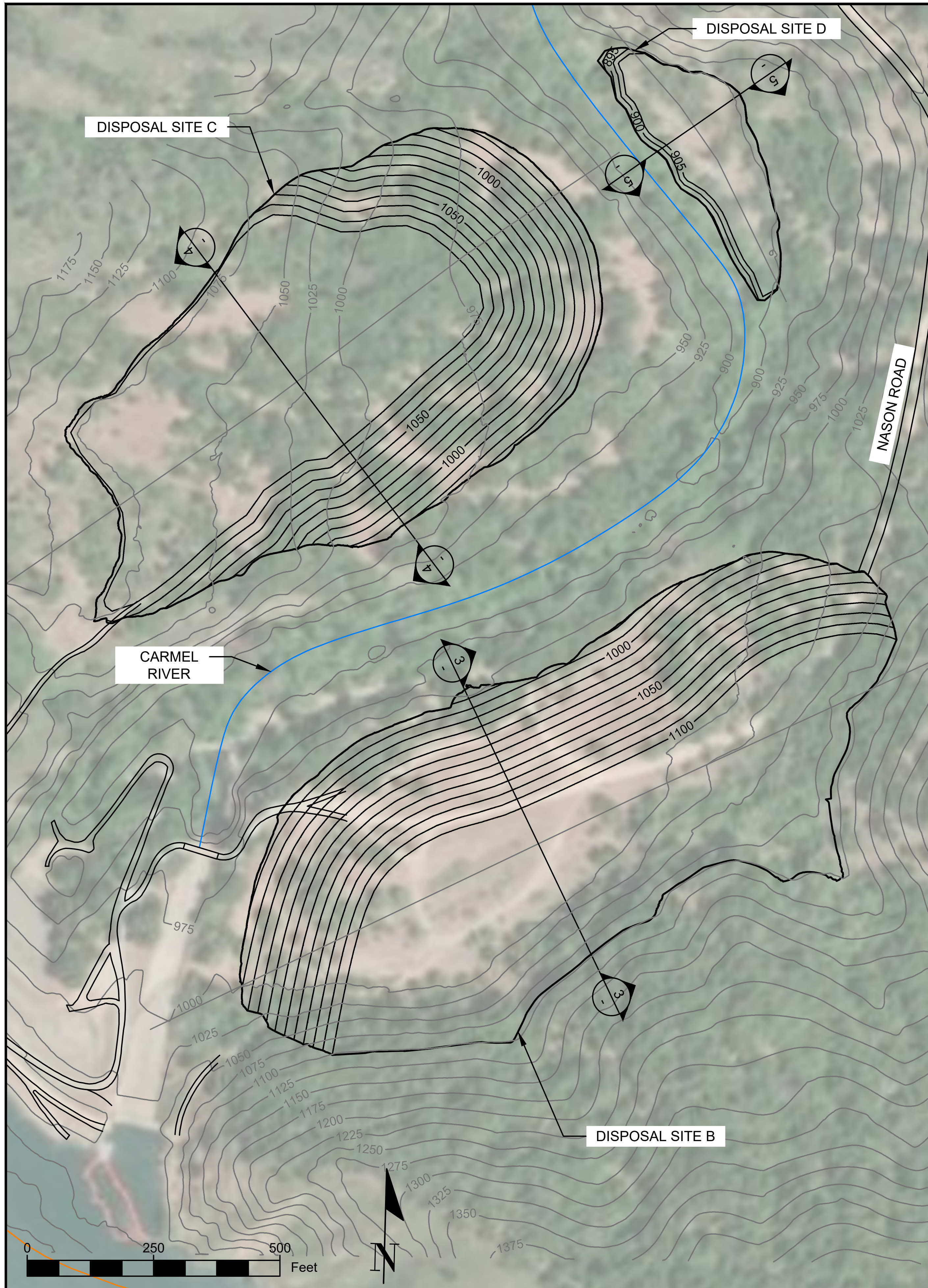
DATE: 3/28/2022
PROJECT: 60536296

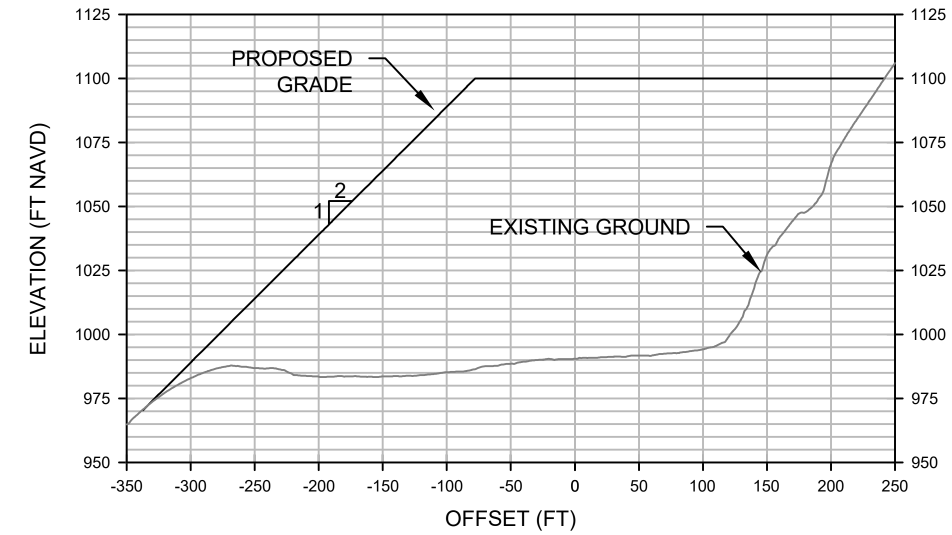
USE DIMENSIONS ONLY
SCALE AS SHOWN

USE APPROVED DRAWINGS ONLY FOR CONSTRUCTION PURPOSES

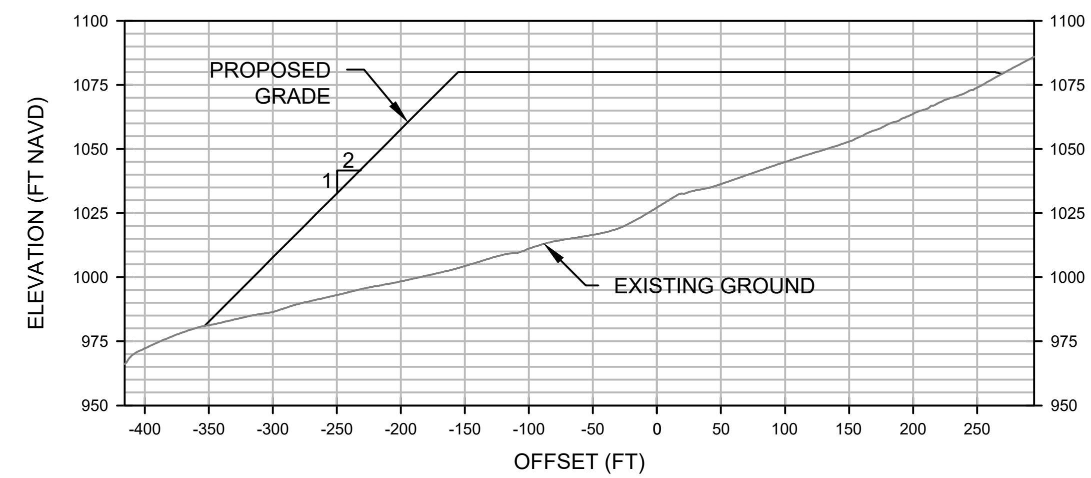
SHEET 6

PRELIMINARY – NOT FOR CONSTRUCTION

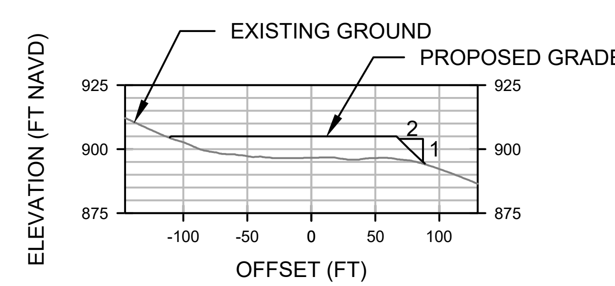




3 - SITE B SECTION



4 - SITE C SECTION



5 - SITE D SECTION

NOTES:

1. ALTERNATIVE 2 ASSUMES USE OF DISPOSAL SITES A, B, AND C
2. ALTERNATIVE 3 ASSUMES USE OF DISPOSAL SITES B, C, D, AND E
3. ALTERNATIVE 4 ASSUMES USE OF DISPOSAL SITES B, C, D, AND/OR E
4. SIDE SLOPES ARE APPROXIMATE AND MAY BE REDUCES TO 3H:1V AS DESIGN PROGRESSES. INTERMEDIATE BENCHES MAY ALSO BE REQUIRE DEPENDING ON SLOPE HEIGHT

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

DISPOSAL SITE B, C & D

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

AECOM

Monterey Peninsula WATER Management District

DRAWN BY: SK
PROJECT ENG'R: SK
APPROVED:

DATE: 3/28/2022
PROJECT: 60536296

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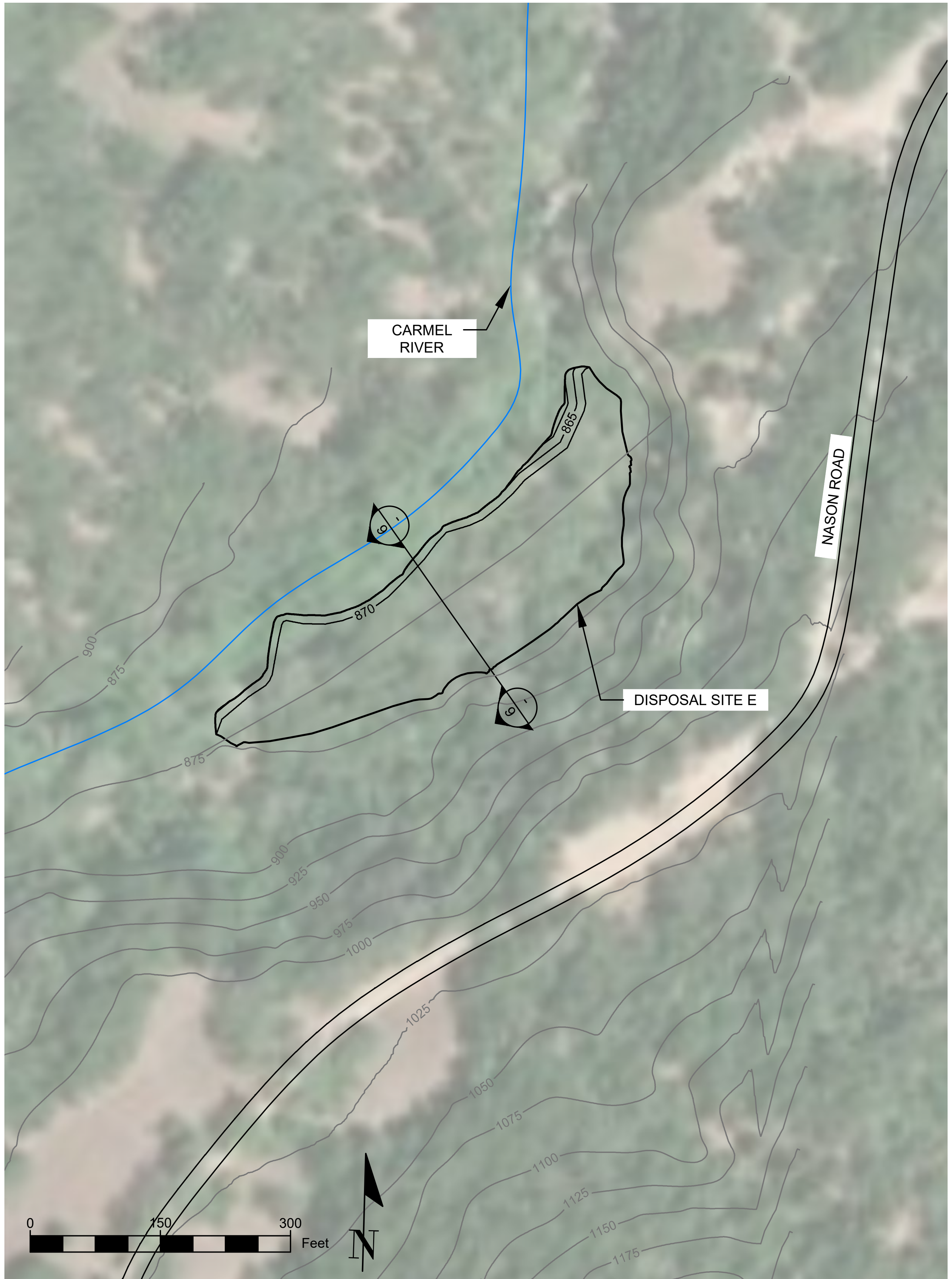
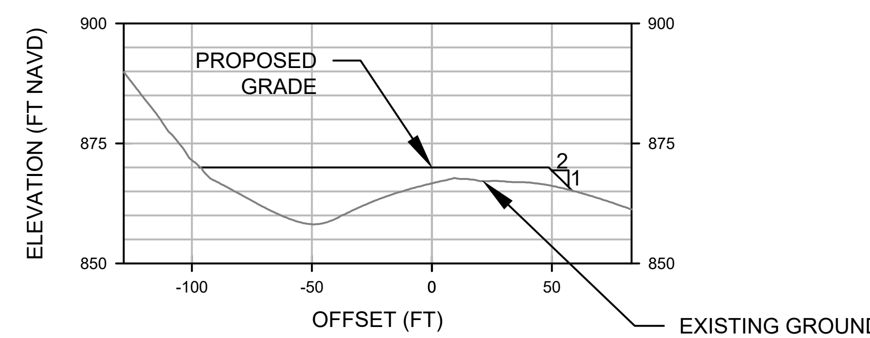
SHEET 7

PRELIMINARY – NOT FOR CONSTRUCTION





6
-
SITE E SECTION

NOTES:
1. ALTERNATIVE 3 ASSUMES USE OF DISPOSAL SITES B, C, D, AND E
2. ALTERNATIVE 4 ASSUMES USE OF DISPOSAL SITES B, C, D, AND/OR E
3. SIDE SLOPES ARE APPROXIMATE AND MAY BE REDUCES TO 3H:1V AS DESIGN PROGRESSES. INTERMEDIATE BENCHES MAY ALSO BE REQUIRE DEPENDING ON SLOPE HEIGHT

REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

DISPOSAL SITE E

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

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MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

DRAWN BY: SK
PROJECT ENG'R: SK
APPROVED:

DATE: 3/28/2022
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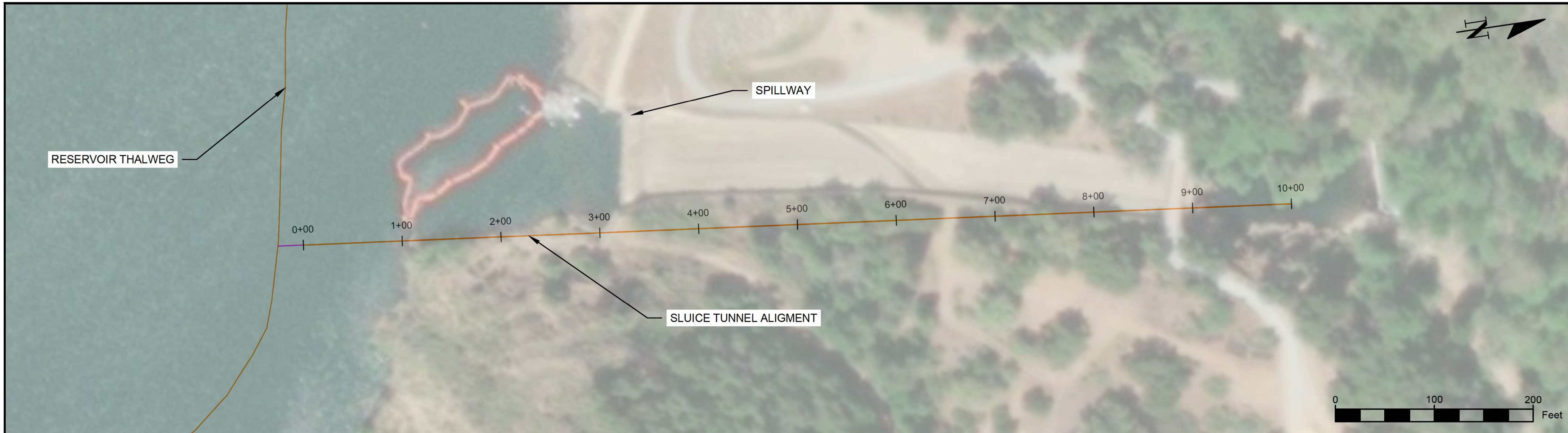
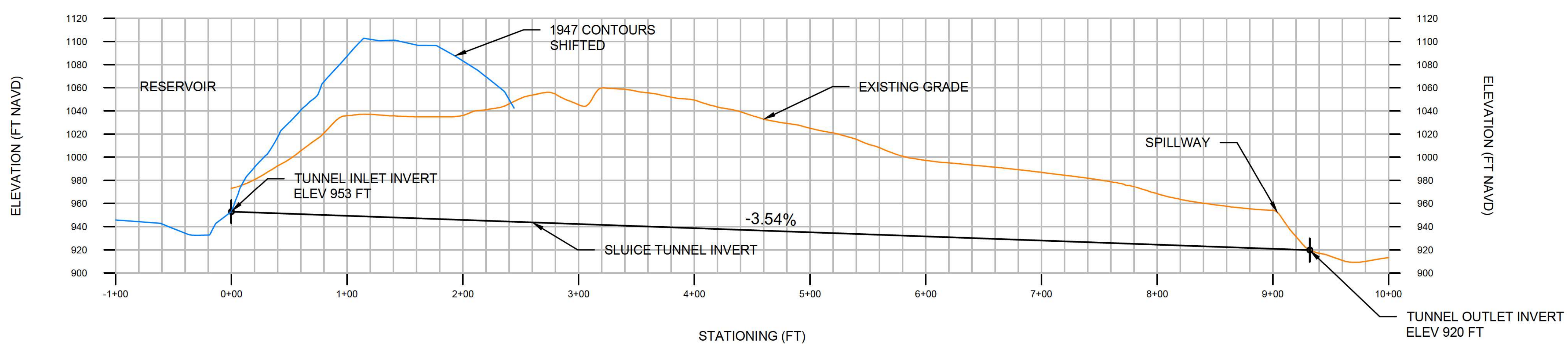
SHEET 8

PRELIMINARY – NOT FOR CONSTRUCTION



SLUICE TUNNEL PROFILE



REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

SLUICE TUNNEL PLAN & PROFILE

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
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PHONE: (510) 893 3600
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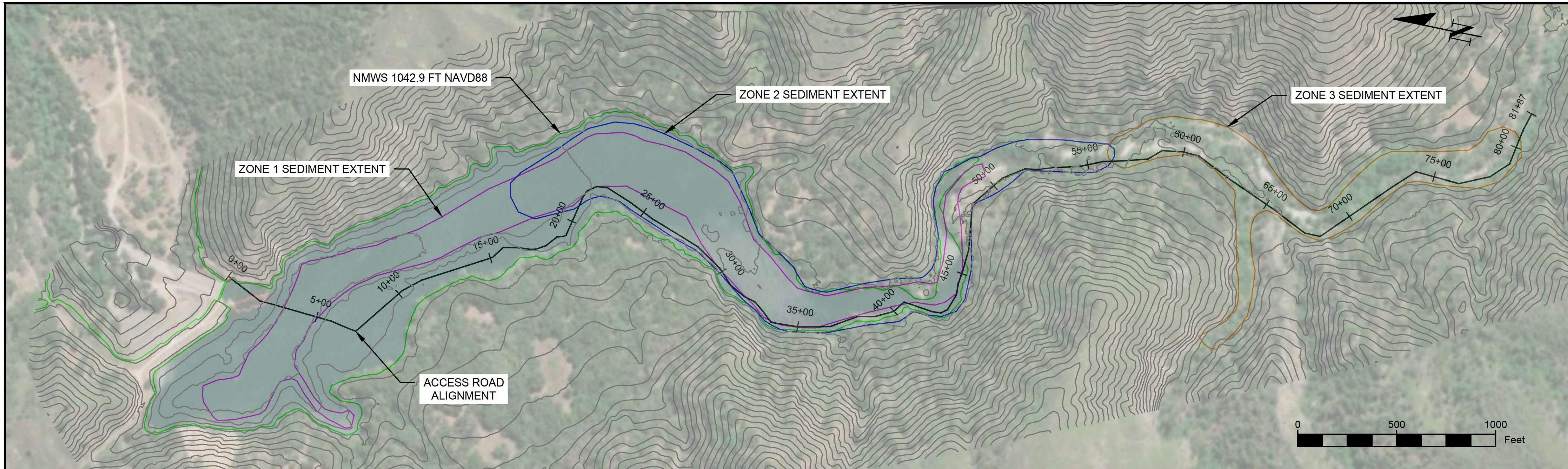
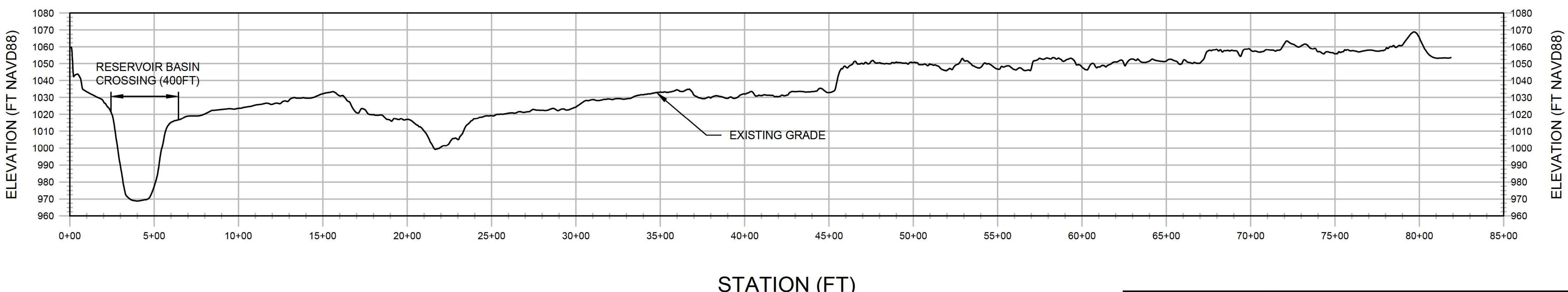
SHEET 9

PRELIMINARY – NOT FOR CONSTRUCTION



ACCESS ROAD PROFILE



REVISIONS

LOS PADRES DAM AND RESERVOIR ALTERNATIVES AND SEDIMENT MANAGEMENT STUDY

ALT 2. ACCESS ROAD PLAN & PROFILE

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

300 LAKESIDE DR., SUITE 400
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

AECOM

Monterey Peninsula Water Management District

DRAWN BY: SK
PROJECT ENG'R: SK
APPROVED:

DATE: 3/28/2022
PROJECT: 60536296

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SHEET 10

PRELIMINARY – NOT FOR CONSTRUCTION

Attachment C
Opinion of Probable Construction Costs Details

Date: 2/1/23

OPCC Breakdown: Alt 1. - Fish Passage, No Sediment Action

LINE ITEM #	LINE ITEM	QUANTITY	UNIT	UNIT COST	AMOUNT
1	**Mobilization/Demobilization**				**$ 1,032,234**
	Mobilization/Demobilization (10%)	1	LS	$ 1,032,234	$ 1,032,234
2	**Site Preparation**				**$ 547,050**
	Improve existing dam crest road	550	LF	$ 100	$ 55,000
	Spillway bridge improvements (for construction loads)	1	LS	$ 250,000	$ 250,000
	Improve and widen existing access ramp from crest to reservoir	200	LF	$ 100	$ 20,000
	Repair access roads	630	LF	$ 35	$ 22,050
	Offsite access improvements	1	LS	$ 200,000	$ 200,000
3	**Spillway Wall Raise**				**$ 1,042,000**
	Raise spillway walls	1,200	LF	$ 660	$ 792,000
	Outlet works contingency	1	LS	$ 250,000	$ 250,000
4	**Dam Embankment Raise**				**$ 8,733,292**
	Excavate rock paving on dam face	10,530	CY	$ 26	$ 273,780
	Haul rock paving debris to disposal site	12,121	CY	$ 5	$ 60,603
	Place debris at disposal site	12,121	CY	$ 15	$ 181,809
	Excavate top of dam & stockpile	19,350	CY	$ 26	$ 503,100
	Import filter/drain material and place	41,000	CY	$ 78	$ 3,198,000
	Place embankment fill (from onsite stockpile)	150,000	CY	$ 26	$ 3,900,000
	Place new rock paving	15,400	CY	$ 40	$ 616,000
	Subtotal				**$ 11,354,576**
	General Conditions (10%)				$ 1,135,458
	Bond (3%)				$ 340,637
	General Contractor's OH and Profit (15%)				$ 1,703,186
	Total Construction Cost				**$ 14,533,857**
	Contingency (50%)				$ 7,266,929
	Total Construction Cost w/ Contingency				**$ 21,800,786**
	Low Side of Class 5 Estimate Range (-30%)				**$ 15,260,550**
	High Side of Class 5 Estimate Range (+50%)				**$ 32,701,179**

Attachment C - OPCC Details

Date: 2/1/23
OPCC Breakdown: Alt. 2 - Dam and Sediment Removal

LINE ITEM #	LINE ITEM	QUANTITY	UNIT	UNIT COST	AMOUNT
1	**Mobilization/Demobilization**				**$ 4,480,427**
	Mobilization/demobilization (10%)	1	LS	$ 4,480,427	$ 4,480,427
2	**Site Preparation**				**$ 5,814,109**
	Clear and grub staging/Disposal Sites B and C	30.9	ACRE	$ 4,156	$ 128,420
	Water Diversion/Controls				
	Install temp. diversion structure (sheetpiles and earthen berm)	6,000	SF	$ 70	$ 420,000
	Install temporary diversion gate	1	LS	$ 10,000	$ 10,000
	Seasonal removal of earthern berm	3	EA	$ 10,000	$ 30,000
	Seasonal re-build of earthern berm	3	EA	$ 15,000	$ 45,000
	Remove diversion structure	1	LS	$ 10,000	$ 10,000
	Install temporary diversion pipeline (<66" CMP)	6,200	LF	$ 150	$ 930,000
	Repair pipeline	1,860	LF	$ 150	$ 279,000
	Remove pipeline	6,200	LF	$ 18	$ 111,600
	Dewatering treatment system - rent package	24	mo	$ 25,000	$ 600,000
	Dewatering treatment system - staffing	12	mo	$ 14,400	$ 172,800
	Dewatering treatment system - O&M	1	LS	$ 60,000	$ 60,000
	Dewatering trenching/pumping system (post-drawdown)	1	LS	$ 500,000	$ 500,000
	Access				
	Improve existing dam crest road	550	LF	$ 100	$ 55,000
	Spillway bridge improvements (for construction loads)	1	LS	$ 250,000	$ 250,000
	Improve and widen existing access ramp from dam crest to reservoir	200	LF	$ 100	$ 20,000
	Access ramp to new Site B access road	2,000	CY	$ 26	$ 52,000
	New Disposal Site B access road grading	778	CY	$ 8	$ 6,222
	New Disposal Site B access road aggregate base	294	TON	$ 35	$ 10,283
	Improve and widen existing Disposal Site C access road	650	LF	$ 100	$ 65,000
	Place fill to cross reservoir to terrace	10,667	CY	$ 26	$ 277,333
	Install temporary culverts under crossing	100	LF	$ 300	$ 30,000
	New access road into upper reservoir (1.25 miles)	6,200	LF	$ 35	$ 217,000
	Repair access roads	2,790	LF	$ 35	$ 97,650
	Traffic control (haul road flaggers/truck safety)	18	mo	$ 57,600	$ 1,036,800
	Lighting for night work	1	LS	$ 200,000	$ 200,000
	Offsite access improvements	1	LS	$ 200,000	$ 200,000
3	**Dam Removal**				**$ 9,660,000**
	Demolish FWC and control house	1	LS	$ 50,000	$ 50,000
	Demolish outlet works (low level, high level and siphon)	1	LS	$ 25,000	$ 25,000
	Demolish electrical	1	LS	$ 25,000	$ 25,000
	Demolish spillway	6,000	CY	$ 50.00	$ 300,000
	Process concrete for disposal	6,000	CY	$ 10.00	$ 60,000
	Excavate dam embankment, haul and place at disposal site	460,000	CY	$ 20.00	$ 9,200,000
4	**Reservoir Restoration**				**$ 7,270,000**
	Channed and floodplain fine grading	200,000	CY	$ 8	$ 1,600,000
	Riparian restoration (incl. irrigation)	10	ACRE	$ 51,000	$ 510,000
	Grassland restoration (incl. irrigation)	20	ACRE	$ 48,000	$ 960,000
	Scrub (incl. irrigation)	5	ACRE	$ 45,000	$ 225,000
	Oak woodland (incl. irrigation)	15	ACRE	$ 45,000	$ 675,000
	Channel engineered improvements	6,000	LF	$ 550	$ 3,300,000
5	**Sediment Removal**				**$ 22,060,163**
	Zone 1 and 2 sediment removal (dry), hauling and placement	1,680,000	CY	$ 7.5	$ 12,600,000
	Disposal Site Management	1,680,000	CY	$ 5.5	$ 9,240,000
	Hydroseeding of disposal areas	38.6	ACRE	$ 5,700	$ 220,163
	Subtotal				**$ 49,284,699**
	General Conditions (10%)				$ 4,928,470
	Bond (3%)				$ 1,478,541
	General Contractor's OH and Profit (15%)				$ 7,392,705
	Total Construction Cost				**$ 63,084,414**
	Contingency (50%)				$ 31,542,207
	Total Construction Cost w/ Contingency				**$ 94,626,621**
	Low Side of Class 5 Estimate Range (-30%)				**$ 66,238,635**
	High Side of Class 5 Estimate Range (+50%)				**$ 141,939,932**

Date: 2/1/23

OPCC Breakdown: Alt 3. - Storage Expansion and Dredging

LINE ITEM #	LINE ITEM	QUANTITY	UNIT	UNIT COST	AMOUNT
1	**Mobilization/Demobilization**				**$ 4,791,640**
	Mobilization/Demobilization (10%)	1	LS	$ 4,791,640	$ 4,791,640
2	**Site Preparation**				**$ 3,121,171**
	Clear and grub staging/Disposal Sites B, C, D and E	34.5	ACRE	$ 4,156	$ 143,382
	Cofferdam for spillway modifications	4,000	SY	$ 110	$ 440,000
	Workpad for spillway modifications	5,186	CY	$ 26	$ 134,834
	Dewatering for spillway modifications	1	LS	$ 100,000	$ 100,000
	Offloading area (per season)	4	LS	$ 10,000	$ 40,000
	Access				
	Improve existing dam crest road	550	LF	$ 100	$ 55,000
	Spillway bridge improvements (for construction loads)	1	LS	$ 250,000	$ 250,000
	Improve and widen existing access ramp from crest to reservoir	200	LF	$ 100	$ 20,000
	Access ramp to new Disposal Site B access road	2,000	CY	$ 26	$ 52,000
	New Disposal Site B access road grading	778	CY	$ 8	$ 6,222
	NewDisposal Site B access road aggregate base	294	TON	$ 35	$ 10,283
	Improve and widen existing Disposal Site C access road	650	LF	$ 100	$ 65,000
	Repair access roads	630	LF	$ 35	$ 22,050
	Traffic control (haul road flaggers/truck safety)	24	mo	$ 57,600	$ 1,382,400
	Lighting for night work	1	LS	$ 200,000	$ 200,000
	Offsite access improvements	1	LS	$ 200,000	$ 200,000
3	**Spillway Modifications and Gate Installation**				**$ 4,093,622**
	Drill & break out concrete	244	CY	$ 150	$ 36,667
	Haul and place concrete in disposal area	281	CY	$ 20	$ 5,622
	Foundation treatment	3,300	SF	$ 100	$ 330,000
	Reconstruct reinforced concrete spillway crest	587	CY	$ 800	$ 469,333
	Raise spillway walls	1,200	LF	$ 660	$ 792,000
	Gate material and installation	1	LS	$ 2,000,000	$ 2,000,000
	PLC system for gate	1	LS	$ 160,000	$ 160,000
	Outlet works contingency	1	LS	$ 250,000	$ 250,000
	Control system start-up	1	LS	$ 50,000	$ 50,000
4	**Dam Embankment Raise**				**$ 8,733,292**
	Excavate rock paving on dam face	10,530	CY	$ 26	$ 273,780
	Haul rock paving debris to disposal site	12,121	CY	$ 5	$ 60,603
	Place debris at disposal site	12,121	CY	$ 15	$ 181,809
	Excavate top of dam & stockpile	19,350	CY	$ 26	$ 503,100
	Import filter/drain material and place	41,000	CY	$ 78	$ 3,198,000
	Place embankment fill (from onsite stockpile)	150,000	CY	$ 26	$ 3,900,000
	Place new rock paving	15,400	CY	$ 40	$ 616,000
5	**Sediment Removal**				**$ 31,968,313**
	Turbidity curtain placement and maintenance	40	LS	$ 2,000	$ 80,000
	Zone 1, 2, 3 sediment removal and aquatic transport	1,885,000	CY	$ 5.5	$ 10,367,500
	Hauling and disposal site management	1,885,000	CY	$ 11	$ 20,735,000
	Sort/rinse and place at Disposal Sites D & E	36,000	CY	$ 15	$ 540,000
	Hydroseeding of disposal areas	43.1	ACRE	$ 5,700	$ 245,813
	Subtotal				**$ 52,708,038**
	General Conditions (10%)				$ 5,270,804
	Bond (3%)				$ 1,581,241
	General Contractor's OH and Profit (15%)				$ 7,906,206
	Total Construction Cost				**$ 67,466,288**
	Contingency (50%)				$ 33,733,144
	Total Construction Cost w/ Contingency				**$ 101,199,432**
	Low Side of Class 5 Estimate Range (-30%)				**$ 70,839,602**
	High Side of Class 5 Estimate Range (+50%)				**$ 151,799,148**

Date: 2/1/23
OPCC Breakdown: Alt. 5 - Recover Storage Capacity with Sluice Tunnel

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount
1	**Mobilization/Demobilization**				**$ 3,857,714**
	Mobilization/Demobilization (10%)	1	LS	$ 3,857,714	$ 3,857,714
2	**Site Preparation**				**$ 871,537**
	Clear and grub staging/disposal areas	22	ACRE	$ 4,156	$ 91,432
	Install temp. diversion structure (sheetpiles and earthen berm)	2,000	SF	$ 70	$ 140,000
	Install temporary diversion gate	1	LS	$ 4,000	$ 4,000
	Install temporary diversion pipeline	200	LF	$ 150	$ 30,000
	Dewatering treatment system - rent package	4	mo	$ 25,000	$ 100,000
	Dewatering treatment system - staffing	4	mo	$ 14,400	$ 57,600
	Dewatering treatment system - O&M	1	LS	$ 10,000	$ 10,000
	Dewatering trenching/pumping system (post-drawdown)	1	LS	$ 20,000	$ 20,000
	Improve and widen ex. access ramp from crest to reservoir	200	LF	$ 100	$ 20,000
	Access ramp to new Disposal Site B access road	2,000	CY	$ 26	$ 52,000
	New Disposal Site B access road grading	778	CY	$ 8	$ 6,222
	NewDisposal Site B access road aggregate base	294	TON	$ 35	$ 10,283
	Construct upstream work platform	5,000	CY	$ 26	$ 130,000
	Offsite access improvements	1	LS	$ 200,000	$ 200,000
3	**Construct Sluice Tunnel**				**$ 27,828,906**
	Sediment excavation after drawdown	5,000	CY	$ 50	$ 250,000
	Upstream portal	1	EA	$ 200,000	$ 200,000
	Downstream portal	1	EA	$ 200,000	$ 200,000
	Tunneling	930	LF	$ 17,578	$ 16,347,656
	Tunnel water proofing	930	LF	$ 2,734	$ 2,542,969
	Reinforced concrete liner in tunnel	930	LF	$ 5,391	$ 5,013,281
	Sluice gate and shaft/structure	1	EA	$ 3,125,000	$ 3,125,000
	Outfall energy dissipation	1	LS	$ 150,000	$ 150,000
3	**Spillway Wall Raise**				**$ 1,042,000**
	Raise spillway walls	1,200	LF	$ 660	$ 792,000
	Outlet works contingency	1	LS	$ 250,000	$ 250,000
4	**Dam Embankment Raise**				**$ 8,733,292**
	Excavate rock paving on dam face	10,530	CY	$ 26	$ 273,780
	Haul rock paving debris to disposal site	12,121	CY	$ 5	$ 60,603
	Place debris at disposal site	12,121	CY	$ 15	$ 181,809
	Excavate top of dam & stockpile	19,350	CY	$ 26	$ 503,100
	Import filter/drain material and place	41,000	CY	$ 78	$ 3,198,000
	Place embankment fill (from onsite stockpile)	150,000	CY	$ 26	$ 3,900,000
	Place new rock paving	15,400	CY	$ 40	$ 616,000
8	**Site Restoration**				**$ 101,400**
	Remove temporary workpads and access	7,000	CY	$ 6.00	$ 42,000
	Hydroseed disposal and staging areas	22	LS	$ 2,700	$ 59,400
	Subtotal				**$ 42,434,849**
	General Conditions (10%)				$ 4,243,485
	Bond (3%)				$ 1,273,045
	General Contractor's OH and Profit (15%)				$ 6,365,227
	Total Construction Cost				**$ 54,316,606**
	Contingency (50%)				$ 27,158,303
	Total Construction Cost w/ Contingency				**$ 81,474,910**
	Low Side of Class 5 Estimate Range (-30%)				**$ 57,032,437**
	High Side of Class 5 Estimate Range (+50%)				**$ 122,212,364**