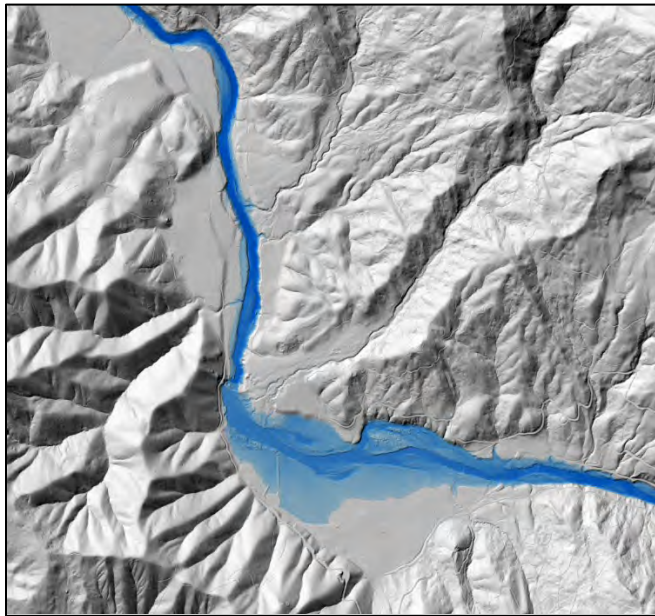


TECHNICAL MEMORANDUM • AUGUST 2021

Hydraulic Model Development and Potential Flood Implications Following the Proposed Scott Dam Removal, Eel River, California



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Cover photo: HEC-RAS 100-year inundation model result of the Eel River, California in the vicinity of Cape Horn Dam (top left); cross section bathymetry surveys in the lower Eel River near the confluence with Garcia Creek (top right); high gradient reach on the Eel River downstream of Scott Dam (bottom).

Table of Contents

1	INTRODUCTION.....	1
1.1	Background.....	1
1.2	Purpose.....	2
1.3	Modeling Needs.....	2
1.4	Sediment Storage.....	4
1.5	Dam Removal.....	4
2	EXISTING TERRAIN DEVELOPMENT.....	4
2.1	Evaluation of Available Data.....	4
2.1.1	Existing Cross-Section Data.....	4
2.1.2	PG&E Bathymetry Survey.....	4
2.1.3	United States Geological Survey Light Detection and Ranging (LiDAR) Data...	5
2.2	Supplemental Field Surveys.....	6
2.3	Data Integration.....	6
3	HYDROLOGIC ANALYSIS.....	6
3.1	Existing Data.....	7
3.2	Flood Frequency Analyses.....	7
4	EXISTING CONDITIONS HYDRAULIC MODELING.....	9
4.1	Model Setup.....	9
4.2	Existing Conditions HEC-RAS Modeling Results.....	12
5	FUTURE CONDITIONS.....	17
5.1	Long-term Impact.....	17
5.2	Short-term Impact.....	17
5.3	Adjustment on Hydrology.....	19
6	SUMMARY AND DISCUSSION.....	23
7	REFERENCES.....	24
	Appendix A Supporting Hydrological Analysis.....	26
	Appendix B Supporting Hydraulic Analysis.....	1

Tables

Table 1.	Existing peak flood flow estimates from various sources.....	7
Table 2.	USGS stream gages used for flood frequency analyses.....	7
Table 3.	Peak discharges used in the hydraulic model.....	8
Table 4.	Manning’s roughness values used in the hydraulic model.....	12
Table 5.	Summary of bridge geometry included in the HEC-RAS model.....	12
Table 6.	Existing conditions model results for road and bridge infrastructure during 100-year flood.....	16

Figures

Figure 1. Hydraulic model study reach and Potter Valley Project vicinity.....3

Figure 2. Cross sections used to develop the HEC-RAS geometry file for the downstream portion of the Eel River study reach.....10

Figure 3. Cross sections used to develop the HEC-RAS geometry file for the upstream portion of the Eel River study reach.11

Figure 4. Existing conditions inundation boundaries.....14

Figure 5. Existing conditions water surface elevation profile.....15

Figure 6. Existing conditions velocity profile.....16

Figure 7. Existing conditions 100-year water surface and future conditions 2-year water surface elevation profiles.18

Figure 8. Existing and future conditions water surface elevation profiles.....20

Figure 9. Increase in water surface elevation during 100-year event following dam removal.21

Figure 10. Existing conditions and future conditions inundation boundaries.....22

Appendices

Appendix A Supporting Hydrological Analysis

Appendix B Supporting Hydraulic Analysis

1 INTRODUCTION

1.1 Background

The Potter Valley Project (Project) is an inter-basin hydroelectric project located 15 miles northeast of Ukiah that annually diverts approximately 60,000 acre-feet (ac-ft) of water from the upper Eel River to the upper Russian River. Project features include Scott Dam, a 130-foot-tall concrete gravity dam that impounds Lake Pillsbury, a 2,300-acre storage reservoir; Cape Horn Dam that impounds the 106-acre Van Arsdale Reservoir; and a diversion system that diverts water from the Eel River at Van Arsdale Intake to the Project's powerhouse located in the headwaters of the Russian River watershed. The Project began diverting water in 1908 when Cape Horn Dam and the Van Arsdale Diversion were built. Scott Dam was built in 1921 approximately 12 miles upstream of Cape Horn Dam at river mile (RM) 168.5.

Pacific Gas and Electric Company's (PG&E's) Project license expires in 2022. PG&E filed a Pre-Application Document (PAD) and Notice of Intent (NOI) to formally initiate the relicensing process for the Project in April 2017. PG&E withdrew its NOI and PAD and discontinued its efforts to relicense the Project in January 2019, and in March 2019, the Federal Energy Regulatory Commission (FERC) issued a notice soliciting interested potential applicants other than PG&E to file an NOI and PAD. In May 2019, the Two-Basin Solution Partners (Partners) entered into a Planning Agreement to explore pathways to obtain a new license for the Project. In June 2019, the Partners filed a NOI with FERC stating the intent to undertake a Feasibility Study of a potential licensing proposal for the Project. The Feasibility Study examined the practicability of potential actions in meeting agreed upon common goals and to inform the Partners of cost and performance tradeoffs associated with those actions. Phase 1 of the Feasibility Study, completed and filed with FERC in May 2020, included the following key elements: (1) a Regional Entity that will apply for the new license and assume the new license if issued, (2) a Project Plan, (3) a Fisheries Restoration Plan, (4) an Application Study Plan, and (5) a Financial Plan. Phase 2 of the Feasibility Study was initiated in April 2020 with grant funding from the California Department of Fish and Wildlife to supplement technical analyses conducted during Phase 1, and to conduct new technical analyses.

This Technical Memorandum was prepared for the Partners by the Consultant Team to supplement technical analyses performed during Phase 1 of the Feasibility Study. The information provided in this document is a continuation of work along a path starting with preliminary analyses of feasibility, transitioning towards more refined analyses of a focused project plan and implementation of the best possible project that meets programmatic goals in a cost-effective manner. This Technical Memorandum is informational, is not binding of any of the Partners, and will not be filed with FERC as the basis for compliance under the Integrated License Process or other FERC regulations. While this Technical Memorandum contributes to the information available to the Partners, the Partners have not solely relied on this document for justification for any decision they have made or will make regarding FERC filings or cooperative agreements. More detailed environmental and engineering studies will be conducted during implementation of the FERC-approved study plan and outside of the FERC process. Accordingly, this Technical Memorandum reflects a step that will be expanded and built upon through additional studies, analysis, synthesis, and ultimately decisions by the Partners on proceeding with a Project Plan.

1.2 Purpose

The potential removal of Scott Dam is being studied because it is the most feasible approach to provide upstream and downstream fish passage and restore anadromous fish access to the 289-square mile watershed upstream of the dam. However, removal of Scott Dam would result in the release of substantial coarse and fine sediment that has accumulated in the reservoir since its construction. Concern has been raised that coarse sediment (sands and larger substrate particles) released following Scott Dam removal could cause the streambed to aggrade and increase flooding risk and potential effects to residential and commercial property and infrastructure (e.g., bridges). To assess this concern, a preliminary evaluation of potential effects of releasing coarse sediment following Scott Dam Removal on flooding risk was performed and is reported in this Technical Memorandum. This preliminary evaluation of flooding risk relies on the results of coarse sediment transport modeling reported in Stillwater Sciences 2021 (*Analyses and Preliminary Modeling of Sediment Transport Following the Proposed Scott Dam Removal, Eel River, California.*)

This Technical Memorandum describes the development and application of the 1-dimensional (1-D) hydraulic modeling approach using U.S. Army Corps of Engineers' (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) for the 49-mile reach of the Eel River from Scott Dam downstream to the Middle Fork Eel River confluence. Development of existing terrain (Section 2) representing channel and floodplain geometry and characterizing roughness and flow attributes included the evaluation and synthesis of existing topography and bathymetry data (Section 2.1), performing supplemental field surveys to collect topography and bathymetry data and fill data gaps (Section 2.2), and data integration (Section 2.3). Section 3 summarizes available hydrologic data (Section 3.1) and describes the flood frequency analysis (Section 3.2) used to develop the design flood flows for hydraulic modeling. Existing conditions hydraulic modeling (Section 4) describes model set-up, input parameters, and results for existing conditions. Future conditions hydraulic modeling (Section 5) describes application of the model to assess short-term and long-term flooding risk following Scott Dam removal based on results from the sediment transport modeling.

1.3 Modeling Needs

A 1-D HEC-RAS model was selected to assess the potential for increased flooding risk resulting from coarse sediment release following Scott Dam removal. Since an existing hydraulic model for the Eel River was not available, a new hydraulic model was needed to support this assessment, with the intention that the new model would support future assessments such as Eel River water temperature modeling that are included in the FERC-approved study plan for Project relicensing.

The hydraulic model extent includes the Eel River from Scott Dam downstream to the Middle Fork Eel River confluence at Dos Rios (Figure 1). This 49-mile reach (study reach) was selected to coincide with the study extent for many of the relicensing study elements. However, the potential effects of releasing coarse sediment following Scott Dam removal are expected to be most pronounced close to the dam and diminish downstream. Key infrastructure to be evaluated for increased flooding risk includes roads, bridges, and the residential community immediately downstream of Cape Horn Dam. Additional analyses are included as part of relicensing studies that would build on and refine the results of this preliminary evaluation.

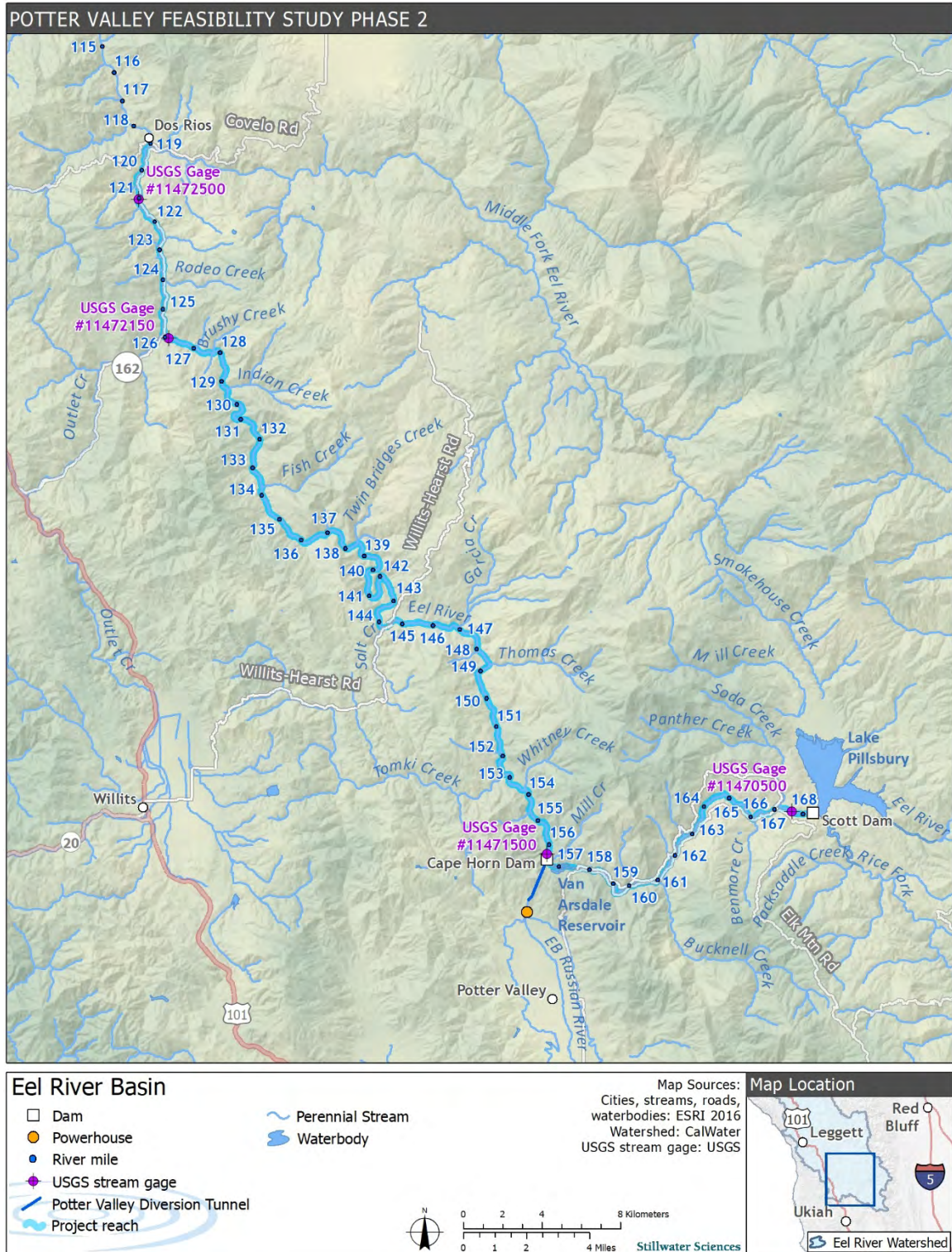


Figure 1. Hydraulic model study reach and Potter Valley Project vicinity.

1.4 Sediment Storage

Scott Dam impounds Lake Pillsbury (Figure 1) with a storage capacity of 94,400 ac-ft at the top of the spillway (i.e., 1,818.3 feet [ft] elevation¹) upon its completion in 1921 (PG&E 2017). The recent estimate of reservoir sedimentation based on Digital Elevation Model (DEM) data and thalweg survey data, estimate a 2015 sediment deposition volume of 13,016 ac-ft (21 million CY) (Stillwater Sciences et al. 2021).

1.5 Dam Removal

There have been several preliminary dam removal alternatives developed to assess potential approaches to removing Scott Dam (e.g., McMillen Jacobs Associates 2018; McBain Associates and Princeton Hydro 2019; Stillwater Sciences 2021) that vary in the way that lake sediment deposits would be managed (e.g., mechanically removed, stabilized, or allowed to erode). This report focuses on two dam removal alternatives that would release sediment through natural erosion: 1) a phased dam removal alternative, in which sediment would be released during multiple low-flow seasons (McBain Associates and Princeton Hydro, 2019); and 2) a rapid sediment release dam removal alternative, in which sediment would be released in a single targeted high-flow event either through a vertical notch or a tunnel (or tunnels) near the base of the dam (Stillwater Sciences 2021).

2 EXISTING TERRAIN DEVELOPMENT

The channel and floodplain geometry data representing the existing site conditions are needed as inputs to the HEC-RAS model. The following sections present data sources and procedures followed to develop the existing channel cross section data.

2.1 Evaluation of Available Data

This section summarizes the readily available topographic and bathymetric data relevant to the study reach.

2.1.1 Existing Cross-Section Data

Topographic and bathymetric survey data was collected in 2018 by PG&E to support various Project relicensing studies. The unpublished data was limited to a small number of cross sections and topography collected at geomorphology study sites near RMs 125, 142, 145, 151, 153, 161, and 167 (PG&E 2018).

2.1.2 PG&E Bathymetry Survey

PG&E provided digital terrain models (DTM) for 2006 bathymetry collected in Van Arsdale Reservoir (PG&E 2006) and 2019 bathymetry collected in the plunge pools immediately downstream of Scott Dam and Cape Horn Dam (PG&E 2019). To match the Stillwater bathymetry survey datum (Section 2.2), the Scott Dam data was converted from local PG&E vertical datum to North American Vertical Datum of 1988 (NAVD88) by subtracting 78.78 ft. The 2006 and 2019 PG&E bathymetric data near Cape Horn Dam was converted from National Geodetic Vertical Datum of 1929 (NGVD29) to NAVD88 by adding 2.92 ft determined by the National Geodetic Survey Coordinate Conversion and Transformation Tool (NCAT). These data were used to supplement the Stillwater bathymetry survey data described in Section 2.2.

¹ National Geodetic Vertical Datum of 1929 (NGVD 29) datum is used throughout the report unless labeled otherwise. Add 81.7 ft to convert to PG&E datum.

2.1.3 United States Geological Survey Light Detection and Ranging (LiDAR) Data

Publicly available aerial Light Detection and Ranging (LiDAR) data was evaluated to determine whether the existing data was sufficient to support hydraulic modeling and other studies. U.S. Geological Survey 3D Elevation Program (USGS 3DEP) LiDAR point cloud data in LAS format for the study reach was obtained using the USGS National Map web service. LAS is a public file format utilized for interchange and archive of LiDAR and other 3-dimensional point cloud data (ASPRS 2019). The National Map is a data repository offering a variety of original source material, including LiDAR data that is provided at various horizontal resolutions, temporal scales, and coverage extents. Two USGS 3DEP primary LiDAR sources that cover the Eel River from Scott Dam to the Middle Fork Eel River were evaluated:

1. 2018–2019 USGS LiDAR: Northern California Wildfire – QL2 (abbreviated to LD1 for remainder of Tech Memo)

The LD1 project covered approximately 16,846 square miles over 27 California counties and was collected in summer, fall, and winter 2018 and winter, spring, and summer 2019 when snow coverage was minimal and when river levels were generally below normal. USGS QL2 refers to LiDAR data that meets or exceeds the following specifications: (a) nominal pulse spacing greater than or equal to 2 points per square meter, and (b) absolute vertical accuracy of less than or equal to 10 cm reported as root mean square error in the Z direction computed over non-vegetated bare ground. In the project area, LD1 covers from the Mendocino County-Lake County boundary near RM 161 downstream to the confluence with the Middle Fork Eel River (RM 119.4) (Figure 1).

2. 2015–2016 Lake County, California Lidar; Classified Point Cloud (abbreviated to LD2)

The LD2 project covered approximately 1,329 square miles of Lake County, California and was collected between December 29, 2015 and February 14, 2016 and met or exceeded USGS QL2 specifications. In the project area, LD2 covers from the Mendocino County-Lake County boundary near RM 161 upstream to Scott Dam (RM 168.5) (Figure 1).

The LiDAR LAS format point cloud data was downloaded as individual tiles, merged into a single LAS file and extracted within a 4,000-foot-wide swath along the Eel River centerline. Hydro-enforcement vector breakline data (hydro-breaklines) was acquired for both LD1 and LD2 datasets and aided data evaluation and integration. Hydro-breaklines ensure continuous downstream sloping flow and water surface elevations that are consistent with the surrounding topography. The LiDAR data was spatially summarized by field collection date and compared with stream gage discharge records and the hydro- breaklines to assess the potential impact of variable water stage on LiDAR data coverage within the channel area.

Examination of the hydro-breaklines and the classified point cloud data revealed the LD1 and LD2 data captured sufficient level of detail and point density for channel banks and portions of the channel area above the water surface, however, channel topography below the water surface was not captured. While water surface elevations and wetted channel area varied during LiDAR data collection, the impact was considered negligible because much of the Eel River channel remains wetted at even the lowest flows.

A limited number of cross sections were extracted from the LiDAR data and compared with 2018 PG&E surveyed cross section data (Section 2.1.2) to help validate vertical resolution and accuracy of the LiDAR data and plan level of effort to integrate LiDAR and the ground survey data. The cross-section comparisons demonstrated a high level of agreement over fixed hard surfaces like bedrock or large boulders and generally acceptable agreement over coarse grained

deposits like boulder-cobble bars with sparse vegetation. LiDAR point densities and vertical agreement degraded as vegetation density increased.

2.2 Supplemental Field Surveys

Supplemental field surveys were conducted from immediately downstream of Scott Dam to the Middle Fork Eel River confluence (Figure 1) from July 2020 to February 2021 to generate the channel geometry below the LiDAR water surface. Survey equipment included a Trimble S7 Robotic Total Station (RTS), Trimble R10-2 Real Time Kinematic Global Navigation Satellite System (RTK GNSS), and a CEEPULSE 200kHz single beam echo sounder.

Temporary control points consisting of small magnetic nails and shiners, wooden hub stakes, or ½" rebar were installed throughout the study reach and coordinates were established with RTK GNSS. GNSS static observations for RTK base station locations were post-processed using the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) and aligned to the North American Datum of 1983 (NAD 83) (2011) State Plane Zone 2, NAVD88 datums.

A total of 255 cross sections throughout the study reach were surveyed orthogonal to the stream flow to the extent feasible. The cross sections were spaced at about 1,000-ft intervals on average, depending on the site accessibility. Overall, the survey effort was focused in areas where significant changes in channel morphological features were observed, following the procedures established by the U.S. Department of Agriculture, Forest Service (Harrelson et al. 1994). Surveys also focused on areas with dense vegetation. Cross section locations were also selected to support future water temperature modeling. Photographs of each cross-section were taken facing upstream, downstream, towards left bank, and towards the right bank to document site conditions during the time of survey.

2.3 Data Integration

The LiDAR and field survey data were combined to develop a triangulated irregular network (TIN) DTM in GeoCue LP360 software, and HEC-RAS cross sections were extracted from the TIN. A 5-ft cell size raster floodplain DEM was generated for the study reach from the LiDAR data to augment HEC-RAS model geometry. Where necessary, additional HEC-RAS cross sections were developed from the floodplain DEM and then adjusted in HEC-RAS to interpolate channel geometry below water. Additional cross sections were extracted from the PG&E bathymetry and integrated with the floodplain DEM (see Section 4).

3 HYDROLOGIC ANALYSIS

The Upper Eel River originates from its headwaters in Bald Mountain and drains approximately 700 square miles (mi²) to its confluence with the Middle Fork Eel River. From its headwaters, the Upper Eel River flows in a southerly direction for 23 miles before turning westward and flowing into Lake Pillsbury, which is formed by Scott Dam, descending an average of 200 feet per mile (fpm). Below Lake Pillsbury, the river flows westward for 12 miles to Van Arsdale Reservoir, which is formed by Cape Horn Dam, descending an average of 29 fpm. Downstream from Van Arsdale Reservoir, the river turns northwestward, dropping an average of 16 fpm to the Middle Fork Eel River confluence. The Upper Eel River watershed is characterized by steep and heavily forested terrain with minimal development (PG&E 2017). Mean annual precipitation for the Upper Eel River watershed is approximately 56 inches (USGS 2021).

Sections below present a summary of existing hydrologic data and results of the flood frequency analyses that were performed to develop the design flood flows for the hydraulic model.

3.1 Existing Data

Existing hydrologic data for the study reach were reviewed and compared to the analyses presented herein. Table 1 summarizes the pertinent hydrologic data available from the Flood Insurance Study (FEMA 2021), USGS StreamStats (Gotvald et al. 2012), and McMillen Jacobs Associates (2018). The StreamStats results are based on the methods developed for estimating the magnitude and frequency of floods in California that are not substantially affected by regulation or diversion. Therefore, the 100-year discharge estimates based on USGS StreamStats indicated in Table 1 do not account for the impacts of the Scott Dam and Cape Horn Dam on the hydrology downstream. Differences between peak discharge values estimated by Federal Emergency Management Association (FEMA) and McMillen Jacobs Associates are attributed to variation in the study location, statistical methodologies, and differences in the period of record analyzed.

Table 1. Existing peak flood flow estimates from various sources.

Year of analysis	Source	100-year discharge (cubic feet per second)	Location	Analysis method
1981	FEMA	82,500	1.8 miles downstream of Cape Horn Dam (Hale Creek confluence)	Bulletin 17B
2018 ^a	McMillen Jacobs Associates	59,200	Immediately downstream of Scott Dam	Bulletin 17B
		64,470	Immediately downstream of Cape Horn Dam	
2012 ^b	USGS StreamStats	60,200	Immediately downstream of Scott Dam	Regional regression equations
		70,800	Immediately downstream of Cape Horn Dam	

^a Representing impaired condition after Scott Dam construction.

^b Representing unimpaired condition.

3.2 Flood Frequency Analyses

A flood frequency analysis (FFA) was performed on annual peaks recorded at the USGS stream gages located along the study reach, as depicted in Figure 1. Table 2 summarizes the stream gages and period of record used in the flood frequency analyses.

Table 2. USGS stream gages used for flood frequency analyses.

USGS Stream gage ID	Location	Period of record	Drainage area (square miles)
11470500	Eel River below Scott Dam	1923–2019	290
11471500	Eel River below Cape Horn Dam	1910–2019	349
11472150	Eel River above Outlet Creek	1964–1997	528
11472500	Eel River above Middle Fork Eel River confluence	1951–1964	705

The FFA was performed in accordance with USGS Bulletin 17C (USGS 2019) for the four gages listed in Table 1 using the Hydrologic Engineering Center's statistical software package (HEC-SSP) (USACE 2019). Station skew was applied to all FFA calculations. Plots of the Bulletin 17C

statistical analysis for the four stream gages are presented in Appendix A and the values are summarized in Table 3. Slight discrepancies in 100-year peak discharges below Scott Dam (59,200 cfs vs. 56,417 cfs) and Cape Horn Dam (64,470 cfs vs. 57,285 cfs) estimated by McMillen Jacobs Associates and Stillwater Sciences are likely due to the differences in the Bulletin 17B and 17C statistical procedures. Furthermore, the period of record analyzed by McMillen Jacobs Associates excluded recent years (2013–2020), most of which were dry years. Because Bulletin 17C is an update of a previously published 17B guidance (USGS 1981), Stillwater recommends that the design discharges for the hydraulic analysis be based on the values estimated with the 17C procedures as provided in Table 3.

Each of the four gages in Table 2 were used as the primary flow change locations in the hydraulic model. After peak flows were determined for the gaged locations, the difference in discharges between gaged locations was distributed to tributaries occurring between the stream gaging stations. The quantity of flow distributed at tributary confluences was determined by the drainage area of respective tributaries relative to the drainage area of the main stem Eel River at the location of the confluence. Table 3 presents the peak discharges and flow changes used in the hydraulic model for a range of flood frequency return intervals.

Table 3. Peak discharges used in the hydraulic model.

Location along Eel River	Peak discharge (cubic feet per second) for floods up to 100-year recurrence interval ¹				
	2-year	10-year	25-year	50-year	100-year
Below Scott Dam (USGS gage 11470500) ²	11,205	34,034	42,026	50,883	56,417
Below Cape Horn Dam (USGS gage 11471500) ²	11,883	36,652	44,534	52,624	57,285
Tomki Creek ³	15,932	47,698	61,429	80,102	94,929
Thomas Creek ³	17,199	51,155	66,716	88,700	106,709
Garcia Creek ³	17,981	53,288	69,979	94,005	113,977
Salt Creek ³	18,612	55,008	72,611	98,286	119,841
Twin Bridges Creek ³	19,448	57,288	76,098	103,958	127,611
Fish Creek ³	19,992	58,774	78,370	107,653	132,674
Indian Creek ³	21,125	61,863	83,095	115,337	143,200
Above Outlet Creek (USGS gage 11472150) ²	21,529	62,966	84,782	118,081	146,959
Below Outlet Creek ³	35,144	93,464	123,793	170,036	210,204
Above Middle Fork Eel River confluence (USGS gage 11472500) ²	41,723	103,960	134,873	180,934	220,186

¹ Peak discharges represent impaired conditions as most of discharge data were recorded after the construction of Scott Dam

² Discharges based on Bulletin 17C flood frequency analysis results

³ Discharges derived from computing difference in flow estimates between gages

4 EXISTING CONDITIONS HYDRAULIC MODELING

4.1 Model Setup

A one-dimensional steady state HEC-RAS (USACE 2021) model was developed for the 49-mile reach of the Eel River from Scott Dam to the Middle Fork Eel River confluence. The channel and floodplain geometry input data were derived from a total of 264 cross sections, which included surveyed cross sections combined with floodplain DEM and supplemental cross sections to better characterize the existing channel and floodplain geometry. Locations of the cross sections overlaid on an aerial photograph with HEC-RAS stations and river mile are presented in Figures 2 and 3. Cross sections shown in the figures are color-coded to differentiate the data source used to develop the cross sections as defined below:

- Orange “Stillwater” cross sections – These were developed from a combination of the Stillwater bathymetry survey data and the floodplain DEM developed from USGS LiDAR data.
- Pink “Interpolated” cross sections – These were supplemental cross sections included near the bridges, just below Scott Dam, between around RM 139 and 137, and areas upstream of downstream of Cape Horn Dam to improve the model geometry resolution, where the Stillwater bathymetry surveyed data was not sufficient. These cross sections were developed from a combination of estimated thalweg elevations based on bathymetry survey data and the floodplain DEM developed from USGS LiDAR data.
- Yellow “PG&E” cross sections – These were supplemental cross sections added upstream and immediately downstream of Cape Horn Dam to improve the model geometry resolution. These cross sections were developed from a combination of PG&E bathymetry survey data (Section 2.1.2) and the floodplain DEM developed from USGS LiDAR data.

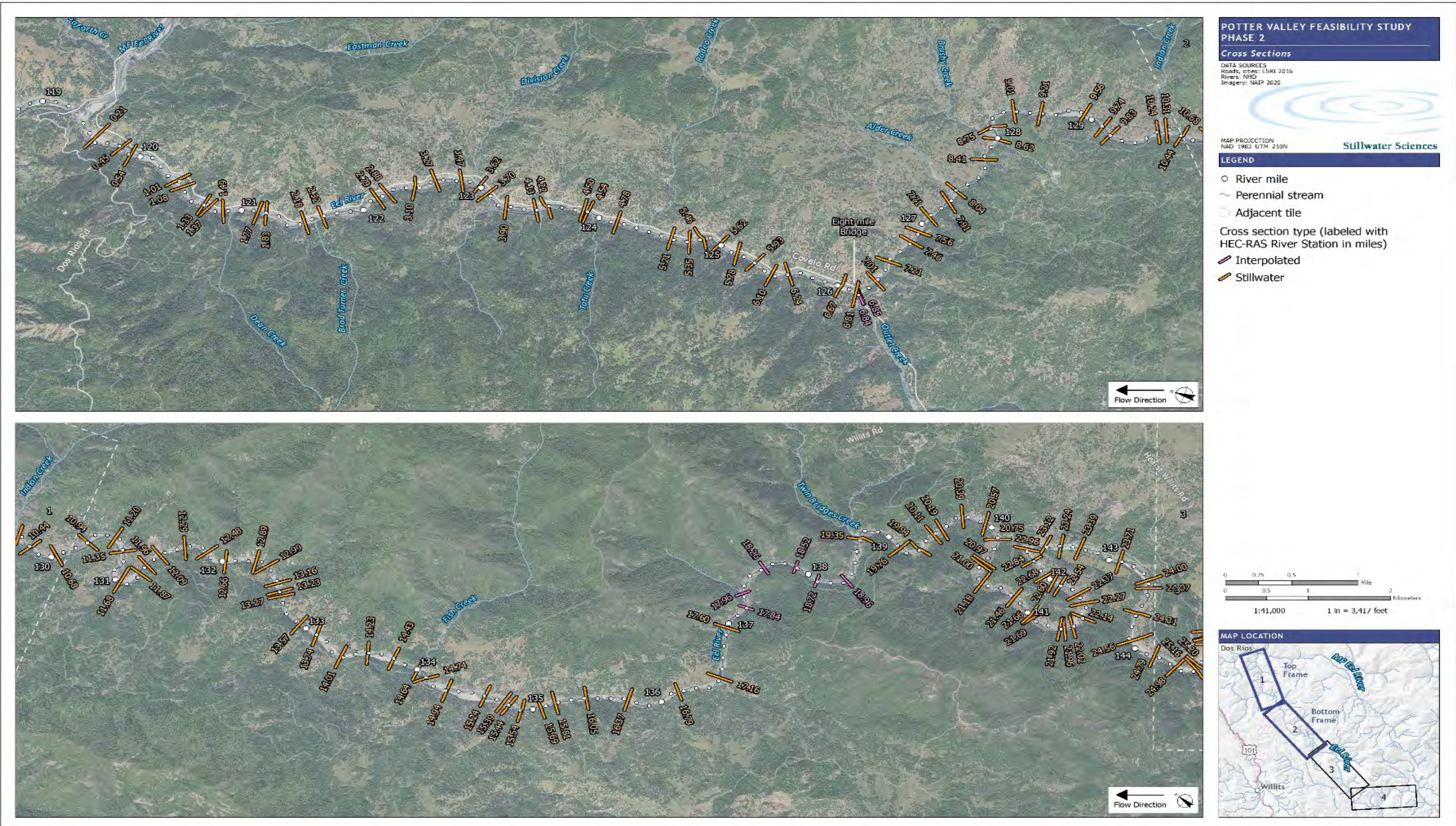


Figure 2. Cross sections used to develop the HEC-RAS geometry file for the downstream portion (RM 119.4-144.5) of the Eel River study reach. Cross sections are color-coded to differentiate the data source used to develop the cross sections: orange cross sections were developed from a combination of the Stillwater bathymetry survey data and the floodplain digital elevation model (DEM) developed from USGS LiDAR data; pink cross sections were developed from a combination of estimated thalweg elevations based on bathymetry survey data and the floodplain DEM developed from USGS LiDAR data; yellow cross sections were developed from a combination of PG&E bathymetry survey data and the floodplain DEM developed from USGS LiDAR data.

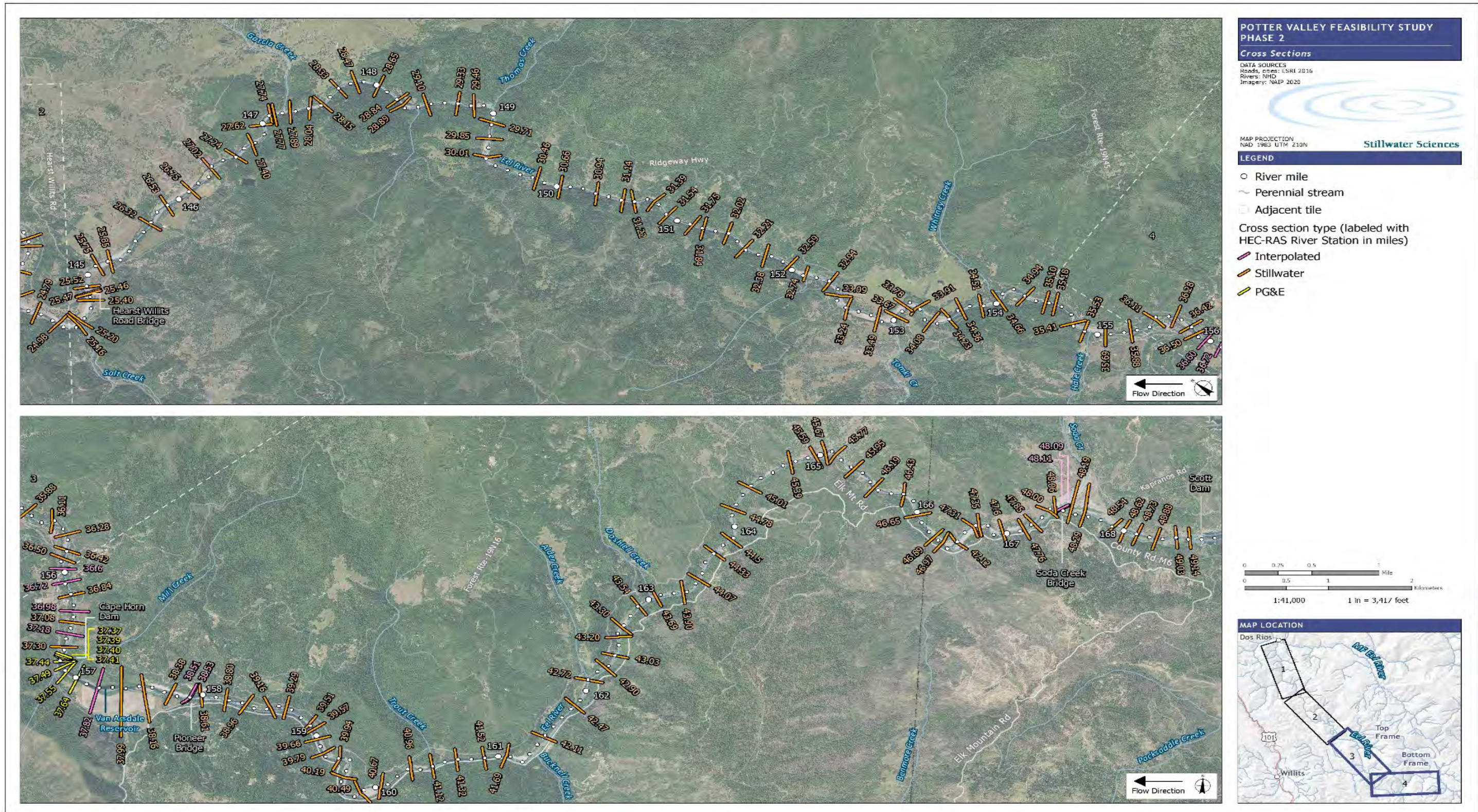


Figure 3. Cross sections used to develop the HEC-RAS geometry file for the upstream portion (RM 144.5-168.5) of the Eel River study reach. Cross sections are color-coded to differentiate the data source used to develop the cross sections: orange cross sections were developed from a combination of the Stillwater bathymetry survey data and the floodplain digital elevation model (DEM) developed from USGS LiDAR data; pink cross sections were developed from a combination of estimated thalweg elevations based on bathymetry survey data and the floodplain DEM developed from USGS LiDAR data; yellow cross sections were developed from a combination of PG&E bathymetry survey data and the floodplain DEM developed from USGS LiDAR data.

Manning's n roughness values ranging between 0.04 and 0.06; and 0.065 and 0.15 were applied in the main channel and overbanks, respectively. The roughness values were estimated by dominant substrate cover and vegetation density in specific sub-reaches using a combination of field photographs, aerial imagery, and engineering judgement. Table 4 summarizes the roughness values used in the model and associated land covers.

Table 4. Manning's roughness values used in the hydraulic model.

Dominant Land Cover	Manning's Roughness Value
Densely forested overbank	0.15
Moderately vegetated overbank	0.065
Bedrock	0.06
Gravel	0.053
Fine sediment and gravel channel	0.04
Roadway	0.015

The model includes four bridge crossings as summarized in Table 5. The bridge locations are depicted in Figures 2 and 3. The low chord elevations and pier widths were measured during supplemental field surveys (Section 2.2). The deck elevations were approximated from the LiDAR (Section 1.0.3). For simplicity, Cape Horn Dam was characterized within the hydraulic model using a single, inline weir structure (the lower weir was not included in the model), and the details of the dam operation were not modeled. The crest elevation (1493.7 ft NAVD 88) for Cape Horn Dam was based on a Supporting Technical Information Document provided by Pacific Gas and Electric (PG&E 2015).

Table 5. Summary of bridge geometry included in the HEC-RAS model.

Bridge	Width per span (feet)	Low chord elevation (NAVD 88, feet) ¹	Deck elevation (NAVD 88, feet) ²	Pier width (feet)
Soda Creek Bridge	120	1,734	1,741	4
Pioneer Bridge	155	1,529	1,537	7
Hearst-Willits Road Bridge	130	1,328	1,331	4
Eight Mile Bridge	100	1,040	1,046	5

¹ Lowest point of the low chord

² Highest point of the bridge deck

4.2 Existing Conditions HEC-RAS Modeling Results

One-dimensional hydraulic modeling was conducted based on the input data described above. Although all peak flow events presented in Table 3 were modeled, this technical report focuses on the 100-year flood event, with a consideration given to a 2-year event to evaluate future conditions (Section 4).

The predicted water surface elevations during the December 22, 1964 flood event (i.e., approximately a 100-year recurrence interval flood) were compared to the measured water surface elevations at two USGS gage locations, USGS gage 11470500 (below Scott Dam) and USGS gage 11474500 (below Cape Horn Dam). The two stream gages measure stage and estimate discharge; however, data necessary to relate the stage data to water surface elevations was not available. Therefore, the stage data at the stream gages were converted to water surface

elevations by using the surveyed water surface elevations (NAVD88) near the stream gages² and recorded stage during time of survey. Based on this approach, the water surface elevations near USGS gage 11470500 and USGS gage 11474500 were approximated to be 1,732 ft and 1,475 ft, respectively, at peak discharge during the December 22, 1964 event. The predicted water surfaces for the 100-year simulation, with the roughness values shown in Table 4 are within 0.02 ft and 1.5 ft of the recorded water surface elevations, respectively.

Additionally, the modeled flooded extents in the reach downstream of Cape Horn Dam were compared to those presented in a FEMA Flood Insurance Rate Map (FIRM) (FEMA 2011). The modeled flow rate was adjusted to 82,500 cfs to match the flow rate used in the Flood Insurance Study. Modeled inundation boundaries generally align well with inundation boundaries reported by FEMA. The sole exception is near Todd Road, where the existing HEC-RAS inundation boundary marginally diverges from the FEMA inundation boundary (Figure 4).

² The water surface elevation associated with USGS gage 11474500 (below Cape Horn Dam) was surveyed approximately 1,500 ft downstream of the stream gage due to access difficulties. Although the hydraulic grade line in the areas immediately downstream of Cape Horn Dam is relatively flat, the actual water surface at the stream gage should be higher than the surveyed value. Thus, the stage to water surface elevation conversion for the stream gage should be taken as a rough estimate.



Figure 4. Existing conditions inundation boundaries.

Based on these results, the HEC-RAS model was considered a reasonable representation of the existing conditions for the purpose of characterizing water levels during 100-year flood events.

The existing conditions water surface elevation profile for the 100-year flood event is provided in Figure 5. Velocities (cross sectional average) for the 100-year flood for the study reach ranged from about 4 ft/s to 25 ft/s, with a reach-average velocity (cross sectional average) of 10 ft/s upstream of Cape Horn Dam and 12 ft/s downstream of Cape Horn Dam (Figure 6).

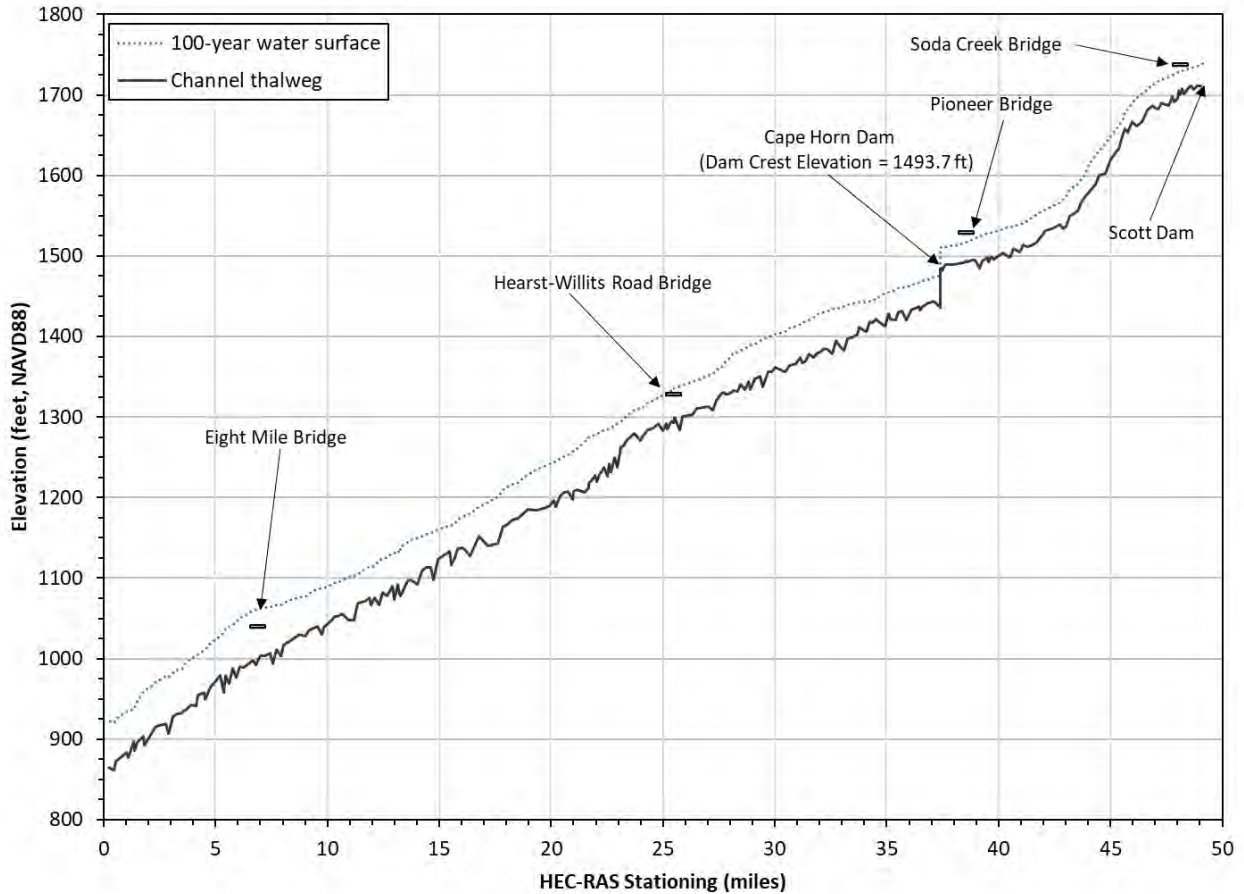


Figure 5. Existing conditions water surface elevation profile. Bold line symbols indicate approximate bridge low chord elevations. HEC-RAS stationing in the Eel River extends from Scott Dam (station 49) downstream to the Middle Fork Eel River confluence (station 0).

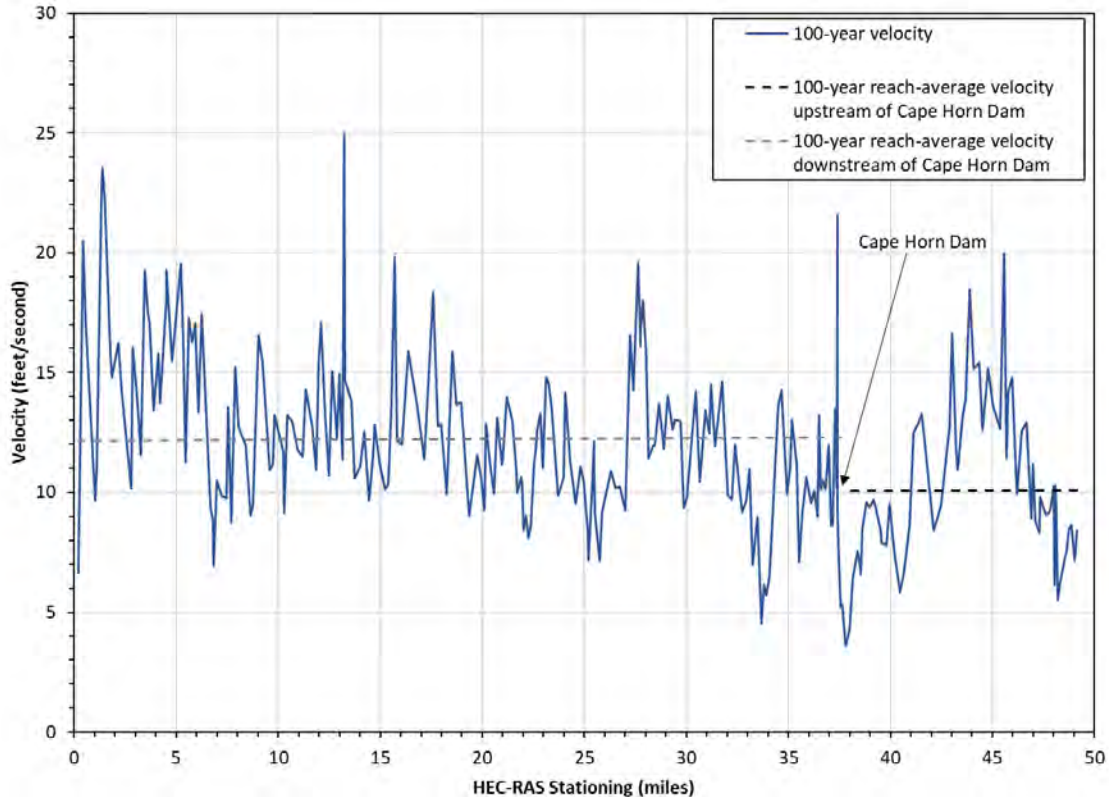


Figure 6. Existing conditions velocity profile. HEC-RAS stationing in the Eel River extends from Scott Dam (station 49) downstream to the Middle Fork Eel River confluence (station 0).

Most of the study reach is located in undeveloped areas, thus flooding concerns are limited to a few key areas with residential development and road and bridge infrastructure. The 100-year water surface elevations projected onto a floodplain DEM (see Section 2.3) show flooded extents in the sub-reach between Cape Horn Dam (RM 156.8) and Hale Creek (RM 155.0) (Figure 4), which is the most developed area within the study reach. Table 6 summarizes modeling results for road and bridge infrastructure.

Table 6. Existing conditions model results for road and bridge infrastructure during 100-year flood.

Infrastructure	Location (river mile) ¹	Description of existing condition model results for road and bridge infrastructure
Soda Creek Bridge	167.5	~5 ft of freeboard
Pioneer Bridge	157.9	~11 ft of freeboard
Hearst-Willits Road Bridge	144.8	Bridge deck overtopped
Eight-mile Bridge	126.2	Bridge deck overtopped
Eel River Road	157.9	Flood depths up to 4 ft over ~1,400 ft long segment
Highway 162	126.2	Flood depths up to 10 ft over ~750 ft-long road segment
	125	Flood depths up to ~3 ft along an ~4,000 ft-long road segment
	122	flood depths up to ~12 ft along an ~1,900 ft-long road segment
	121	flood depths up to ~10 ft along an ~2,800 ft-long road segment

¹ Refer to Figures 1 through 3 of this technical memorandum

5 FUTURE CONDITIONS

Stillwater Sciences (2021) completed a sediment transport analysis and evaluated the long-term and short-term coarse sediment impacts of Scott Dam removal. This section examines potential impacts on water levels during a 100-year flood event based on the outcome of the sediment transport modeling results. Potential flood impacts due to an alternation in hydrology was also investigated.

5.1 Long-term Impact

Sediment transport modeling results (Stillwater Sciences 2021) showed that, at long-term scales, sediment deposition would primarily occur within Van Arsdale Reservoir after sediment transport continuity is reestablished following Scott Dam removal. For instance, the sediment transport model results indicated that the maximum thickness of sediment deposition would increase from about 0.5 ft under the existing conditions to about 3 ft near Pioneer Bridge (RM 157.9) after dam removal. Negligible amounts (maximum thickness of about 0.4 ft) of deposition were predicted in the reach between Cape Horn Dam (RM 156.8) and Middle Fork Eel River confluence (RM 119.4). The model results also demonstrated that a maximum sediment thickness of 3 ft would culminate during periods of low flow and be flushed out of the reservoir by relatively frequent events (i.e., roughly a 5-year event with a peak flow of approximately 20,000 cfs), leaving the impacted area mostly sediment free by the time the peak of a less frequent event reaches the area.

Infrastructure around Van Arsdale Reservoir (Pioneer Bridge and roads along the margins of the reservoir) are outside of the estimated 100-year flooded extents and should be able to accommodate the temporal sedimentation of up to about 3 ft. Under the existing condition for a 100-year flood event, the freeboard at Pioneer Bridge is predicted to be 11 ft (total vertical clearance of about 35 ft). For these reasons, it is unlikely that the long-term sediment deposition due to Scott Dam removal would adversely increase the flooding risk during a 100-year event.

5.2 Short-term Impact

Stillwater Sciences (2021) sediment transport modeling results showed that, at short-term scales, sediment deposition would primarily occur within Van Arsdale Reservoir and negligible amount of sediment deposition would occur elsewhere following dam removal. According to the study, the short-term sediment deposition thickness and duration varied widely in response to hydrologic conditions and dam removal alternatives, including notching, tunneling, and staged removal alternatives. Compared to the long-term sediment transport modeling results, the short-term models predicted much higher deposition thicknesses in the Van Arsdale Reservoir area following dam removal for all alternatives considered. For instance, the sediment transport simulation depicting the notching alternative that would be implemented during a median hydrologic cycle predicted a brief, two-month period in which the sediment thicknesses reached approximately 14 ft at Pioneer Bridge (RM 157.9) and about two miles upstream (RM 160). While such a significant sediment deposition may imply potential flood concerns following dam removal, the probability of a 100-year event to occur within the study reach over the two-month period is low (i.e., probability of 0.002). More importantly, similar to the conditions predicted for the long-term sediment transport model, the short-term sediment transport model demonstrated that the majority of the accumulated sediment would be flushed out of the Van Arsdale Reservoir area by a relatively frequent peak flow event (i.e., 5-year flood event), leaving the impacted area mostly sediment free by the time a less frequent and higher magnitude peak flow event reaches the area. For these reasons, it is unlikely that the short-term sediment deposition due to the dam removal would adversely increase the flooding risk during a 100-year event.

To further investigate the impacts of sedimentation due to dam removal on channel flood hydraulics, a 2-year event was simulated using the modified channel geometry that reflected the sediment laden conditions in the Van Arsdale Reservoir area (RM 156.8 to RM 160). The 2-year event was selected for the evaluation, because unlike the 100-year event, flows for a 2-year event do not have sufficient capacity to flush out accumulated sediment. The existing conditions HEC-RAS geometry file was adjusted by adding an “obstruction” at the bottom 14 ft of each cross section located between Cape Horn Dam (RM 156.8) and RM 160 to characterize the sediment laden channel conditions, as predicted by the notching dam removal alternative sediment transport model. The 2-year peak flood flow in HEC-RAS was adjusted to reflect the post-dam removal unimpaired hydrologic conditions by uniformly increasing the impaired 2-year flood flows by 4,000 cfs (see Section 5.3 and footnote 3). As mentioned above, the sediment laden channel conditions would persist only during the first two months following the dam removal. As seen in Figure 7, the model results showed that the water surface elevation profile simulated with the unimpaired 2-year flow with a sediment laden channel is below the existing 100-year flood water surface elevations.

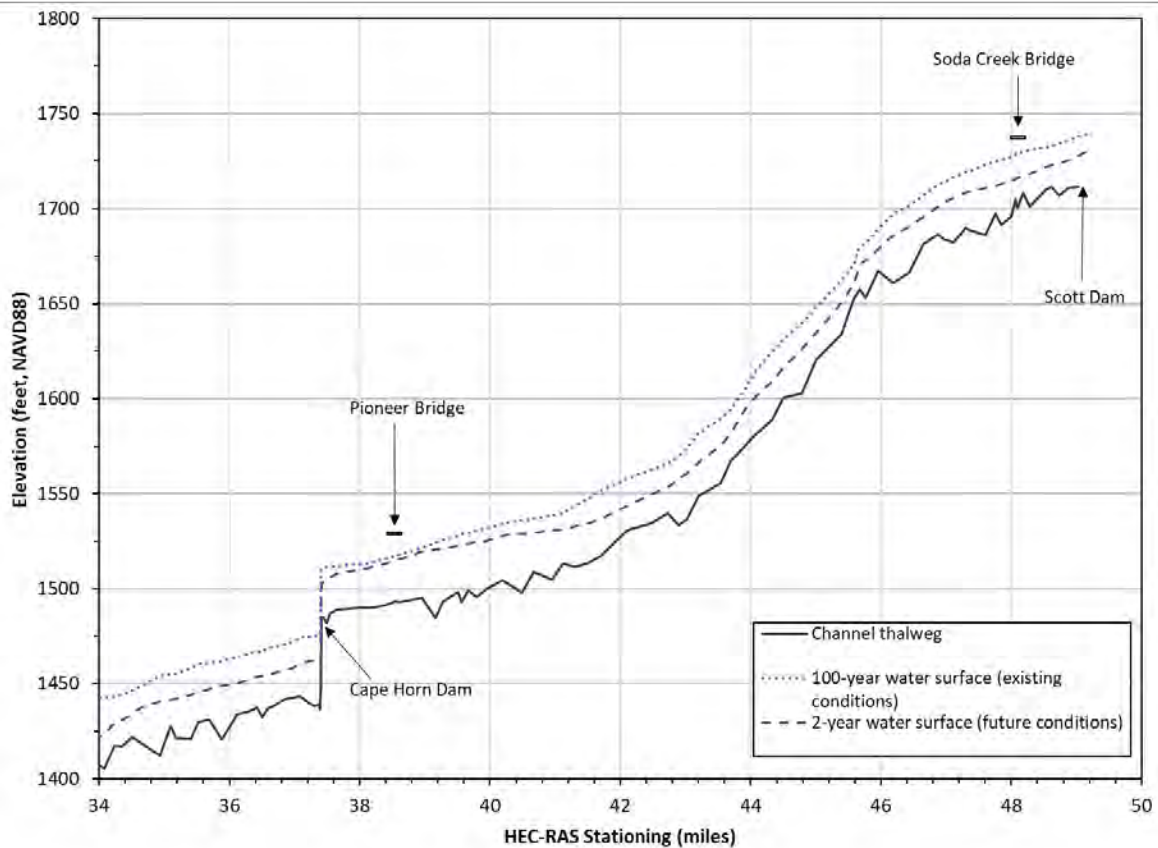


Figure 7. Existing conditions 100-year water surface and future conditions 2-year water surface elevation profiles. The 2-year water surface profile is based on sediment laden channel conditions predicted by a short-term sediment transport model under the notching scenario with a median hydrologic cycle. Sediment laden channel conditions are predicted to last only for a brief period following dam removal. HEC-RAS stationing extends from Scott Dam (station 49) downstream to the Middle Fork Eel River confluence (station 0).

5.3 Adjustment on Hydrology

The existing hydraulic model presented in Section 3 applies impaired hydrology that accounts for flow regulation imposed by Scott Dam. Following dam removal, the river's natural hydrology will be restored. Thus, the flow input in the HEC-RAS model was modified to reflect the future condition by applying the unimpaired discharge at Scott Dam (Table 1, USGS StreamStats result) and uniformly increasing the impaired discharges by the difference between unimpaired and impaired discharges³ in all downstream flow change locations. The channel geometry in the HEC-RAS model was not altered, because as stated in sections above, it is likely that the accumulated sediment would be flushed out during the 100-year event. Figure 8 presents the existing and future water surface profiles predicted during the 100-year event (unimpaired hydrology). For clarity, an increase in water surfaces along the profile is plotted in Figure 9, which indicates that the maximum increase in water surface elevation is predicted to be no more than 1.2 ft though the study reach. Figure 10 shows computed existing and future (post-dam removal) flood boundaries for a 100-year recurrence interval flood in the reach between Cape Horn Dam (RM 156.8) and Hale Creek (RM 155.0), where the majority of development exists within the study reach. Compared with the existing 100-year flood conditions (Table 6), the future freeboard heights at Soda Creek and Pioneer bridges are predicted to decrease by no more than 1 ft. The Hearst-Willits Road and Eight-mile bridge decks would be inundated. The flood water depths along Eel River Road (RM 157.9) and Highway 162 (between around RM 126 and 121) are predicted to increase slightly but no more than 1 ft.

A table summarizing changes in water surface elevation and velocity between existing conditions and future (post-dam removal) conditions under the 100-year flood event is provided in Appendix B.

³ The unimpaired 100-year discharges were estimated by uniformly increasing the impaired 100-year discharges by 4,000 cfs ($60,200 - 56,417 = 3,783$ cfs or 4,000 cfs after rounding up to the nearest 1,000 cfs).

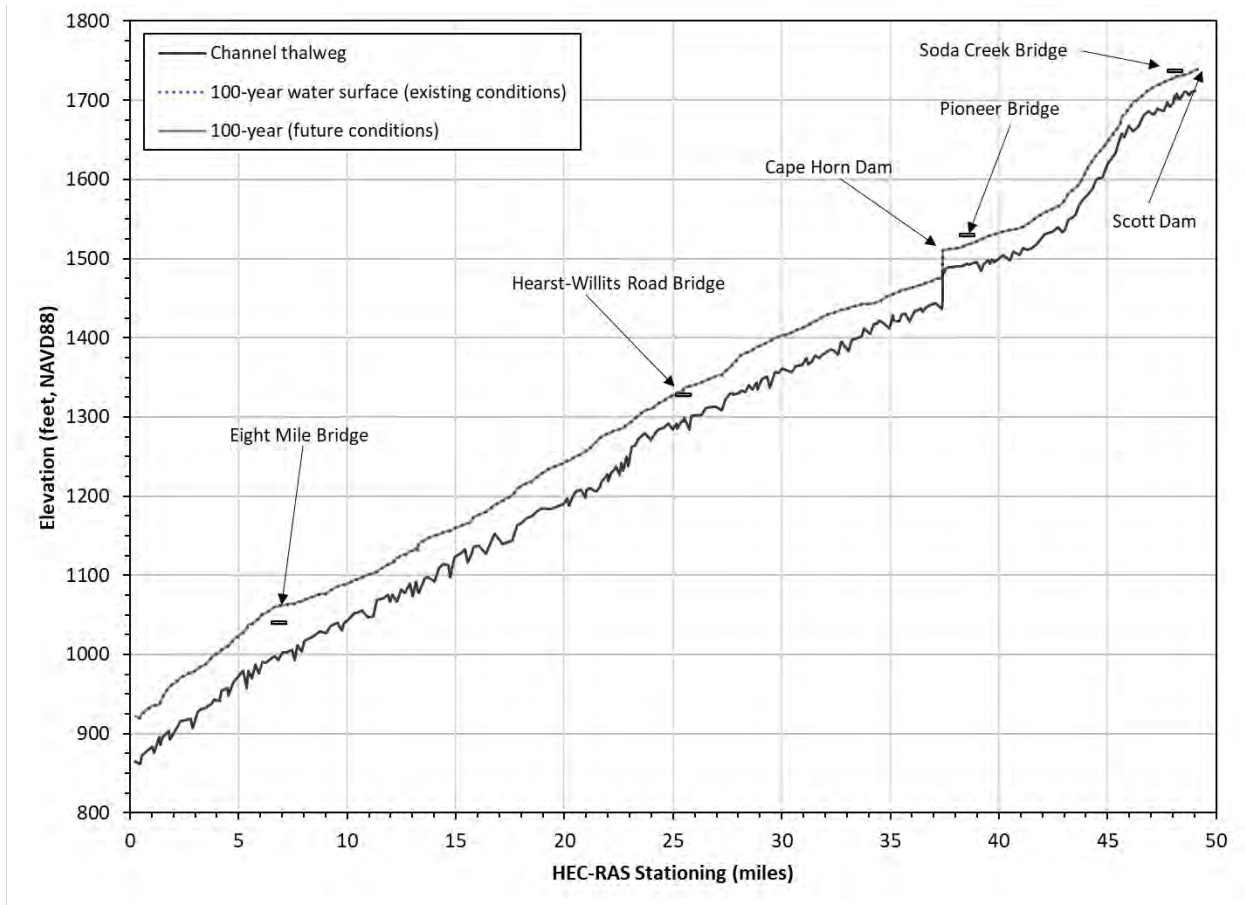


Figure 8. Existing and future conditions water surface elevation profiles. Note that the water surface elevations between existing and future conditions are indistinguishable at this scale. HEC-RAS stationing extends from Scott Dam (station 49) downstream to the Middle Fork Eel River confluence (station 0).

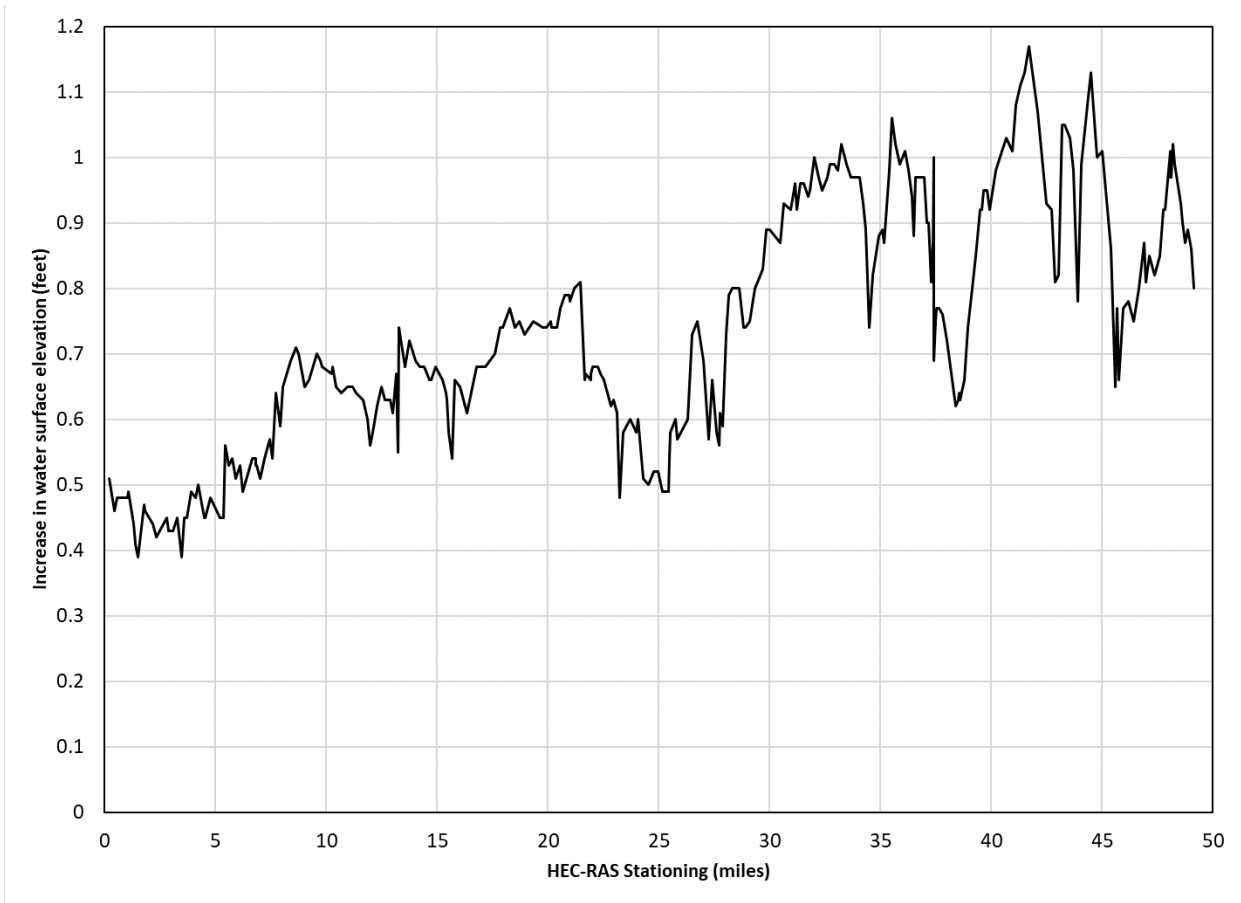


Figure 9. Increase in water surface elevation during 100-year event following dam removal. HEC-RAS stationing extends from Scott Dam (station 49) downstream to the Middle Fork Eel River confluence (station 0).

It should be noted that uniformly increasing impaired 100-year peak discharge by 4,000 cfs to approximate unimpaired peak discharge is likely a conservative approach, and the difference between the analyzed impaired 100-year peak discharge (60,200 cfs) and unimpaired 100-year peak discharge (56,417 cfs) is most likely due to the method of analysis (USGS StreamStates for unimpaired peak flow vs. Bulletin 17C for impaired peak flow). Due to the relatively small Lake Pillsbury storage capacity, it is expected that the 100-year peak flow is minimally affected by the presence of Scott Dam, as Lake Pillsbury would be quickly filled during the time of moderate flow prior to the arrival of the 100-year peak flow, and thus, would provide minimal attenuation to the peak flood. That is, results presented in Figure 8 and Figure 9 should be viewed as conservative results.



Figure 10. Existing conditions and future conditions inundation boundaries.

6 SUMMARY AND DISCUSSION

A 1-D HEC-RAS hydraulic model was developed to assess the potential for increased flooding risk resulting from coarse sediment release following Scott Dam removal. The model included the 49-mile reach of Eel River between Scott Dam (RM 168.5) and Middle Fork Eel River confluence (RM 119.4), including Cape Horn Dam (RM 156.8) and four bridge crossings (Table 5) present within the modeled reach. The flood frequency analyses were performed on annual peaks obtained from the USGS stream gages (Table 2) to estimate flood flows for a range of return intervals (Table 3) under the existing hydrologic conditions. The predicted 100-year water surface elevations under the existing conditions were calibrated to estimated water surface elevations during the December 1964 event at USGS gage 11470500 (below Scott Dam) and USGS gage 11474500 (below Cape Horn Dam).

It is expected that the impacts on the post-dam removal hydraulics for the 100-year event will be characterized mainly by changes in hydrology, and not so much by the coarse sediment transport and deposition. Although the sediment transport analysis (Stillwater Sciences 2021) indicated that the coarse sediment accumulation was predicted to vary in magnitude and timing under the long-term and short-term assessments, the general findings were that substantial sediment accumulation would occur only within Van Arsdale Reservoir, and sediment that accumulates temporarily during periods of low flow within the reservoir would be removed with each flushing event (5-year return interval). Hence it was concluded that the long-term and short-term coarse sediment deposition due to dam removal would not adversely increase the flood risk associated with the 100-year flood event. There will be some impacts of short-term sedimentation on water surface elevations generally within Van Arsdale Reservoir during frequent events that lack the transport capacity to flush the accumulated sediment downstream. This sediment laden future channel condition was simulated in HEC-RAS for a 2-year event, and the model results predicted the 2-year water surface profile to be below the existing 100-year water surface profile (Figure 7).

The impacts of altered hydrology on flood hydraulics were evaluated in HEC-RAS using unimpaired 100-year discharge to reflect the future post-dam removal conditions. The channel geometry was not altered, because the accumulated sediment would be flushed out during the 100-year event. Based on this approach, an increase in the water surface elevation was predicted to be no more than 1.2 ft (Figure 9) compared to the existing conditions.

Results of this preliminary evaluation suggest that short-term and long-term 100-year flooding risk is not expected to substantially increase following Scott Dam removal based on available information. Additional data collection and analyses are included as part of Project relicensing studies that would build on and refine the results of the work presented in this technical memorandum. However, the general results reported herein are not expected to substantially change. In addition, this technical memorandum describes the development of the 1-D HEC-RAS hydraulic model for the 49-mile reach of Eel River between Scott Dam (RM 168.5) and Middle Fork Eel River confluence (RM 119.4). Similarly, additional calibration/validation data collection and model refinement are included as part of Project relicensing studies.

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APPENDIX A

SUPPORTING HYDROLOGICAL ANALYSIS

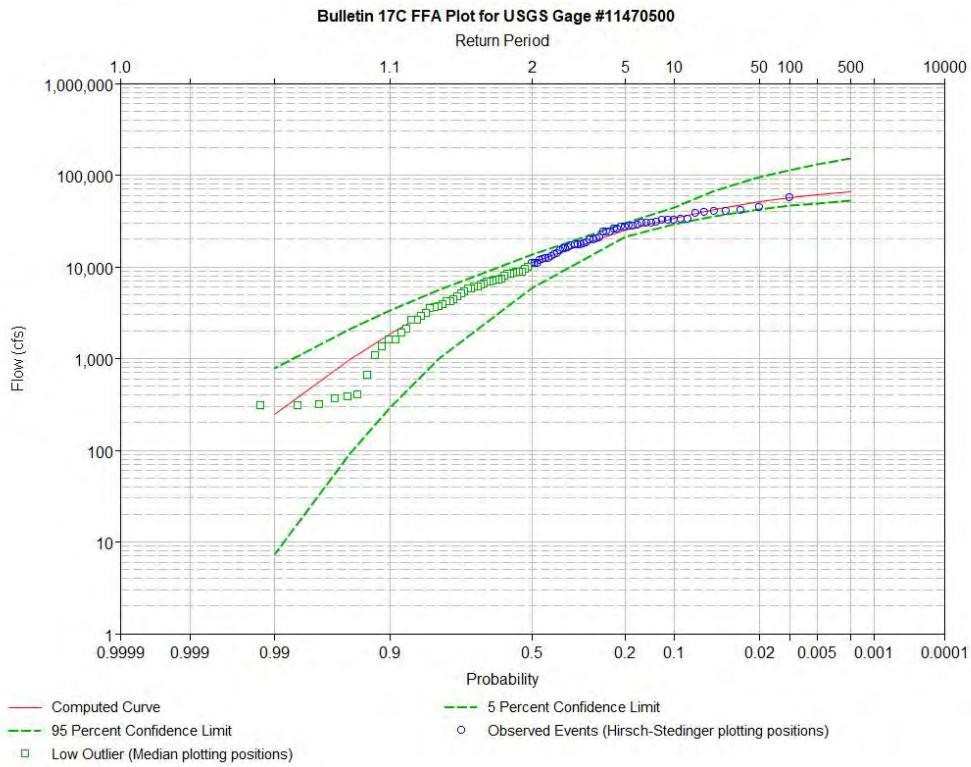


Figure A-1. Flood frequency curve for USGS gage 11470500 (Eel River below Scott Dam).

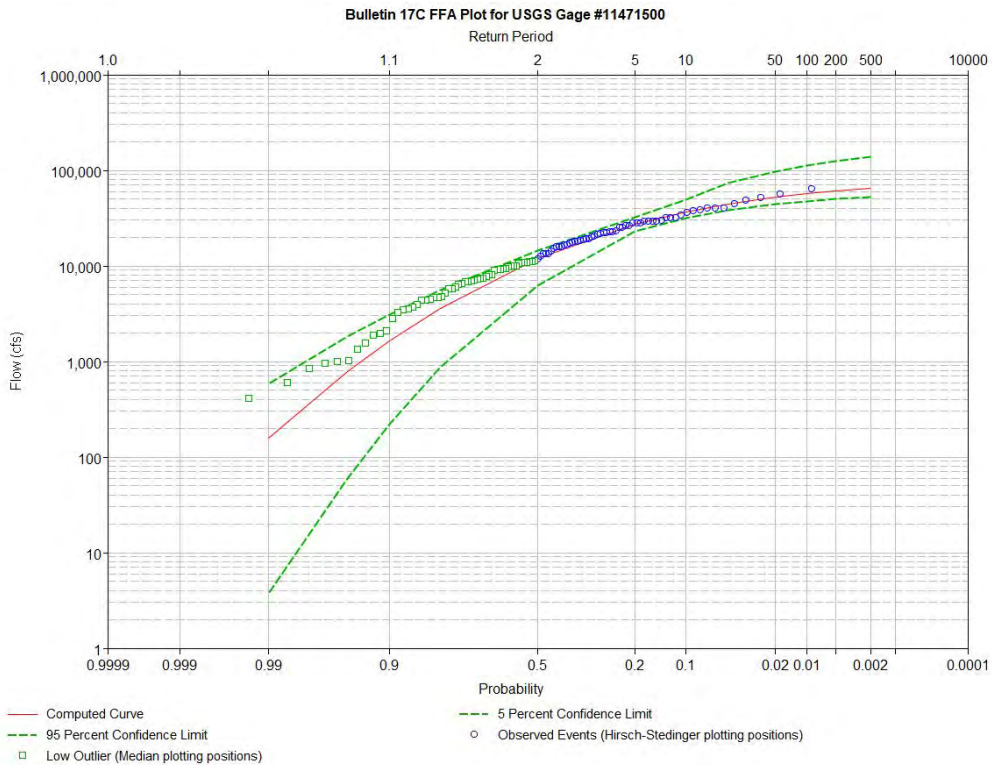


Figure A-2. Flood frequency curve for USGS gage 11471500 (Eel River below Cape Horn Dam).

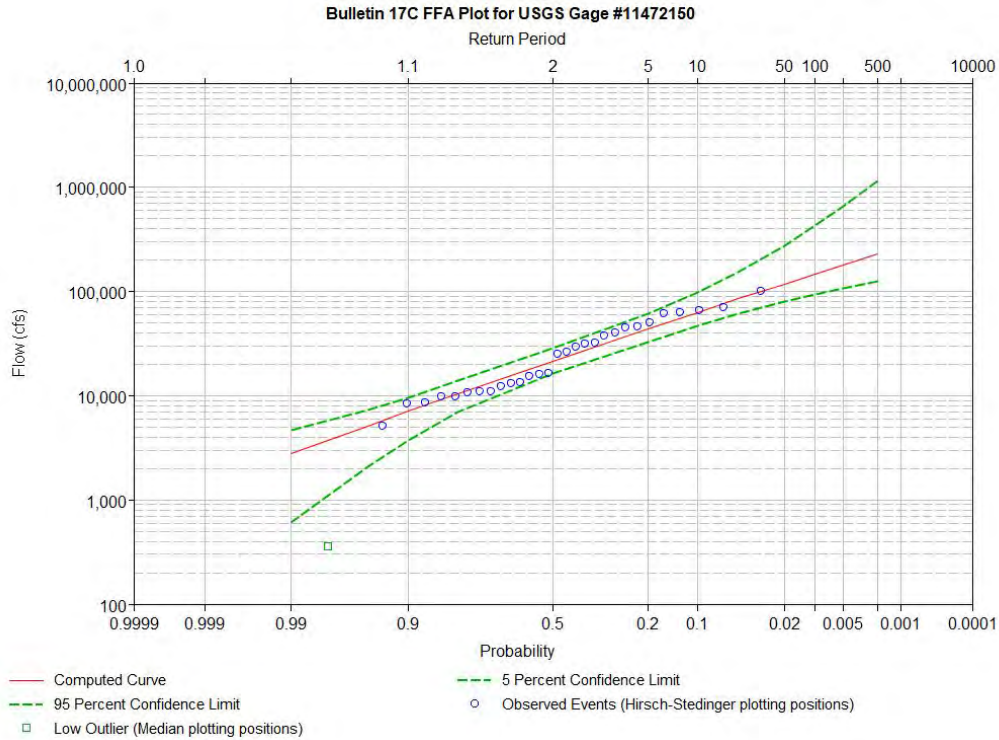


Figure A-3. Flood frequency curve for USGS gage #11472150 (Eel River above Outlet Creek).

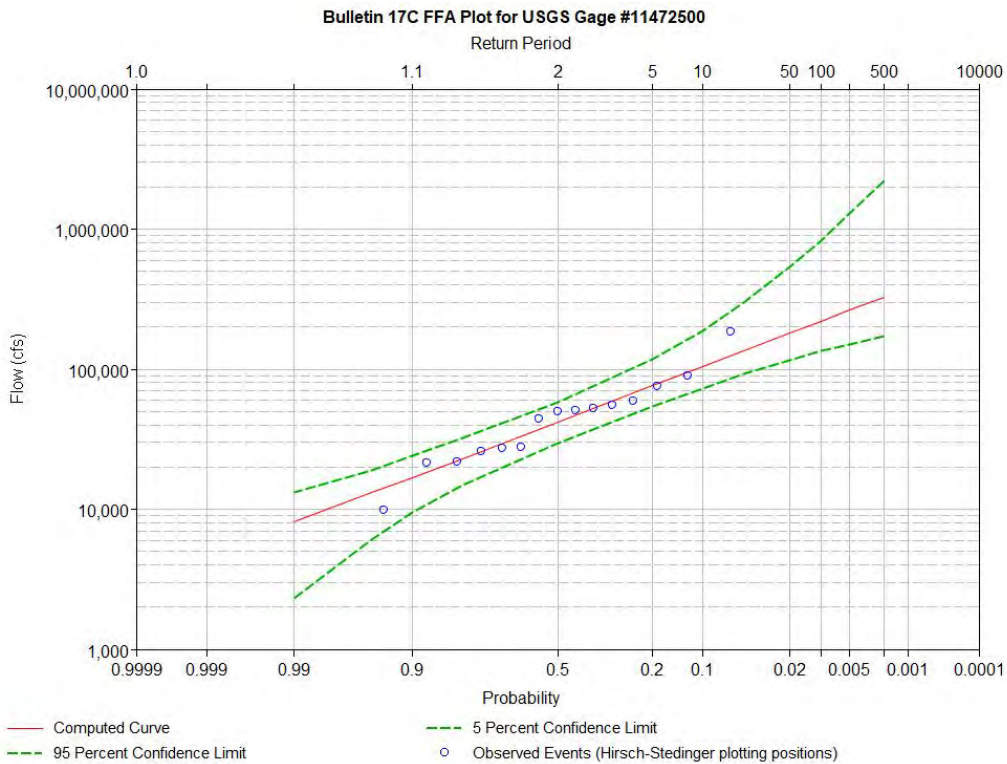


Figure A-4. Flood frequency curve for USGS gage #11472500 (Eel River above Middle Fork Eel River confluence).

APPENDIX B
SUPPORTING HYDRAULIC ANALYSIS

Table B-7. Modeled changes in water surface elevation (WSE) and velocity during 100-year event following Scott Dam removal.

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
259441	49.14	0.8	0.15
258874	49.03	0.86	0.07
258078.2	48.88	0.89	0.08
257312.4	48.73	0.87	0.17
256718.3	48.62	0.9	0.12
256269.2	48.54	0.93	0.11
254962.6	48.29	0.99	0.09
254431	48.19	1.02	0.11
254002	48.11	0.97	0.21
253923	48.09	0.97	0.2
253757	48.06	1.01	0.1
253466.2	48.00	0.98	0.19
252621.6	47.85	0.92	0.24
252162.1	47.76	0.92	0.15
251320.5	47.60	0.85	0.28
250012	47.35	0.82	0.19
249777.2	47.31	0.83	0.18
248785.2	47.12	0.85	0.16
247979.4	46.97	0.81	0.26
247564.6	46.89	0.87	0.14
246329.9	46.65	0.8	0.36
245142.1	46.43	0.75	0.32
243860.5	46.19	0.78	0.24
242629.3	45.95	0.77	0.25
241641.1	45.77	0.66	0.45
241141.2	45.67	0.77	0.15
240702.4	45.59	0.65	0.43
239641	45.39	0.86	0.23
237646.3	45.01	1.01	0.24
236447.8	44.78	1	0.33
234979.1	44.50	1.13	0.21
234086.7	44.33	1.08	0.33
232665.7	44.07	0.99	0.39
231775.4	43.90	0.78	0.49
230673.3	43.69	0.98	0.23
229867.6	43.54	1.03	0.23
228632	43.30	1.05	0.24

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
228081.1	43.20	1.05	0.24
227194.4	43.03	0.82	0.5
226505.2	42.90	0.81	0.32
225579.1	42.72	0.92	0.13
224239	42.47	0.93	0.25
222343.2	42.11	1.07	0.02
220148.7	41.69	1.17	0.23
219239.7	41.52	1.13	0.31
218146.7	41.32	1.11	0.29
217127.9	41.12	1.08	0.04
216245.8	40.96	1.01	0.23
214719.1	40.67	1.03	0.06
213775.1	40.49	1.01	0.15
212192.5	40.19	0.98	0.15
210879.4	39.94	0.92	0.28
210106.3	39.79	0.95	0.17
209410.3	39.66	0.95	0.16
208910.1	39.57	0.92	0.24
208631.7	39.51	0.92	0.19
207430	39.29	0.85	0.27
206766.6	39.16	0.8	0.3
205715	38.96	0.74	0.31
204887	38.80	0.66	0.35
203860.3	38.61	0.63	0.19
203452	38.53	0.64	0.19
203357	38.51	0.63	0.2
202631.3	38.38	0.62	0.19
201476.5	38.16	0.68	0.09
200603	37.99	0.72	0.02
199667	37.82	0.76	-0.11
198757	37.64	0.77	0.07
198250	37.55	0.77	0.1
197953	37.49	0.75	0.17
197659	37.44	0.72	0.26
197538	37.41	0.69	0.31
197479	37.40	1	-0.04
197397	37.39	0.85	0.32
197331	37.37	0.87	0.26

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
196952	37.30	0.81	0.33
196322	37.18	0.9	0.13
195775.6	37.08	0.9	0.19
195249	36.98	0.97	0.04
194499.9	36.84	0.97	0.16
193856	36.72	0.97	0.18
193224	36.60	0.97	0.23
192709.9	36.50	0.88	0.32
192300.5	36.42	0.94	0.16
191561	36.28	0.98	0.12
190668.9	36.11	1.01	0.14
189444.5	35.88	0.99	0.22
188435.7	35.69	1.02	0.14
187579.1	35.53	1.06	0.09
186940.9	35.41	0.98	0.28
185731.7	35.18	0.87	0.39
185336.4	35.10	0.89	0.32
184471.4	34.94	0.88	0.27
183005	34.66	0.82	0.21
182227.9	34.51	0.74	0.31
181402.9	34.36	0.89	-0.01
180749.7	34.23	0.93	0.12
179926.1	34.08	0.97	0.06
179033.5	33.91	0.97	0.13
178367	33.78	0.97	0.17
177771	33.67	0.97	0.14
176830.7	33.49	0.99	0.01
175516.5	33.24	1.02	0.04
174689.1	33.09	0.98	0.11
173924.3	32.94	0.99	0.1
172887	32.74	0.99	0.09
172065	32.59	0.97	0.13
170989.4	32.38	0.95	0.15
170083.1	32.21	0.97	0.11
169088.3	32.02	1	0.07
168108.7	31.84	0.95	0.17
167649.4	31.75	0.94	0.17
166554.6	31.54	0.96	0.14

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
165726.5	31.39	0.96	0.14
164865.5	31.22	0.92	0.19
164443.8	31.14	0.96	0.13
163362.6	30.94	0.92	0.19
161861.6	30.66	0.93	0.14
160849.6	30.46	0.87	0.2
158478	30.01	0.89	0.14
157633.5	29.85	0.89	0.13
156868.8	29.71	0.83	0.23
155523.6	29.46	0.81	0.17
154874.3	29.33	0.8	0.17
153634.5	29.10	0.75	0.21
152565.4	28.89	0.74	0.18
152270.6	28.84	0.74	0.17
151276.6	28.65	0.8	0.04
150315.8	28.47	0.8	0.14
149575.5	28.33	0.8	0.15
148627.6	28.15	0.79	0.14
148064.4	28.04	0.73	0.21
147257.8	27.89	0.59	0.32
146625.6	27.77	0.61	0.21
146471.8	27.74	0.56	0.29
145811.9	27.62	0.58	0.19
144693.2	27.40	0.66	0.13
143819.7	27.24	0.57	0.23
142648.2	27.02	0.69	0.03
141238.5	26.75	0.75	0.04
140053.5	26.53	0.73	0.01
138947.1	26.32	0.6	0.1
136494.5	25.85	0.57	0.08
135960.3	25.75	0.6	0.04
134763.4	25.52	0.58	0.09
134495	25.47	0.54	0.14
134434.5	25.46	0.49	0.17
134129.7	25.40	0.49	0.13
133033.1	25.20	0.49	0.12
132836.4	25.16	0.49	0.11
131891.1	24.98	0.52	0.07

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
130897.8	24.79	0.52	0.1
129659.1	24.56	0.5	0.13
128334	24.31	0.51	0.1
127086.7	24.07	0.6	0.01
126701.6	24.00	0.58	0.12
125212	23.71	0.6	0.07
123482	23.39	0.58	0.06
122726.8	23.24	0.48	0.14
122060.6	23.12	0.61	0
121205.4	22.96	0.63	0.1
120594.6	22.84	0.62	0.11
119729.2	22.68	0.64	0.09
119317.6	22.60	0.65	0.08
118985.5	22.54	0.66	0.11
118113.4	22.37	0.67	0.08
117610	22.27	0.68	0.06
116904.4	22.14	0.68	0.1
116273	22.02	0.68	0.08
115939.8	21.96	0.67	0.1
115752.4	21.92	0.66	0.12
114535.7	21.69	0.67	0.09
114377.7	21.66	0.66	0.07
113335.1	21.46	0.81	-0.03
111835.7	21.18	0.8	0.1
110899.8	21.00	0.78	0.11
110741.1	20.97	0.79	0.06
109541.9	20.75	0.79	0.08
108630	20.57	0.77	0.11
107645.9	20.39	0.74	0.13
106590	20.19	0.74	0.1
106188.6	20.11	0.75	0.11
105295.2	19.94	0.74	0.11
104358.1	19.76	0.74	0.11
102183.7	19.35	0.75	0.08
100114	18.96	0.73	0.11
98863	18.72	0.75	0.13
97777	18.52	0.74	0.16
96426	18.26	0.77	0.1

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
94853	17.96	0.74	0.14
94171	17.84	0.74	0.15
92909.69	17.60	0.7	0.13
90605.27	17.16	0.68	0.09
88660	16.79	0.68	0.09
86411.49	16.37	0.61	0.2
84735.91	16.05	0.65	0.09
83470.23	15.81	0.66	0.11
82862.23	15.69	0.54	0.22
82064.78	15.54	0.58	0.12
81516.75	15.44	0.63	0.04
81258.56	15.39	0.64	0.05
80456.69	15.24	0.66	0.07
78899.58	14.94	0.68	0.08
77825.01	14.74	0.66	0.15
77300.93	14.64	0.66	0.12
76206.79	14.43	0.68	0.07
75125.57	14.23	0.68	0.09
73993.82	14.01	0.69	0.1
72524.19	13.74	0.72	0.06
71665.7	13.57	0.68	0.14
70073.64	13.27	0.74	0.05
69861.81	13.23	0.56	0.26
69464.79	13.16	0.67	0.1
68570.44	12.99	0.6	0.19
68059.19	12.89	0.63	0.12
66835.38	12.66	0.64	0.1
65901.69	12.48	0.65	0.11
64910.81	12.29	0.61	0.15
63853.02	12.09	0.58	0.15
63166.26	11.96	0.56	0.2
62695.77	11.87	0.6	0.09
61647.71	11.68	0.62	0.07
59919.18	11.35	0.63	0.13
59130.63	11.20	0.65	0.13
57778.48	10.94	0.65	0.14
56372.72	10.68	0.63	0.15
55144.69	10.44	0.64	0.16

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
54425.12	10.31	0.67	0.1
54071.47	10.24	0.66	0.11
51925.05	9.83	0.67	0.13
51439.75	9.74	0.69	0.13
50493.05	9.56	0.7	0.11
48649.94	9.21	0.66	0.18
47595.78	9.01	0.66	0.17
46185.27	8.75	0.73	0.08
45534.59	8.62	0.75	0.06
44397	8.41	0.74	0.12
42426.4	8.04	0.76	0.14
41771.26	7.91	0.71	0.2
40735.12	7.71	0.77	0.1
39917.88	7.56	0.7	0.21
39378.48	7.46	0.74	0.14
38081.04	7.21	0.7	0.18
37021	7.01	0.7	0.15
36153	6.85	0.74	0.08
36107	6.84	0.82	0.06
35948.32	6.81	0.83	0.06
35207.29	6.67	0.84	0.03
32961.61	6.24	0.86	0.04
32224.89	6.10	0.8	0.05
31330.51	5.93	0.67	0.13
30521.61	5.78	0.67	0.12
29681.04	5.62	0.65	0.14
28844.18	5.46	0.68	0.1
28269.42	5.35	0.57	0.25
27515	5.21	0.59	0.14
25237.62	4.78	0.62	0.12
23957.24	4.54	0.6	0.14
23768.49	4.50	0.61	0.12
22267.38	4.22	0.66	0.09
21795.24	4.13	0.64	0.11
20579.13	3.90	0.65	0.1
19561.86	3.70	0.62	0.14
19089	3.62	0.62	0.14
18335.87	3.47	0.57	0.18

HEC-RAS River Station (feet)	HEC-RAS River Station (miles)	Change in WSE (feet) [Future conditions - existing conditions]	Change in channel velocity (feet/second) [Future conditions - existing conditions]
17281.49	3.27	0.57	0.09
16369.48	3.10	0.52	0.14
15219.01	2.88	0.5	0.14
14747.18	2.79	0.52	0.09
12246.72	2.32	0.44	0.16
11494	2.18	0.45	0.08
9687.817	1.83	0.48	0.06
9350.2	1.77	0.49	0.09
7916.624	1.50	0.4	0.17
7272.345	1.38	0.41	0.13
7041.46	1.33	0.45	0.09
5746.322	1.09	0.5	0.08
5385.522	1.02	0.5	0.07
2902.869	0.55	0.5	0.07
2391.486	0.45	0.46	0.12
1091	0.21	0.51	0.05