ADDENDUM TO OPS-1 WATER CONVEYANCE ASSESSMENT
INTERIM TECHNICAL MEMORANDUM: TUNNEL STABILITY

KERN RIVER NO. 3 HYDROELECTRIC PROJECT
FERC PROJECT NO. 2290

PREPARED FOR:

SOUTHERN CALIFORNIA EDISON®
Energy for What's Ahead®

KERNVILLE, CALIFORNIA

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

CEII	Critical Energy Infrastructure Information
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
KR3	Kern River No. 3
Project	Kern River No. 3 Hydroelectric Project (FERC Project No. 2290)
SCE	Southern California Edison

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1.0 INTRODUCTION

Southern California Edison (SCE) filed an interim Technical Memorandum associated with the Study *OPS-1 Water Conveyance Assessment* as part of its Initial Study Report on October 9, 2023 (SCE, 2023), in support of SCE's Kern River No. 3 (KR3) Hydroelectric Project (Project) relicensing, Federal Energy Regulatory Commission (FERC) Project No. 2290. The interim Technical Memorandum included the analysis and results from the Phase 1 desktop analysis and Phase 2 hydraulic assessment.

In response to Stakeholder comments on the Initial Study Report filed January 9, 2024 (SCE, 2024), SCE committed to providing an addendum in the first quarter of 2024 that included the results of the Phase 2 structural integrity assessment. The findings and recommendations provided as part of this Phase 2 analysis are summarized below.

The OPS-1 Study was conducted with support from engineering firms MarshWagner and Kleinschmidt Associates, who have documented expertise in hydropower, hydraulic analyses, and tunnels/underground structures. MarshWagner led the evaluation of tunnel and lining integrity based on their desktop review of documentation available on the tunnel design and construction and supported by tunnel hydraulic characteristics developed by Kleinschmidt Associates.

A site visit was not conducted, and all analyses were based on available information on the geology, tunnel design and construction, and hydraulic flow data.

2.0 STUDY GOALS AND OBJECTIVES

The objectives of the study, as outlined in OPS-1 Study Plan (SCE, 2022), include:

- Conduct an engineering review and evaluation of current water conveyance conditions (e.g., hydrostatic pressure, flow depth) under varying flow conditions.
- Identify guidelines for future operational conditions using current Project information and industry best practices to maintain water conveyance system integrity.

3.0 STUDY AREA AND STUDY SITES

The study area includes the approximately 13 miles of water conveyance infrastructure that runs along the eastern hillslope above the North Fork Kern River between Fairview Dam and the KR3 Forebay. The water conveyance infrastructure included in the analysis and described herein was limited to tunnels, open and covered aboveground flumes, a steel siphon, and a regulated pressure flume.

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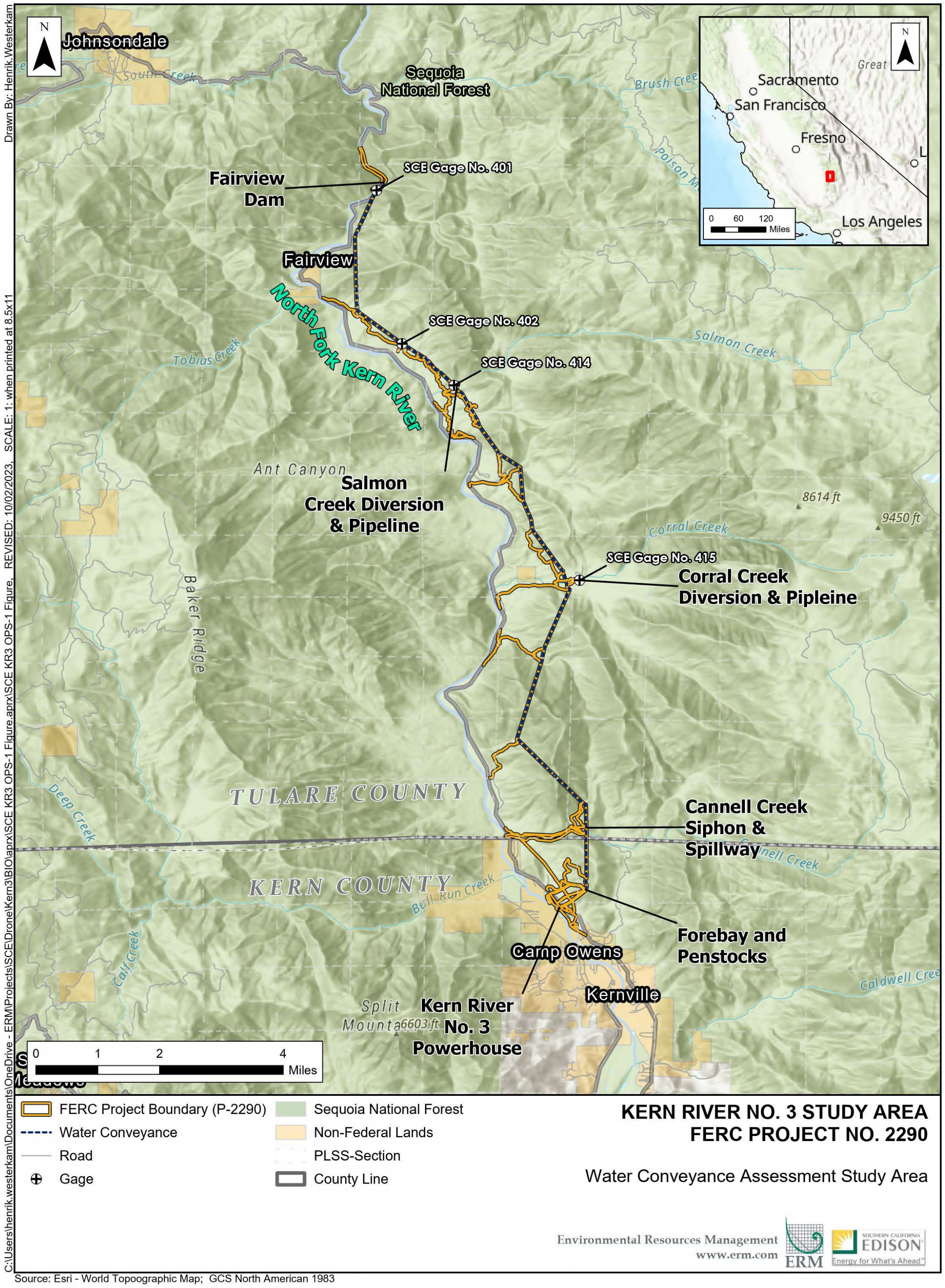

Figure 3-1. Water Conveyance Assessment Study Area.

4.0 DATA SUMMARY

4.1. STRUCTURAL INTEGRITY ASSESSMENT

This study evaluates tunnel conditions (i.e., stability of the tunnel lining) when water levels are decreased and presents recommendations for the continued operation of the underground tunnel sections of the water conveyance. The analysis was conducted using (1) results of hydraulic calculations presented in the *OPS-1 Water Conveyance Assessment Interim Technical Memorandum* prepared by Kleinschmidt (SCE, 2023), (2) information on the tunnel presented in a tunnel inspection and evaluation report prepared by Woodward-Clyde (WCC, 1998), and (3) SCE maintenance and inspection documents.

A summary of the structural integrity assessment results and recommendations is below. Additional details are presented in a separate hydraulic assessment Technical Memorandum, including calculations for the upward pressure differential on the invert due to a flow reduction (Appendix A, filed as CEII).

4.1.1. REPORT FINDINGS AND CONCLUSIONS

Hydropower conveyances are subject to continuous flow changes due to the operation of the hydroelectric equipment. These usual variations are typically not considered detrimental to the stability of the tunnel conveyances. However, recent research (Neupane et al., 2020; Neupane and Panthi 2021) indicates that variation of pressures in the power conveyance can result in changes in the rock mass pore pressure leading to “fatigue” of the rock mass. This is an active research area, and it would be difficult to quantify the effect for the Project, but there is sufficient information to ascertain that variations in water level in the power conveyance could lead to unfavorable tunnel conditions over the long-term.

The purpose of the concrete tunnel wall and floor lining is to provide a smooth surface to convey flows efficiently through the tunnel, rather than serve as an integral piece of tunnel stability. The tunnel invert (i.e., the floor of the tunnel) is probably susceptible to effects from rapid changes in tunnel flows over time, as the concrete lining was likely cast on top of tunnel muck, which typically has less adhesion and contact with the concrete lining material. A simple estimate of the upward pressure differential on the invert (uplift) due to a flow reduction (draw down rate) of 50 cubic feet per second (cfs) per hour (0.5 foot of water level drop per hour) results in an invert slab at the verge of “floating,” increasing the potential for the concrete floor to break apart and be mobilized within the tunnel (calculations provided in Appendix A). This is a reasonable but conservative estimate. If parts of the tunnel invert were cleaned before casting the floor slab, then there would be adhesion between the concrete and the rock and the tunnel floor slab could withstand higher differential uplift pressures and faster draw down rates. If the tunnel lining invert fails and the conveyance flowline is not maintained, the broken concrete pieces could be mobilized by the flow and slowly migrate downstream, which could result in reduced tunnel capacity and functionality.

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SCE operates the tunnel with a constant flow when feasible, but flow reductions greater than 50 cfs per hour have occurred in the past (e.g., unplanned drop in flow due to generating unit tripping or planned flow adjustments to comply with license conditions). Observations from routine (monthly and annual) inspections of the conveyance flowline have not documented excessive leaking, cracking, or broken concrete along the floor. Additionally, periodic inspection of the "rock trap"[1] located upstream of the Cannel Creek siphon have not noted any large pieces of concrete.

Conclusions and recommendations for continued operation of the water conveyance to mitigate potential long-term effects of water level changes include:

- The tunnel lining, specifically the tunnel invert is potentially the most susceptible for cracking and uplift of concrete fragments during tunnel dewatering and subsequent mobilization further down the tunnel.
- While current operational practices have not observed uplift of tunnel invert sections, rapid changes in depth of flow, specifically reducing flow in the conveyance, could have an unfavorable effect on the long-term integrity of section of the tunnel invert.
- The KR3 water conveyance should be operated at near-constant flows. If flow reduction is necessary, a ramping rate of 50 cfs per hour or less is recommended when operationally feasible to mitigate long-term potential impacts on the lining invert.
- No constraints on ramping rates to increase the flow in the water conveyance were found necessary for tunnel floor integrity.

5.0 REFERENCES

Neupane, B., K.K. Panthi, and K. Vereide. 2020. "Effect of Power Plant Operation on Pore Pressure in Jointed Rock Mass of an Unlined Hydropower Tunnel: An Experimental Study." *Rock Mechanics and Rock Engineering* 53: 3073–3092

Neupane, B., and K.K. Panthi. 2021. "Evaluation on the Effect of Pressure Transients on Rock Joints in Unlined Hydropower Tunnels Using Numerical Simulation." *Rock Mechanics and Rock Engineering* 54: 2975–2994.

SCE (Southern California Edison). 2022. *Kern River No. 3 Hydroelectric Project, Revised Study Plan*. Filed with FERC on July 1. Accessed: August 2023. Retrieved from: sce.com/sites/default/files/custom-files/Web files/Revised_Study_Plan_KR3_20220701.pdf

_____. 2023. *Kern River No. 3 Hydroelectric Project (FERC Project No. 2290) Initial Study Report*. Filed October 9, 2023.

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WCC (Woodward – Clyde Consultants). 1998, Reconnaissance Inspection and Evaluation of Kern River No. 3 Tunnels, prepared for SCE.

[1] The rock trap collects large rocks or material entrained within the conveyance flowline.

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APPENDIX A
OPS-1 WATER CONVEYANCE ASSESSMENT: TUNNEL STABILITY
(FILED AS CEII)

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