ZINFANDEL LANE BRIDGE
FISH PASSAGE ASSESSMENT

ST. HELENA – NAPA RIVER RESTORATION PROJECT
NAPA COUNTY, CALIFORNIA

PREPARED FOR:

U. S. ARMY CORPS OF ENGINEERS
SAN FRANCISCO DISTRICT
333 MARKET ST.
SAN FRANCISCO, CA 94105

PROJECT # 105309

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FINAL REPORT

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INTRODUCTION

The Zinfandel Lane Bridge is located on the Napa River approximately two miles east of the city of St. Helena in Napa County, California (Figure 1). The concrete bridge apron supporting the structure has been identified as a barrier to fish migration in the Napa River, warranting further study of alternative scenarios to improve conditions. The U. S. Army Corps of Engineers funded the Napa County Resource Conservation District (RCD) in April 2006 to complete this study.

Zinfandel Lane Bridge prevents upstream passage of adult Chinook salmon (*Oncorhynchus tshawytscha*) during tailing limbs of early season flows, which occur after the first few storms of the rainy season. The bridge also hinders migration of adult steelhead (*Oncorhynchus mykiss*) under a range of winter flows. During periods of low baseflow, typically from June through October, the bridge is a complete barrier to all fish movement and prevents upstream and downstream dispersal of juvenile salmonids and other native fishes. Under all conditions, the bridge is a complete barrier to upstream movement by juvenile salmonids and most native fishes due to high velocities and excessively high jump heights.

Migration barriers, such as Zinfandel Lane Bridge, exert significant pressure on steelhead and salmon populations by delaying or preventing access to high-quality upstream spawning habitat. The highest quality known habitat for Chinook salmon is located in the mainstem Napa River upstream of Zinfandel Lane, as well as several significant steelhead tributaries including York Creek, Sulphur Creek, Selby Creek, and Ritchie Creek (NCRCD 2005, NCRCD 2002). During low flows the structure requires repeated leap attempts to pass, which causes exhaustion, injury, and even mortality to migrating fish. The physical and physiological stress from such an obstacle can considerably reduce a fish’s fitness and chances for survival.

The bridge likely has an adverse impact on steelhead and Chinook smolt outmigration due to shallow sheet flow over the concrete apron during late spring. As flow diminishes in late spring and early summer, it begins to flow under the concrete bridge structure rather than over it, effectively cutting off passage at flows below approximately 15 cubic feet per second (cfs). Smolts that migrate while flows are sufficiently high may become disoriented after plunging through the existing bridge jump pool structure, making them more vulnerable to predatory fish such as Sacramento pikeminnow (*Ptychocheilus grandis*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieu*) in the pool below.

Approximately 105 feet downstream of the bridge, there is a partial fish migration barrier consisting of a 4.7 foot high bedrock and concrete wall (Figure 2). This structure has a narrow step-pool channel constructed along the east bank to facilitate fish passage. However, adult salmon have a difficult time passing this structure at flows below approximately 20 cfs due to a lack of sufficient depth. Additionally, the constructed step pools are too short in length to accommodate most adult salmon.

In the past five years, significant numbers fall-run Chinook salmon have been documented in the mainstem Napa River and several key tributaries (Koehler 2005, Koehler 2006).

Approximately 60 adult salmon were observed in Sulphur Creek in 2004, and numerous sightings of spawning salmon have been made in other tributaries upstream of Zinfandel Lane. Salmon that are unable to pass the bridge structure must spawn in marginal spawning habitat in the reach immediately downstream. During surveys in 2003 – 2005, the RCD documented unusually high redd densities below the bridge, which likely reduced egg-to-emergence survival and consequently overall salmon production within the Napa River basin.

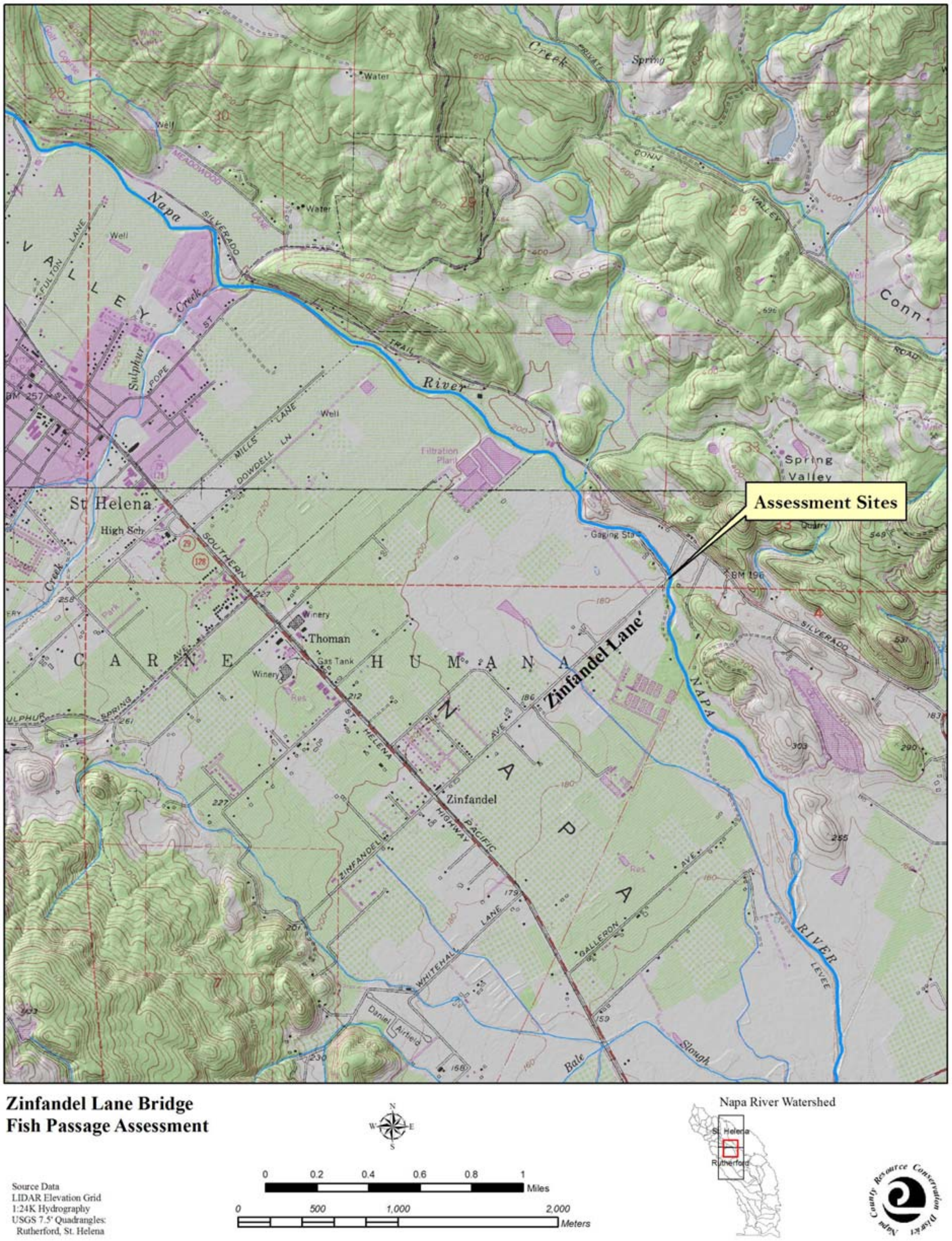

Figure 1. Project location map.

Figure 2. Aerial photo of Zinfandel Lane Bridge over the Napa River.

HYDRAULIC MODELING

Design Flows

Design flows for the Napa River at Zinfandel Lane were computed using the HEC-SSP program of the United States Army Corps of Engineers (USACE), using *station skew* as opposed to *weighted skew*, for the return intervals 1.5, 10 and 20 years. In addition to these design flows, the RCD biologist recommended modeling a flow of 15 ft^3/s, considered to be the minimum flow for fish passage. The 10-year and 20-year flows were obtained as estimates of the maximum flow that the channel can contain; modeling in HEC-RAS subsequently showed the 10-year flow to be well over the bank above the bridge, so the 20-year flow was dropped from consideration. The following table shows the design flows used in the model:

Return interval or other description	*Q, ft^3/s*
Desirable minimum flow for fish passage	15
1.5 yr	4220
10 yr	12,400

Field Surveying

The RCD obtained field cross sections from the USACE at approximately 500-ft spacing through the project reach, from a point approximately 1500 ft upstream of the bridge to approximately 800 ft downstream of it. RCD staff surveyed additional cross sections at approximately 250-ft spacing through the central part of the reach and added further cross sections in the immediate vicinity of the bridge. RCD also surveyed the longitudinal profile of the thalweg throughout the project reach (Appendix A).

HEC-RAS model

The RCD developed a HEC-RAS[1] model of the surveyed reach on the basis of the combined USACE/RCD survey. The standard step method was used for the bridge. Cross sections were located at the immediate upstream and downstream faces of the bridge, and the neighboring cross sections on each side of the bridge were located so as to allow appropriate room for expansion or contraction losses at the bridge. Elevated expansion/contraction coefficients were applied at cross sections ***2*** and ***4*** (following the numbering convention used in the HEC-RAS manual for bridge cross sections). To test the sensitivity of the model to large expansion and contraction coefficients, RCD ran the model with no elevated coefficients at all, and water levels were reduced 0.35 ft at **2** and approximately 5 ft at **4**. The downstream water level for each design discharge was determined by an iterative procedure that calculated velocity by continuity and by Manning's equation for varying assumed water levels, until the two calculations agreed within five percent[2]

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[1] HEC-RAS is a hydraulic modeling program developed by the USACE Hydrologic Engineering Center (HEC).

[2] For an assumed water level, the discharge at that cross section was calculated by applying the following two equations:

$V = Q/A$ where Q is the design discharge and A is the approximate area of flow for the assumed water level

$V = (1.5/n) R^{2/3} S^{1/2}$ where n is the overall channel roughness (taken to be 0.06), R is the approximate hydraulic radius, and S is the slope (taken to be 0.0058). The factor 1.5 is the correction for U.S. customary units.

Field observation led to the following determinations of channel roughness (Manning's n): from the upstream model limit down to the bridge the channel is dominated by one long pool with silt and bedrock outcrops; banks are also fairly smooth bedrock, with willows at toe and more vegetation higher up, e.g. blackberries and occasional oaks; but bank vegetation is fairly sparse throughout. Downstream of the bridge, however, both channel bed and banks are quite different. The bed is cobbles & gravel, there are a number of pronounced riffles with cobbles & gravel, and the banks are heavily vegetated with willow, Arundo donax, etc. Both are much rougher than the upstream reach. The values of roughness assigned are shown in this table:

Reach	Manning's n, channel	Manning's n, banks
Upstream of bridge	0.04	0.06
Downstream of bridge	0.05	0.08

These roughness values, while more site specific, are in general consistent with those used in the modeling done for the Rutherford Dust Restoration Team (RDRT) Preliminary Design project. The bank stations were set to correspond roughly to field-identified breaks in roughness.

Validation

The model results were compared with the RDRT model. The RDRT model has considerably simplified cross section geometry, and the concrete sill under the bridge is 8 ft higher than our survey information would indicate. In addition, there are no elevated expansion or contraction coefficients at the bridge in the RDRT model.

Comparison of the results indicated that the RCD's 1.5-year water surface is within a foot of the 1.5-year water surface in the RDRT model, well within the tolerance of the RDRT model validation. However, the 10-year water surface has substantially greater backwater upstream of the bridge (approximately 4 ft) and a correspondingly lower level on the downstream side (2-3 ft), which may be attributed to our use of expansion/contraction coefficients as recommended in the *HEC-RAS Hydraulic Reference Manual* v. 3.1 (November 2002). Because the model developed for this project includes expansion/contraction coefficients and represents the geometry and roughness of the channel in a far more detailed manner than the RDRT model did, RCD considers it a more accurate representation of the actual effects of the bridge under very high flows.

DESIGN CRITERIA

Design criteria were based on the following project objectives

- Provide full upstream passage for adult Chinook salmon and steelhead.
- If feasible, provide juvenile upstream passage for dispersal.
- Incorporate public viewing and educational opportunities.

To achieve these objectives, we used the following design criteria based on NOAA Fisheries and California Department of Fish and Game guidelines.

- Low passage flow = 15 cfs[3]
- Maximum jump height = 0.5 ft (juvenile), 1 ft (adult)
- Maximum water velocity = 6 ft/sec (adult), 1 ft/sec (juvenile)
- Resting pools sized for adult Chinook salmon (6-8 ft. long)

MEASURES DEVELOPMENT

A range of measures for improving fish passage at the Zinfandel Lane Bridge were identified based on the design criteria described above, and evaluated to inform the alternatives development and evaluation process that will occur during the Corps study. The measures were grouped into 3 general categories based on the characteristics of the study area: 1) modifications to the bridge opening; 2) modifications to the existing downstream step-pool sequence (approximately river station 1025 to 975); and 3) creating a new step-pool sequence (approximately river station 1140 to 975). Several of the measures identified under these categories were dropped from further consideration based on an initial evaluation of feasibility, potential environmental impacts, maintenance requirements, and possible benefits. These measures are described below:

- **Western Bridge Opening.** Although the western bridge apron appears to be slightly lower in elevation than the eastern apron, the eastern opening is more aligned with the upstream and downstream reaches of the main river channel and would provide a better-defined flow path for fish passage (Figure 3 & 4).

- **Fish Ladder.** High storm flows and associated debris and sediment loads could result in extensive maintenance requirements and/or potential damage to a fish ladder, adversely affecting its ability to provide passage.

- **Constructing a Low-Flow Notch in the Existing Apron.** Because of concerns regarding the stability of the existing concrete bridge apron, it was determined that constructing a low-flow channel or notch in the apron was not feasible without additional geotechnical analysis. This measure was not pursued further; however, additional geotechnical analysis could render this measure a viable one.

- **Expanding the "Bathtub."** Expanding the existing pool or "bathtub" downstream of the western bridge apron would improve the ability of salmonids to reach the apron; however, because of limited water depth over the apron during low-flow periods upstream passage would still be impeded.

- **Roughened Rock Ramps.** Filling the channel immediately downstream (approximately river station 1140 to 980) of the bridge with rock to create a single

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[3] 15 cfs represents a threshold passage flow when all known downstream impediments are passable for adult salmonids.

roughened ramp, or a series of roughened ramps, to facilitate fish passage would result in significant impacts to aquatic habitat.

- **0.5-foot Hydraulic Drop.** As described above under design criteria, NOAA Fisheries design criterion for juvenile passage prescribes a maximum hydraulic drop of 0.5 feet. Because of the length of the study reach and the gradient, it is not possible to construct a series of weirs or other structures with a 0.5-foot hydraulic drop without substantially compromising pool size and potentially adult passage.

Figure 3. Western bridge opening, looking upstream

Figure 4. Eastern bridge opening, looking upstream.

DESCRIPTION OF PROPOSED MEASURES

The following section provides a brief description of the measures carried forward for further consideration and evaluation. Table 1 provides an overview of construction and permitting issues, and order of magnitude construction costs associated with each measure. Distances described in the measures are relative to the thalweg profile conducted by the RCD (Appendix A).

Modification to the Bridge Opening

Two measures involving modifying the eastern bridge opening were identified as part of this study: 1) constructing a grouted rock channel; and 2) constructing a natural bottom channel. These measures are described below.

Measure 1: Grouted Rock Channel

Measure 1 involves removing the existing concrete apron and constructing a grouted rock channel through the eastern bridge opening to provide fish passage during low flows. The new channel would be approximately 60 feet long and 20 feet wide, and would contain a 2-foot wide low-flow channel (Figure 5). Because of the narrow width of the existing bay, the channel side slopes would be 1.5:1 (Figure 6). The invert of the new channel would be approximately 6 feet below the bridge apron, and would slope approximately 0.5 feet from upstream to downstream (slope of 0.008) (Figure 7). The existing downstream rock weir, which is approximately 4.5 feet lower in elevation than the bridge apron would backwater the new channel to a depth of approximately 1.5 feet. The new channel would be constructed of reinforced concrete (low-flow channel), and rock grouted with cement. Boulders would also be installed along the low-flow channel to add roughness. Reinforced concrete cut-off walls would be constructed upstream and downstream of the bridge apron to reduce seepage during low-flow conditions. The elevation of the cut-off walls would be determined based on future geotechnical analyses.

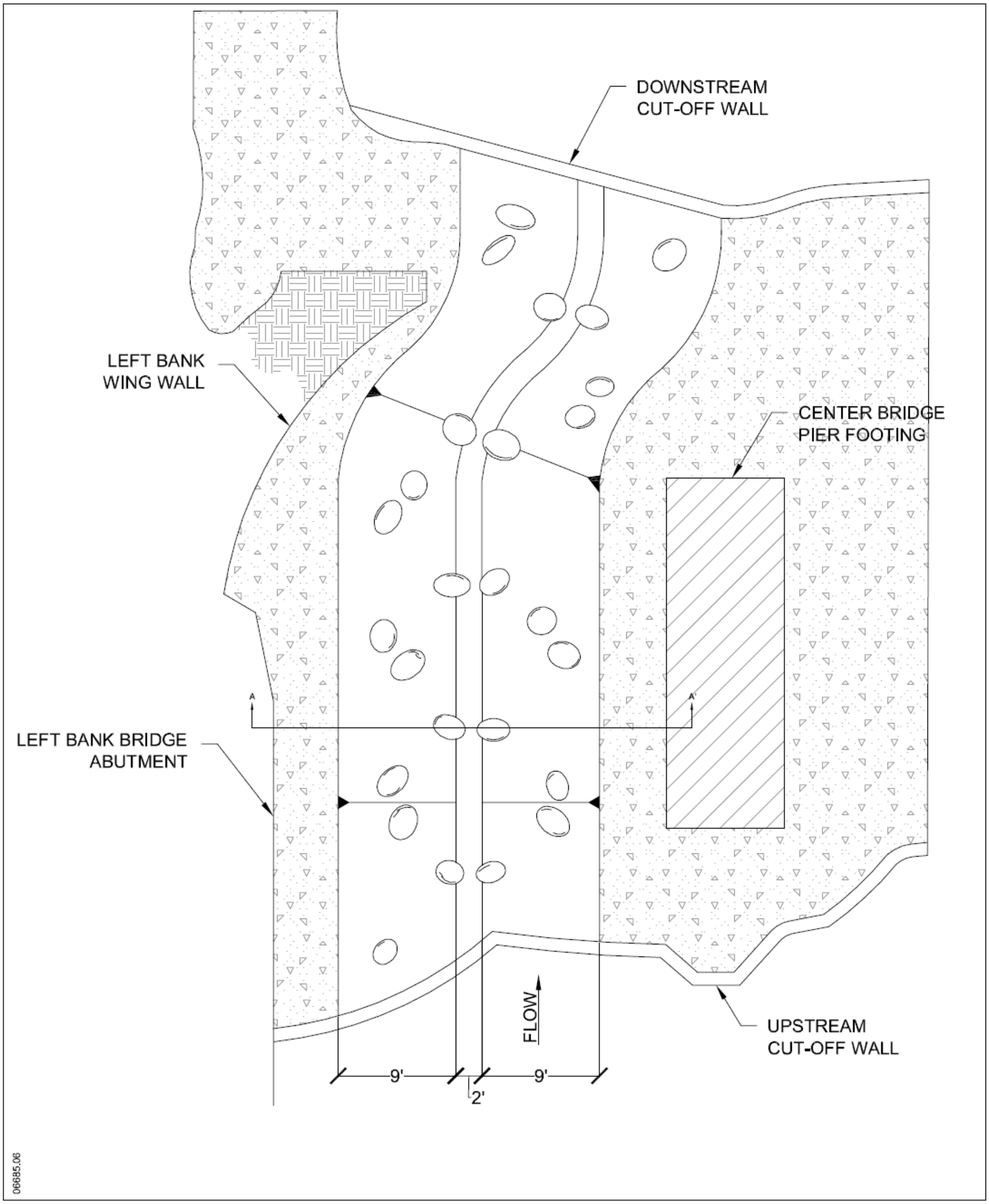

Figure 5. Grouted Rock Channel (Plan View)

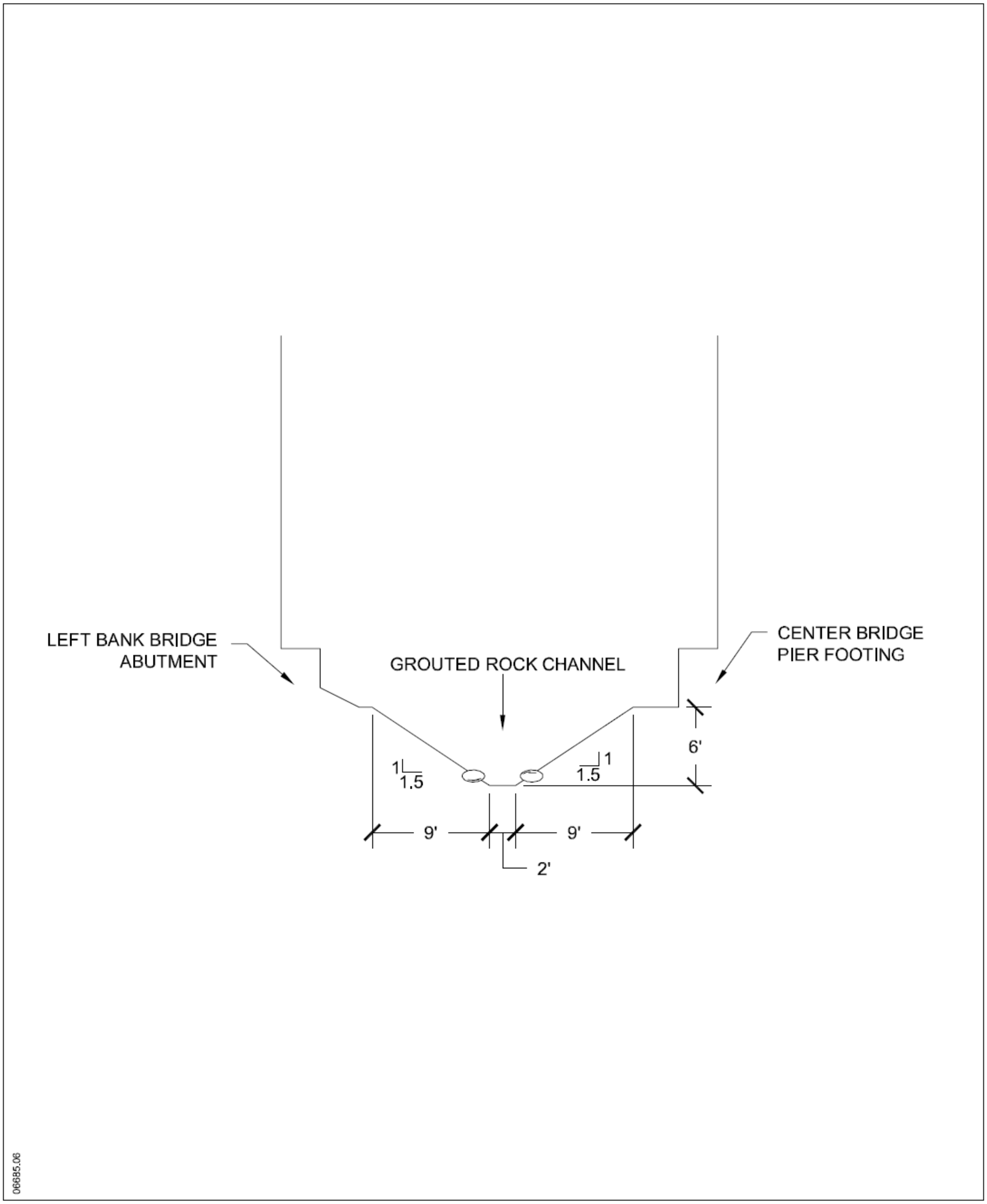

Figure 6. Grouted Rock Channel (Section A-A')

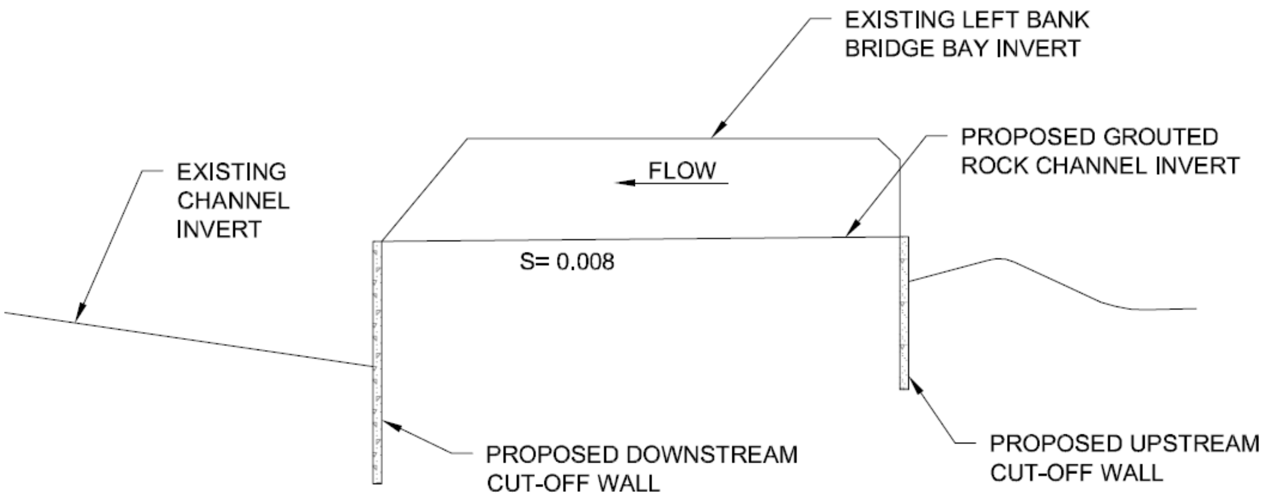

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Figure 7. Grouted Rock Channel (Profile)

Measure 2: Natural Bottom Channel

Similar to Measure 1, Measure 2 involves improving upstream passage by removing the existing concrete apron to construct a natural bottom channel through the eastern bridge opening. The new channel would be approximately 60 feet long and 25 feet wide (Figure 8). Large boulders (24- to 36-inch) would be keyed into the channel bottom to stabilize the new invert, and encourage accumulation of cobbles and gravels and development of a natural bottom. The invert elevation of the new channel would be approximately 6 feet below the existing bridge apron to backwater the new channel to a depth of approximately 1.5 feet and ensure that a minimum water depth of 1-foot is maintained upstream of the bridge. Reinforced concrete walls would be constructed on either side of the new channel to protect the bridge foundation, and upstream and downstream of the bridge apron to reduce seepage during low-flow conditions. The elevation of the rock channel invert and the concrete walls would be determined based on future geotechnical and hydraulic analyses.

Modification to the Downstream Step-Pool Sequence.

Two measures involving modifying the downstream step-pool sequence were identified as part of this study: 1) rebuilding the existing step-pool sequence along the east bank; and 2) constructing a new step-pool sequence along the west bank. These measures are described below. Figures 9 and 10 depict the existing downstream step-pool sequence.

Measure 3: Modified Step-Pool Sequence – East Bank

Measure 3 involves rebuilding the existing east bank step-pool sequence to increase the size of the pools to better support Chinook salmon. Five rock weirs (Figure 11) would be constructed along the east bank of the channel to create a series of 1-foot hydraulic drops (Figure 12). The crest of the upstream weir would be set at an elevation of 161 feet to provide a 1-foot drop from the existing grouted rock weir. The crest of the downstream weir would be set at an elevation of 157 feet to provide a 1-foot drop to the downstream bedrock control. The weirs would be constructed using 24- to 36-inch rock and the base of the weir would be keyed into the channel invert (approximately 4 feet) and banks to ensure stability during high flows. Rock size and key depth would be determined based on future hydraulic analyses. The new weirs would also be tied into the existing grouted rock structures along the channel centerline.

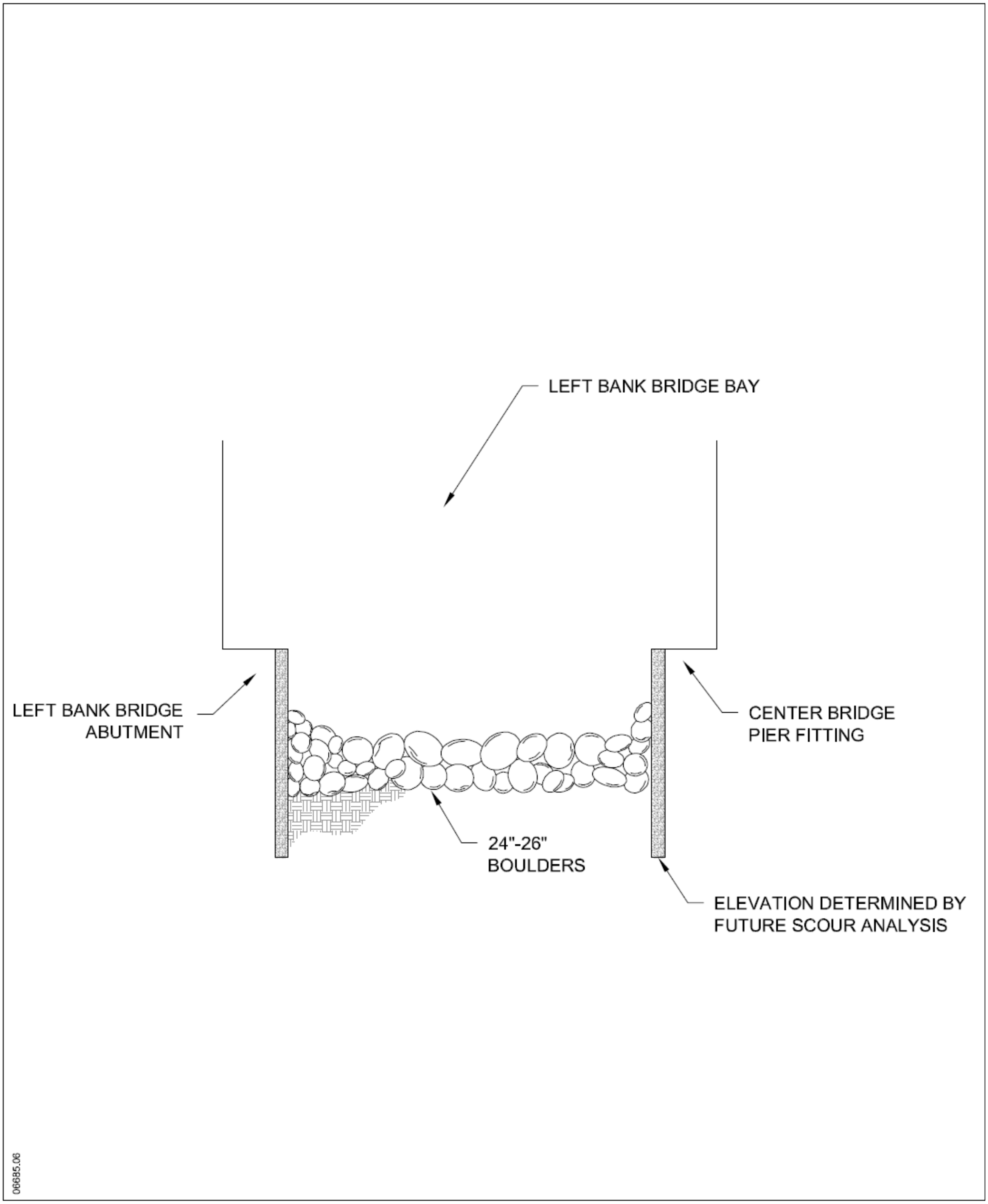

Figure 8. Open Bottom Channel

Figure 9. Downstream step-pool sequence and grouted rock weir, looking upstream.

Figure 10. Existing downstream step-pool sequence, looking downstream.

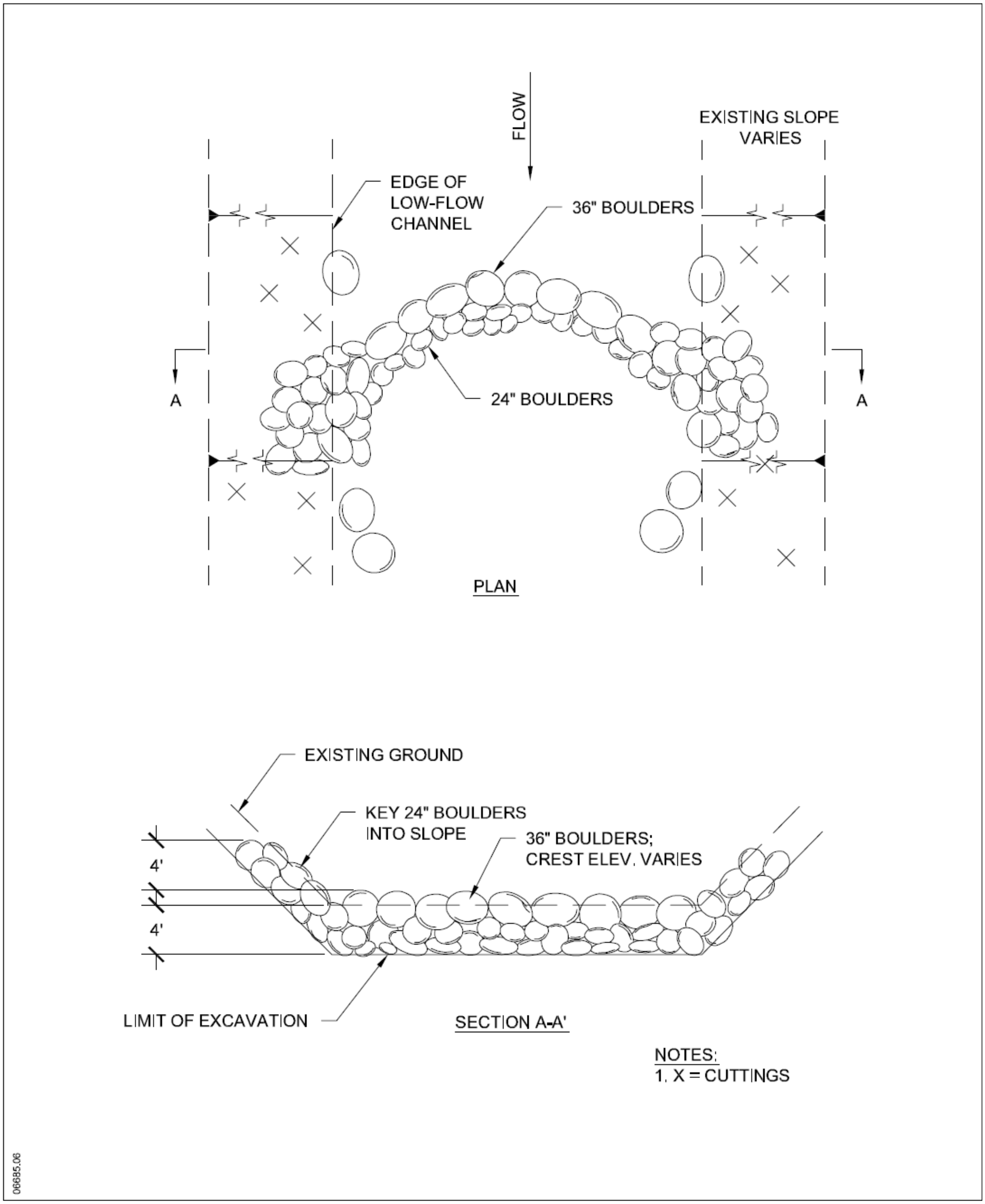

Figure 11. Typical Rock Weir

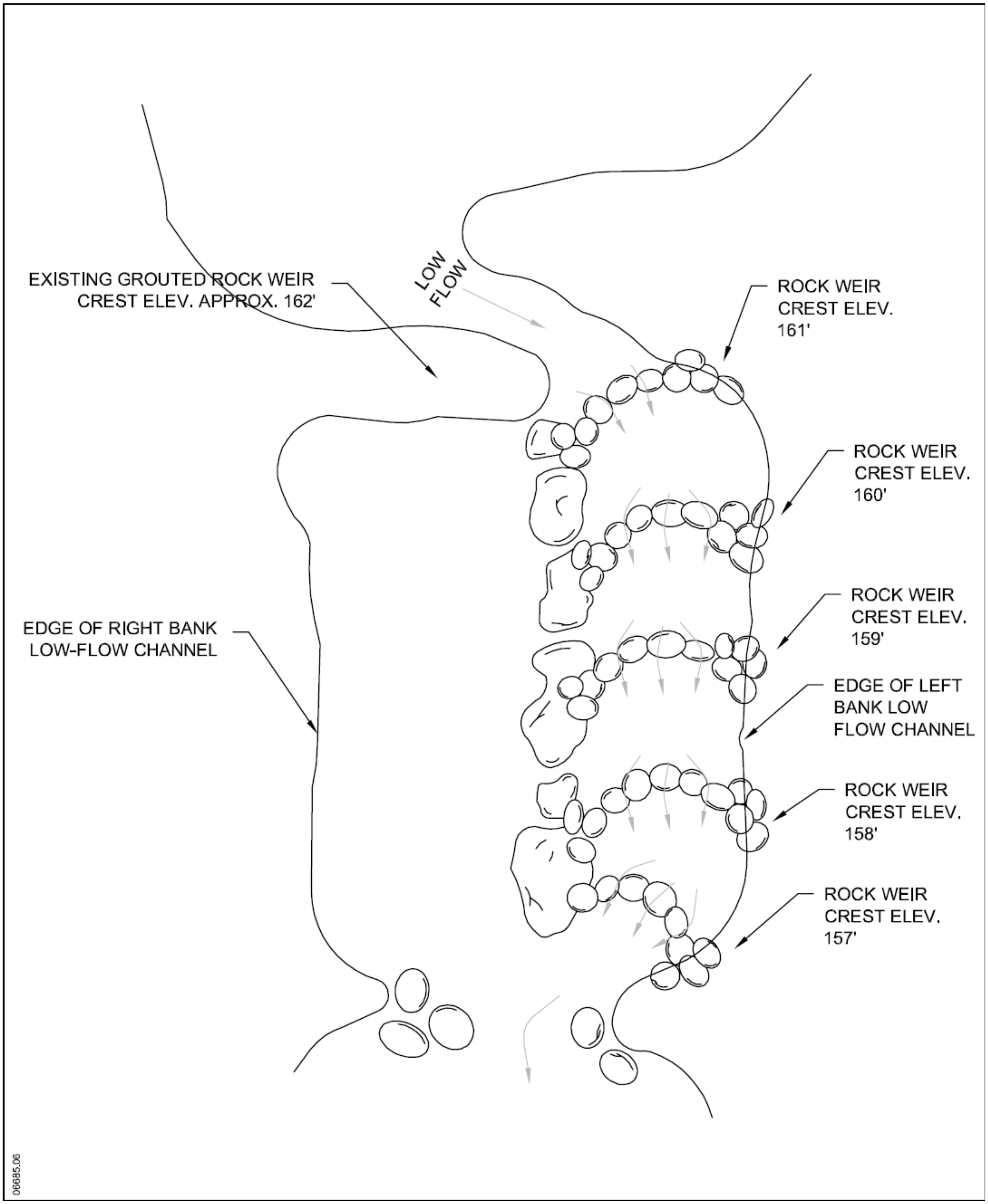

Figure 12. Modified Step-Pool Sequence (East Bank)

Measure 4: Constructed Step-Pool Sequence – West Bank

Measure 4 involves constructing a new step-pool sequence along the west bank of the channel to improve passage. Five rock weirs (Figure 11) would be constructed along the west bank of the channel to create a series of 1-foot hydraulic drops (Figure 13). The crest of the upstream weir would be set at an elevation of 161 feet to provide a 1-foot drop from the existing grouted rock weir. The crest of the downstream weir would be set at an elevation of 157 feet to provide a 1-foot drop to the downstream bedrock control. The weirs would be constructed using 24- to 36-inch rock and the base of the weir would be keyed into the channel invert (approximately 4 feet) and banks to ensure stability during high flows. Rock size and key depth would be determined based on future hydraulic analyses. The new weirs would also be tied into the existing grouted rock structures along the channel centerline.

Measure 5: Creation of a New Downstream Step-Pool Sequence.

Measure 5 involves constructing a new step-pool sequence within the main channel from approximately river station 1140 to 975. Eleven rock weirs (Figure 11) would be constructed within the main channel to create a series of 1-foot hydraulic drops (Figure 14). The crest of the upstream weir would be set at an elevation of 167 feet to backwater the bridge apron to an approximate 1-foot depth. The crest of the downstream weir would be set at an elevation of 157 feet to provide a 1-foot drop to the downstream bedrock control. The weirs would be constructed using 24- to 36-inch rock and the base of the weir would be keyed into the channel invert (approximately 4 feet) and banks to ensure stability during high flows. Rock size and key depth would be determined based on future hydraulic analyses.

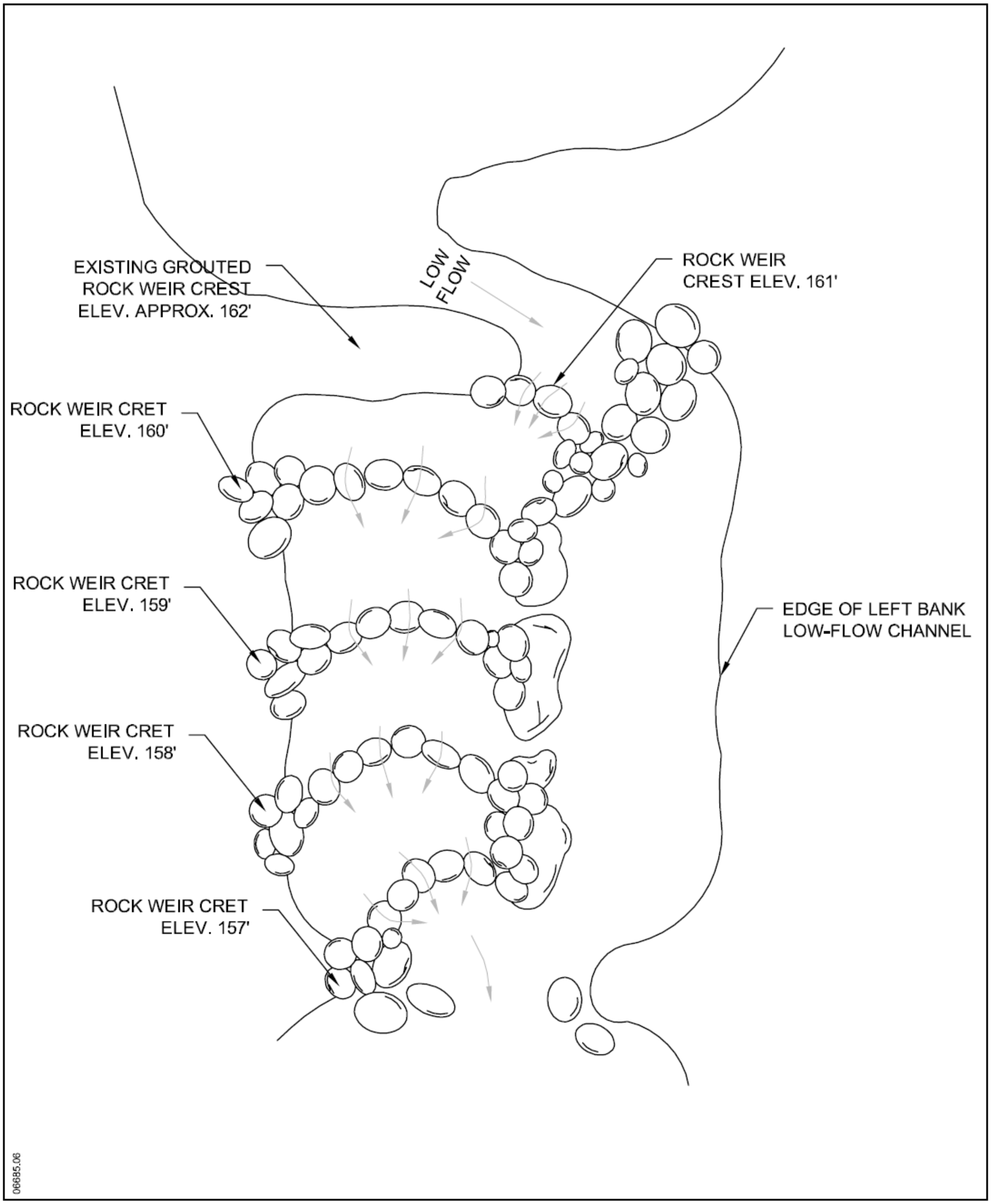

Figure 13. Modified Step-Pool Sequence (West Bank)

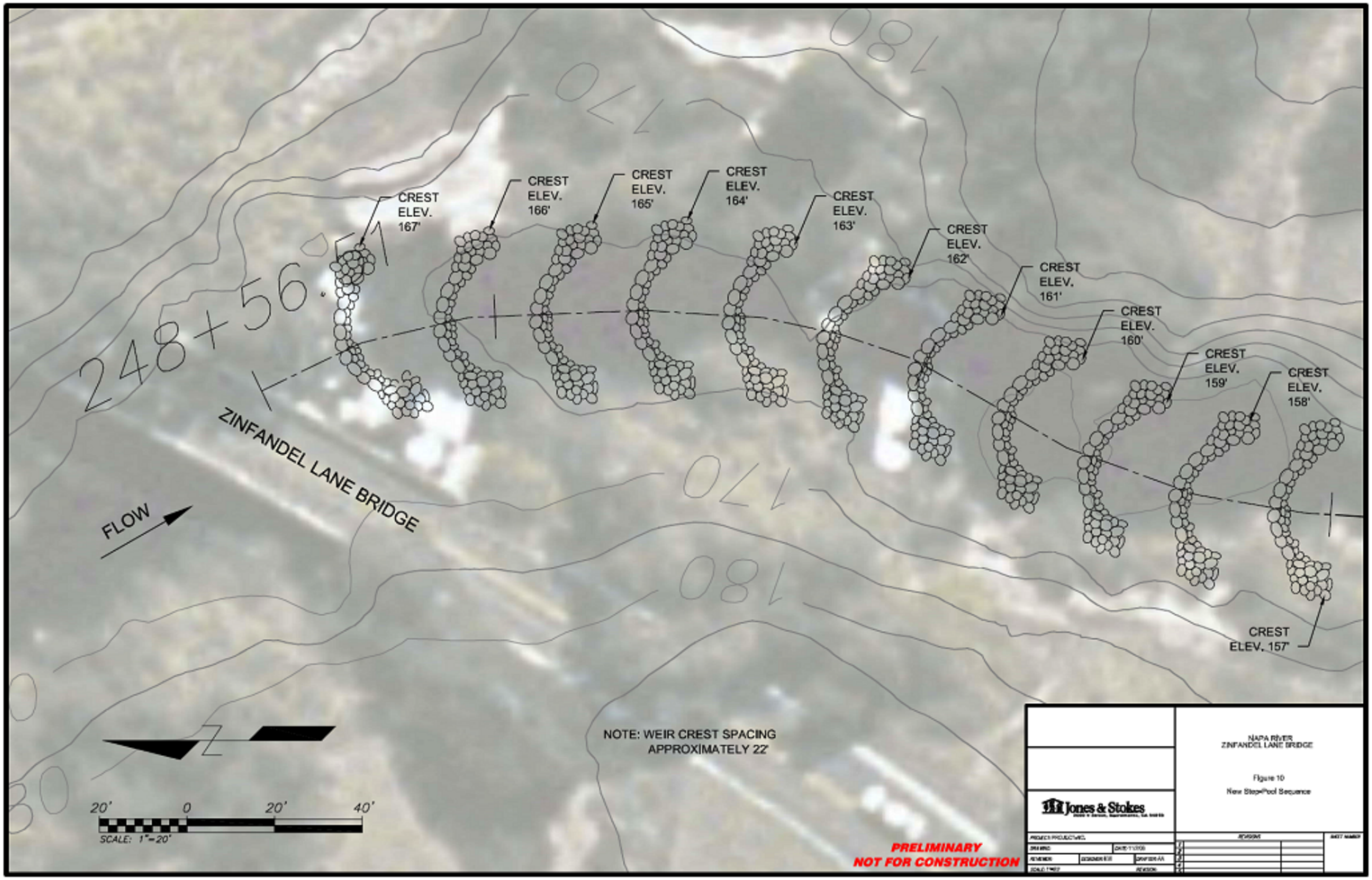

Figure 14. New Step Pool Sequence.

Table 1. Comparison of Measures for Improving Fish Passage at the Zinfandel Lane Bridge.

Measure	**Construction Feasibility**	**Permitting Difficulty**	**Maintenance Requirements**	**Order-of Magnitude Construction Cost**[1]
1. Grouted Rock Channel	Medium – will require diversion of stream flows, dewatering, and construction of ramps and pads for equipment access.	Low to Medium – would not require any permanent channel fill, but would require substantial amounts of temporary fill to provide equipment access to the bridge. May adversely affect CA freshwater shrimp habitat and/or historic context.	Low to Medium – some debris and/or sediment may accumulate in the low-flow channel.	$160,000
2. Natural Bottom Channel	Medium – will require diversion of stream flows dewatering, and construction of ramps and pads for equipment access.	Low to Medium – would not require any permanent channel fill, but would require substantial amounts of temporary fill to provide equipment access to the bridge. May adversely affect CA freshwater shrimp habitat and/or historic context.	Low – the larger opening will allow most debris to pass through. Larger sediment particles will accumulate helping to create a natural bottom.	$220,000
3. Modified Step-Pool Sequence (East Bank)	Low – work area is relatively small but will require diversion of stream flows, dewatering, and construction of ramps and pads for equipment access.	Low– would require only limited temporary and permanent channel fill.	Medium – some debris and/or sediment may accumulate in the step-pools. Higher flows and associated scour may flank the weirs requiring repair.	$100,000
4. Constructed Step-Pool Sequence (West Bank)	Low – work area is relatively small but will require diversion of stream flows, dwatering, and construction of ramps and pads for equipment access.	Low– would require only limited temporary and permanent channel fill.	Medium – some debris and/or sediment may accumulate in the step-pools. Higher flows and associated scour may flank the weirs requiring repair.	$110,000
5. New Downstream Step-Pool Sequence	Medium – will require diversion of stream flows, dewatering, and construction of ramps and pads for equipment access.	Medium to High – would require substantial amounts of temporary and permanent channel fill.	Medium – some debris and/or sediment may accumulate in the step-pools. Higher flows and associated scour may flank the weirs requiring repair.	$220,000

[1] Order of magnitude construction cost estimates were based on materials and labor costs from similar projects constructed in the San Francisco Bay Area. These costs are for comparison purposes only, and would be refined based on future geotechnical analyses and engineering design.

CONCLUSIONS AND RECOMMENDATIONS

As shown in Table 1 the five measures developed as part of this assessment were evaluated and compared based on: construction feasibility, permitting difficulty, and order of magnitude construction costs. The construction approach for all five measures is similar, requiring the construction of an access ramp and pads. However, modification of the downstream step-pool sequence (Measures 3 and 4) would require less material because of the smaller work area and shallower water depth. Measure 5 would require the placement of substantial amounts of fill material to construct the eleven rock weirs necessary to backwater the eastern bridge opening and facilitate passage through the Project reach. The amount of fill required to construct this measure would increase both construction and permitting difficulty. Implementation of Measures 1 and 2 which involve modification to the degraded concrete bridge apron to improve passage would also provide needed protection to the bridge foundation.

Based on the studies conducted as part of this assessment, the biological requirements of the target fish species, and site-specific constraints, it is recommended that a combination of Measures 1 and 4 be carried forward for additional analysis. This combination of measures would create the conditions necessary to provide upstream passage through the Zinfandel Lane Bridge for adult salmonids during most flow conditions. Modification to the bridge apron may also provide additional protection to the bridge foundation and help focus low flows through the opening rather than under the apron. Additionally, placement of fill material within the existing channel would be relatively minor, making the Project easier to permit. However, geotechnical analysis of the bridge foundation will be required to more fully assess the feasibility of Measure 1 and to further define the engineering requirements and construction costs.

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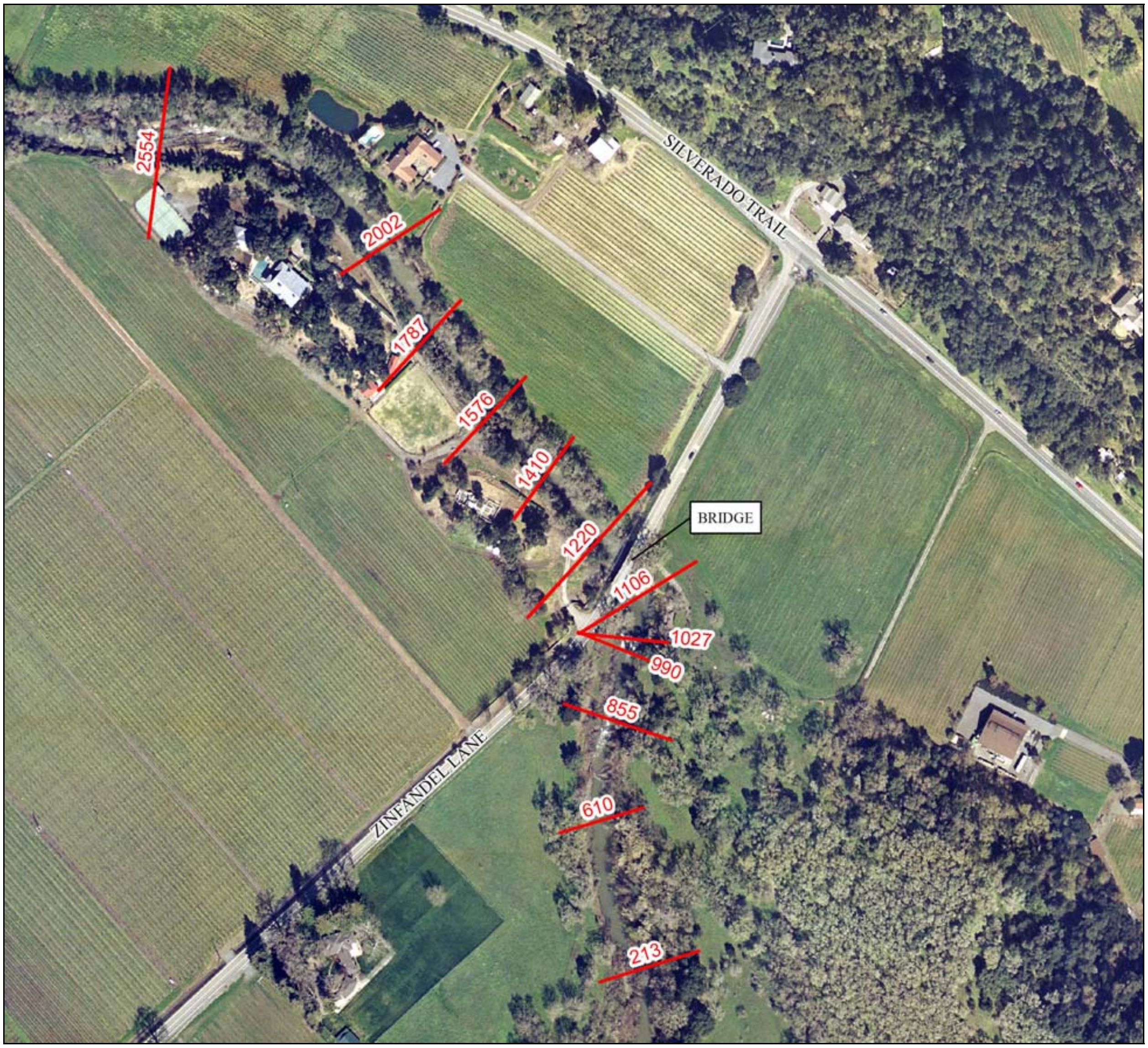
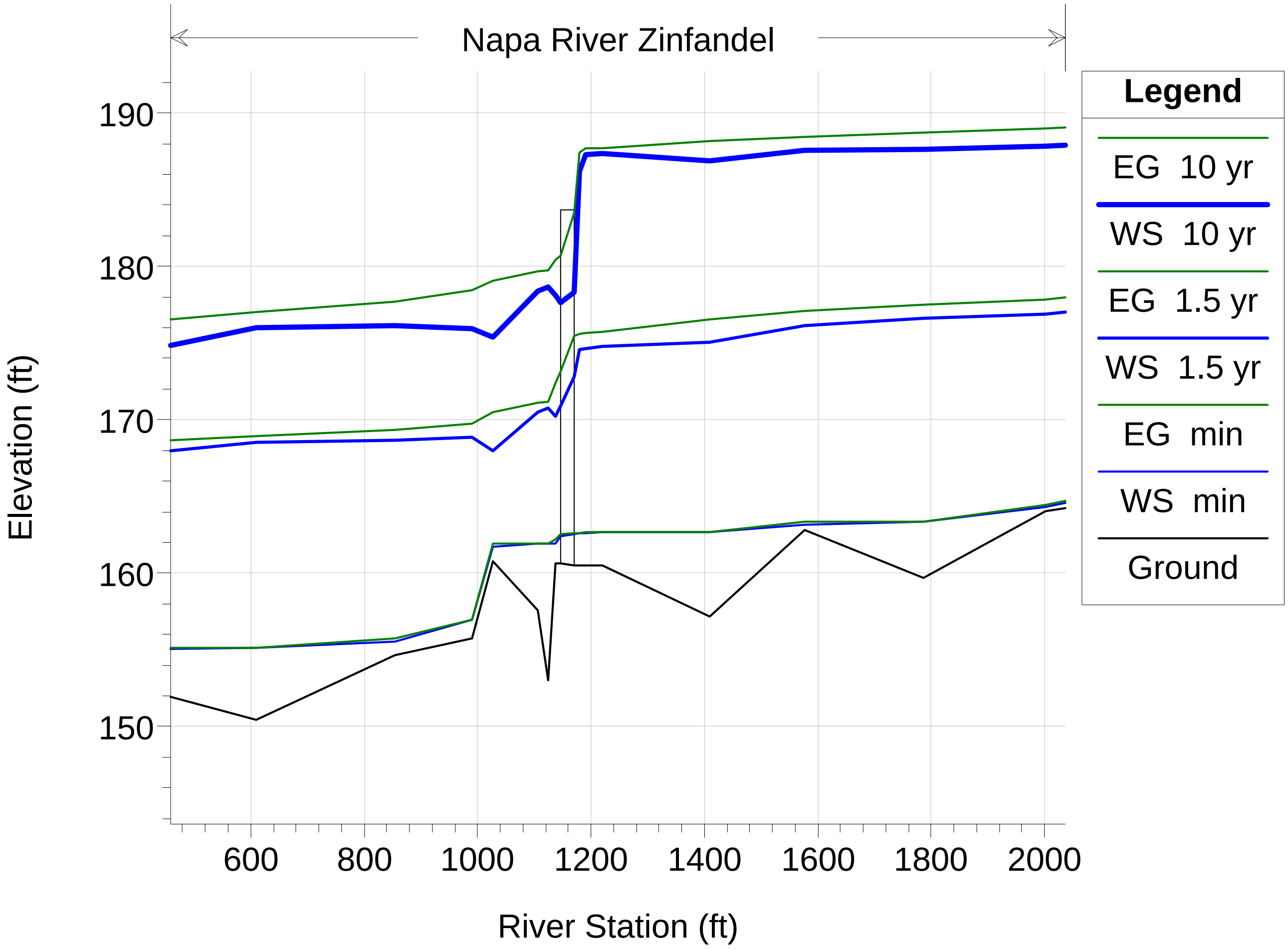
APPENDIX A: HYDRAULIC MODELING AND SURVEY RESULTS

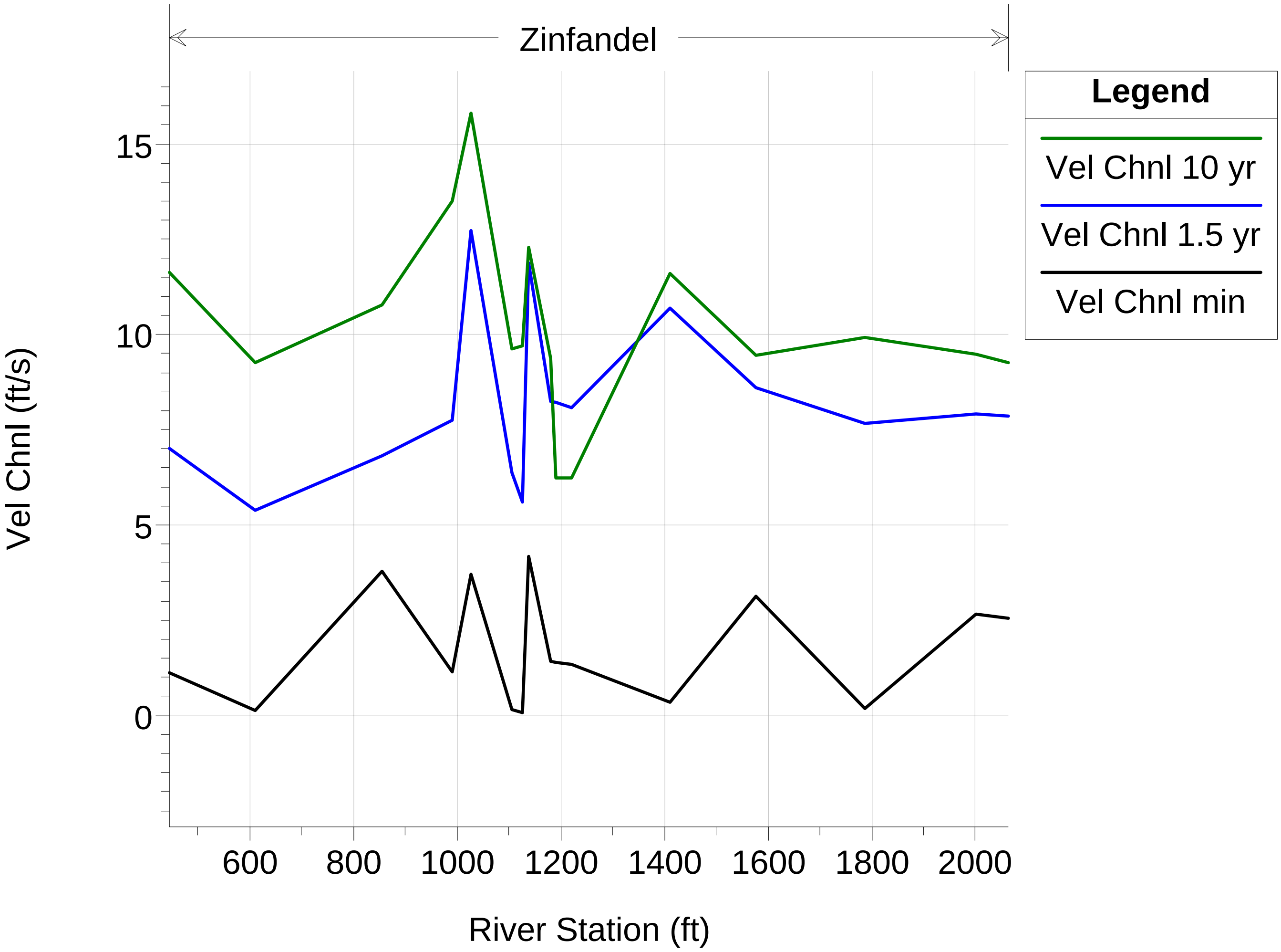


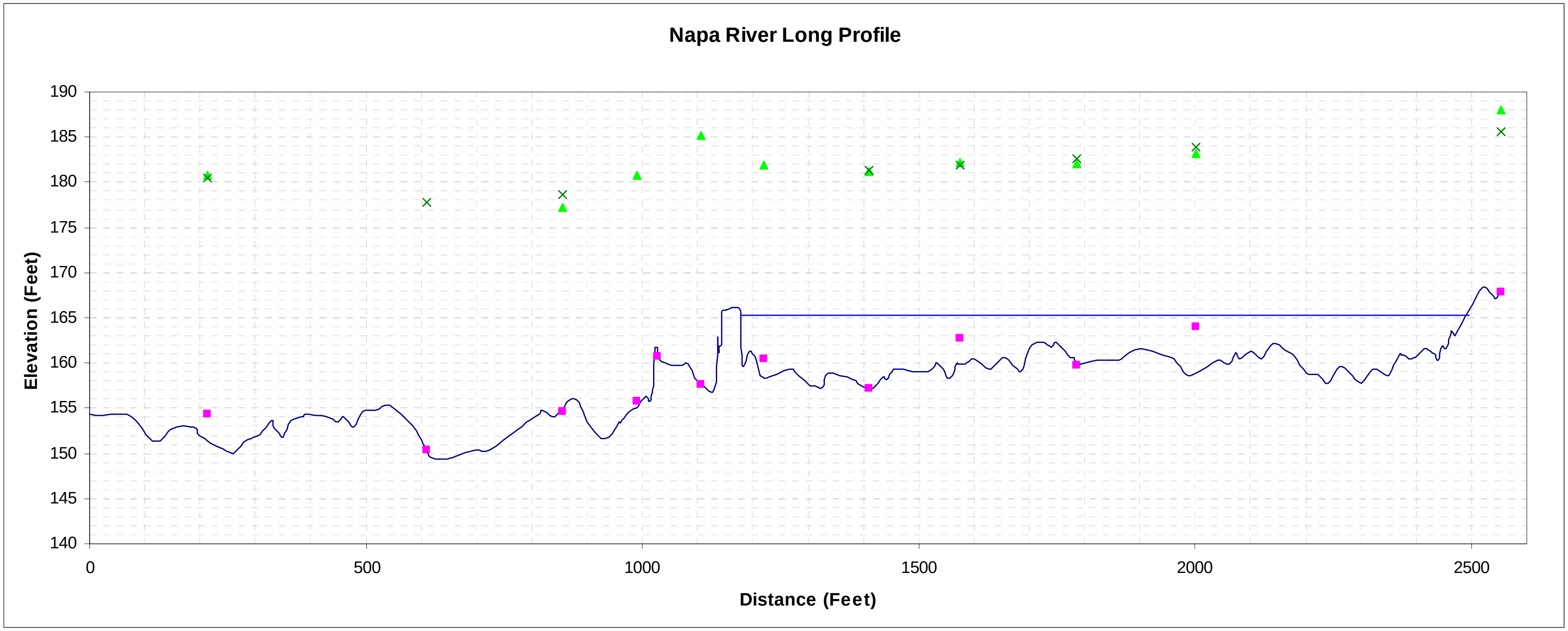
Surveyed cross section locations with approximate river station shown in feet.

Water Surface Elevation Modeling Results



Water Velocity Modeling Results




Napa River Long Profile
190
185
180
175
170
165
160
155
150
145
140
Elevation (Feet)
0
500
1000
1500
2000
2500
Distance (Feet)

APPENDIX B: SITE PHOTOS


Zinfandel Lane Bridge facing east (12-20-05)


West bay facing upstream (11-16-05)

Chinook salmon leaping into existing jump pool “bathtub” (12-5-05)

Stranded Chinook salmon carcasses on Zinfandel Lane bridge apron (11-19-04)