State of California
Natural Resources Agency
California Department of Fish and Wildlife

HYDRAULIC MODEL CALIBRATION REPORT FOR INSTREAM FLOW EVALUATION: JUVENILE STEELHEAD AND COHO SALMON REARING IN REDWOOD CREEK, HUMBOLDT COUNTY

STREAM EVALUATION REPORT 2021-03

April 2021

Cover photo: Redwood Creek, Humboldt County.

California Department of Fish and Wildlife
Stream Evaluation Report 2021-03

Hydraulic Model Calibration Report for Instream Flow Evaluation: Juvenile Steelhead and Coho Salmon Rearing

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California Department of Fish and Wildlife
Water Branch
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Stream Evaluation Report 2021-03

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

1D	one-dimensional modeling
AWS	area-weighted suitability
cfs	cubic feet per second
Department	California Department of Fish and Wildlife
ft	foot (feet)
ft/s	foot (feet) per second
GLD	glide
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HSC	habitat suitability criteria
IFG4	Instream Flow Group Model #4 hydraulic rating utility in SEFA
IFIM	Instream Flow Incremental Methodology
LGR	low gradient riffle
MANSQ	Manning's stage-discharge hydraulic rating utility in SEFA
Q	flow (discharge)
Q_{SF}	survey flow
Q_{SV}	flow calculated by SEFA from the Q_{SF} velocity profile
PHABSIM	Physical Habitat Simulation system
RHABSIM	Riverine Habitat Simulation software
SEFA	System for Environmental Flow Analysis (computer software)
SOP	standard operating procedure
SZF	stage of zero flow
USGS	U. S. Geological Survey
VAF	velocity adjustment factor
VDFs	velocity distribution factors
WSEL	water surface elevation
WSP	water surface profile hydraulic rating utility in SEFA

CONVERSIONS

1 cubic foot per second ≈ 2.83 × 10^{-2} cubic meters per second
1 inch = 2.54 centimeters
1 foot ≈ 0.31 meters
1 mile ≈ 1.61 kilometers

1.0 INTRODUCTION

This report describes the calibration methods and steps employed to develop flow-habitat relationships using one-dimensional (1D) modeling in the Redwood Creek watershed (Figure 1). The completed hydraulic models were later combined with juvenile salmonid habitat suitability criteria (HSC) to estimate habitat availability, expressed as area-weighted habitat suitability (AWS), available to the species and life stages present in the watershed over a range of flows.

In 2016, the California Department of Fish and Wildlife (Department) implemented an instream flow study in mainstem Redwood Creek and five of its major tributaries including Seely, Somerville, Miller, Upper Redwood, and China creeks. Department staff performed 1D modeling following standard procedures developed by the Department, U.S. Geological Survey (USGS), and U.S. Fish and Wildlife Service.

Information typically required to develop flow-habitat relationships using the 1D modeling approach include, but are not limited to:

- Mesohabitat type mapping and inventory;
- Transect selection;
- Transect surveys at three distinct flows on the descending limb of the hydrograph;
- Calibration flow selection;
- Hydraulic model utility selection;
- Hydraulic model calibration by application of performance standards;
- Selection of HSC or development of site-specific HSC;
- Computation of AWS by species and life stage; and
- Habitat time series development to recommend flows by month and water year type.

This report presents the results of the mesohabitat mapping and inventory for Redwood Creek and its tributaries, transect selection, field methods used to collect the data for the hydraulic model, hydraulic model utility selection, and the hydraulic model calibration results. Site-specific HSC were developed for the South Fork Eel River watershed and appear in a companion report, *Habitat Suitability Criteria for Juvenile Salmonids in the South Fork Eel River Watershed, Mendocino and Humboldt Counties* (Gephart et al. 2020). The results of the HSC report and this report will be combined to estimate AWS for the species and life stages present in Redwood Creek, in a third report: *Instream Flow Evaluation: Juvenile Steelhead and Coho Salmon Rearing in Redwood Creek, Humboldt County* (Maher et al. in prep). The scope of this report is limited to presenting the data required to perform the 1D hydraulic modeling and model calibration.

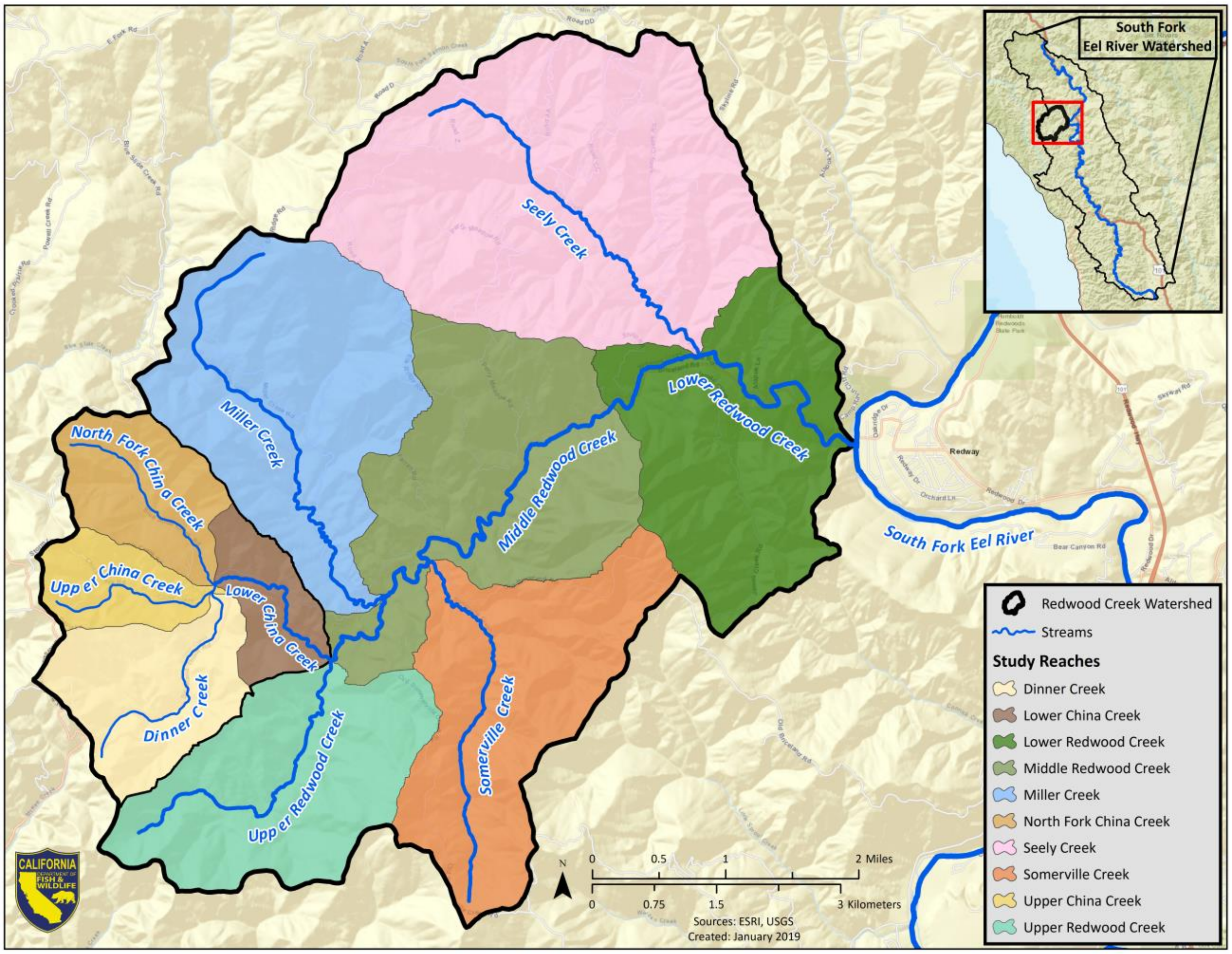

Figure 1. Redwood Creek study reaches within the South Fork Eel River watershed.

2.0 METHODS

The Department uses the Instream Flow Incremental Methodology (IFIM) to conduct aquatic instream flow evaluations in California's streams and rivers (CDFG 2008). IFIM is a comprehensive and incremental framework used to guide instream flow evaluations and associated decision-making processes. The 1D method, developed by the U.S. Fish and Wildlife Service Instream Flow Group (Milhous et al. 1989), is one assessment tool available within the suite of IFIM methodologies. The 1D method can be used to simulate a relationship between streamflow and physical habitat for various life stages of a species of fish. The method includes three major components: river hydraulics, species life stage microhabitat suitability, and physical habitat modeling.

One-dimensional modeling was selected to determine the relationship between streamflow and hydraulic habitat for rearing juvenile salmonids in Redwood Creek. The 1D method is typically performed using a computer software program that integrates the three modeling components (i.e., river hydraulics, species life stage microhabitat suitability, and physical habitat modeling) together. The Department selected the commercially available program System for Environmental Flow Analysis (SEFA; Jowett et al. 2014) to perform 1D modeling in the Redwood Creek watershed. The development and implementation of an instream flow study using 1D modeling contains numerous steps (Figure 2) as were followed in the current study. This report describes steps shown in green ("Hydraulic Data Collection and Modeling"). The other steps are described in the companion report, *Instream Flow Evaluation: Juvenile Steelhead and Coho Salmon Rearing in Redwood Creek, Humboldt County* (Maher et al. in prep).

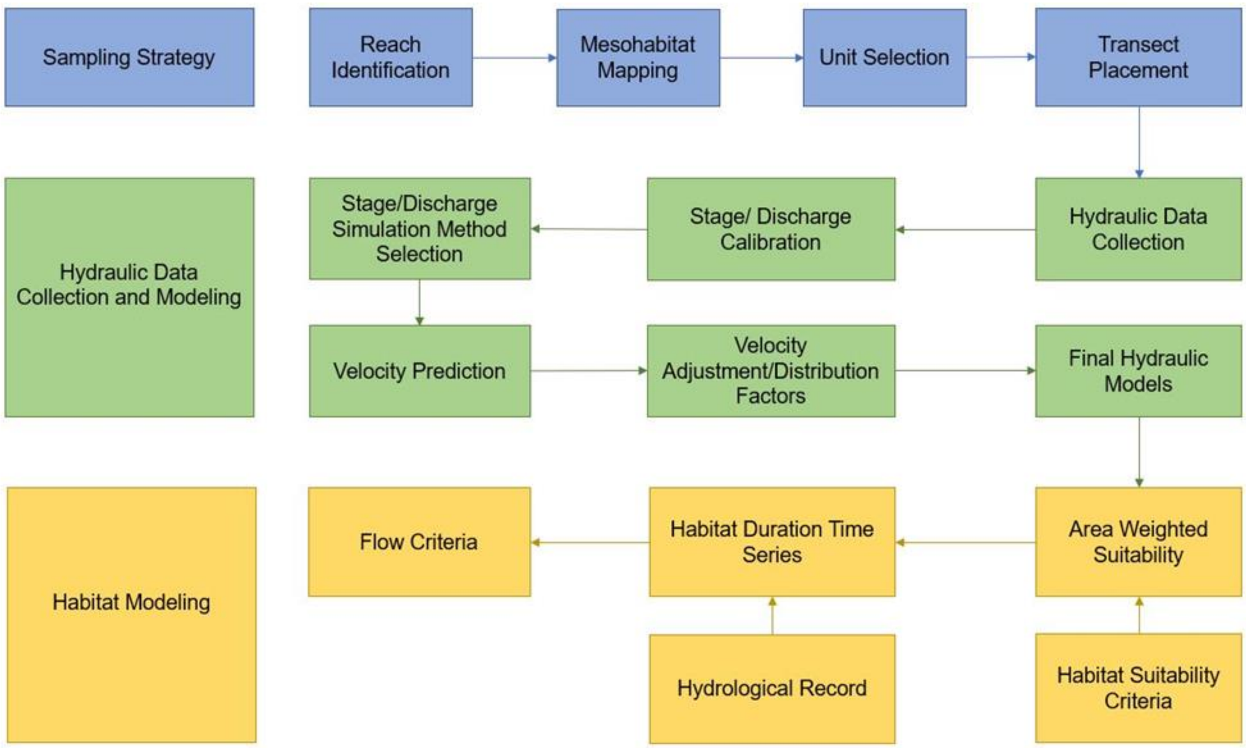

Figure 2. Workflow chart for Redwood Creek instream flow models.

2.1 Mesohabitat Mapping and Transect Selection

The Redwood Creek watershed was divided into 10 reaches representing homogeneous stream segments (see Figure 1 and Maher et al. in prep for more details). A mesohabitat mapping survey was performed throughout each reach. The survey was conducted intermittently between December 2015 and April 2016, dependent on precipitation events and safe wading conditions. Hydraulic model relationships are sensitive to lateral and longitudinal changes in the streambed profile.

Lateral changes affect the relative relationship between water surface elevation (WSEL) measured along a transect line at different points in time. Longitudinal changes affect transects where the slope of the hydraulic gradient is a function of a downstream hydraulic control point, typically pool units. Obtaining the necessary range of water stage/discharge pairs proved challenging in Redwood Creek. Spring storms delayed the start of data collection due to exceedingly high flows and subsequent safety concerns. Once the spring storms had subsided, flows quickly receded due to pressure from competing land uses. To widen the range of flows sampled, staff attempted to obtain late fall stage and discharge measurements once rainfall returned to the watershed and flow volumes increased. The attempt to measure higher water stage and discharge was successful in some of the reaches, but in others, earlier fall storms had altered several previously sampled streambed profiles. In these circumstances, the late fall data could not be used as they did not compare with the previously surveyed streambed profile. Some transects were omitted due to lack of high flow measurements.

Initially, 105 randomly located transects were selected for 1D hydraulic model simulation (Table 1 to Table 10). However, a total of 30 transects were eventually omitted from use in their respective reaches because the hydraulic model outputs did not meet existing performance standards provided in the literature (Milhous et al. 1989; Thomas R. Payne and Associates 1998; USFWS 1994; USFWS 2011; USGS 2001). The final number of transects considered for the hydraulic model portion of the study was 75. Three transects were selected per mesohabitat type. Transects rejected through calibration are indicated by strikethrough and asterisks (*) in Table 1 through Table 10. A map of each reach is provided in Appendix A. The approximate location of each transect is shown in each reach map.

Table 1. Lower Redwood Creek transects.

Transect	Mesohabitat Type
LRT16	LGR
LTR26	POOL
LRT31	RUN
LRT62	GLD
LRT64	GLD
LRT65	RUN
LRT76	POOL
LRT77	LGR
LRT78	POOL
LRT81	GLD
LRT88	LGR
LRT91	RUN

Table 2. Middle Redwood Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
MRT129	LGR
MRT134	POOL
MRT140	RUN
MRT144	RUN
MRT149	POOL
MRT178	LGR
MRT179	GLD
MRT275	RUN
MRT286	LGR
~~MRT290~~*	~~GLD~~*
~~MRT306~~*	~~POOL~~*
MRT342	GLD

Table 3. Upper Redwood Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
~~URT12~~*	~~LGR~~*
~~URT14~~*	~~POOL~~*
URT25	RUN
URT43	LGR
URT46	POOL
URT53	RUN
URT92	LGR
URT108	RUN
URT109	POOL

Table 4. Seely Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
~~ST6~~*	~~GLD~~*
ST8	RUN
ST16	LGR
ST19	POOL
ST23	GLD
ST27	POOL
ST29	LGR
~~ST31~~*	~~GLD~~*
ST33	LGR
ST46	RUN
ST49	POOL
~~ST61~~*	~~RUN~~*

Table 5. Somerville Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
SCT10	RUN
SCT12	POOL
~~SCT49~~*	~~LGR~~*
SCT52	POOL
~~SCT59~~*	~~LGR~~*
SCT84	RUN
~~SCT85~~*	~~POOL~~*
SCT88	LGR
SCT95	RUN

Table 6. Miller Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
MCT17	LGR
MCT21	RUN
~~MCT27~~*	~~POOL~~*
MCT59	POOL
~~MCT60~~*	~~RUN~~*
MCT92	POOL
~~MCT112~~*	~~LGR~~*
MCT133	RUN
MCT137	LGR

Table 7. Lower China Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
LCT2	LGR
LCT22	POOL
LCT32	LGR
~~LCT38~~*	~~POOL~~*
LCT52	RUN
~~LCT69~~*	~~RUN~~*
~~LCT138~~*	~~RUN~~*
LCT140	LGR
LCT150	POOL

Table 8. Upper China Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
~~UCT6~~*	~~LGR~~*
UCT13	POOL
~~UCT15~~*	~~GLD~~*
~~UCT16~~*	~~RUN~~*
UCT35	RUN
UCT40	GLD
UCT43	RUN
UCT52	LGR
~~UCT57~~*	~~POOL~~*
~~UCT63~~*	~~POOL~~*
~~UCT64~~*	~~LGR~~*
UCT72	GLD

Table 9. North Fork China Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
NFCT7	RUN
NFCT8	POOL
NFCT16	LGR
NFCT25	LGR
~~NFCT27~~*	~~RUN~~*
~~NFCT40~~*	~~RUN~~*
~~NFCT56~~*	~~POOL~~*
~~NFCT57~~*	~~POOL~~*
NFCT58	LGR

Table 10. Dinner Creek transects. Transects rejected through calibration are indicated by strikethrough and asterisks (*).

Transect	Mesohabitat Type
DT7	LGR
~~DT13~~*	~~LGR~~*
DT14	POOL
DT15	RUN
DT17	GLD
~~DT20~~*	~~POOL~~*
DT21	GLD
DT28	POOL
DT37	RUN
DT45	RUN
~~DT46~~*	~~LGR~~*
~~DT48~~*	~~GLD~~*

2.2 Hydraulic Model Data Collection

Hydraulic data collection procedures were consistent with pre-established standards and protocols intended to characterize the hydraulic habitat potential in each representative mesohabitat unit type (Bovee 1997; CDFW 2013b). The data required for use in 1D modeling were collected at three distinct flow regimes referred to here as the Low, Mid, and High Flows. Sample flows were targeted using the 80, 50, and 20 percent exceedance flows for mainstem Redwood Creek. A long-term hydrologic record does not exist for Redwood Creek. A relatively unimpaired, long term stream gage record was available from Bull Creek, a nearby watershed with comparable hydrologic properties (Cowan 2018). The Bull Creek stream gage record was scaled to estimate Low, Mid, and High Flow regime exceedance flows of 3, 19, and 126 cubic feet per second (cfs), respectively, for mainstem Redwood Creek.

Data collection was scheduled to coincide as near as possible to predetermined target flows intended to capture the range of flows frequently experienced within the Redwood Creek watershed. Hydraulic data were collected along the descending limb of the hydrograph from March through June of 2016. Staff returned to some sites in November and December of 2016 to capture an adequate range of flows.

The streambed profile, substrate, and cover coding for each transect were surveyed during the first data collection event, typically the High Flow survey. WSEL was recorded and discharge was measured at each survey event. The velocity profile was generally recorded during the Mid Flow survey, but seasonal fluctuations in flow led to the occasional velocity profile collection at the High Flow survey. Stage of zero flow (SZF) measurements were collected at Low Flow (Table 11).

Table 11. Data collected for target flow regimes used in 1D modeling.

Flow Regime	Streambed Profile, Substrate, & Cover	WSEL/ Discharge	Velocity Profile	SZF
High	Collected	Collected	Collected	-
Mid	-	Collected	Collected	-
Low	-	Collected	-	Collected

2.2.1 Streambed Profile Surveys, WSEL, and Vertical Controls

To provide a complete elevational bed profile, steel rebar were set at the ends of each transect, establishing a head pin and tail pin. An upstream facing convention was used to establish the position of the head pin on the left bank and the tail pin on the right bank. Fiberglass measuring tapes were hooked to the head pins and wrapped around the tail pins during each survey to demarcate transect stations for velocity profiles and elevation surveys (Bovee 1997). Surveys were performed using standard differential survey methods consistent with the Department's *Standard Operating Procedure for Streambed and Water Surface Elevation Data Collection in California* (CDFW 2013b). Streambed elevation measurements and were collected at one-foot intervals along the transect using a stadia rod and an auto level fixed to a tripod. Vertical control was maintained at each unit by a vertical benchmark, consisting of lag bolts typically pounded into mature tree roots or trunks (Figure 3). All streambed elevations and WSELs were measured using a Nikon AE-7 automatic level and stadia rod (Figure 4). WSELs were measured at a minimum of three significantly different stream discharges to the nearest 0.01 feet (ft). Staff gages were installed at each unit to monitor change in stage during the course of WSEL, velocity, and discharge data collection. Staff gages were graduated and read to the nearest 0.01 ft.

One-dimensional modeling assumes the WSEL at each transect is of constant elevation. One representative WSEL must be chosen from the measurements recorded during each WSEL transect survey. The user's manual for 1D modeling (USGS 2001) provides the following guidance to select a representative WSEL based on levels of variance in the measurements as follows:

> *The difference between the measured right and left bank water surface elevations can vary considerably with differences of 0.1 to 0.5 ft occurring in highly turbulent conditions. The analyst should select the average of the left bank and the right bank, only left or only right bank, or other water surface elevation at each cross section in the regression equations based on the conditions reported in the field notes.*

A minimum of three WSELs were recorded along each transect. One measurement was taken near each bank and another near the middle of the channel. Typically, the water surface was flat and WSELs did not vary by more than 0.05 ft. The mean was taken for WSELs within this range generating a single representative WSEL. In some instances where the water surface was varied, more measurements were recorded to accurately depict changes in water surface height. Where WSELs ranged between 0.05 and 0.1 ft, each transect was evaluated to determine if any of the WSEL measurements recorded were not representative of the water surface surveyed because of turbulent surface conditions or physical obstructions like large substrates at isolated areas along the transect line. Where the range in WSEL exceeded 0.1 ft, transects were evaluated in detail by reviewing field notes, schematic diagrams, and digital images to understand potential causes of variance. Specific WSEL measurements that appeared to be impacted by the conditions described above were excluded from computation of the mean WSEL.

In mesohabitat units with a downstream control point, typically pool units, the elevation of that control point represents the SZF (Figure 5). At that flow stage, all surface flow will be blocked by the control point. Locating the SZF can be difficult and is best found at the lowest flow surveyed (USGS 2001). As a result, the SZF for each pool unit was surveyed during the Low Flow event. The recorded SZF was later entered into SEFA for WSEL and discharge calibration.

Figure 3. Vertical benchmark driven into the base of tree trunk marked with flagging tape in foreground, and auto level in background.

Figure 4. Measuring WSEL and velocity along transect LRT62 in Lower Redwood Creek reach.

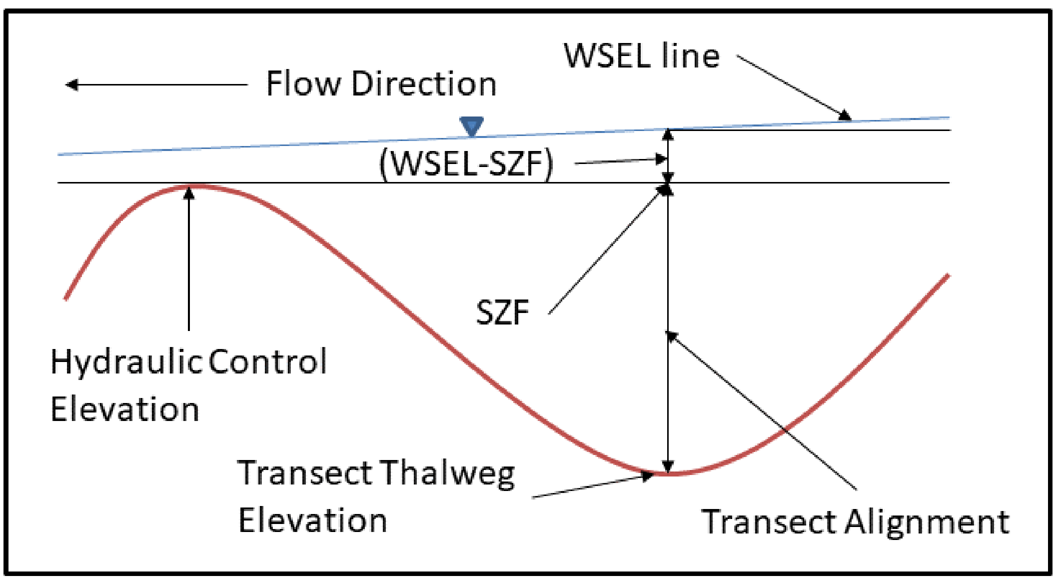

Figure 5. Stage of zero flow diagram.

2.2.2 Discharge

Discharge measurements were collected for each WSEL survey event at each distinct flow (either Low, Mid, or High) near the corresponding transect being surveyed. Discharge surveys were consistent with the Department's *Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California* (Discharge

SOP; CDFW 2013a). A single discharge measurement could be used to represent the flow for multiple transects when transects were in close proximity to one another and where there were no flow inputs or diversions between transects. If necessary, multiple discharge measurements were taken within a given reach to account for additional flow inputs or diversions.

Discharge sites were selected where the best hydraulic characteristics could be found in the stream reach near the transect(s). Ideal discharge transects are relatively wide, uniform, and shallow (Bovee 1997; Figure 6). In all transects surveyed for discharge, a minimum of 20 cells were sampled. In areas of greater depth, cells were sampled to maintain the percent of any one cell less than 5% of the volume of flow. A temporary staff gage was installed during each discharge measurement (CDFW 2013a). The depth of the staff gage was read before and after each discharge to ensure the stream stage remained constant during the measurement.

Figure 6. Discharge measurement in the Lower Redwood Creek reach.

2.2.3 Water Depth and Velocity

Bed elevations and velocity measurements were collected along each transect at one-foot increments across each transect at either the High or the Mid Flow event. Water depth was later calculated in SEFA by subtracting the surveyed bed profile elevations from the representative WSEL. The resulting velocity profile was used to simulate depth and velocity in SEFA. In SEFA, the transect survey when the velocity profile is measured is defined as the Survey Flow.

Velocities were measured using a Marsh-McBirney Flowmate Model 2000 or Hach FH950 velocity meter. Velocity meters were calibrated and used in accordance with the Discharge SOP (CDFW 2013a). The meters measured velocity in the water column to the nearest 0.01 feet per second (ft/s). For depths less than 2.5 ft, one velocity measurement was made at 0.6 of the total depth as measured down from the water's surface. Where the water depth was equal to or exceeded 2.5 ft, two velocity measures were collected and the mean of these two velocities was calculated; one at 0.2 and another at 0.8 of the total depth measured down from the water surface.

2.2.4 Substrate and Cover Classifications

Substrate and cover are additional attributes that can be used to estimate AWS, depending upon life stage. Substrate and cover data were collected concurrently at points selected for bed elevation measurements. All substrate data collected on the transects were assessed by one observer based on the visually estimated average of multiple particle sizes. Cover data were collected by visual observation of the presence and type of cover and proximity to the survey point. The codes used to classify substrate and cover are provided in Table 12 and Table 13, respectively.

Table 12. Substrate codes, descriptors, and particle sizes (USFWS 2011).

Code	Type	Particle Size (inches)
0.1	Sand/Silt	<0.1
1	Small gravel	0.1 – 1
1.2	Medium gravel	1 – 2
1.3	Medium/Large gravel	1 – 3
2.3	Large gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small cobble	3 – 4
3.5	Small cobble	3 – 5
4.6	Medium cobble	4 – 6
6.8	Large cobble	6 – 8
8	Large cobble	8 – 10
9	Boulder/Bedrock	>12
10	Large cobble	10 – 12

Table 13. Cover categories and codes (USFWS 2011).

Cover Category	Cover Code
No cover	0
Cobble	1
Boulder	2
Fine woody vegetation (<1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (>1' diameter)	5
Log + overhead	5.7
Overhead cover (>2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

2.2.5 Data Quality Control

To ensure accuracy during data collection, equipment was calibrated according to the manufacturer's instructions. Details about field equipment calibration can be found in the Discharge SOP (CDFW 2013a).

Data including but not limited to flow velocity, water depths, substrate, cover, WSELs, and bed elevations were documented in the field on Rite in the Rain paper. Field data were checked for accuracy and completeness by the field crew leader at the end of each field day. Any incomplete data were corrected in the field on the data sheets. Photographs of each transect were taken during each survey to document site conditions. Schematic drawings were prepared of each transect on the WSEL data sheet, indicating the location of obstacles such as downed trees, cobble bars, and boulders that may have affected WSELs and/or flow velocities.

Department scientific staff transcribed numerical data into Excel workbooks upon return to the office. If any errors in the physical data sheets were identified during the transcription process, the error on the physical data sheet was marked by strikethrough, correction added, and each correction was initialed and dated by staff. After the data were entered electronically, a different Department scientific staff member reviewed the electronic data against the paper field data sheets to confirm the accuracy of the transcription. Any errors found by this second reviewer were corrected using the original datasheets. Staff logged data entry date, quality control check completion date, and any data omissions or corrections in a spreadsheet to ensure that all field data forms were electronically entered and checked. Once the electronic data were verified and paper field forms were filed, the electronic forms were used in future analysis. All data generated by this project will be maintained in scanned field logbooks and/or data sheets, and electronic spreadsheet format. The Department will store all electronic data (including photographs, scanned datasheets, Excel workbooks, study plans, and report documents) on Department-maintained servers that are regularly backed up.

Some data were discarded after returning to the office due to data quality issues, such as discharge measurements that did not comply with standards outlined in the SOP (CDFW 2013a), WSEL measurements that exceeded the margin of error, and changes in the bed profile due to substrate movement. These issues were noted in a data collection data quality log and the data were excluded from future analysis. When necessary, staff returned to the field site to re-take the field measurements.

During data analysis, data copied from one spreadsheet to another or from a spreadsheet to the report were quality checked by the Department's scientific staff using the same method described above. When data were imported into SEFA, HydroCalc, and Excel for analysis, the staff member verified that correct and complete data had been used and that the proper output data were incorporated in the reports. To verify the habitat duration time series analysis, a second staff member re-created the entire analysis and results.

2.2.6 Model Limitations

The two limitations of Physical Habitat Simulation system (PHABSIM) are transect location and the range of flows that can be simulated. The hydraulic models in PHABSIM assume the water surface is level across each transect (USGS 2001); therefore, randomly selected transects located where the WSEL varies by more than 0.1 ft are assumed to not be acceptable for hydraulic modeling in PHABSIM (see Section 2.2.1). The WSEL-discharge rating relationship of transects located where the WSEL varies beyond 0.1 ft are more likely to fail to meet standards for mean error, measured versus predicted WSEL, and/or velocity adjustment factor (VAF). Randomly selected transects where the WSEL varied beyond 0.1 ft were resampled. Simulation flow range is described in detail in Section 2.3.5.

2.3 SEFA

The 1D method simulates the relationship between streamflow and physical habitat for fish by combining the results of hydraulic models with HSC to estimate AWS. The SEFA software program (Jowett et al. 2014) contains the suite of computer models developed by USGS (Milhous et al. 1989). The SEFA program was used to perform the 1D method computations for each study reach in Redwood Creek. Hydraulic model preparation, calibration, and simulation in SEFA followed the standard procedures and guidance given in the PHABSIM user's manual (USGS 2001).

Hydraulic modeling in the 1D method generally consists of the following procedures:

- Rating curve development and calibration using stage-discharge pairs measured in the field;
- Predictive hydraulic model utility selection;
- Water surface elevation simulation;
- Velocity simulation; and
- Results validation using standard guidance criteria.

2.3.1 Hydraulic Data Preparation and SEFA Input

The verified electronic data were organized by reach and imported into SEFA directly from Excel. Before transect data was entered into SEFA, senior engineering staff review the input files prepared by staff. The data entered into SEFA for each transect included the streambed profile, paired WSEL and discharge data, SZF (if applicable), the velocity profile, and substrate and cover codes. The mesohabitat type was entered manually into SEFA for each transect and reach.

2.3.2 Calculation Preferences

The calculation options in SEFA are set in one main menu, Hydraulic Habitat Options. The traditional default 1D options were used unless the SEFA support information indicated user inputs should be processed using another available option. The only non-default option selected was to use Instream Flow Group Model #4 (IFG4) emulation for the rating curve development and velocity prediction. IFG4 emulation is the recommended method when the bed profile elevations are derived from differential level measurements as opposed to water depth measurements (Jowett et al. 2014). The options selected in the Hydraulic Habitat Options menu are summarized in Table 14.

Table 14. Summary of SEFA user settings selected.

Menu Item	Menu Sub-Item	Selected Setting
Cross section extrapolation	Vertical bank created if slope at section start or end is less than	0.05
Velocity distribution calculation method	N/A	Conveyance (traditional method)
Conveyance for WSP	N/A	Harmonic and/or arithmetic mean
Hydraulic rating roughness	N/A	Flow
Rating curve method	N/A	IFG4 emulation
Velocity prediction method	N/A	IFG4 emulation
Habitat calculations	Method of calculating combined suitability index	Multiplication of individual suitabilities

2.3.3 WSEL and Discharge Calibration

The program SEFA was used to develop rating curves from the paired WSEL and discharge measurements. Stage-discharge relationships are derived from rating curves developed for each transect (Figure 7). SEFA contains the three utilities for developing stage-discharge relationships: IFG4 referred herein as log-log regression; Manning's stage-discharge using Manning's n (MANSQ), and Water Surface Profile Model via step-back computation (WSP; Jowett et al. 2014).

Log-log regression uses three or more measured stage and discharge pairs, along with the SZF elevation, to develop a relationship between stage and discharge based on the following equation:

$$Q = A \times (WSEL - SZF)^{exp}$$

Where:

Q = flow (cfs)
A = regression coefficient
WSEL = water surface elevation (ft)
SZF = stage of zero flow (ft)
exp = exponential regression coefficient

The above equation is converted to log-log format and a log-log linear relationship is fit to the data. In a habitat unit where the slope of the longitudinal water surface is determined by a downstream hydraulic control point, like a pool or deep run, the elevation of that downstream control point is the SZF. In SEFA, a SZF optimization utility called *Best SZF* solves for the best fit to the log-log linear relationship by varying the SZF. In SEFA, the *Best SZF* rating is automatically provided in the displayed ratings field (Figure 7) with MANSQ and log-log regression ratings.

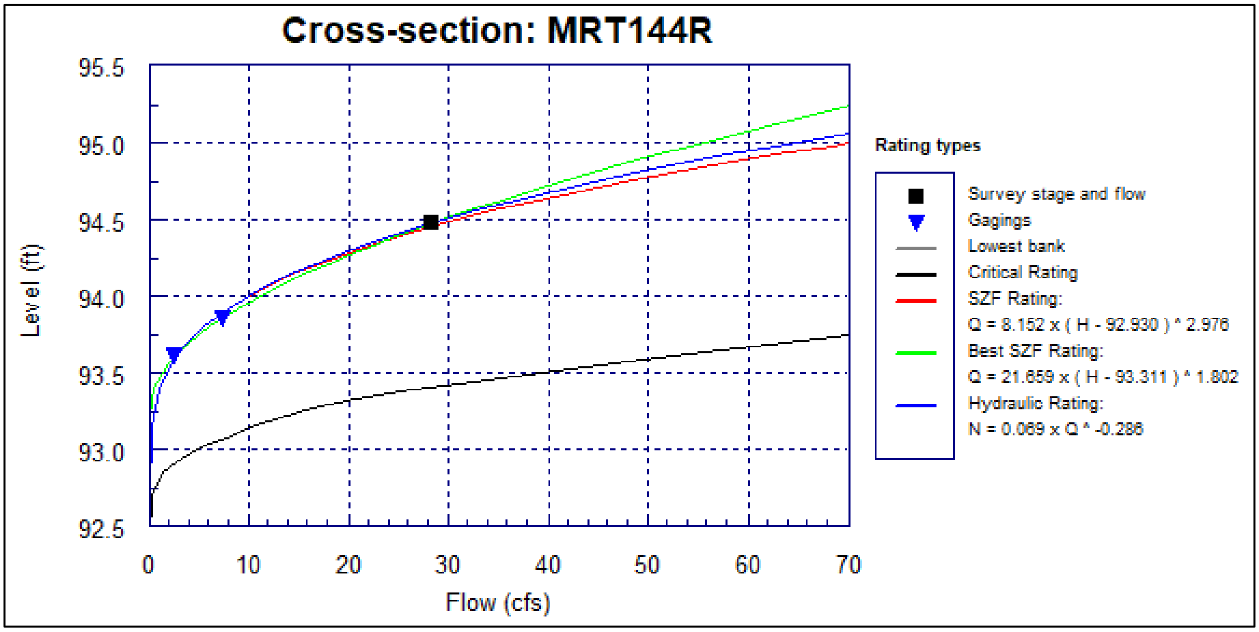

Figure 7. Example SEFA rating curve output.

In Figure 7, the red line is the SZF rating or log-log regression rating, the green line is the *Best SZF* Rating or log-log regression with a synthetic SZF that optimizes the log-log regression rating, the blue line is the Hydraulic Rating (MANSQ), the red line is the SZF Rating or log-log regression rating, the black line is the critical flow rating, the black square is the Survey stage used for velocity calibration, and the blue chevrons are the other stage-discharge pairs used to develop the ratings.

The critical flow rating refers to the rating curve derived so that the flow in the cross section is critical. SEFA uses Manning's equation to solve for open channel flow, where the depth is assumed to be above the critical depth (Gupta 1995). The hydraulic utility MANSQ uses transect survey data and three or more measured stage and discharge pairs to develop a relationship between stage and discharge based on Manning's equation as follows:

$$Q = 1/N \times Area \times (R - R_{SZF})^{2/3} \times S^{1/2}$$

Where:

Q = flow (cfs)

N = A x Q^{beta}

A = regression coefficient

beta = MANSQ exponential regression coefficient

Area = cross sectional area of the transect (ft)

R = hydraulic radius

R_{SZF} = hydraulic radius at the SZF

S = slope of the water surface

The water surface profile model, WSP, calculates the energy loss between transects to determine WSELs. The use of WSP requires data from the transect of interest and one downstream transect, at least three stages at both transects, and the three corresponding flows to perform a step backwater calculation (similar to HEC-RAS) to develop the stage-discharge relationship. The data collection required to perform WSP was beyond the scope of this study and the method was not used.

Log-log regression and MANSQ were run on each transect, with MANSQ set as the default modeling method for transects where there was no clear downstream hydraulic control point. Log-log regression was used as the default modeling method for pool transects and for transects that did not calibrate well using MANSQ. The optimized *Best SZF* rating was used when field-based estimates of SZF were obscured from measurement by large boulders or wood substrates (see Section 4.0 *Discussion* for specific examples).

The default hydraulic utility MANSQ was selected to predict stage-discharge at all the transects except those with downstream hydraulic control points. MANSQ is based on the Manning's equation to solve for WSEL, whereas log-log is an empirical data regression. Log-log regression was used as the default modeling method for pool transects and for transects where the MANSQ mean error was 10% or greater. The optimized *Best SZF* rating was used when field-based estimates of SZF were obscured from measurement by large boulders or wood substrates.

Multiple references related to the use of 1D were consulted when developing a rationale for evaluating the calibration results of the stage-discharge rating utilities. These references included: *User's Guide to the Physical Habitat Simulation System (PHABSIM)* (Milhous et al. 1981); *Using the computer based physical habitat simulation system* (USFWS 1994); *PHABSIM for Windows: User's Manual and Exercises* (USGS 2001); and *User's Manual RHABSIM 3.0 Riverine Habitat Simulation Software for DOS and Windows* (Thomas R. Payne and Associates 1998).

The guidelines presented below were used when selecting the stage/discharge method for each transect.

- The mean error of predicted versus measured discharge does not exceed 10%;
- The maximum variance of any one predicted discharge compared to a measured discharge does not exceed 25%; and
- The difference between measured and predicted WSELs does not exceed 0.1 ft at a given calibration flow.

In addition, for MANSQ models, transects with beta values outside the range of 0 to 0.4 were evaluated further. For log-log regression models, the beta value must be within the range of 2.0 to 4.5. Preferred ranges of MANSQ beta vary amongst practitioners of instream flow studies. For example, the RHABSIM user's manual suggests 0 to 0.4 (Thomas R. Payne and Associates 1998) while the PHABSIM manual recommends 0 to 0.6 (USGS 2001).

Where MANSQ beta values exceeded 0.4, the senior engineering staff reviewed unit data to confirm stage/discharge results were not affected by errors in data collection or method application. Where predicted results for all the methods did not accurately predict measured values, staff reviewed field notes and digital images to understand potential causes for variance in predictive values versus field measurements.

Variance in discharge was assessed by reporting the VAF for each Survey Flow discharge. If the field velocities equal the simulated velocities at the Survey Flow, the VAF has an ideal value of 1.0. Based on recommended USFWS (1994) guidelines, a range of 0.75 to 1.25 was used to evaluate Survey Flow discharge VAFs.

2.3.4 Velocity Adjustment Factor Discharge Calibration

The survey flow (Q_{SF}) is the field discharge measurement associated with the selected velocity profile used to simulate velocities in SEFA. The VAF is the ratio between the survey flow and the discharge calculated in SEFA using the surveyed velocity profile.

$$VAF = Q_{SF}/Q_{SV}$$

For each transect, each velocity from the selected velocity profile is multiplied by the VAF such that $Q_{SV} = Q_{SF}$. A VAF can be used as one indicator of how well the transect velocity profile relates to the survey flow. The range of VAF factors used to calibrate flows for each transect should be 0.75 to 1.25 (Milhous et al. 1989). Transects with VAFs outside of the recommended range are omitted from further analysis.

2.3.5 Discharge Simulation Range

Extrapolation beyond the highest measured flow is often necessary to evaluate the possible range of flows needed by a species for activities such as spawning or upstream passage. The range of discharge that can be simulated in 1D for a site while maintaining meaningful results is dependent on the characteristics of the transect including substrate size, hydraulic radius, bank geometry, and the presence of floodplains. Generally, to ensure extrapolated flows maintain their integrity, PHABSIM manuals have reported that 0.4 to 2.5 is an acceptable simulation range (USGS 2001), but more accurately, simulation range is limited by channel configuration, model performance, and data availability (USGS 2001).

2.3.6 Water Velocity Prediction

Velocities are simulated by multiplying the velocity profile collected during the survey flow by a range of VAF values. For velocity simulation, the recommended range of VAF factors should be 0.1 to 5.0 (TRPA 1998). SEFA computes velocity distribution factors (VDFs) from the velocity profile measured in the field at each transect (Jowett et al. 2014). A VDF is the ratio of the field measured velocities to the velocities calculated by SEFA using the transect VAF described above in the *Velocity Adjustment Factor Discharge Calibration* section. A VDF is used to modify the magnitude of individual transect cell velocities to improve the shape of the velocity profile simulation. The VDFs are automatically modulated by the SEFA program to improve the VAF. Note that SEFA refers to VDFs and Manning N values interchangeably.

Modifications to VDFs can be useful when small negative velocities caused by eddies occur along the transect near the stream margin. Eddies are typically caused by vegetation or large obstacles upstream of a transect (Figure 8). In SEFA, simulation velocity profiles are generated by multiplying the Survey Flow velocities by the VAF. A byproduct of this method is that the magnitude of small negative velocities become increasingly negative with higher simulated flows (Figure 9).

As the mid-column velocity depth rises with increased flow volume, the effect of bank vegetation and obstacles naturally dissipates or remains the same depending upon the severity of the vegetation or size of the upstream obstacle. In Figure 9, the small left side margin velocity increases in negative magnitude to over -2 ft/s at the high simulation flow. Adjustments were made to VDFs if the negative magnitude of a simulated cell velocity exceeded -1 ft/s or where the shape of the simulated velocity profile was not consistent with the surveyed velocity profile.

Modifications to VDFs are also useful when the shape of the simulated velocity profile contradicts the shape of the velocity profile measured in the field. For example, in Figure 10 the shape of the field velocity profile near stations 35 and 36 is inconsistent with the shape of the simulated velocity profile. The SEFA Software Manual (Jowett et al. 2014) recommends reviewing the field notes and reducing VDFs accordingly to improve the shape of the velocity profile.

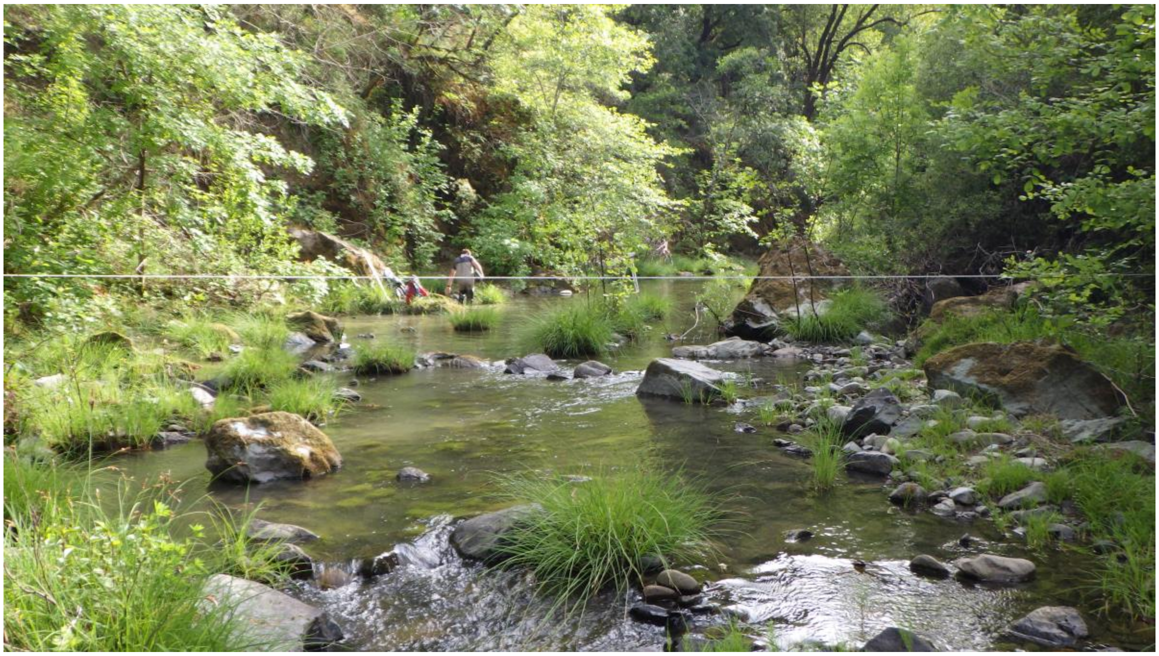

Figure 8. Example of vegetation and obstacles near the stream margins causing velocity eddies. Lower Redwood Creek reach transect.

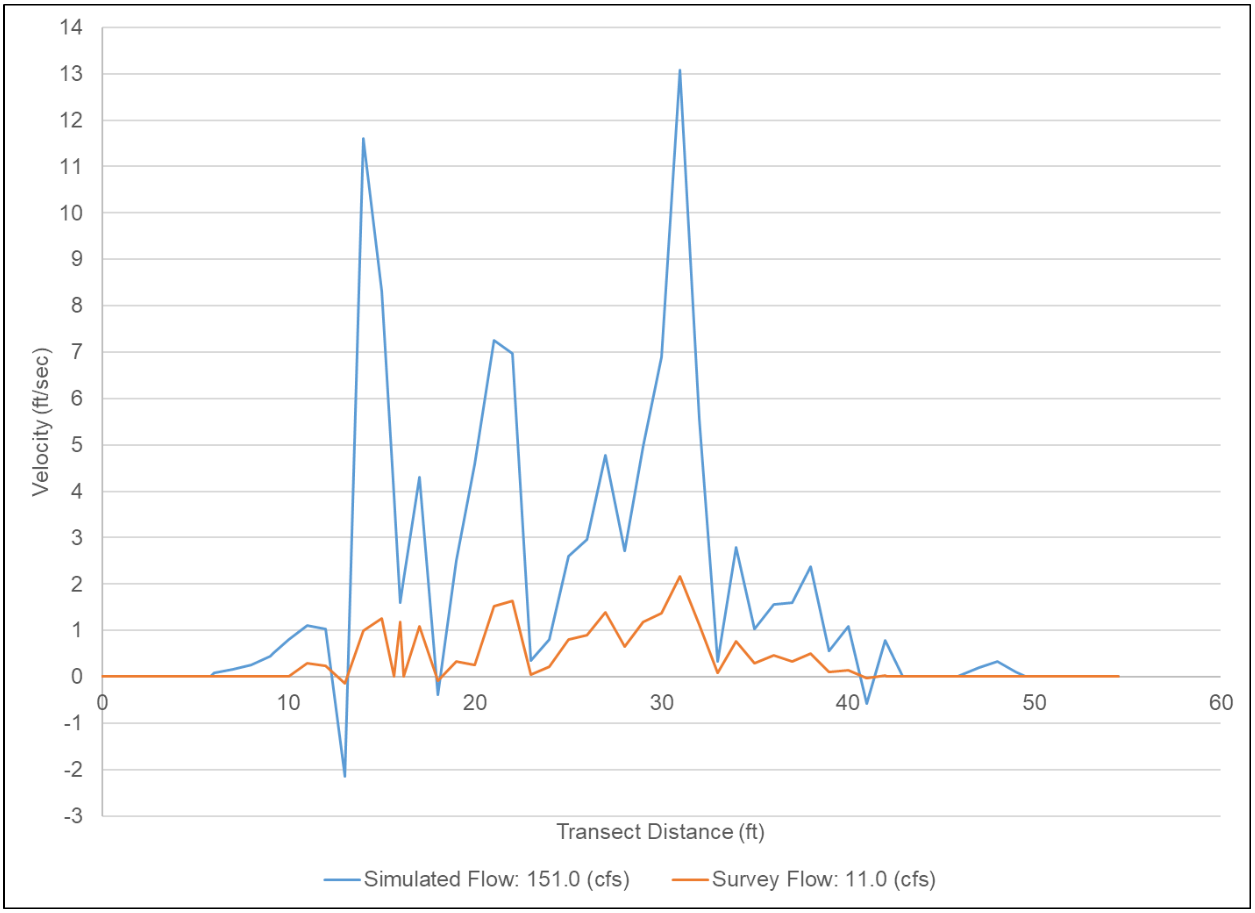

Figure 9. Example simulation of small negative velocities in SEFA. Velocities increase in negative magnitude at higher simulated flow levels.

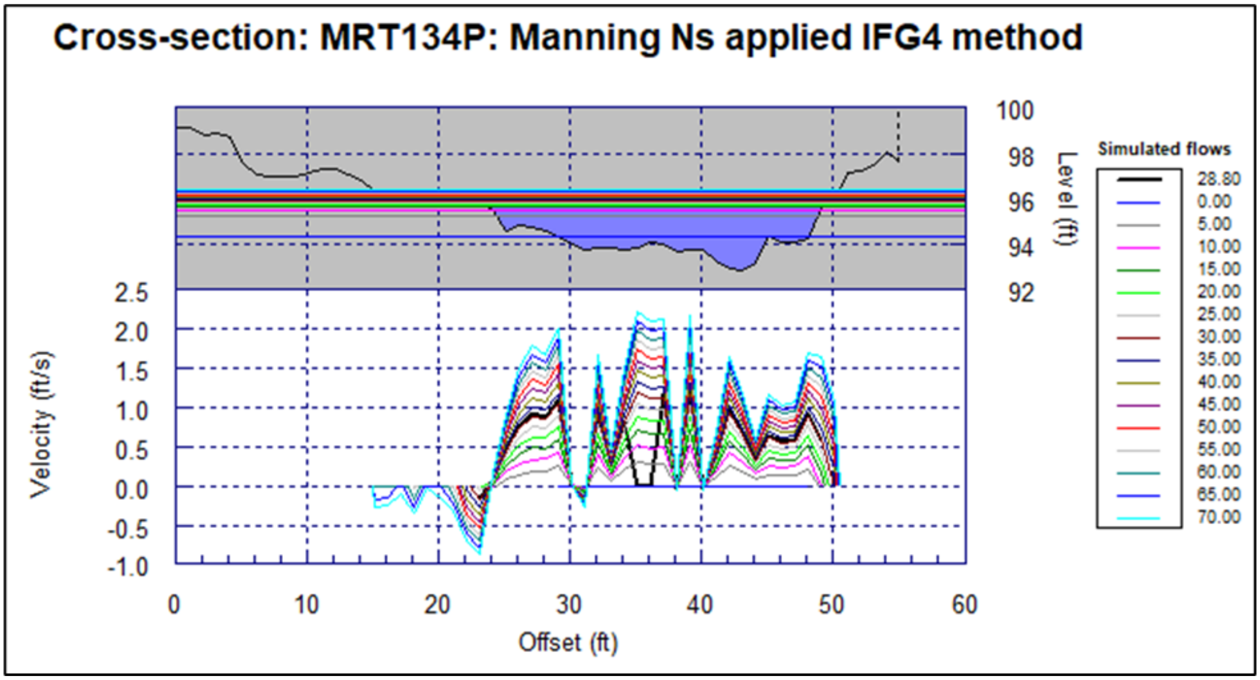

Figure 10. Example transect where the pattern of the simulated velocities does not appear to follow the trend of the field measured velocity profile (bold black line at stations 35 and 36).

3.0 RESULTS

The habitat mapping and model calibration results for the 10 reaches in Redwood Creek are described in the following sections. The specific outputs related to model performance are provided in Appendices B through G.

3.1 Mesohabitat Unit Weighting

Staff completed mesohabitat surveys of all 10 study reaches. The mesohabitat types found to represent more than five percent of the total length of each study reach were identified for site selection. The term 'weighted' in AWS refers to the way the contribution of each mesohabitat type is weighted in 1D models by length. The weight of a given mesohabitat type in each reach is proportional to the percentage of the reach that mesohabitat type comprised. Table 15 through Table 24 summarizes the percent by length of each mesohabitat type in each reach, the final number of calibrated transects in each mesohabitat type by reach and resulting transect weights used in SEFA to compute AWS.

Table 15. Lower Redwood Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	9.30%	3	3.10%
POOL	31.10%	3	10.40%
GLD	9.10%	3	3.00%
RUN	50.50%	3	16.80%

Table 16. Middle Redwood Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	13.20%	3	4.40%
POOL	46.70%	2	23.30%
GLD	5.90%	2	3.00%
RUN	34.10%	3	11.40%

Table 17. Upper Redwood Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	7.80%	2	3.90%
POOL	57.70%	2	28.90%
RUN	34.50%	3	11.50%

Table 18. Seely Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	23.10%	3	7.70%
POOL	21.50%	3	7.20%
GLD	16.80%	1	16.80%
RUN	38.70%	2	19.30%

Table 19. Somerville Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	20.60%	1	20.90%
POOL	19.90%	2	10.10%
RUN	57.80%	3	19.60%

Table 20. Miller Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	13.20%	2	6.70%
POOL	52.50%	2	26.20%
RUN	34.10%	2	17.10%

Table 21. Lower China Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	5.60%	3	1.90%
POOL	55.50%	2	27.70%
RUN	38.90%	1	38.90%

Table 22. Upper China Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	16.80%	1	16.80%
POOL	31.10%	1	31.10%
GLD	6.60%	2	3.30%
RUN	45.50%	2	22.80%

Table 23. North Fork China Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	11.40%	3	3.80%
POOL	36.20%	1	36.20%
RUN	52.40%	1	52.40%

Table 24. Dinner Creek transect weighting factors by percent.

Mesohabitat Type	Weight of Mesohabitat Type Sampled (%)	Number of Transects	Transect Weights (%)
LGR	27.20%	1	27.20%
POOL	40.60%	2	20.30%
GLD	5.60%	2	2.80%
RUN	26.50%	3	8.80%

3.2 Calibration Discharge

The discharge measurements used to develop the stage-discharge rating for each transect in SEFA are provided in Appendix B. Stage-discharge rating development requires at least three distinct flows be measured. Discharge measurements were taken at locations near the transect to minimize the impact of stream gains and losses between the position of the transect and the discharge measurement. Typically, the discharge measurements were taken at the closest glide unit to the transect unit being surveyed. The positions of the transects are provided in the reach maps, Appendix A.

3.3 Stage-discharge Rating Curve Utility Selection and Calibration

The stage-discharge rating relationship was computed for each transect using two utilities available in SEFA: log-log regression and MANSQ. The hydraulic model utility calibration results are given in Appendix C. These results include the reach calibration results for mean error of predicted versus measured discharge, beta value for either method, and VAF for the selected rating utility. In Appendix C, the mean error of the rating utility selected is indicated in bold. The minimum, maximum, and mean of calibration mean error by reach are summarized in Table 25 through Table 34.

Table 25. Lower Redwood Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	1.09%	9.66%	5.09%
WSEL (Error)	≤0.1	0.00	0.10	0.02
Calibration Flow VAF	0.75-1.25	0.82	1.25	0.99
Simulation Velocity VAFs	0.1-5.0	0.14	3.15	1.37

Table 26. Middle Redwood Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.61%	9.21%	4.76%
WSEL (Error)	≤0.1	0.00	0.07	0.02
Calibration Flow VAF	0.75-1.25	0.90	1.20	1.02
Simulation Velocity VAFs	0.1-5.0	0.10	2.40	1.05

Table 27. Upper Redwood Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	1.20%	10.10%	5.57%
WSEL (Error)	≤0.1	0.00	0.08	0.02
Calibration Flow VAF	0.75-1.25	0.87	1.03	0.94
Simulation Velocity VAFs	0.1-5.0	0.13	3.63	1.36

Table 28. Seely Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	1.87%	9.03%	6.54%
WSEL (Error)	≤0.1	0.00	0.09	0.02
Calibration Flow VAF	0.75-1.25	0.85	1.15	1.00
Simulation Velocity VAFs	0.1-5.0	0.12	4.68	1.76

Table 29. Somerville Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	2.79%	7.15%	4.44%
WSEL (Error)	≤0.1	0.00	0.06	0.02
Calibration Flow VAF	0.75-1.25	0.86	1.06	0.99
Simulation Velocity VAFs	0.1-5.0	0.11	1.69	1.10

Table 30. Miller Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.75%	9.91%	4.89%
WSEL (Error)	≤0.1	0.00	0.08	0.02
Calibration Flow VAF	0.75-1.25	0.93	1.19	1.04
Simulation Velocity VAFs	0.1-5.0	0.10	2.21	1.08

Table 31. Lower China Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.15%	8.34%	3.84%
WSEL (Error)	≤0.1	0.00	0.06	0.01
Calibration Flow VAF	0.75-1.25	0.85	1.03	0.95
Simulation Velocity VAFs	0.1-5.0	0.13	4.95	1.41

Table 32. Upper China Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.66%	10.20%	4.36%
WSEL (Error)	≤0.1	0.00	0.10	0.02
Calibration Flow VAF	0.75-1.25	0.76	1.21	0.93
Simulation Velocity VAFs	0.1-5.0	0.12	1.67	0.98

Table 33. North Fork China Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAF results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.34%	6.71%	4.11%
WSEL (Error)	≤0.1	0	0.07	0.02
Calibration Flow VAF	0.75-1.25	0.97	1.20	1.11
Simulation Velocity VAFs	0.1-5.0	0.12	2.05	1.10

Table 34. Dinner Creek summary of Calibration Mean Error, WSEL Error, Calibration Flow VAF, and Simulation Velocity VAFs results.

Parameter	Guidance Range	Min.	Max.	Mean
Calibration Mean Error	≤10%	0.48%	5.73%	3.16%
WSEL (Error)	≤0.1	0	0.08	0.02
Calibration Flow VAF	0.75-1.25	0.87	1.16	1.03
Simulation Velocity VAFs	0.1-5.0	0.37	4.86	1.05

3.4 WSEL Simulation

The stage-discharge utility selected in SEFA (above) was used to predict WSELs. The field-measured WSELs and the WSELs predicted by SEFA are reported in Appendix D for each transect by reach. All predicted WSELs were within the threshold in the USFWS guidelines for PHABSIM, which recommended a difference of 0.1 ft or less (USFWS 1994) between surveyed and modeled WSEL The minimum, maximum, and mean difference between measured and predicted WSEL by reach are summarized in Table 25 through Table 34.

3.5 Simulated Flow Range and Velocity Calibration by VAF

The transect velocity profiles collected during the survey flow were imported into SEFA and used to predict velocity profiles over the range of simulated flows. The simulated velocity profiles for each transect are presented in Appendix E for each transect by reach. Appendix F also includes the revised velocity simulated profiles for transects that were subject to VDF modification summarized in Table 35. The VAFs for all the simulated flows were plotted, with discharge on the x-axis and VAF on the y-axis. The discharge/VAF plots for each reach are given in Appendix F.

Velocities for each reach were initially simulated using the recommended range of 0.4 times the lowest measured flow to 2.5 times the highest measured flow (USGS 2001). Depending upon the discharge versus VAF results, the simulation discharge range was limited to meet the recommended VAF ratio for simulated velocity (Thomas R. Payne and Associates 1998). The final simulation range of each reach is indicated in the plots in Appendix F. The minimum, maximum, and mean range of VAFs for the velocities simulated by reach are summarized in Table 25 to Table 34.

Table 35. Adjusted VDFs.

Transect	Offset Distance (ft)	Default VDF	Initial Maximum Simulated Velocity (ft/s)	Revised VDF	Final Maximum Simulated Velocity (ft/s)
LRT88L	13	-0.020	-2.150	-0.050	-0.895
MRT134P	35	0.250	2.259	4.670	0.105
MRT134P	36	0.250	2.133	4.670	0.099
ST33L	31	0.015	3.866	0.191	0.319
ST33L	34	0.059	1.054	0.076	0.870
ST33L	35	0.026	2.387	0.154	0.432
MCT133R	33	-0.180	-1.149	-0.250	-0.796
MCT133R	34	-0.110	-1.289	-0.200	-0.709
LCT32L	8	0.023	3.731	0.079	1.133

3.6 Velocity Distribution Factors

The simulated velocity profiles for each transect were reviewed to determine whether the simulated velocity patterns were consistent with the pattern of the velocity profile measured in the field. Attention was placed on transects containing negative velocities. As discussed in Section 2.4, small negative velocities were present in some of the transects near the stream margins. Two of the 77 transects were found to have negative velocities near the stream margins with negative magnitudes greater than -1 ft/s at the maximum simulation flow. The initial VDF factors were reduced in one cell for transect LRT88L and two cells for MCT113R to minimize extrapolation of negative velocities to -1 ft/s (Table 35).

The other three transects listed in Table 35 possessed simulated velocity patterns that did not appear to be consistent with the pattern measured in the field (see Figure 10). The cross section VDF plots for all five transects before and after modification are presented in Appendix G.

4.0 DISCUSSION

The hydraulic calibration of 1D transects involves applying guidance standards from the literature (Milhous et al. 1989; Thomas R. Payne and Associates 1998; USFWS 1994; USFWS 2011; USGS 2001) to the model outputs to ensure the model performance meets existing standards. In situations where transect outputs do not meet the standards, the transect data are further evaluated. Data were evaluated to determine whether a mistake was made in the data collection or entry process, if the stage-discharge relationship was altered between surveys by a change in the transect lateral or longitudinal profile, or if the transect was a poor candidate for hydraulic modeling in 1D.

Transects were omitted if their hydraulic modeling outputs did not meet the standards given in Table 25 to Table 34. Omitted transects are included in Table 1 to Table 10 and the rationale for each omission is reported in Appendix C.

4.1 Application of *Best SZF* Utility

Two pool habitat units, Middle Redwood Creek reach habitat unit 149 (MRT149P) and Dinner Creek habitat unit 14 (DT14P), did not meet the standard for mean error of 10% using the log-log regression utility. Digital images of the sites taken during the field surveys indicated that large substrates, boulders and/or down tree trunks obscured the actual SZF elevation from view or made placing the stadia rod on the location impossible. In these isolated incidents staff were unable to survey the correct bed elevation for SZF. The pool unit, MRT149P, was dominated by large substrates (Figure 11) obscuring the SZF elevation. In pool unit DT14P (Figure 12) the downstream hydraulic control elevation was obscured by the combination of a large boulder and downed tree trunk. The *Best SZF* utility was used to estimate the SZF for these two pool units.

Figure 11. Large substrates in habitat unit MRT149P.

Figure 12. Surveying SZF flow in habitat unit DT14P.

The *Best SZF* utility is described in detail in the Section 2.4. The utility solves for the SZF that gives the best fit for the hydraulic rating curve. In the absence of a reliable field measurement, the *Best SZF* function optimizes the log-log regression.

4.2 Mean Error Threshold Units

Two transects with mean errors just above the acceptable threshold of 10% were included in the analysis because the transect performance was well within the other standards. In Upper Redwood Creek, the low gradient riffle habitat unit URT43L was included in the analysis even through the MANSQ mean error was 10.095%. The maximum variance of WSEL at any of the stage-discharge pairs was 0.03 ft. The calibration VAF was equal to 0.89, and the range of velocity simulation VAF was 0.459 to 1.347. The glide transect UCT72G in Upper China Creek was included in the analysis with a MANSQ mean error of 10.197%. The maximum variance of WSEL at any of the stage-discharge pairs was 0.04 ft. The calibration VAF was equal to 1.07, and the range of velocity simulation VAF was 0.370 to 1.611.

5.0 CONCLUSION

Department staff developed a series of hydraulic models at selected 1D transects in 10 reaches of the anadromous portion of Redwood Creek including tributaries using the computer program SEFA. This report documents the Department's efforts to collect and compile field data and develop and calibrate those hydraulic models used to compute flow versus habitat relationships. As is described in the report, Department staff followed standard methods while collecting field data and applied standard techniques during model development and calibration.

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APPENDIX A: TRIBUTARY MAPS

This appendix presents the watershed boundary maps for each Redwood Creek study reach evaluated and includes the approximate locations of each sampled 1D habitat unit.

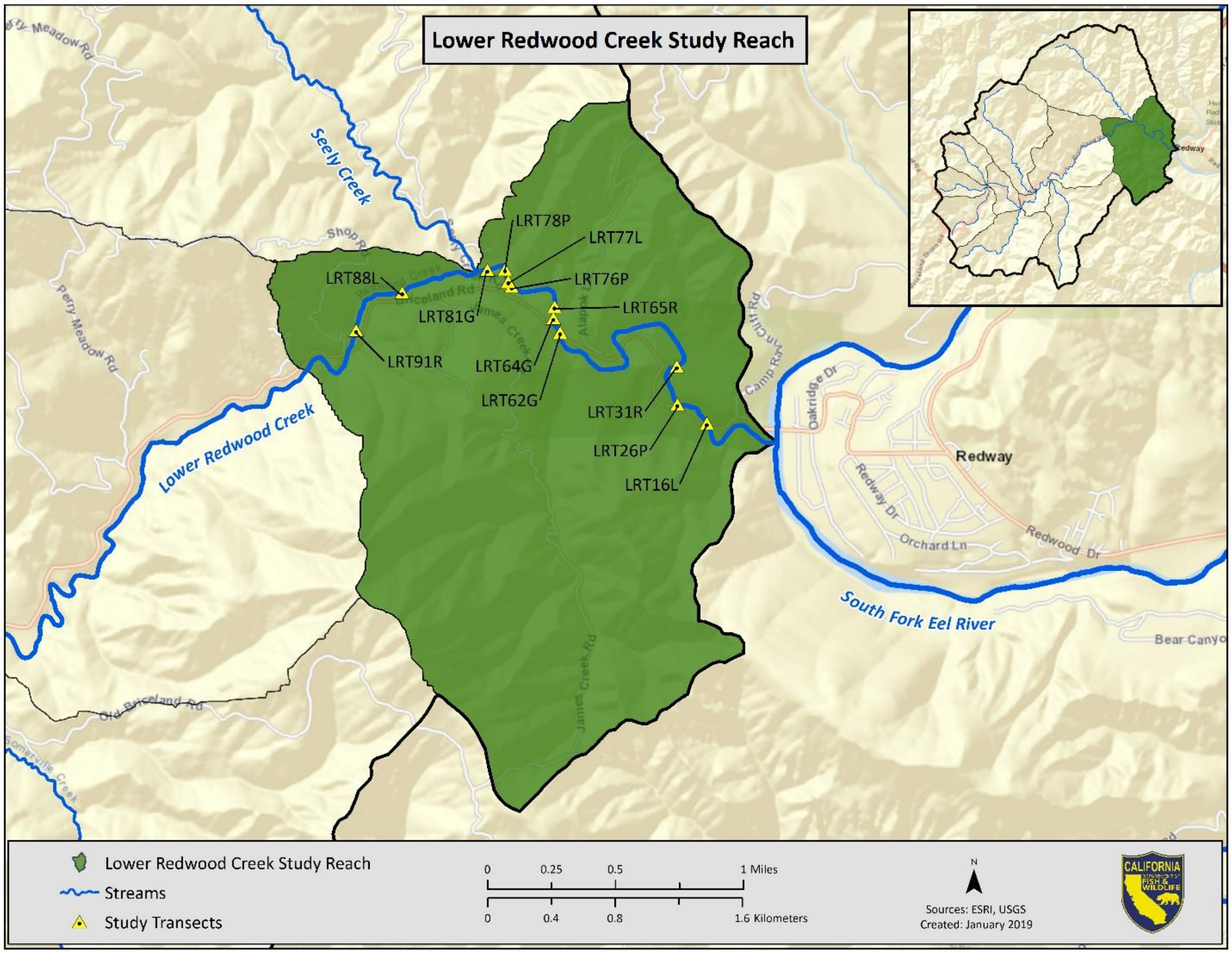

Figure A-1. Lower Redwood Creek sampled transect locations.

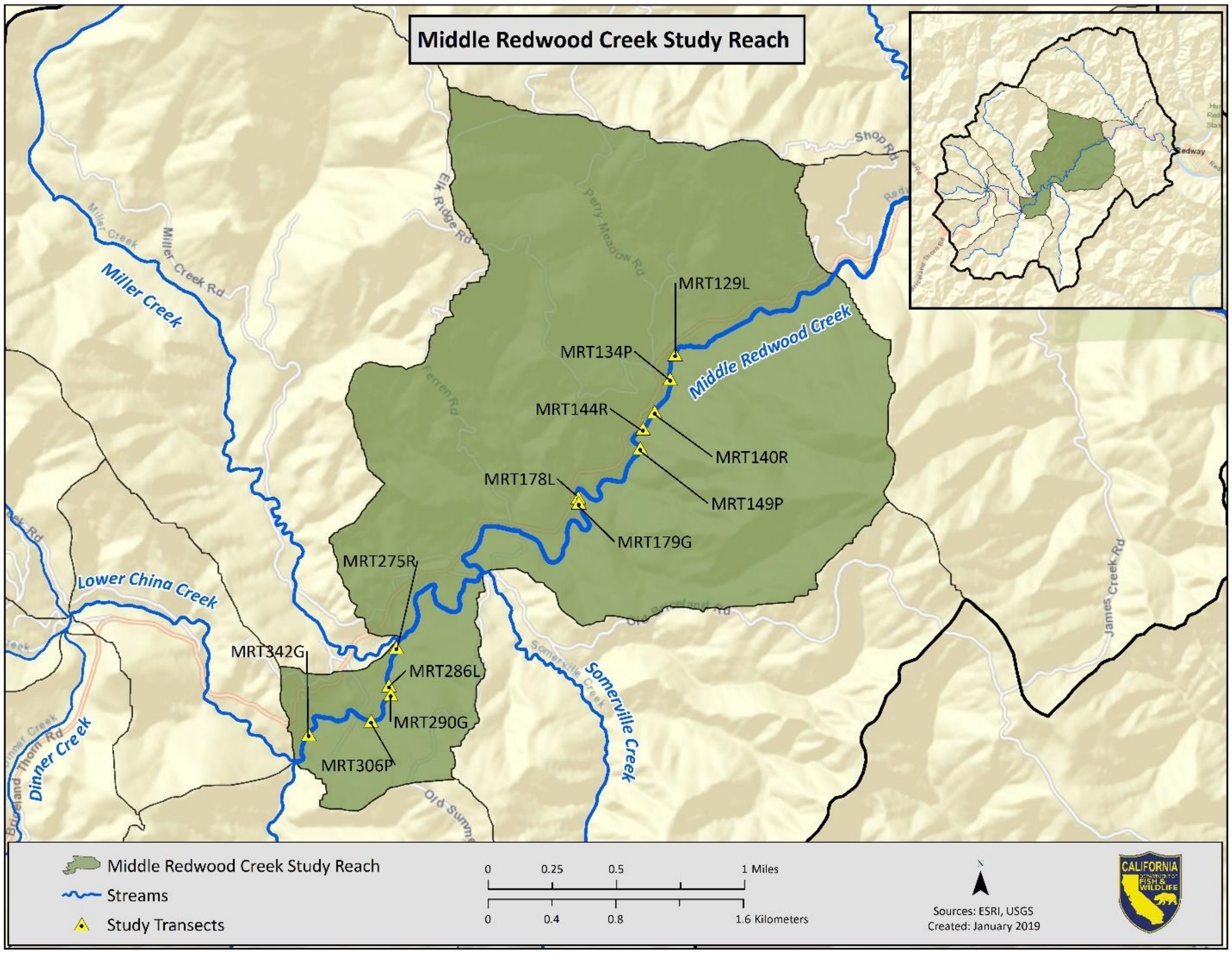

Figure A-2. Middle Redwood Creek sampled transect locations.

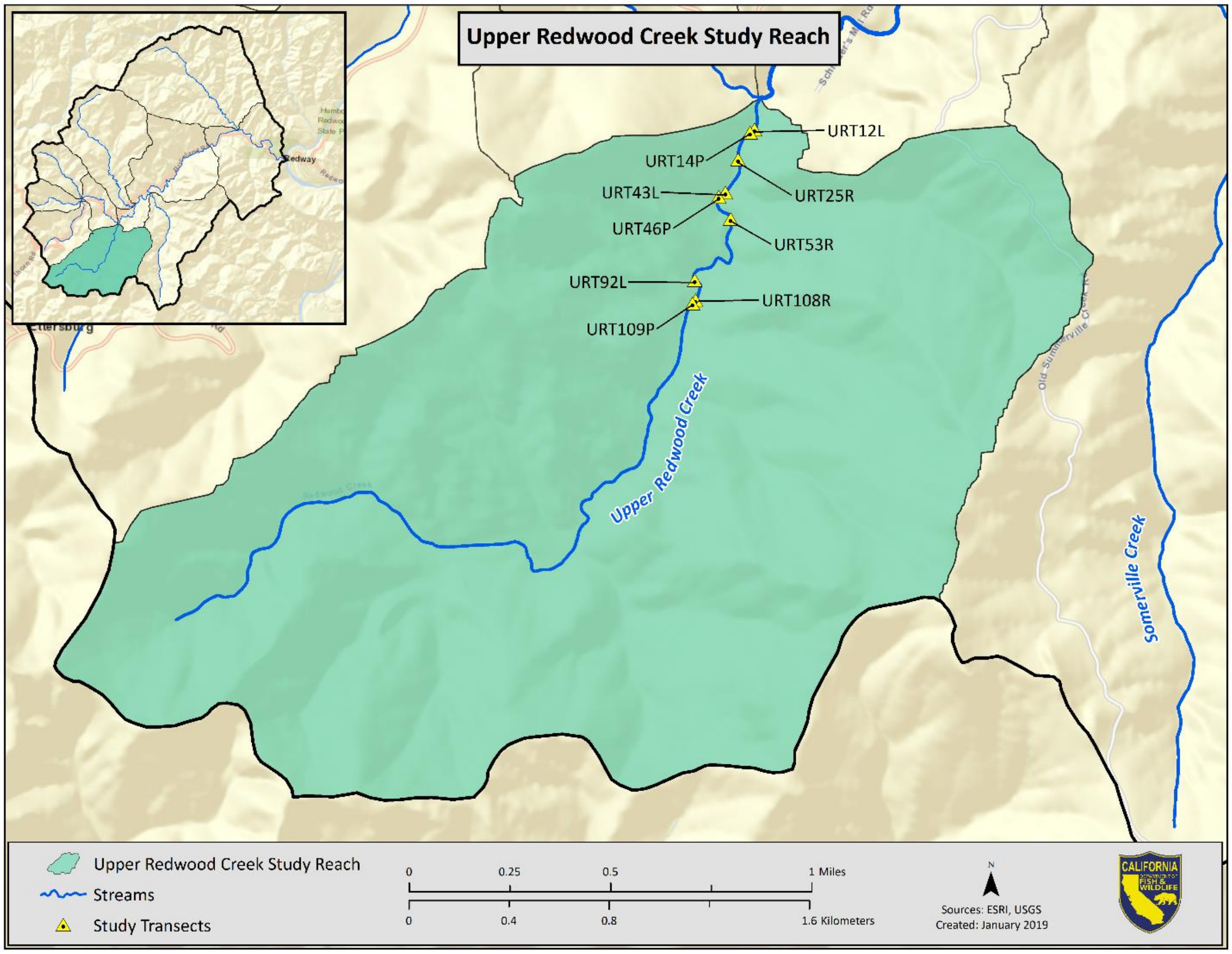

Figure A-3. Upper Redwood Creek sampled transect locations.

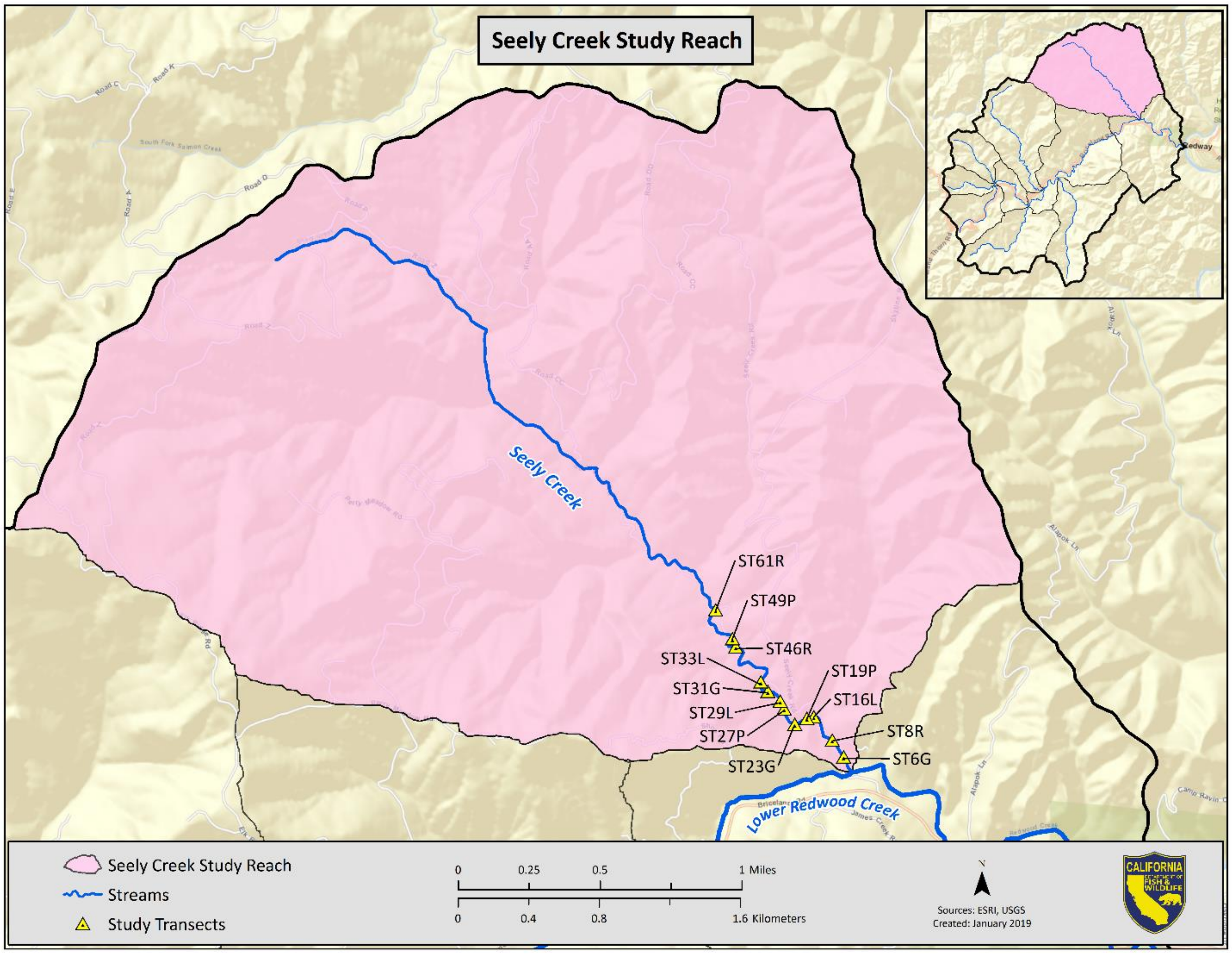

Figure A-4. Seely Creek sampled transect locations.

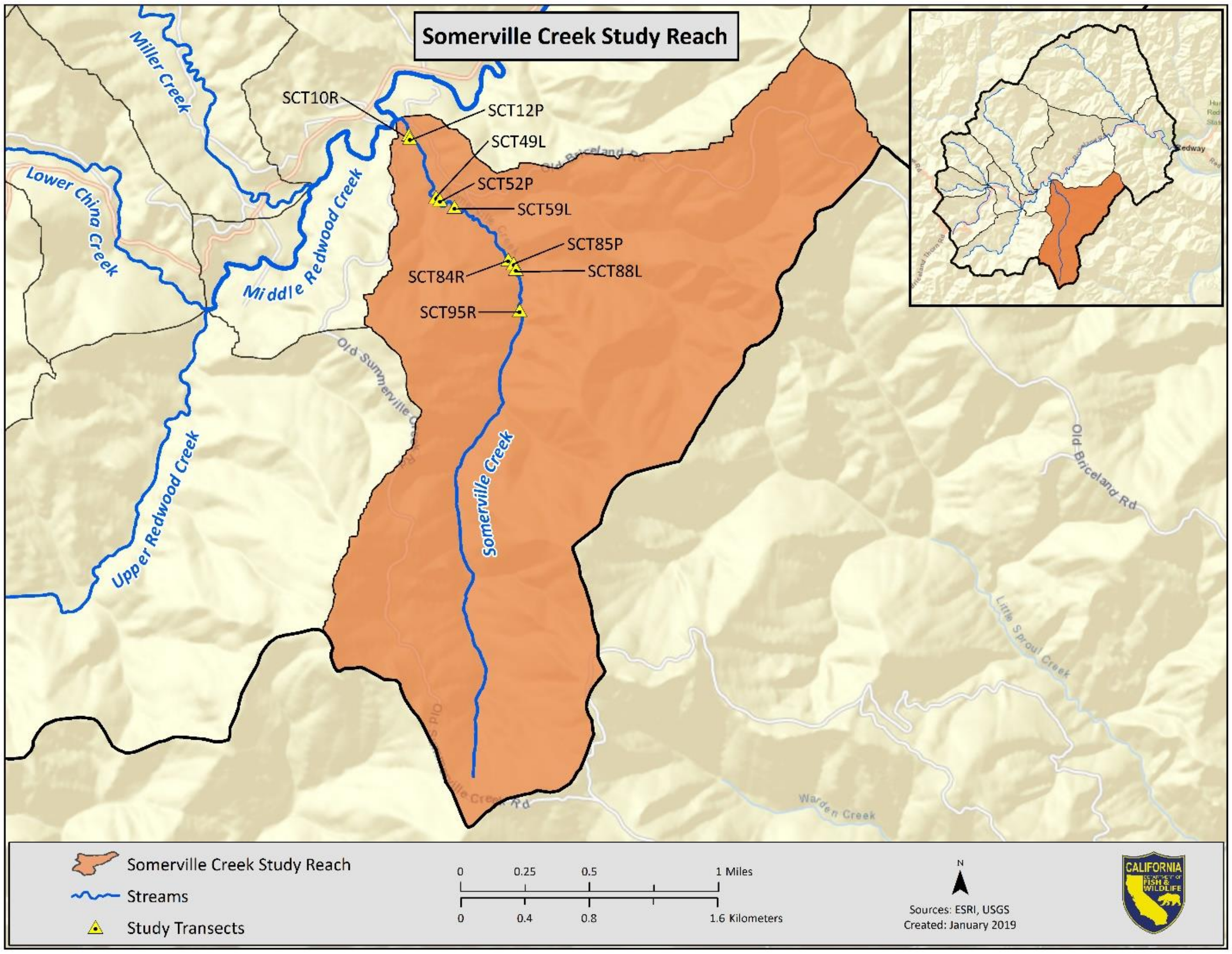

Figure A-5. Somerville Creek sampled transect locations.

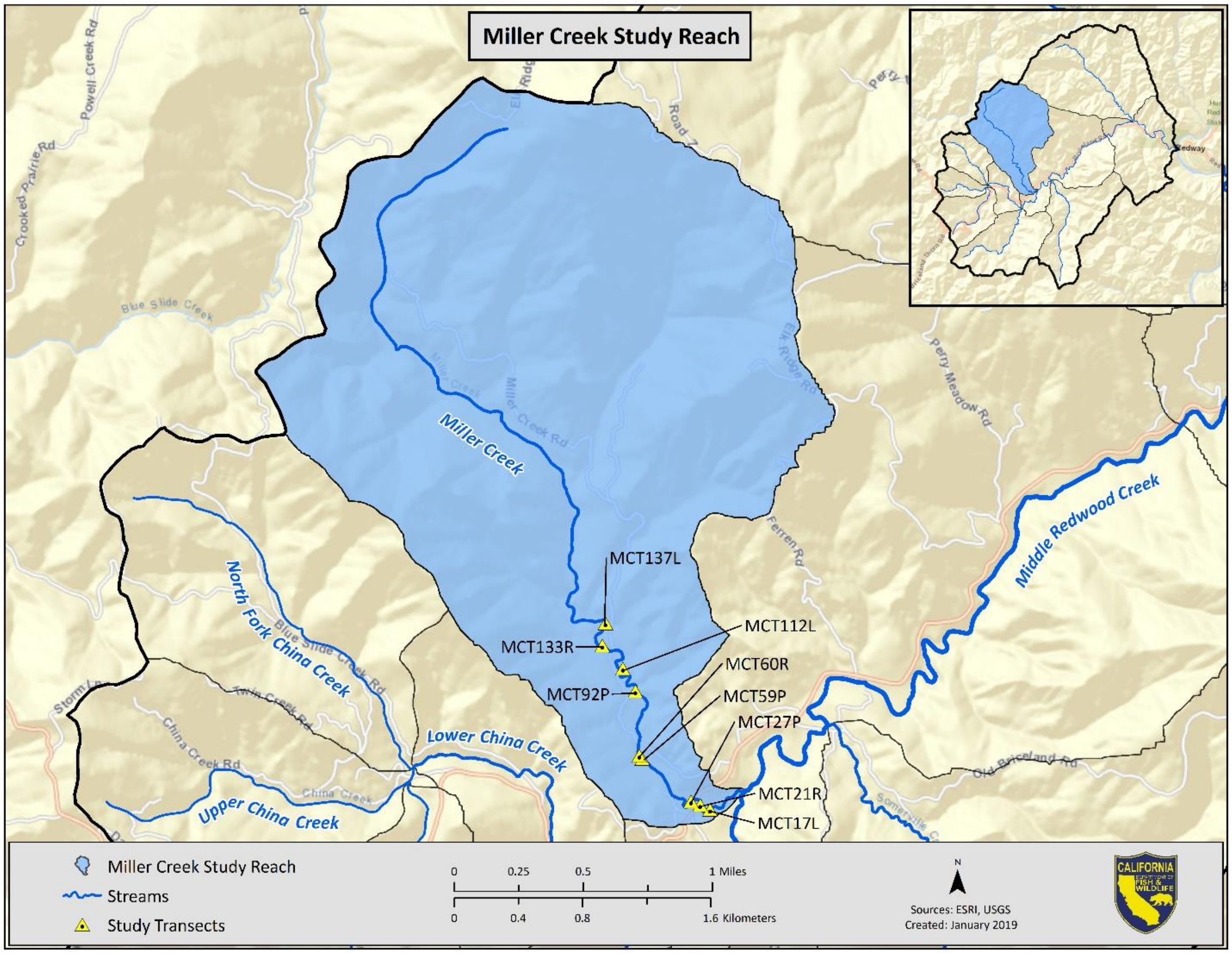

Figure A-6. Miller Creek sampled transect locations.

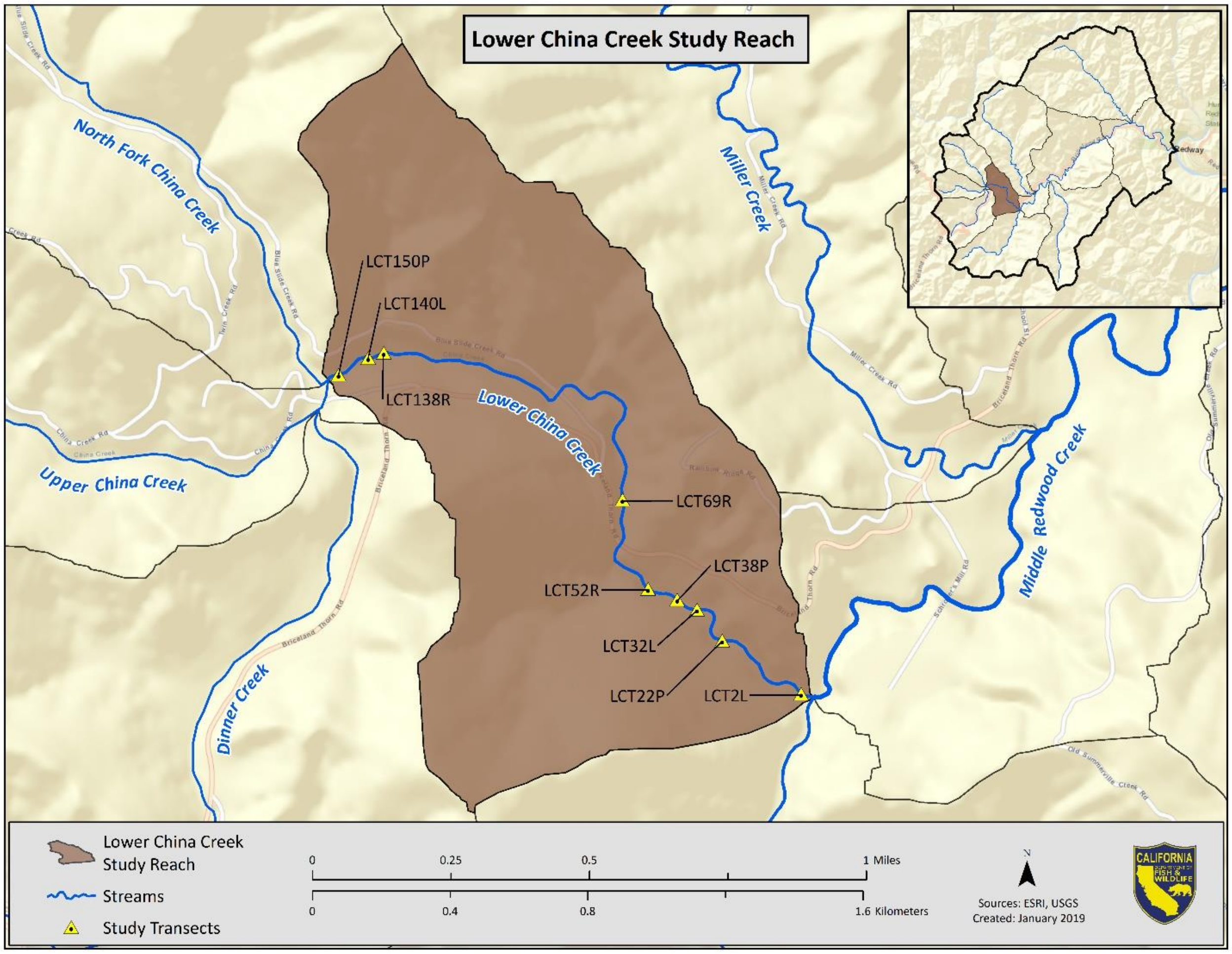

Figure A-7. Lower China Creek sampled transect locations.

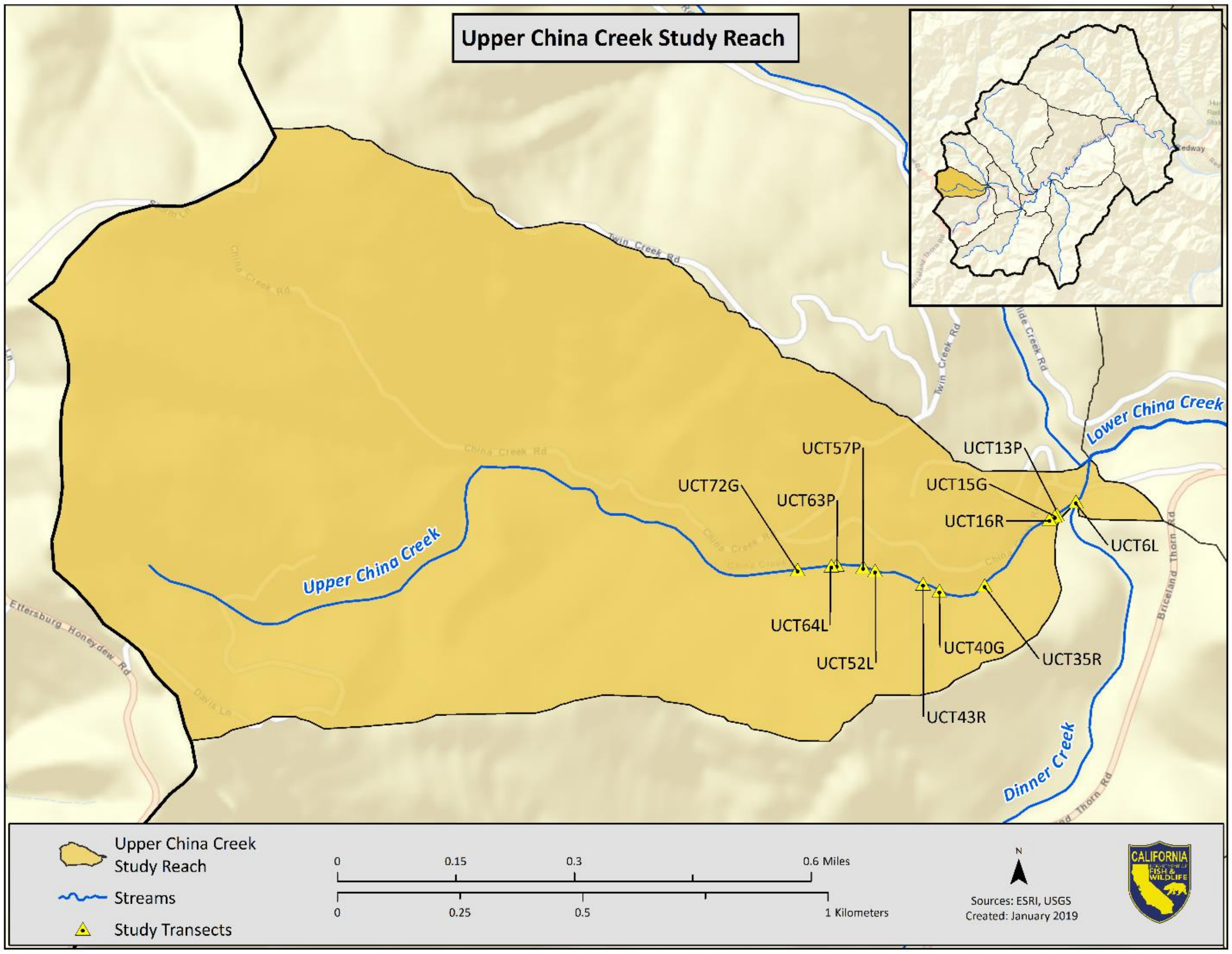

Figure A-8. Upper China Creek sampled transect locations.

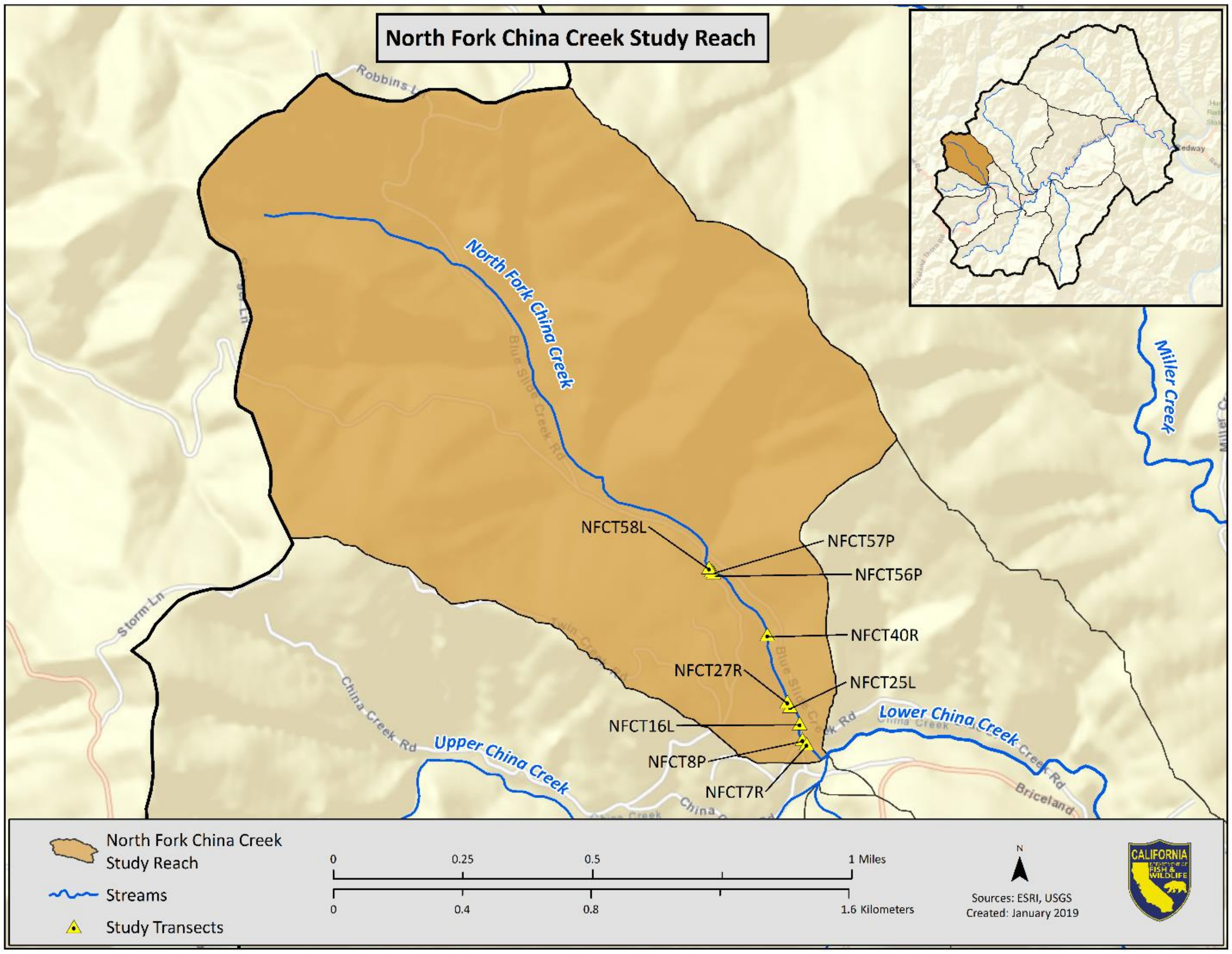

Figure A-9. North Fork China Creek sampled transect locations.

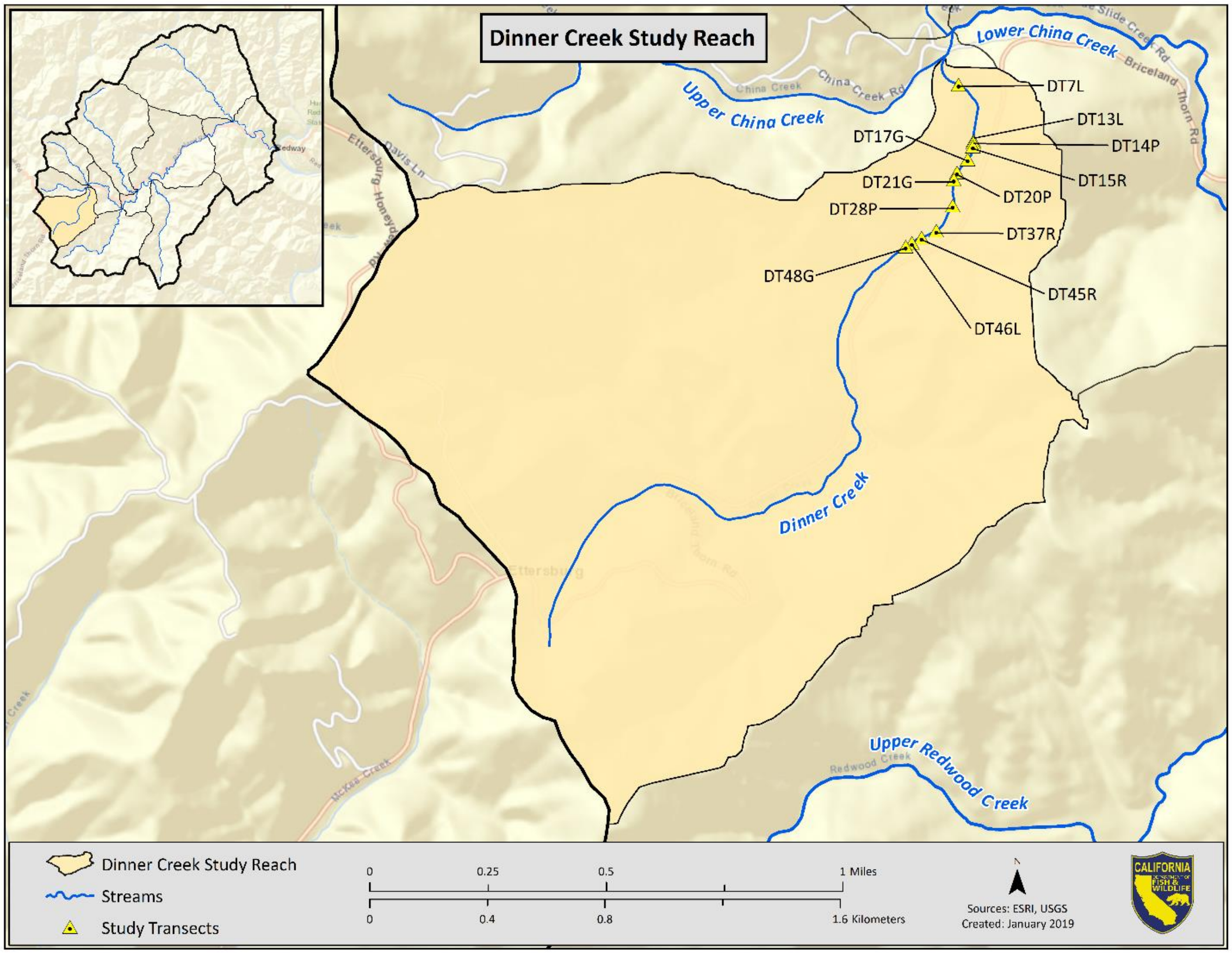

Figure A-10. Dinner Creek sampled transect locations.

APPENDIX B: TRANSECT DISCHARGE

Discussed in Section 3.2.

Table B-1. Lower Redwood Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
LRT16L	6/14/2016	3.4
LRT16L	5/17/2016	9.5
LRT16L	5/3/2016	16.1
LRT16L	11/2/2016	132.8
LRT26P	6/14/2016	3.4
LRT26P	5/17/2016	9.5
LRT26P	5/3/2016	16.1
LRT31R	6/14/2016	3.4
LRT31R	5/17/2016	9.5
LRT31R	5/3/2016	16.1
LRT62G	6/14/2016	2.9
LRT62G	5/25/2016	7.7
LRT62G	5/4/2016	13.9
LRT64G	6/14/2016	2.9
LRT64G	5/25/2016	7.7
LRT64G	5/4/2016	13.9
LRT64G	11/2/2016	107.4
LRT65R	6/14/2016	2.9
LRT65R	5/25/2016	7.7
LRT65R	5/4/2016	13.9
LRT65R	11/16/2016	30.7
LRT76P	6/14/2016	2.9
LRT76P	5/25/2016	7.5
LRT76P	5/5/2016	13.7
LRT77L	6/14/2016	2.9
LRT77L	5/25/2016	7.5
LRT77L	5/5/2016	13.7
LRT77L	11/3/2016	81.1
LRT78P	6/14/2016	2.9

Transect	Date	Flow (cfs)
LRT78P	5/25/2016	7.5
LRT78P	4/20/2016	16.3
LRT78P	11/3/2016	81.1
LRT81G	6/14/2016	2.9
LRT81G	5/25/2016	7.5
LRT81G	4/20/2016	16.3
LRT81G	11/3/2016	81.1
LRT88L	6/14/2016	2.6
LRT88L	5/24/2016	7.2
LRT88L	5/4/2016	11.0
LRT91R	6/14/2016	2.6
LRT91R	5/25/2016	7.2
LRT91R	5/4/2016	11.0

Table B-2. Middle Redwood Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
MRT129L	6/15/2016	2.3
MRT129L	5/5/2016	10.4
MRT129L	11/15/2016	28.8
MRT134P	6/15/2016	2.3
MRT134P	5/5/2016	10.4
MRT134P	11/15/2016	28.8
MRT140R	6/15/2016	2.3
MRT140R	5/5/2016	10.4
MRT140R	11/15/2016	28.0
MRT144R	6/15/2016	2.3
MRT144R	5/19/2016	7.1
MRT144R	11/15/2016	28.0
MRT149P	6/15/2016	2.3
MRT149P	5/19/2016	7.1
MRT149P	11/15/2016	28.0
MRT178L	6/15/2016	2.5
MRT178L	5/19/2016	6.0
MRT178L	11/15/2016	23.5
MRT179G	6/15/2016	2.5
MRT179G	5/25/2016	5.8
MRT179G	11/15/2016	23.5
MRT275R	6/15/2016	1.1
MRT275R	11/14/2016	11.2
MRT275R	11/4/2016	24.5
MRT286L	6/15/2016	1.1
MRT286L	5/25/2016	2.3
MRT286L	11/4/2016	24.5
MRT342G	11/16/2016	10.1
MRT342G	11/3/2016	28.6
MRT342G	12/1/2016	42.0

Table B-3. Upper Redwood Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
URT25R	6/15/2016	0.5
URT25R	11/2/2016	14.5
URT25R	11/29/2016	26.6
URT43L	6/15/2016	0.4
URT43L	4/12/2016	3.0
URT43L	11/2/2016	13
URT43L	11/29/2016	21.3
URT46P	6/15/2016	0.4
URT46P	11/2/2016	13.0
URT46P	11/29/2016	21.3
URT53R	6/15/2016	0.4
URT53R	4/12/2016	3.0
URT53R	11/2/2016	13.8
URT53R	11/29/2016	21.2
URT92L	4/12/2016	3.0
URT92L	11/2/2016	13.3
URT92L	11/29/2016	21.4
URT108R	5/24/2016	0.8
URT108R	4/12/2016	2.5
URT108R	11/2/2016	12.5
URT108R	11/29/2016	18.6
URT109P	5/24/2016	0.8
URT109P	11/2/2016	12.5
URT109P	11/29/2016	18.6

Table B-4. Seely Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
ST8R	5/24/2016	1.3
ST8R	11/14/2016	5.5
ST8R	11/30/2016	27.5
ST16L	5/24/2016	1.2
ST16L	4/19/2016	2.5
ST16L	11/15/2016	6.9
ST19P	5/24/2016	1.2
ST19P	4/19/2016	2.5
ST19P	11/15/2016	6.9
ST19P	11/30/2016	26.2
ST23G	5/24/2016	1.2
ST23G	4/19/2016	2.5
ST23G	11/15/2016	6.9
ST23G	11/30/2016	26.2
ST27P	5/24/2016	1.2
ST27P	4/19/2016	2.5
ST27P	11/15/2016	6.9
ST29L	5/24/2016	1.2
ST29L	4/19/2016	2.5
ST29L	11/15/2016	6.9
ST33L	5/24/2016	1.2
ST33L	4/19/2016	2.5
ST33L	11/15/2016	6.9
ST33L	11/30/2016	26.2
ST46R	5/24/2016	1.2
ST46R	4/19/2016	2.3
ST46R	11/15/2016	8.6
ST46R	11/30/2016	25.3
ST49P	5/24/2016	1.2
ST49P	4/19/2016	2.3
ST49P	11/15/2016	8.6
ST49P	11/30/2016	25.3

Table B-5. Somerville Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
SCT10R	5/18/2016	0.7
SCT10R	4/13/2016	2.3
SCT10R	11/14/2016	3.4
SCT10R	11/30/2016	19.5
SCT12P	5/18/2016	0.7
SCT12P	4/13/2016	2.3
SCT12P	11/14/2016	3.4
SCT12P	11/30/2016	19.5
SCT52P	5/18/2016	0.7
SCT52P	4/13/2016	2.3
SCT52P	11/16/2016	3.2
SCT52P	11/30/2016	19.5
SCT84R	5/18/2016	1.0
SCT84R	4/13/2016	2.3
SCT84R	11/15/2016	3.1
SCT84R	11/30/2016	12.6
SCT88L	4/13/2016	2.0
SCT88L	11/30/2016	8.9
SCT88L	11/29/2016	12.1
SCT95R	11/15/2016	2.0
SCT95R	11/30/2016	8.9
SCT95R	11/29/2016	12.1

Table B-6. Miller Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
MCT17L	5/23/2016	1.2
MCT17L	4/12/2016	3.6
MCT17L	11/29/2016	32.0
MCT21R	5/23/2016	1.2
MCT21R	4/12/2016	3.6
MCT21R	11/29/2016	32
MCT59P	4/18/2016	2.9
MCT59P	4/6/2016	5.3
MCT59P	11/29/2016	28.5
MCT92P	5/23/2016	1.2
MCT92P	4/18/2016	2.9
MCT92P	11/29/2016	30.1
MCT133R	5/23/2016	1.1
MCT133R	4/18/2016	2.7
MCT133R	4/7/2016	4.6
MCT133R	11/29/2016	27.7
MCT137L	5/23/2016	1.1
MCT137L	4/18/2016	2.7
MCT137L	4/7/2016	4.6
MCT137L	11/30/2016	22.9

Table B-1. Lower China Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
LCT2L	5/17/2016	1.6
LCT2L	4/13/2016	4.1
LCT2L	11/3/2016	17.7
LCT22P	5/18/2016	1.6
LCT22P	4/13/2016	4.1
LCT22P	11/4/2016	15.1
LCT32L	5/17/2016	1.6
LCT32L	4/13/2016	4.1
LCT32L	11/4/2016	15.1
LCT52R	5/18/2016	1.6
LCT52R	4/13/2016	4.1
LCT52R	11/3/2016	16.9
LCT140L	4/21/2016	2.7
LCT140L	4/11/2016	4.0
LCT140L	11/1/2016	33.6
LCT150P	5/18/2016	1.4
LCT150P	4/21/2016	2.7
LCT150P	4/11/2016	4.0
LCT150P	11/1/2016	33.6

Table B-2. Upper China Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
UCT13P	4/5/2016	1.5
UCT13P	12/2/2016	3.8
UCT13P	11/30/2016	5.8
UCT35R	4/5/2016	1.5
UCT35R	12/2/2016	3.6
UCT35R	11/30/2016	5.5
UCT40G	4/5/2016	1.5
UCT40G	12/1/2016	3.8
UCT40G	11/28/2016	7.7
UCT43R	4/5/2016	1.5
UCT43R	12/1/2016	3.8
UCT43R	11/28/2016	7.7
UCT52L	4/5/2016	1.5
UCT52L	12/1/2016	3.8
UCT52L	11/28/2016	7.7
UCT72G	11/15/2016	1.1
UCT72G	12/1/2016	4.1
UCT72G	11/28/2016	8.3

Table B-3. North Fork China Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
NFCT7R	12/2/2016	6.2
NFCT7R	12/1/2016	7.3
NFCT7R	11/30/2016	9.8
NFCT8P	5/19/2016	0.4
NFCT8P	4/6/2016	1.8
NFCT8P	3/24/2016	8.8
NFCT16L	5/19/2016	0.4
NFCT16L	4/6/2016	1.8
NFCT16L	3/24/2016	8.8
NFCT25L	5/19/2016	0.4
NFCT25L	4/6/2016	1.8
NFCT25L	3/24/2016	8.8
NFCT58L	11/16/2016	1.4
NFCT58L	11/30/2016	8.6
NFCT58L	11/28/2016	14.5

Table B-4. Dinner Creek surveyed flows at each transect.

Transect	Date	Flow (cfs)
DT7L	5/19/2016	0.5
DT7L	4/5/2016	2.4
DT7L	3/24/2016	10.7
DT14P	5/19/2016	0.5
DT14P	4/5/2016	2.4
DT14P	3/23/2016	15.5
DT15R	5/19/2016	0.5
DT15R	4/5/2016	2.4
DT15R	12/1/2016	9.0
DT15R	3/23/2016	15.5
DT17G	5/19/2016	0.5
DT17G	12/1/2016	9.0
DT17G	3/23/2016	15.5
DT21G	5/19/2016	0.5
DT21G	4/5/2016	2.4
DT21G	12/1/2016	9.0
DT21G	3/23/2016	15.5
DT28P	5/19/2016	0.5
DT28P	4/7/2016	2.3
DT28P	12/1/2016	9.0
DT28P	3/22/2016	16.3
DT37R	5/19/2016	0.5
DT37R	4/7/2016	2.3
DT37R	3/22/2016	16.3
DT45R	5/19/2016	0.5
DT45R	4/7/2016	2.3
DT45R	3/22/2016	16.3

APPENDIX C: SEFA HYDRAULIC MODEL UTILITY CALIBRATION RESULTS

The following notes and definitions explain the equations and quantities used to quantify the hydraulic model utility calibration results for each reach of the Redwood Creek 1D analysis using the program SEFA. The hydraulic model utility selected for simulation of depth and velocity is indicated by the **bolded mean error** and an asterisk (*) in the following tables.

SZF rating (log-log regression): Fitted as best fit to survey stage and flow, rating calibration stages and flows, and stage for zero flow: Flow = A x $(\text{Water level - SZF})^{exp}$

Where:

Q = flow (cfs)
A = regression coefficient
WSEL = water surface elevation (ft)
SZF = stage of zero flow (ft)
exp = exponential regression coefficient

Best SZF **rating (log-log regression using the** ***Best SZF*** **utility):** Fitted as best fit to survey stage and flow, rating calibration stages and flows, with best fit stage for zero flow: Flow = A x $(\text{Water level - const})^{exp}$

Where:

Q = flow (cfs)
A = regression coefficient
WSEL = water surface elevation (ft)
exp = exponential regression coefficient
const = constant

Hydraulic formula (MANSQ): $Q = 1/N \times Area \times (R - R_{SZF})^{2/3} \times S^{1/2}$

Where:

Q = flow (cfs)
$N = A \times Q^{beta}$

A = regression coefficient
beta = MANSQ exponential regression coefficient

Area = cross-sectional area of the transect (ft^2)
R = hydraulic radius (ft)
R_{SZF} = hydraulic radius at the SZF (ft)

S = slope of the water surface (ft/ft)

- The mean error (%) and coefficient of determination (R2) show the goodness of fit of the rating to the gagings.
- The mean error is the mean percentage error in predicted and rating calibration discharges as a % of the rating calibration discharges.
- The coefficient of determination is derived by comparing measured and predicted stages.
- R2 = 1 - Residual sum of squares / Total sum of squares
- Residual sum of squares = Sum ((Measured stage - predicted stage)^2)
- Total sum of squares = Sum (Measured stage^2) - (Sum (Measured stage))^2 / Number of points on rating
- Ratings are fitted by the least-squares geometric mean method to x and y deviations as described in the manual.

Table C-1. Lower Redwood Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
LRT16L	2.495	28.349	94.25	1.000	3.327	0.231	-0.217	1.000	**3.888***	1.25
LRT26P	1.790	22.078	96.21	0.999	**1.726***	0.127	-0.037	0.999	1.667	1.04
LRT31R	1.382	37.353	95.64	0.964	8.330	0.025	0.293	0.971	**7.581***	0.92
LRT62G	3.986	17.064	96.62	0.992	5.101	0.130	-0.136	0.996	**2.977***	0.98
LRT64G	2.693	15.146	97.31	0.998	7.798	0.040	-0.330	0.999	**7.303***	0.98
LRT65R	3.016	40.795	96.74	0.986	9.770	0.037	-0.412	0.990	**9.664***	1.12
LRT76P	2.741	15.607	97.80	1.000	**1.093***	0.211	-0.366	1.000	0.837	0.94
LRT77L	3.082	25.794	97.92	0.998	**6.606***	0.065	-0.308	0.993	15.654	0.88
LRT78P	2.785	8.072	95.24	1.000	**1.757***	0.020	-0.296	1.000	2.008	1.07
LRT81G	1.657	39.440	96.60	0.999	6.713	0.017	0.117	0.999	**5.849***	1.03
LRT88L	2.732	35.937	96.01	0.980	6.438	0.030	-0.314	0.984	**7.348***	0.82
LRT91R	2.990	18.642	96.18	0.987	5.726	0.088	-0.282	0.984	**5.318***	0.82

Table C-2. Middle Redwood Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
MRT129L	3.237	13.710	95.47	0.996	5.867	0.084	-0.343	0.994	**6.513***	0.91
MRT134P	3.419	5.968	94.34	0.999	**2.638***	0.326	-0.466	0.999	2.468	1.11
MRT140R[a]	1.866	22.167	97.48	1.000	**0.605***	0.072	-0.190	0.996	5.200	0.99
MRT144R	2.976	8.152	92.93	0.995	7.777	0.069	-0.286	0.996	**6.021***	1.13
MRT149P[b]	1.446	39.110	94.98	1.000	**0.914***	-	-	-	-	1.20
MRT178L	2.191	54.414	96.77	0.997	5.709	0.038	0.130	0.994	**8.121***	0.93
MRT179G	3.875	9.705	96.23	0.988	10.591	0.074	-0.551	0.989	**9.214***	0.95
MRT275R	2.563	19.481	95.10	0.985	11.311	0.065	-0.090	0.986	**9.581***	0.98
MRT286L	1.800	42.046	95.84	1.000	2.594	0.087	-0.218	1.000	**2.883***	0.89
MRT290G[c]	1.015	12.929	96.91	0.997	21.364	0.025	0.788	0.998	17.409	-
MRT306P[d]	12.518	0.001	94.34	1.000	0.045	-	-	-	-	1.27
MRT342G	3.132	5.935	96.93	0.989	4.776	0.392	-0.361	0.989	**5.519***	1.09

[a] SZF rating utility was chosen because the WSELs predicted by the hydraulic rating did not meet the 0.1 threshold when compared to the field measured WSELs.
[b] *Best SZF* utility was used to predict simulated stage-discharges.
[c] Omitted because the calibration did not meet the standard for mean error.
[d] Omitted because the calibration did not meet the guidance standard for mean error with log-log regression and did not meet the calibration standard for VAF when the *Best SZF* utility was applied. *Best SZF* utility was used to predict simulated stage-discharges.

Table C-3. Upper Redwood Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
URT12L[e]	1.904	44.958	96.17	0.993	6.714	0.033	-0.386	0.998	6.779	0.71
URT14P[f]	3.064	10.267	95.89	0.982	**12.795***	0.118	-0.377	0.987	13.135	-
URT25R	2.143	23.178	97.74	0.999	2.042	0.067	-0.364	0.999	**3.864***	0.87
URT43L	2.918	95.387	95.91	0.995	11.150	0.065	-0.392	0.993	**10.095***	0.89
URT46P	9.004	0.234	96.86	0.997	**7.189***	0.130	-0.764	0.996	9.480	1.03
URT53R	2.404	28.189	96.57	0.999	4.254	0.032	-0.373	0.995	**8.042***	0.98
URT92L	2.580	23.762	97.92	0.998	2.384	0.061	-0.084	0.999	**2.275***	0.88
URT108R	3.284	23.128	96.33	0.998	5.912	0.061	-0.155	1.000	**1.197***	0.96
URT109P	7.597	0.352	93.56	0.996	**6.314***	0.058	-0.749	0.996	7.524	0.98

[e] Omitted because the calibration VAF was less than 0.75.
[f] Omitted because the calibration did not meet guidance criteria for mean error. URT14P cannot use *Best SZF* rating because the optimized SZF is less than the minimum transect elevation.

Table C-4. Seely Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ. ST61P was omitted because the stage-discharge relationship was in error. The omitted transect calibration results could not be reported by SEFA due to the severity of the error.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
ST6G[g]	3.940	10.773	96.28	0.977	19.972	0.030	-0.462	0.972	45.674	-
ST8R	3.323	24.126	96.18	1.000	1.451	0.048	-0.329	1.000	**1.872***	0.86
ST16L	5.160	1,005.480	93.61	0.991	6.748	0.054	-0.604	0.991	**5.664***	1.15
ST19P	2.577	16.521	98.89	0.995	**9.029***	0.194	-0.313	0.995	9.956	1.02
ST23G	2.231	20.832	97.58	0.996	10.061	0.038	-0.190	0.996	**8.977***	1.07
ST27P	1.746	14.309	96.98	0.995	**5.835***	0.009	0.061	0.996	6.598	0.85
ST29L	3.108	167.613	95.84	0.983	9.225	0.046	-0.600	0.991	**6.643***	0.94
ST31G[h]	1.821	27.334	94.91	0.967	26.27	0.081	-0.229	0.982	18.748	-
ST33L	3.796	27.098	96.78	0.998	5.198	0.069	-0.317	0.998	**5.566***	0.90
ST46R	3.498	122.120	98.14	1.000	2.805	0.019	-0.519	0.997	**7.971***	1.09
ST49P	2.370	21.235	96.94	0.993	**7.338***	0.012	-0.225	0.996	7.520	1.09

[g] Omitted because the calibration did not meet the standard for mean error.
[h] Omitted because the calibration did not meet the standard for mean error.

Table C-5. Somerville Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
SCT10R	3.480	26.716	95.87	0.999	**4.578***	0.282	-0.695	0.990	11.171	0.89
SCT12P	2.955	14.685	97.85	0.996	**7.153***	0.083	-0.537	0.985	12.742	1.04
SCT49L[i]	2.349	32.811	96.01	0.996	11.540	0.085	-0.580	0.999	**4.250***	-
SCT52P	2.838	15.683	97.81	0.999	**3.236***	0.118	-0.336	0.999	3.434	1.04
SCT59L[j]	3.910	99.230	97.97	0.991	14.755	0.082	-0.521	0.995	12.172	-
SCT84R	3.313	7.076	97.40	0.996	5.565	0.064	-0.369	0.995	**5.188***	1.06
SCT85P[k]	2.475	23.082	97.07	0.997	**4.342***	0.022	-0.326	0.998	4.292	1.34
SCT88L	2.694	21.788	97.96	0.998	2.648	0.046	-0.307	0.995	**3.684***	0.86
SCT95R	2.383	22.211	98.21	0.997	2.781	0.035	-0.263	0.998	**2.794***	1.05

[i] Omitted because the predicted WSELs exceeded the measured WSELs by more than 0.1 ft.
[j] Omitted because the calibration did not meet the standard for mean error.
[k] Omitted because the calibration VAF exceeded the standard of 1.25.

Table C-6. Miller Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
MCT17L	2.733	33.422	97.19	0.997	**9.910***	0.050	-0.169	0.995	13.973	1.02
MCT21R	2.259	26.724	97.91	1.000	3.076	0.073	-0.181	0.999	**6.281***	0.97
MCT27P[l]	1.413	45.875	94.23	0.997	13.604	0.006	0.198	0.997	13.499	-
MCT59P	3.293	4.113	95.99	0.997	**6.157***	0.252	-0.422	0.998	5.403	1.00
MCT60R[m]	3.546	3.818	94.68	0.992	14.470	0.037	-0.293	0.993	13.079	-
MCT92P	3.106	14.660	97.22	1.000	**2.260***	0.102	-0.461	1.000	1.979	1.11
MCT112L[n]	-	-	-	-	-	-	-	-	-	-
MCT133R	2.757	14.427	95.84	0.999	5.695	0.090	-0.430	1.000	**0.750***	1.19
MCT137L	2.823	46.743	95.62	1.000	2.231	0.067	-0.152	0.999	**4.006***	0.93

[l] Omitted because the calibration did not meet the standard for mean error.
[m] Omitted because the calibration did not meet the standard for mean error.
[n] Omitted because the calibration did not meet the standard for mean error.

Table C-7. Lower China Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
LCT2L	2.449	67.046	98.05	0.998	4.917	0.072	-0.356	0.995	**6.722***	0.85
LCT22P	2.429	17.566	96.27	0.998	**4.768***	0.032	-0.231	0.998	4.598	1.02
LCT32L	2.858	64.558	97.19	1.000	1.089	0.048	-0.387	1.000	**0.086***	0.92
LCT38P[o]	2.652	19.191	98.71	1.000	**1.440***	0.069	-0.358	1.000	1.705	0.91
LCT52R	3.287	20.508	97.85	1.000	0.195	0.065	-0.188	1.000	**0.147***	1.01
LCT69R[p]	2.105	19.274	95.57	0.999	2.637	0.061	-0.029	0.999	**2.240***	1.96
LCT138R[q]	2.283	9.095	97.04	0.997	10.457	0.018	-0.164	0.995	24.483	-
LCT140L	3.281	31.725	97.26	0.997	7.350	0.019	-0.212	0.997	**8.336***	1.01
LCT150P[r]	2.828	34.266	98.50	1.000	**1.644***	0.041	-0.387	1.000	1.243	0.90

[o] Omitted because the simulated VAF range exceeded 5.0 within the simulation range of the remaining transects.
[p] Omitted because the calibration VAF exceeded the standard of 1.25.
[q] Omitted because the calibration did not meet the guidance criteria for mean error and the calibration VAF exceeded the standard of 1.25.
[r] Velocity simulation range was limited to 48.5 cfs. LCT150P can only be used for juvenile rearing and not adult spawning.

Table C-8. Upper China Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ. UC6L, UC15G, UC57P, UC63P, and UC64L were omitted because the calibration did not meet the standard for mean error. The omitted transect calibration results could not be reported by SEFA due to the severity of the errors.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
UCT13P	2.780	27.863	98.39	1.000	**0.658***	0.010	-0.365	1.000	0.541	0.80
UCT16R[s]	4.994	35.050	97.66	0.968	8.185	0.045	-0.476	0.965	10.283	-
UCT35R	2.924	8.849	97.08	0.998	2.136	0.039	-0.303	0.998	**2.201***	1.21
UCT40G	1.603	14.748	98.44	0.994	4.331	0.056	-0.231	1.000	**0.754***	0.83
UCT43R	2.022	11.135	96.96	0.994	4.340	0.059	-0.062	0.994	**6.261***	0.76
UCT52L	2.307	12.513	96.74	0.989	6.008	0.039	-0.250	0.990	**6.092***	0.90
UCT72G	3.957	45.693	98.85	0.969	13.188	0.042	-0.512	0.971	**10.197***	1.07

[s] Omitted because the hydraulic calibrations cross below the critical flow level at approximately 10 cfs.

Table C-9. North Fork China Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by transect. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Transect	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
NFCT7R	2.309	22.198	95.82	1.000	1.664	0.107	-0.373	0.996	**6.705***	1.14
NFCT8P	2.182	13.464	97.31	0.999	**4.480***	0.064	-0.455	0.999	4.685	1.15
NFCT16L	1.927	22.724	96.93	0.999	3.982	0.059	-0.090	0.996	**6.349***	1.06
NFCT25L	3.750	72.457	95.17	1.000	0.004	0.055	-0.458	1.000	**0.337***	1.20
NFCT27R[t]	2.967	14.380	96.53	1.000	1.231	0.043	-0.065	1.000	**1.818***	1.27
NFCT40R[u]	3.464	18.304	96.59	0.936	26.972	0.055	-0.391	0.955	22.580	-
NFCT56P[v]	0.205	3.825	95.11	0.002	126.679	0.104	-0.950	1.000	679128231	-
NFCT57P[w]	3.340	14.503	97.94	0.922	35.932	0.208	-0.691	0.920	30.731	-
NFCT58L	2.810	10.835	98.67	1.000	0.894	0.114	-0.419	0.998	**2.684***	0.97

[t] Omitted because the calibration VAF exceeded the standard of 1.25.
[u] Omitted because the calibration did not meet the standard for mean error.
[v] Omitted because the calibration did not meet the standard for mean error.
[w] Omitted because the calibration did not meet the standard for mean error.

Table C-10. Dinner Creek SEFA outputs comparing SZF rating (log-log regression) with hydraulic rating (MANSQ) by cross section. An asterisk (*) by the bolded mean error signifies which WSEL/flow rating utility was chosen, log-log regression or MANSQ.

Cross section	SZF rating exp	SZF rating A	SZF rating SZF	SZF rating R	SZF rating mean error	Hydraulic rating A	Hydraulic rating beta	Hydraulic rating R	Hydraulic rating mean error	VAF of chosen utility
DT7L	2.117	23.015	98.40	0.998	**5.727***	0.060	-0.228	0.990	10.690	0.87
DT13L[x]	2.393	5.996	97.49	0.993	8.700	0.031	0.092	0.990	9.487	-
DT14P[y]	3.558	3.430	97.77	1.000	**0.482***	-	-	-	-	-
DT15R	2.996	11.860	96.50	0.998	3.979	0.070	-0.429	0.998	**5.251***	1.11
DT17G	2.894	19.139	93.29	0.999	2.366	0.012	-0.365	1.000	**1.245***	1.13
DT20P[z]	2.767	15.326	96.64	0.980	24.503	0.083	-0.326	0.975	20.225	-
DT21G	2.175	33.648	97.05	0.999	**3.686***	0.026	-0.415	0.992	11.219	1.01
DT28P	2.399	8.885	96.68	0.999	**2.365***	0.039	-0.286	0.999	1.914	0.91
DT37R	2.623	7.487	94.90	0.999	6.101	0.053	-0.372	1.000	**1.078***	1.01
DT45R	1.410	15.699	97.49	1.000	1.340	0.103	0.472	0.999	**5.414***	1.03
DT46L[aa]	1.964	24.873	98.00	0.996	6.638	0.033	-0.477	0.997	**8.149***	1.43
DT48G[bb]	2.763	18.433	97.89	0.990	17.769	0.036	-0.414	0.986	17.365	-

[x] Omitted because the magnitude of the gage VDFs were beyond the guidance limits.
[y] *Best SZF* utility was used to predict simulated stage-discharges.
[z] Omitted because the calibration did not meet the standard for mean error.
[aa] Omitted because the calibration VAF exceeded the standard of 1.25.
[bb] Omitted because the calibration did not meet the standard for mean error.

APPENDIX D: CALIBRATION FLOWS AND WATER SURFACE ELEVATIONS

The maximum allowable variance between measured and predicted WSELs was 0.1 ft. Transects that failed the WSEL standard are indicated by strikethrough in the tables. Transects that met the WSEL standard but failed the Calibration VAF standard or the VAF velocity simulation standard are also indicated by strikethrough and were subsequently omitted.

Table D-1. Lower Redwood Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
LRT16L	3.4	94.68	94.67	0.01
LRT16L	9.5	94.90	94.91	0.01
LRT16L	16.1	95.05	95.05	0.00
LRT16L	132.8	96.11	96.09	0.02
LRT26P	3.4	96.56	96.56	0.00
LRT26P	9.5	96.83	96.84	0.01
LRT26P	16.1	97.05	97.04	0.01
LRT31R	3.4	95.82	95.81	0.01
LRT31R	9.5	96.00	96.05	0.05
LRT31R	16.1	96.15	96.15	0.00
LRT62G	2.9	97.26	97.27	0.01
LRT62G	7.7	97.44	97.42	0.02
LRT62G	13.9	97.58	97.58	0.00
LRT64G	2.9	97.85	97.87	0.02
LRT64G	7.7	98.07	98.07	0.00
LRT64G	13.9	98.25	98.25	0.00
LRT64G	107.4	99.32	99.42	0.10
LRT65R	2.9	97.18	97.15	0.03
LRT65R	7.7	97.33	97.34	0.01
LRT65R	13.9	97.44	97.51	0.07
LRT65R	30.7	97.62	97.62	0.00
LRT76P	2.9	98.34	98.34	0.00
LRT76P	7.5	98.57	98.57	0.00
LRT76P	13.7	98.75	98.75	0.00
LRT77L	2.9	98.41	98.43	0.02
LRT77L	7.5	98.59	98.57	0.02
LRT77L	13.7	98.73	98.72	0.01
LRT77L	81.1	99.37	99.39	0.02
LRT78P	2.9	95.93	95.93	0.00
LRT78P	7.5	96.21	96.22	0.01
LRT78P	16.3	96.53	96.53	0.00

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
LRT78P	81.1	97.53	97.52	0.01
LRT81G	2.9	96.80	96.80	0.00
LRT81G	7.5	96.97	96.99	0.02
LRT81G	16.3	97.19	97.19	0.00
LRT81G	81.1	98.15	98.10	0.05
LRT88L	2.6	96.40	96.39	0.01
LRT88L	7.2	96.56	96.59	0.03
LRT88L	11.0	96.64	96.64	0.00
LRT91R	2.6	96.70	96.70	0.00
LRT91R	7.2	96.92	96.89	0.03
LRT91R	11.0	97.03	97.03	0.00

Table D-2. Middle Redwood Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
MRT129L	2.3	96.07	96.05	0.02
MRT129L	10.4	96.43	96.36	0.07
MRT129L	28.8	96.75	96.75	0.00
MRT134P	2.3	95.10	95.09	0.01
MRT134P	10.4	95.52	95.53	0.01
MRT134P	28.8	95.93	95.91	0.02
MRT140R	2.3	97.78	97.78	0.00
MRT140R	10.4	98.15	98.14	0.01
MRT140R	28.0	98.61	98.62	0.01
MRT144R	2.3	93.59	93.60	0.01
MRT144R	7.1	93.89	93.85	0.04
MRT144R	28.0	94.47	94.47	0.00
MRT149P	2.3	95.12	95.12	0.00
MRT149P	7.1	95.29	95.29	0.00
MRT149P	28.0	95.77	95.77	0.00
MRT178L	2.5	97.02	97.01	0.01
MRT178L	6.0	97.14	97.15	0.01
MRT178L	23.5	97.45	97.44	0.01
MRT179G	2.5	96.94	96.96	0.02
MRT179G	5.8	97.11	97.07	0.04
MRT179G	23.5	97.50	97.50	0.00
MRT275R	1.1	95.43	95.43	0.00
MRT275R	11.2	95.91	95.85	0.06
MRT275R	24.5	96.19	96.24	0.05
MRT286L	1.1	96.01	95.97	0.04
MRT286L	2.3	96.10	96.04	0.05
MRT286L	24.5	96.58	96.58	0.00
MRT342G	10.1	98.12	98.11	0.01
MRT342G	28.6	98.56	98.62	0.06
MRT342G	42.0	98.76	98.76	0.00

Table D-3. Upper Redwood Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
URT25R	0.5	97.99	97.91	0.08
URT25R	14.5	98.56	98.56	0.00
URT25R	26.6	98.80	98.79	0.01
URT43L	0.4	96.06	96.07	0.01
URT43L	3.0	96.22	96.19	0.03
URT43L	13.0	96.42	96.42	0.00
URT43L	21.3	96.51	96.52	0.01
URT46P	0.4	97.92	97.92	0.00
URT46P	13.0	98.42	98.40	0.02
URT46P	21.3	98.51	98.53	0.02
URT53R	0.4	96.78	96.74	0.04
URT53R	3.0	97.02	96.95	0.07
URT53R	13.8	97.32	97.32	0.00
URT53R	21.2	97.48	97.46	0.02
URT92L	3.0	98.37	98.37	0.00
URT92L	13.3	98.72	98.71	0.01
URT92L	21.4	98.88	98.89	0.01
URT108R	0.8	96.70	96.70	0.00
URT108R	2.5	96.83	96.82	0.01
URT108R	12.5	97.15	97.15	0.00
URT108R	18.6	97.26	97.28	0.02
URT109P	0.8	94.67	94.68	0.01
URT109P	12.5	95.16	95.14	0.02
URT109P	18.6	95.25	95.26	0.01

Table D-4. Seely Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
ST8R	1.3	96.61	96.60	0.01
ST8R	5.5	96.82	96.82	0.00
ST8R	27.5	97.22	97.22	0.00
ST16L	1.2	93.88	93.89	0.01
ST16L	2.5	93.92	93.92	0.00
ST16L	6.9	93.99	93.99	0.00
ST19P	1.2	99.25	99.26	0.01
ST19P	2.5	99.37	99.35	0.02
ST19P	6.9	99.60	99.64	0.04
ST19P	26.2	100.09	100.06	0.03
ST23G	1.2	97.88	97.87	0.00
ST23G	2.5	97.99	97.94	0.05
ST23G	6.9	98.21	98.21	0.00
ST23G	26.2	98.71	98.68	0.03
ST27P	1.2	97.22	97.23	0.01
ST27P	2.5	97.35	97.33	0.02
ST27P	6.9	97.64	97.65	0.01
ST29L	1.2	96.10	96.04	0.06
ST29L	2.5	96.15	96.11	0.04
ST29L	6.9	96.19	96.19	0.00
ST33L	1.2	97.22	97.23	0.01
ST33L	2.5	97.31	97.31	0.00
ST33L	6.9	97.46	97.46	0.00
ST33L	26.2	97.75	97.78	0.03
ST46R	1.2	98.44	98.41	0.03
ST46R	2.3	98.49	98.46	0.03
ST46R	8.6	98.61	98.61	0.00
ST46R	25.3	98.69	98.78	0.09
ST49P	1.2	97.24	97.24	0.00
ST49P	2.3	97.33	97.32	0.01
ST49P	8.6	97.62	97.66	0.04
ST49P	25.3	98.02	97.98	0.04

Table D-5. Somerville Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
SCT10R	0.7	96.22	96.23	0.01
SCT10R	2.3	96.36	96.36	0.00
SCT10R	3.4	96.42	96.41	0.01
SCT10R	19.5	96.78	96.79	0.01
SCT12P	0.7	98.21	98.21	0.00
SCT12P	2.3	98.38	98.39	0.01
SCT12P	3.4	98.46	98.43	0.03
SCT12P	19.5	98.95	98.97	0.02
SCT52P	0.7	98.15	98.14	0.01
SCT52P	2.3	98.32	98.33	0.01
SCT52P	3.2	98.38	98.37	0.01
SCT52P	19.5	98.89	98.89	0.00
SCT84R	1.0	97.96	97.96	0.00
SCT84R	2.3	98.12	98.12	0.00
SCT84R	3.1	98.19	98.15	0.04
SCT84R	12.6	98.60	98.60	0.00
SCT88L	2.0	98.43	98.37	0.06
SCT88L	8.9	98.73	98.67	0.06
SCT88L	12.1	98.77	98.77	0.00
SCT95R	2.0	98.59	98.63	0.04
SCT95R	8.9	98.89	98.90	0.01
SCT95R	12.1	98.97	98.97	0.00

Table D-6. Miller Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
MCT17L	1.2	97.49	97.48	0.01
MCT17L	3.6	97.63	97.66	0.03
MCT17L	32.0	98.17	98.15	0.02
MCT21R	1.2	98.19	98.17	0.02
MCT21R	3.6	98.36	98.31	0.05
MCT21R	32.0	99.00	99.00	0.00
MCT59P	2.9	96.89	96.91	0.02
MCT59P	5.3	97.07	97.04	0.03
MCT59P	28.5	97.79	97.80	0.01
MCT92P	1.2	97.67	97.66	0.01
MCT92P	2.9	97.81	97.82	0.01
MCT92P	30.1	98.48	98.48	0.00
MCT133R	1.1	96.30	96.22	0.08
MCT133R	2.7	96.46	96.40	0.06
MCT133R	4.6	96.57	96.51	0.06
MCT133R	27.7	97.09	97.09	0.00
MCT137L	1.1	95.89	95.89	0.00
MCT137L	2.7	95.98	95.98	0.00
MCT137L	4.6	96.05	96.07	0.02
MCT137L	22.9	96.39	96.39	0.00

Table D-7. Lower China Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
LCT2L	1.6	98.31	98.27	0.04
LCT2L	4.1	98.42	98.36	0.06
LCT2L	17.7	98.64	98.64	0.00
LCT22P	1.6	96.64	96.65	0.01
LCT22P	4.1	96.82	96.80	0.02
LCT22P	15.1	97.21	97.22	0.01
LCT32L	1.6	97.49	97.46	0.03
LCT32L	4.1	97.59	97.57	0.02
LCT32L	15.1	97.79	97.79	0.00
LCT52R	1.6	98.31	98.31	0.00
LCT52R	4.1	98.46	98.46	0.00
LCT52R	16.9	98.79	98.79	0.00
LCT140L	2.7	97.76	97.72	0.04
LCT140L	4.0	97.81	97.81	0.00
LCT140L	33.6	98.24	98.27	0.03
LCT150P	1.4	98.82	98.82	0.00
LCT150P	2.7	98.91	98.91	0.00
LCT150P	4.0	98.97	98.97	0.00
LCT150P	33.6	99.49	99.49	0.00

Table D-8. Upper China Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
UCT13P	1.5	98.74	98.74	0.00
UCT13P	3.8	98.88	98.88	0.00
UCT13P	5.8	98.96	98.96	0.00
UCT35R	1.5	97.63	97.62	0.01
UCT35R	3.6	97.81	97.82	0.01
UCT35R	5.5	97.92	97.92	0.00
UCT40G	1.5	98.78	98.68	0.10
UCT40G	3.8	98.97	98.89	0.08
UCT40G	7.7	99.09	99.09	0.00
UCT43R	1.5	97.35	97.33	0.02
UCT43R	3.8	97.55	97.57	0.02
UCT43R	7.7	97.78	97.78	0.00
UCT52L	1.5	97.16	97.13	0.03
UCT52L	3.8	97.34	97.36	0.02
UCT52L	7.7	97.53	97.53	0.00
UCT72G	1.1	99.25	99.25	0.00
UCT72G	4.1	99.41	99.37	0.04
UCT72G	8.3	99.52	99.52	0.00

Table D-9. North Fork China Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
NFCT7R	6.2	96.54	96.53	0.01
NFCT7R	7.3	96.58	96.59	0.01
NFCT7R	9.8	96.65	96.64	0.01
NFCT8P	0.4	97.51	97.51	0.00
NFCT8P	1.8	97.71	97.72	0.01
NFCT8P	8.8	98.13	98.12	0.01
NFCT16L	0.4	97.07	97.06	0.01
NFCT16L	1.8	97.23	97.19	0.04
NFCT16L	8.8	97.55	97.55	0.00
NFCT25L	0.4	95.42	95.42	0.00
NFCT25L	1.8	95.55	95.54	0.01
NFCT25L	8.8	95.74	95.74	0.00
NFCT58L	1.4	99.22	99.15	0.07
NFCT58L	8.6	99.66	99.59	0.07
NFCT58L	14.5	99.78	99.78	0.00

Table D-10. Dinner Creek calibration flows and WSELs for each transect.

Transect	Flow (cfs)	SEFA WSEL (ft)	Field WSEL (ft)	(+/-)
DT7L	0.5	98.56	98.55	0.01
DT7L	2.4	98.74	98.73	0.01
DT7L	10.7	99.10	99.11	0.01
DT14P	0.5	98.36	98.35	0.01
DT14P	2.4	98.62	98.67	0.05
DT14P	15.5	99.37	99.30	0.07
DT15R	0.5	96.89	96.85	0.04
DT15R	2.4	97.13	97.08	0.05
DT15R	9.0	97.44	97.43	0.01
DT15R	15.5	97.58	97.58	0.00
DT17G	0.5	93.60	93.57	0.03
DT17G	9.0	94.08	94.07	0.01
DT17G	15.5	94.21	94.21	0.00
DT21G	0.5	97.19	97.20	0.01
DT21G	2.4	97.35	97.34	0.01
DT21G	9.0	97.60	97.59	0.01
DT21G	15.5	97.75	97.76	0.01
DT28P	0.5	96.98	96.98	0.00
DT28P	2.3	97.25	97.26	0.01
DT28P	9.0	97.69	97.67	0.02
DT28P	16.3	97.97	97.98	0.01
DT37R	0.5	95.33	95.25	0.08
DT37R	2.3	95.62	95.56	0.06
DT37R	16.3	96.22	96.22	0.00
DT45R	0.5	97.58	97.58	0.00
DT45R	2.3	97.72	97.74	0.02
DT45R	16.3	98.52	98.52	0.00

APPENDIX E: TRANSECT VELOCITY PROFILES

The following figures present the predicted discharge-WSEL pairs and velocity profiles for each transect. The predicted discharge-WSEL pairs and velocity profiles were plotted over a range of flows. Each of the figures contains a layered plot with the transect length coordinates (Offset (ft)) on the x-axis, water level (ft) on the upper y-axis, and velocity (ft/s) on the lower y-axis. The thicker black lines represent the survey flow (the reference discharge-WSEL pair) used to predict WSEL and velocity within SEFA. The upper half of each figure shows the transect profile with a horizontal line representing the water level of each simulated flow, including the survey flow. The filled-in blue area represents water below the survey flow. The lower half of each figure is the velocity profile for each flow simulated to compute AWS, including the survey flow (thicker black line). Please refer to Section *2.3.5 Discharge Simulation Range* and Section *2.3.6 Water Velocity Prediction* for further details about discharge-WSEL and velocity prediction.

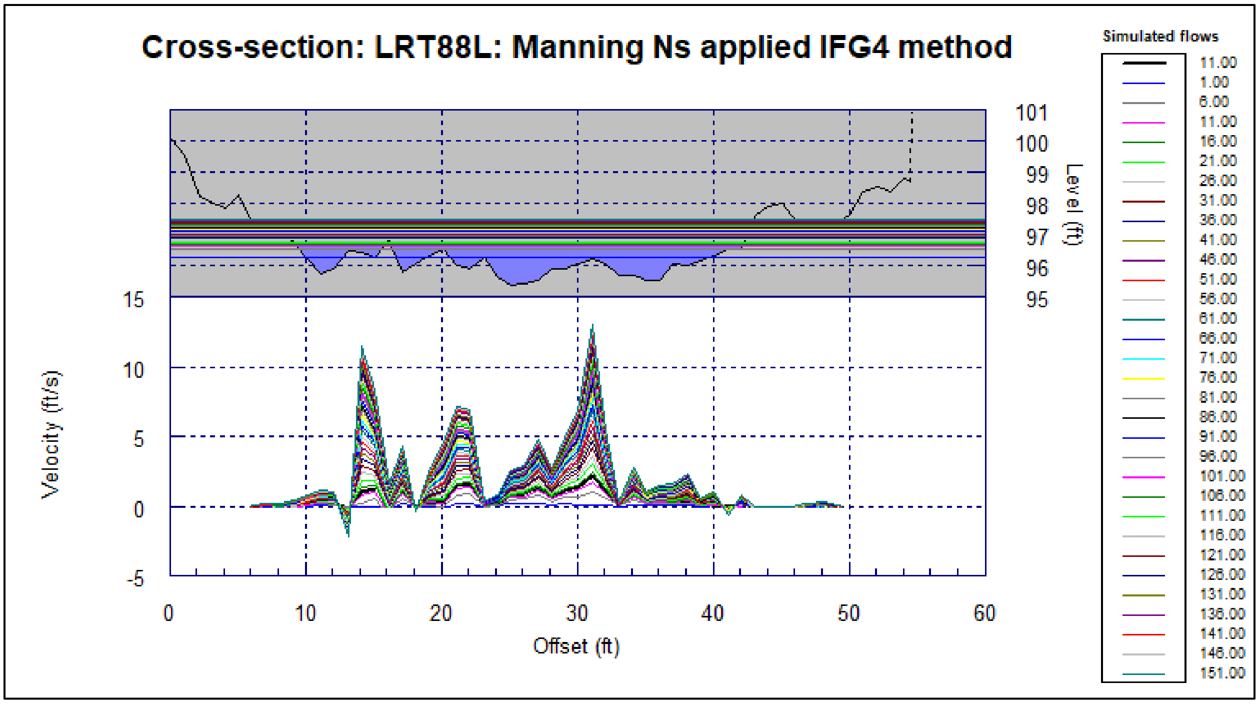

Figure E-1. Lower Redwood Creek cross-section LRT88L before VDF modification at simulated flows ranging from 1 cfs to 151 cfs.

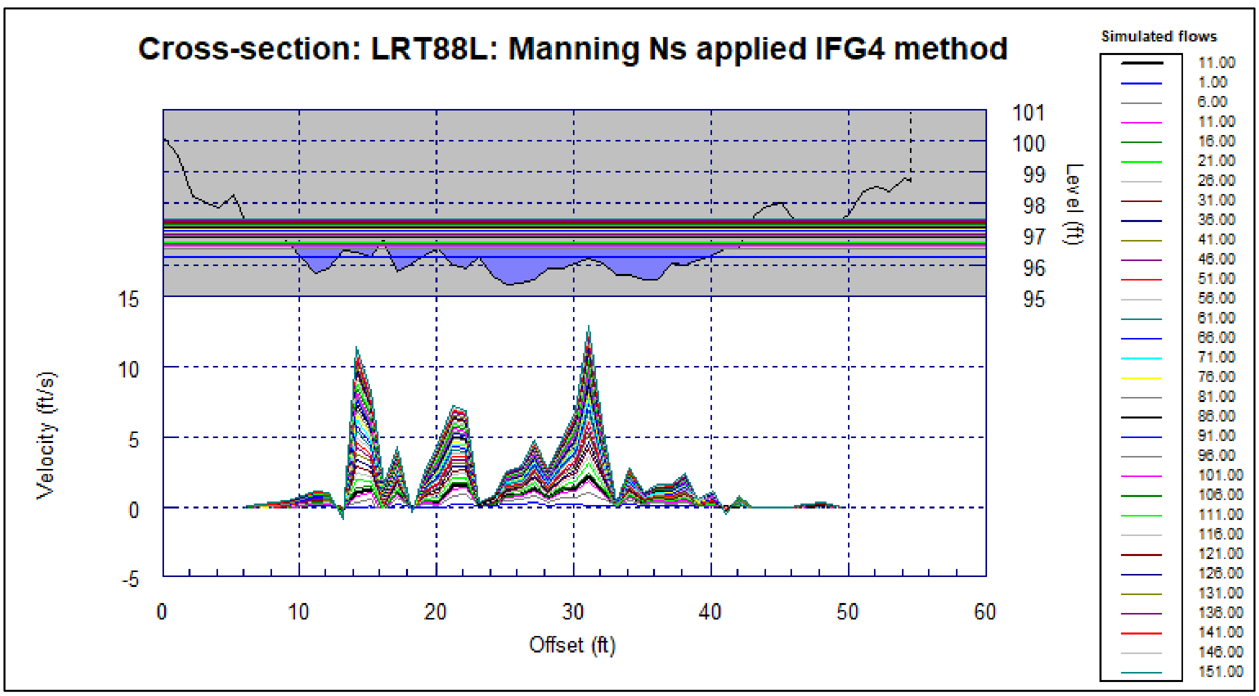

Figure E-2. Lower Redwood Creek cross-section LRT88L after VDF modification at simulated flows ranging from 1 cfs to 151 cfs.

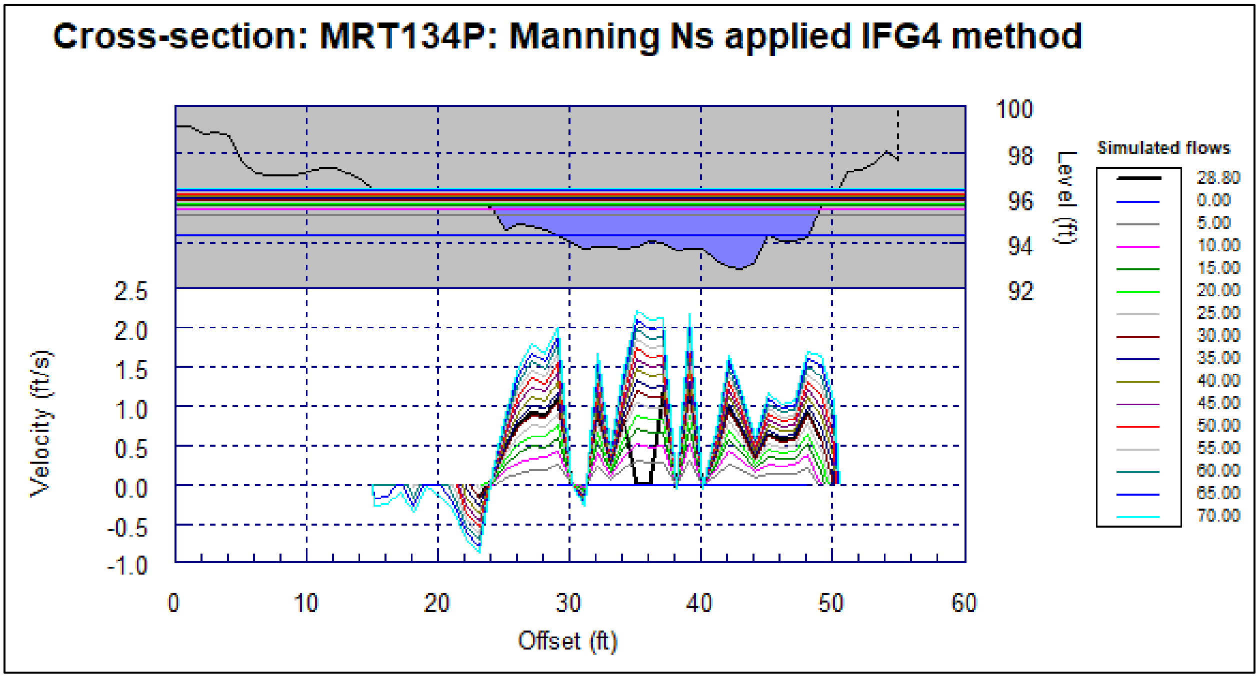

Figure E-3. Middle Redwood Creek cross-section MRT134P before VDF modification at simulated flows ranging from 0 cfs to 70 cfs.

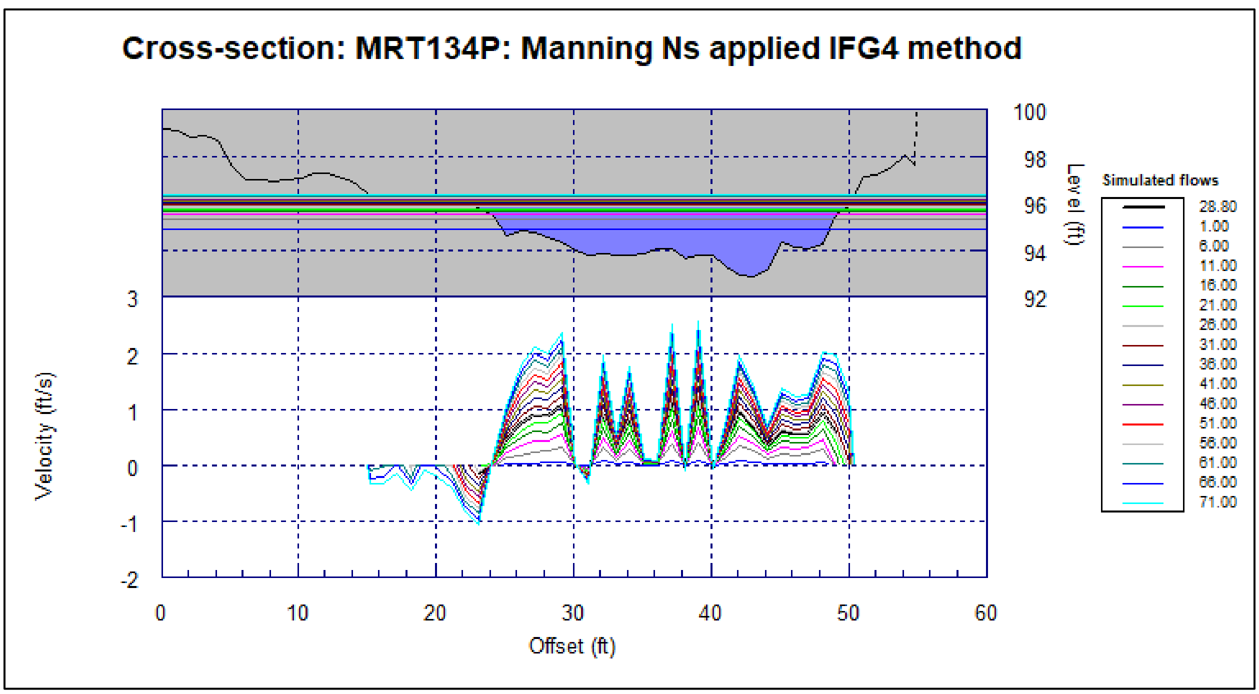

Figure E-4. Middle Redwood Creek cross-section MRT134P after VDF modification at simulated flows ranging from 1 cfs to 71 cfs.

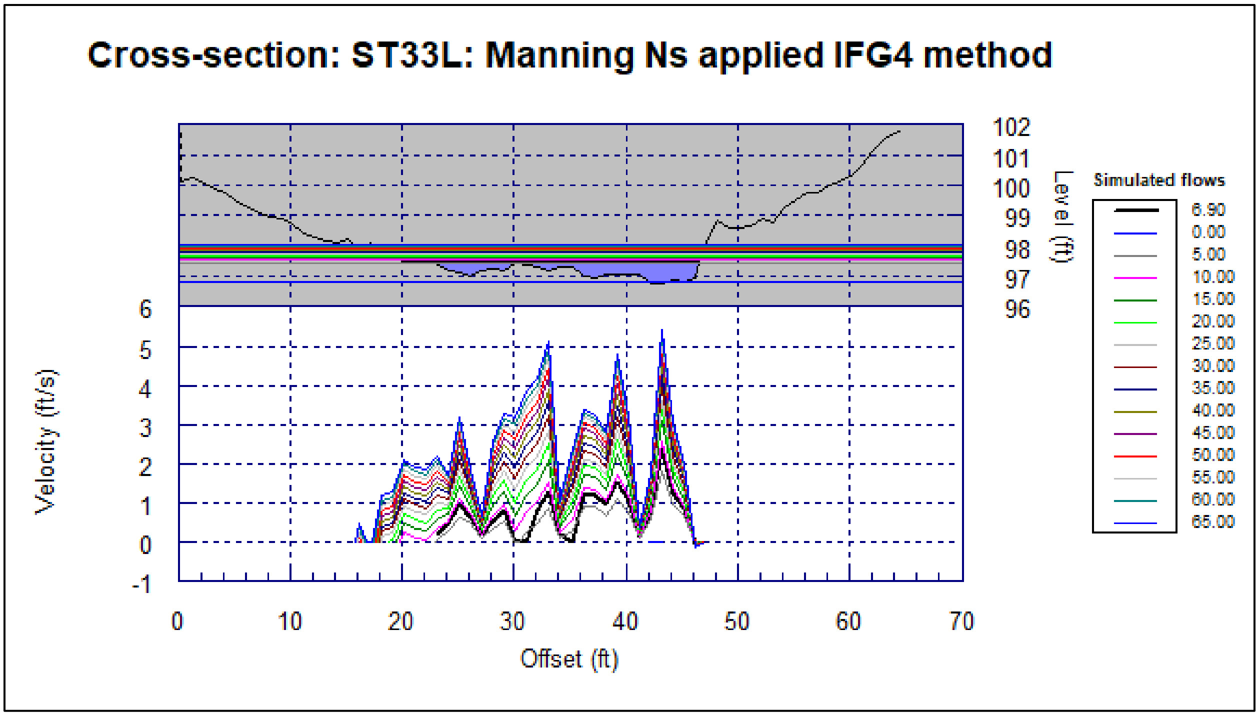

Figure E-5. Seely Creek cross-section ST33L before VDF modification at simulated flows ranging from 0 cfs to 65 cfs.

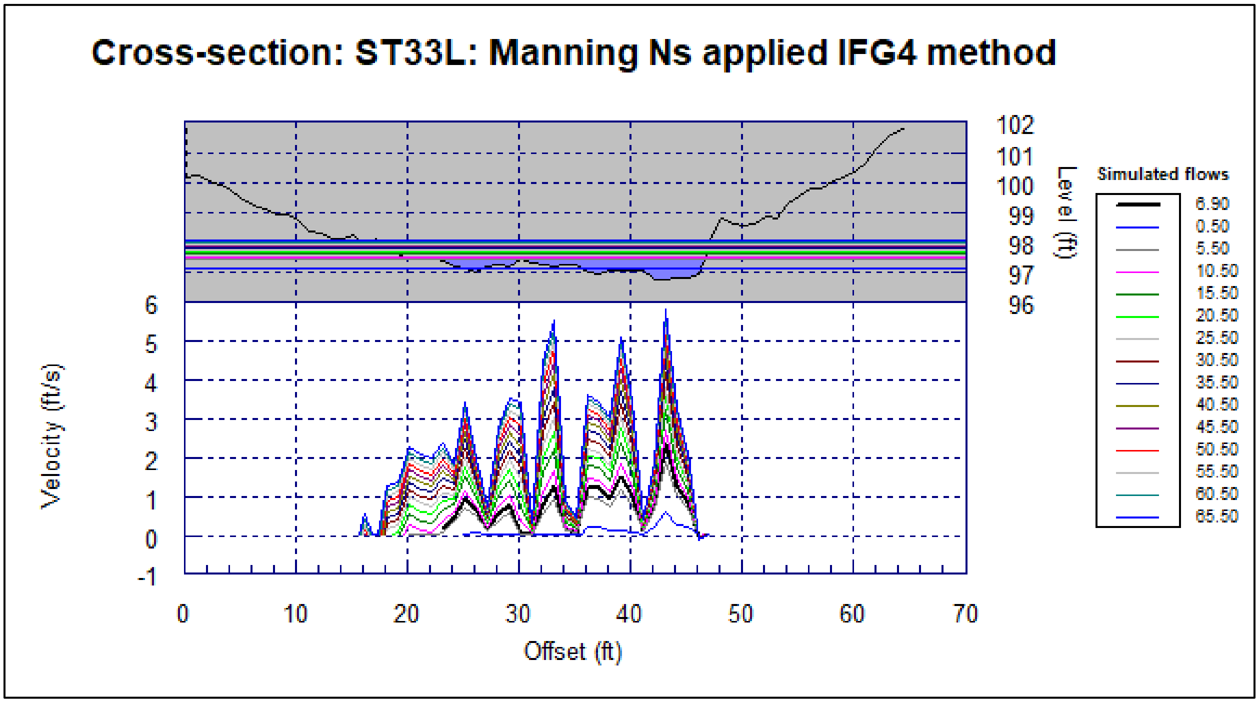

Figure E-6. Seely Creek cross-section ST33L after VDF modification at simulated flows ranging from 0.5 cfs to 65.5 cfs.

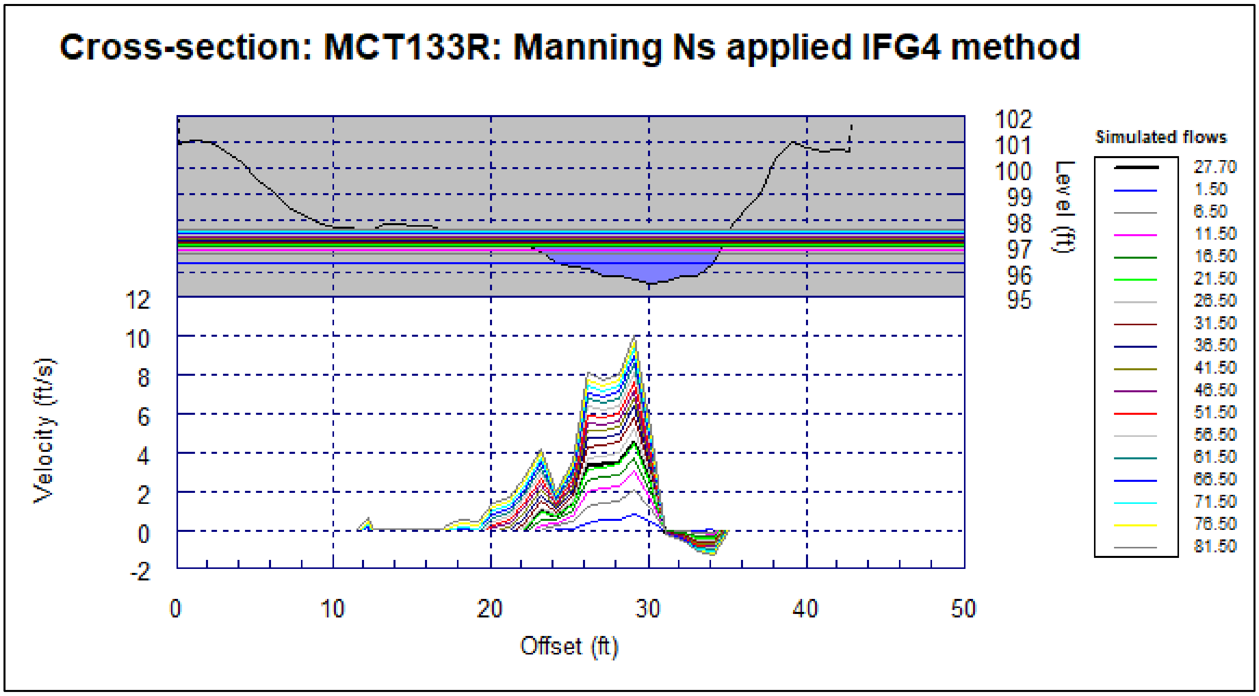

Figure E-7. Miller Creek cross-section MCT133R before VDF modification at simulated flows ranging from 1.5 cfs to 81.5 cfs.

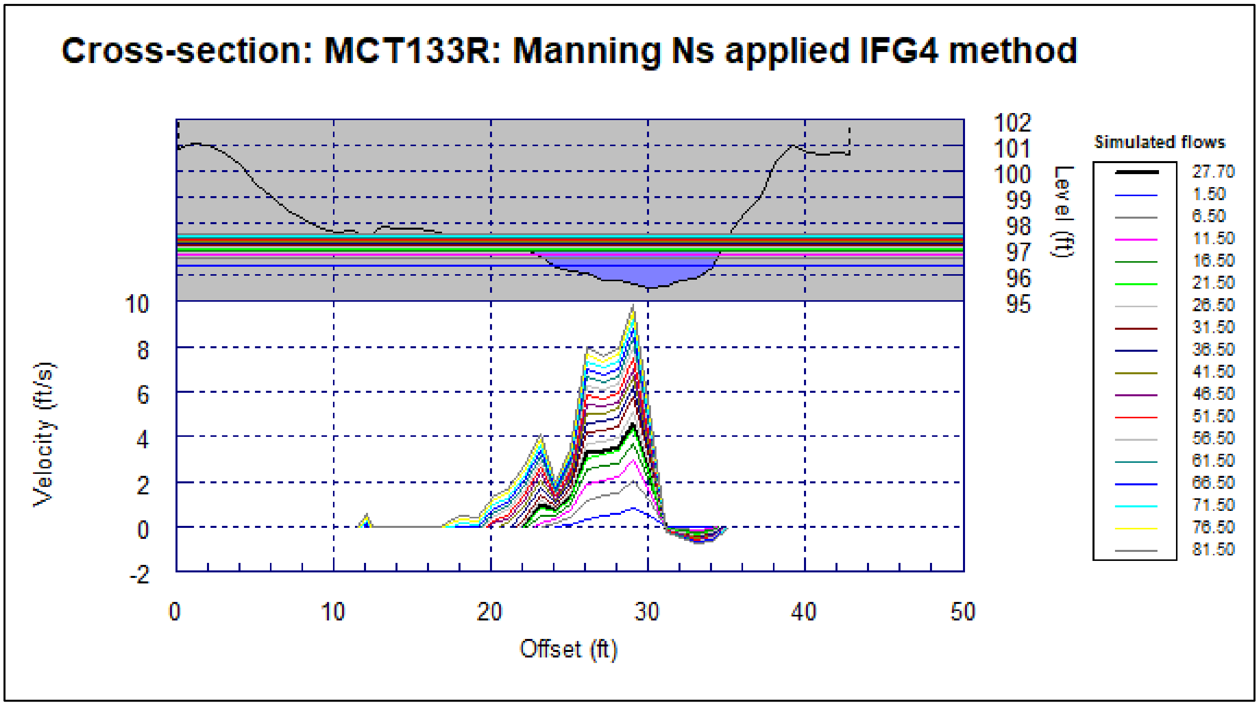

Figure E-8. Miller Creek cross-section MCT133R after VDF modification at simulated flows ranging from 1.5 cfs to 81.5 cfs.

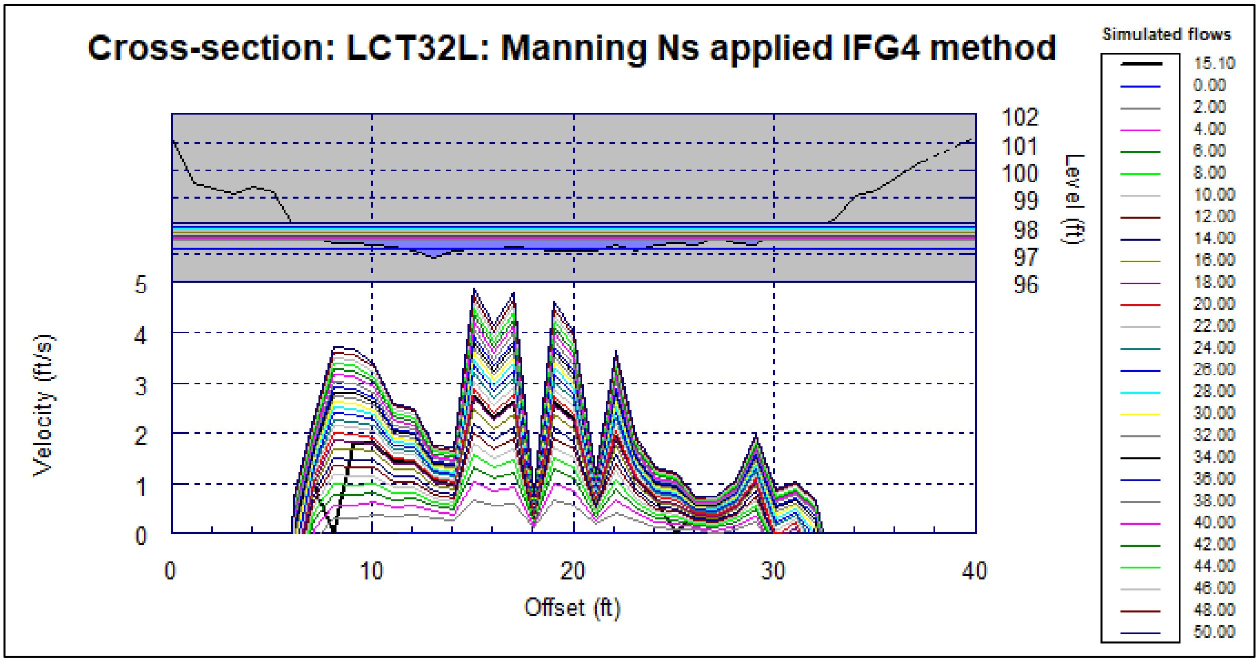

Figure E-9. Lower China Creek cross-section LCT32L before VDF modification at simulated flows ranging from 0 cfs to 50 cfs.

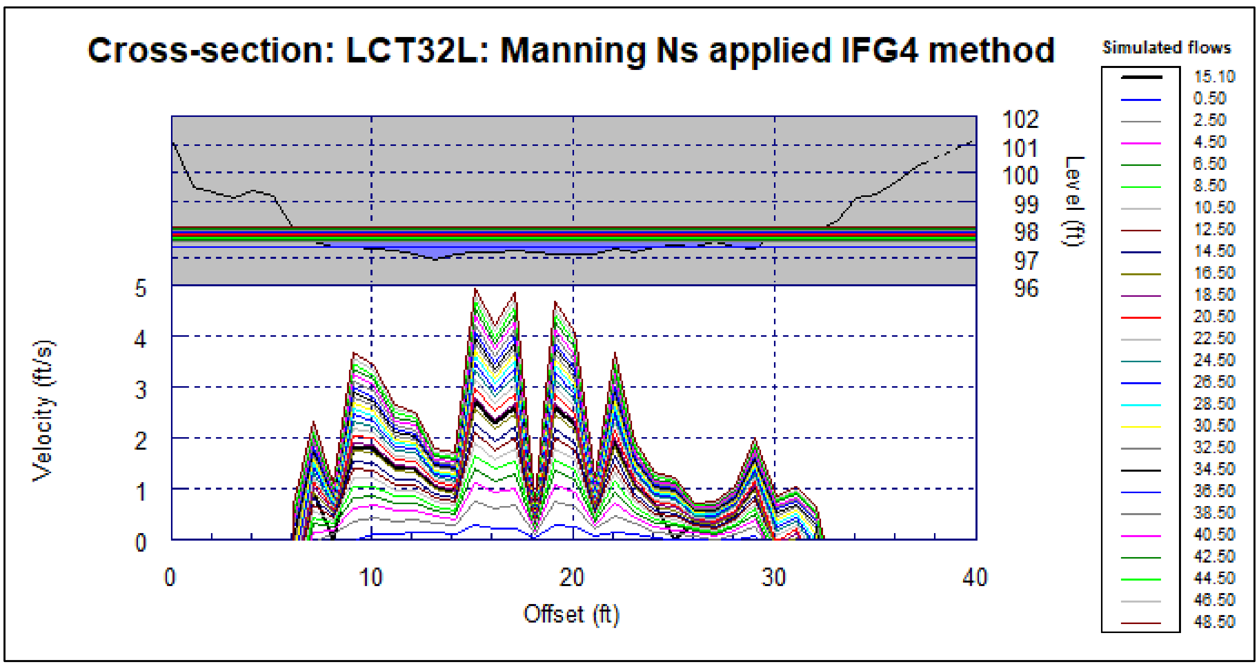

Figure E-10. Lower China Creek cross-section LCT32L after VDF modification at simulated flows ranging from 0.5 cfs to 48.5 cfs.

APPENDIX F: VELOCITY SIMULATION VELOCITY ADJUSTMENT FACTORS

The standard variance for velocity simulation VAFs is 0.1 to 5.0. The results for each reach were plotted, with discharge on the x-axis and VAF on the y-axis. The range of simulated flows was modified slightly from 0.4 times the lowest measured reach discharge to 2.5 times the highest measured reach discharge to ensure that velocity simulation VAF fell within the guidance standard.

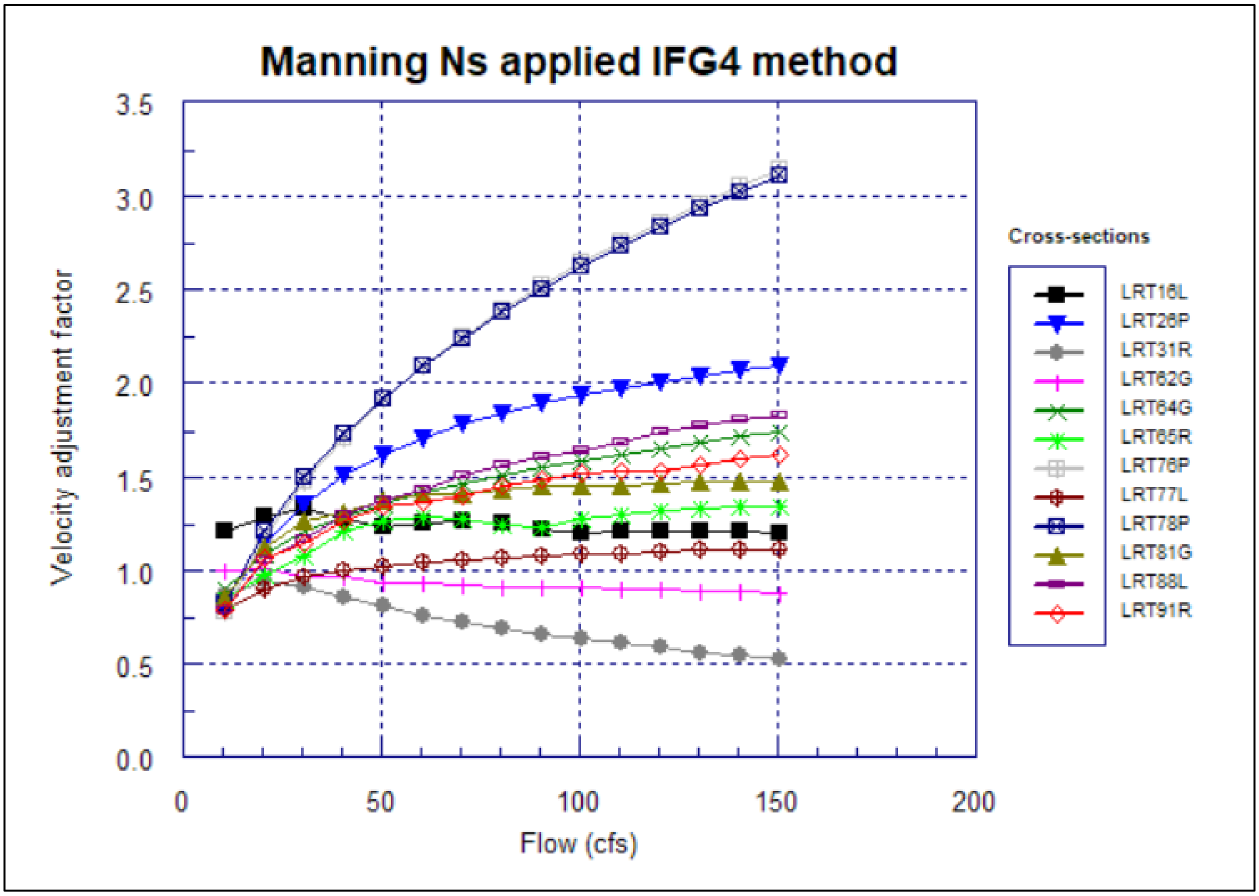

Figure F-1. Velocity simulation VAFs by discharge in Lower Redwood Creek.

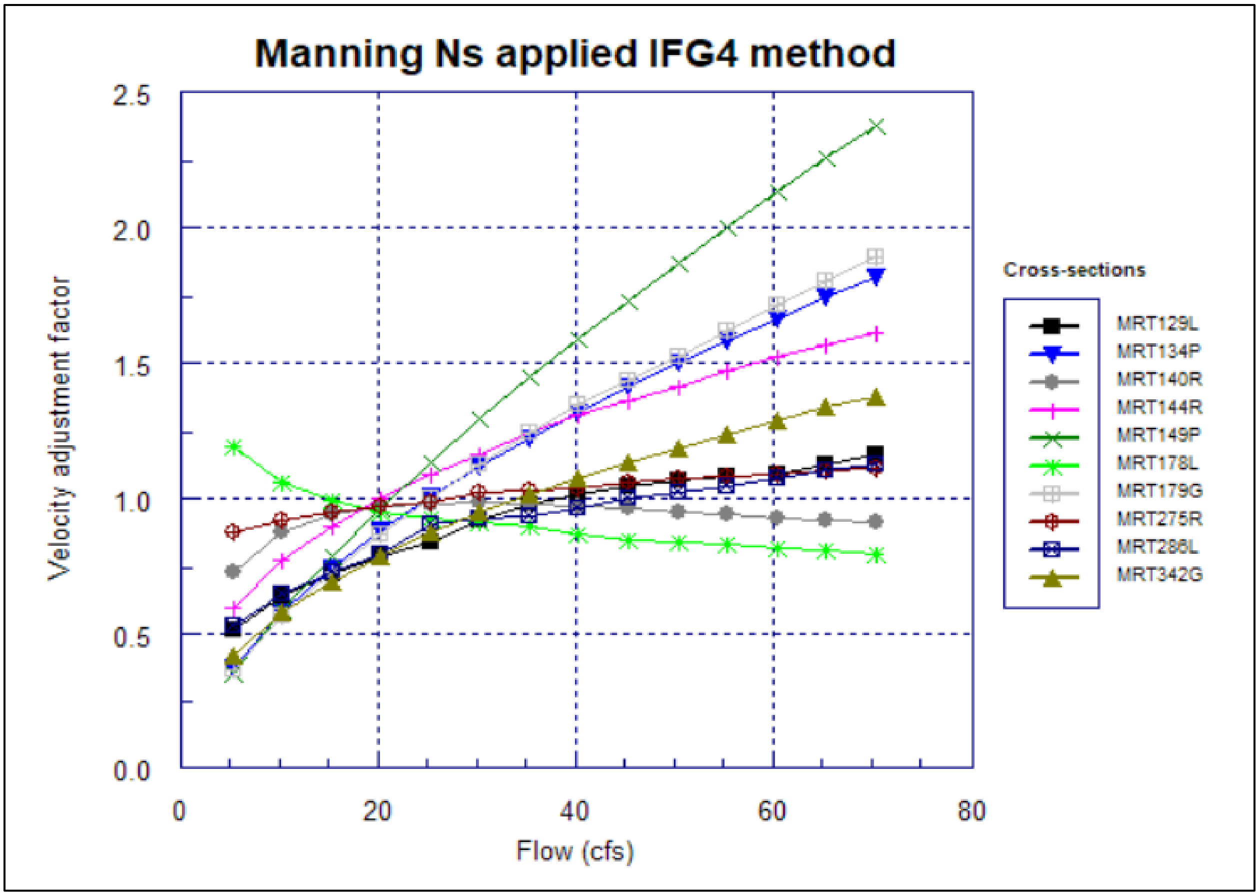

Figure F-2. Velocity simulation VAFs by discharge in Middle Redwood Creek.

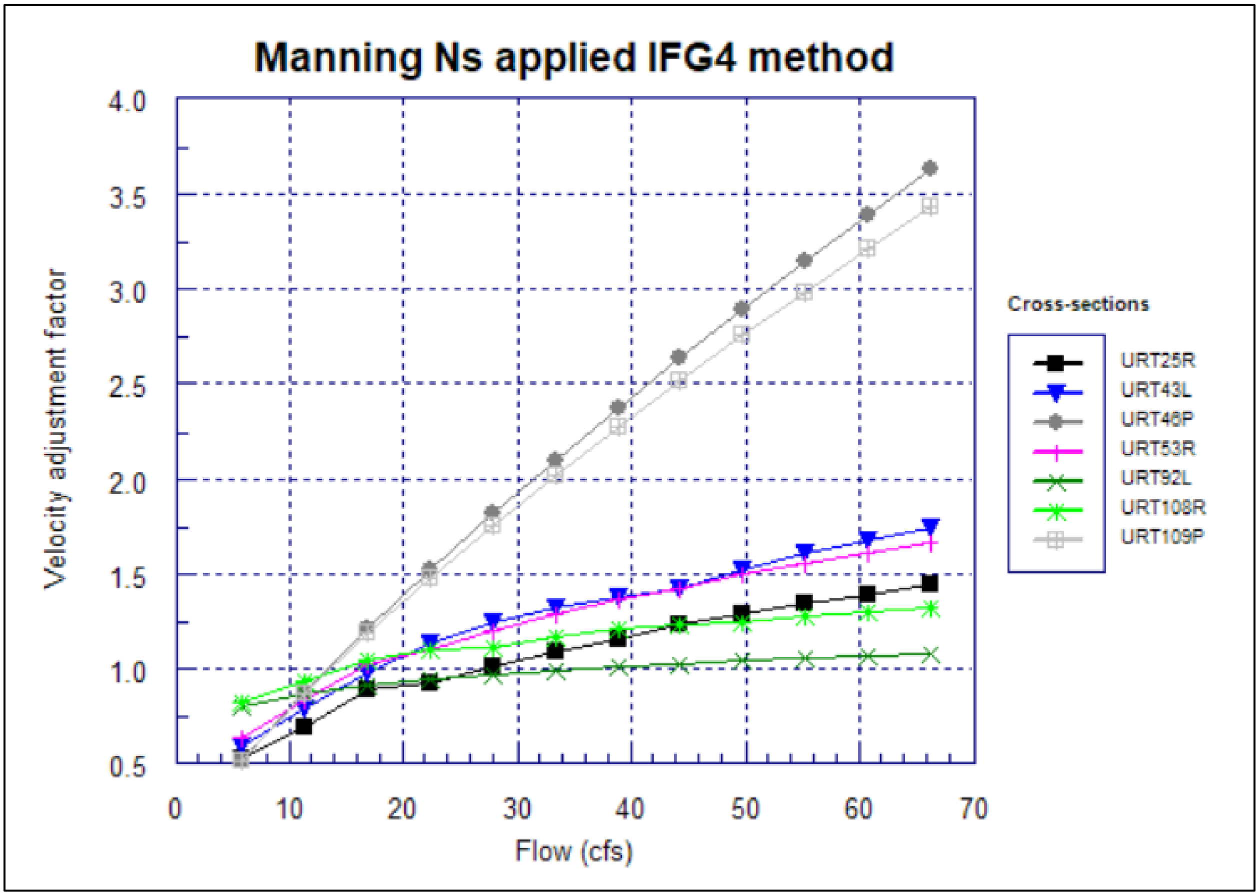

Figure F-3. Velocity simulation VAFs by discharge in Upper Redwood Creek.

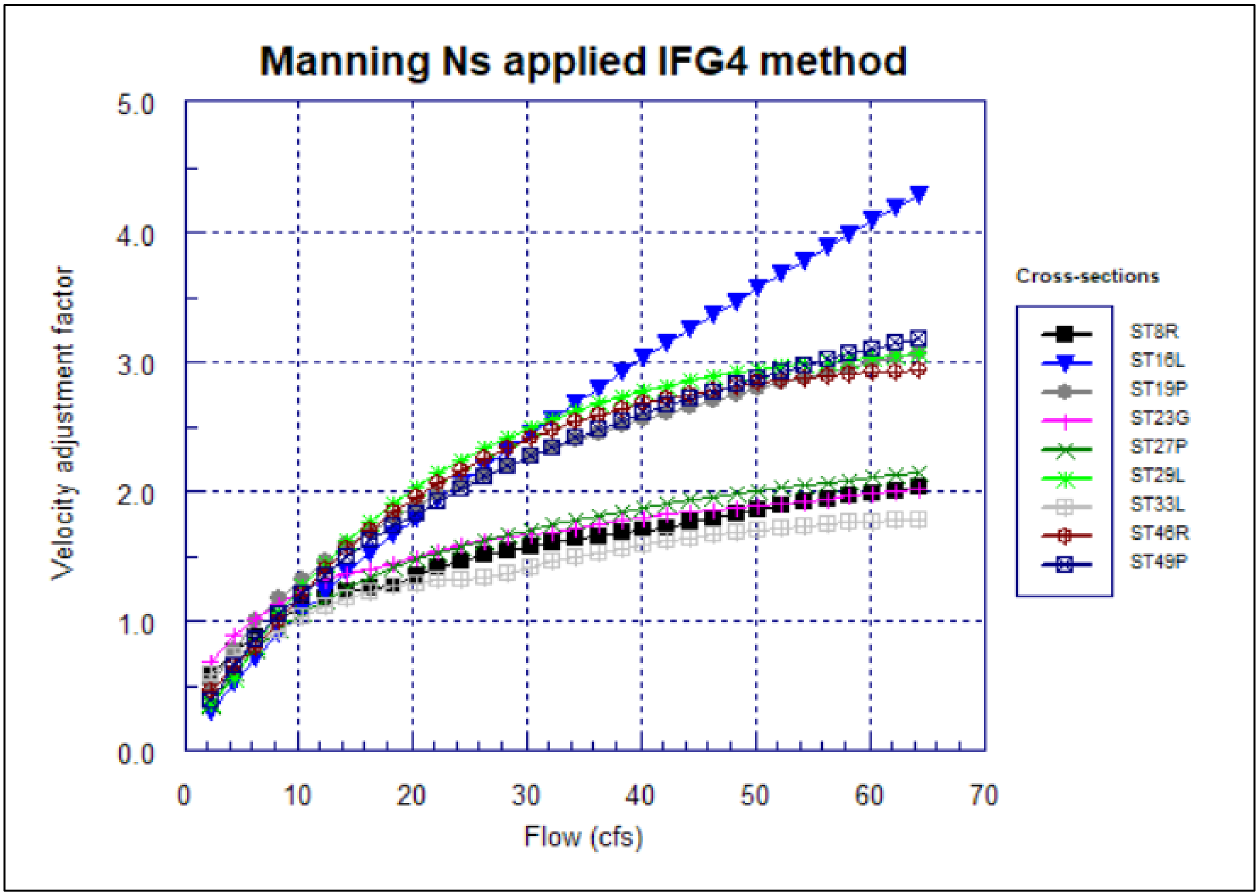

Figure F-4. Velocity simulation VAFs by discharge in Seely Creek.

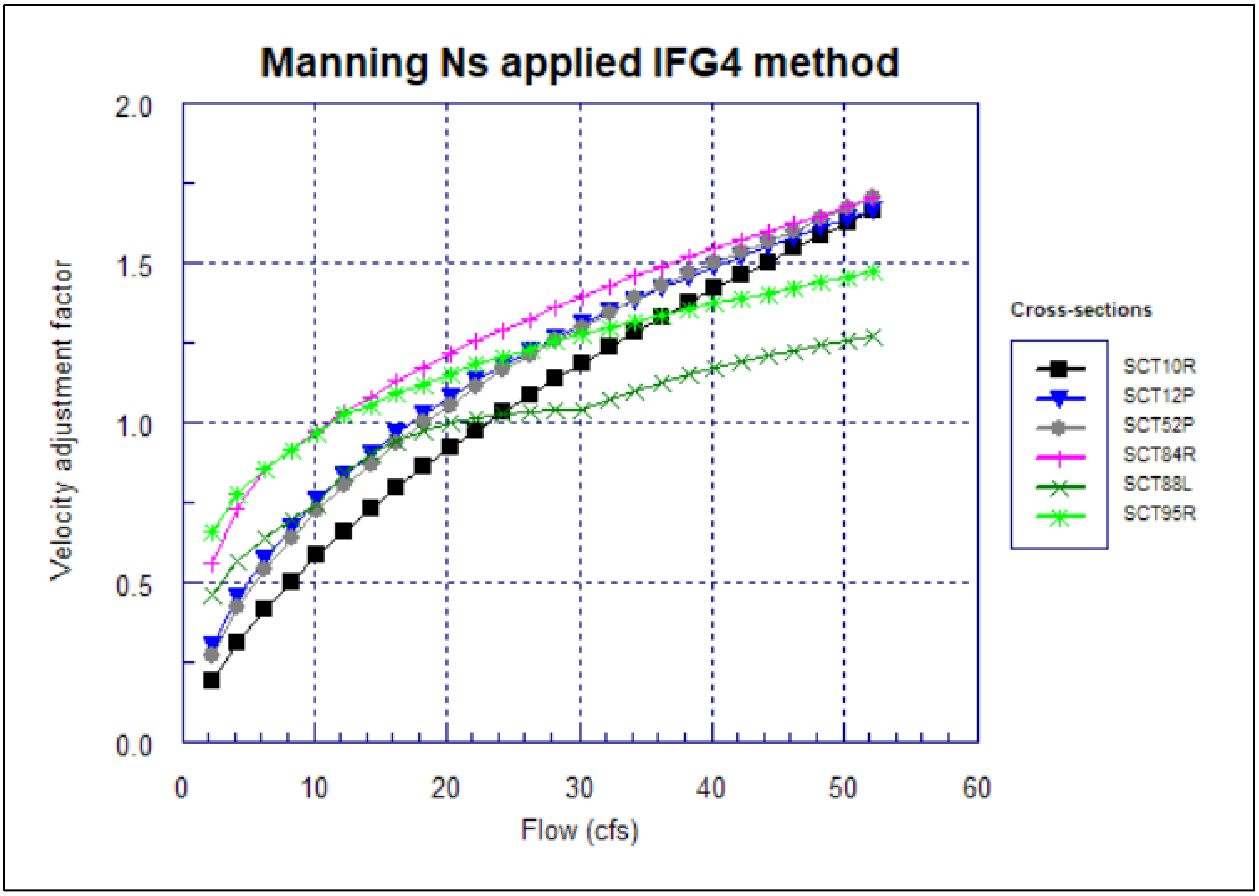

Figure F-5. Velocity simulation VAFs by discharge in Somerville Creek.

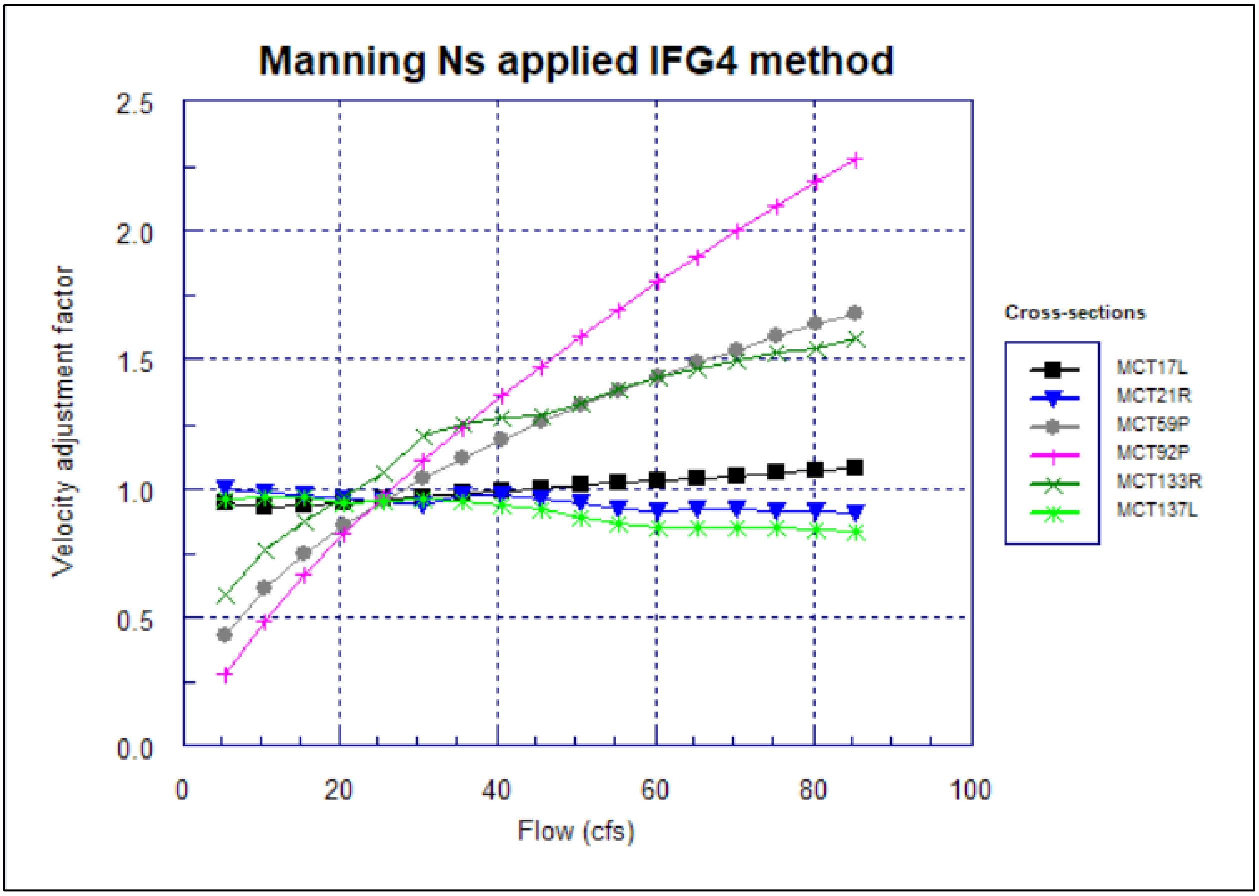

Figure F-6. Velocity simulation VAFs by discharge in Miller Creek.

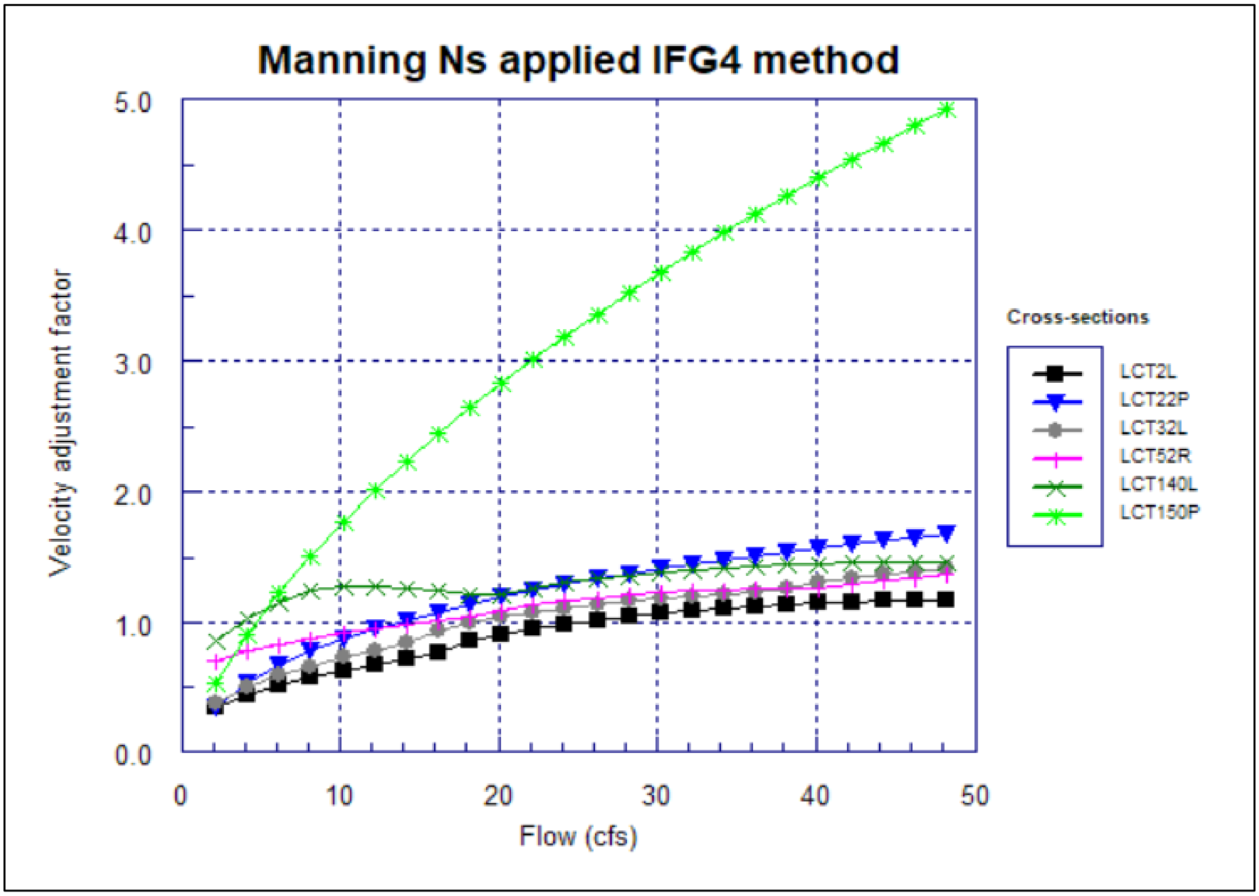

Figure F-7. Velocity simulation VAFs by discharge in Lower China Creek.

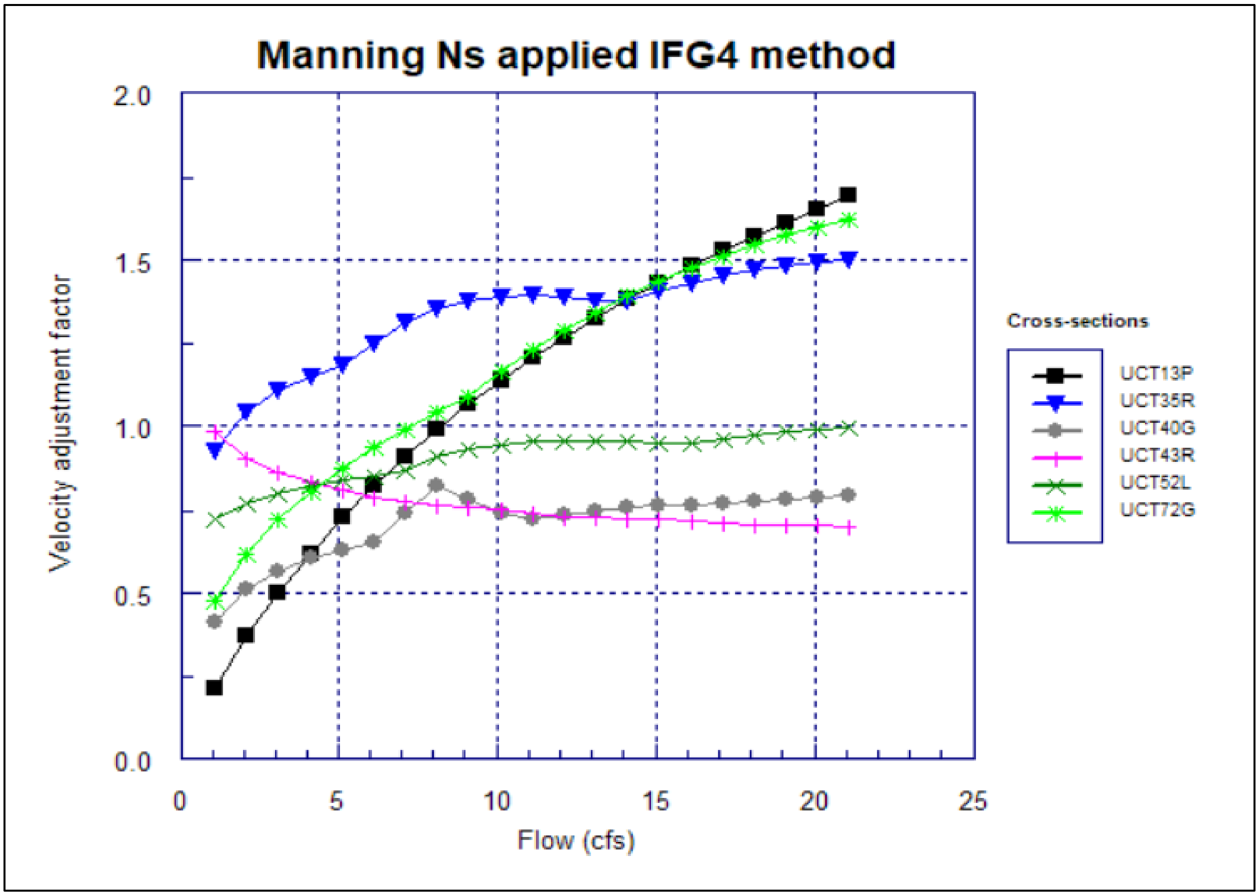

Figure F-8. Velocity simulation VAFs by discharge in Upper China Creek.

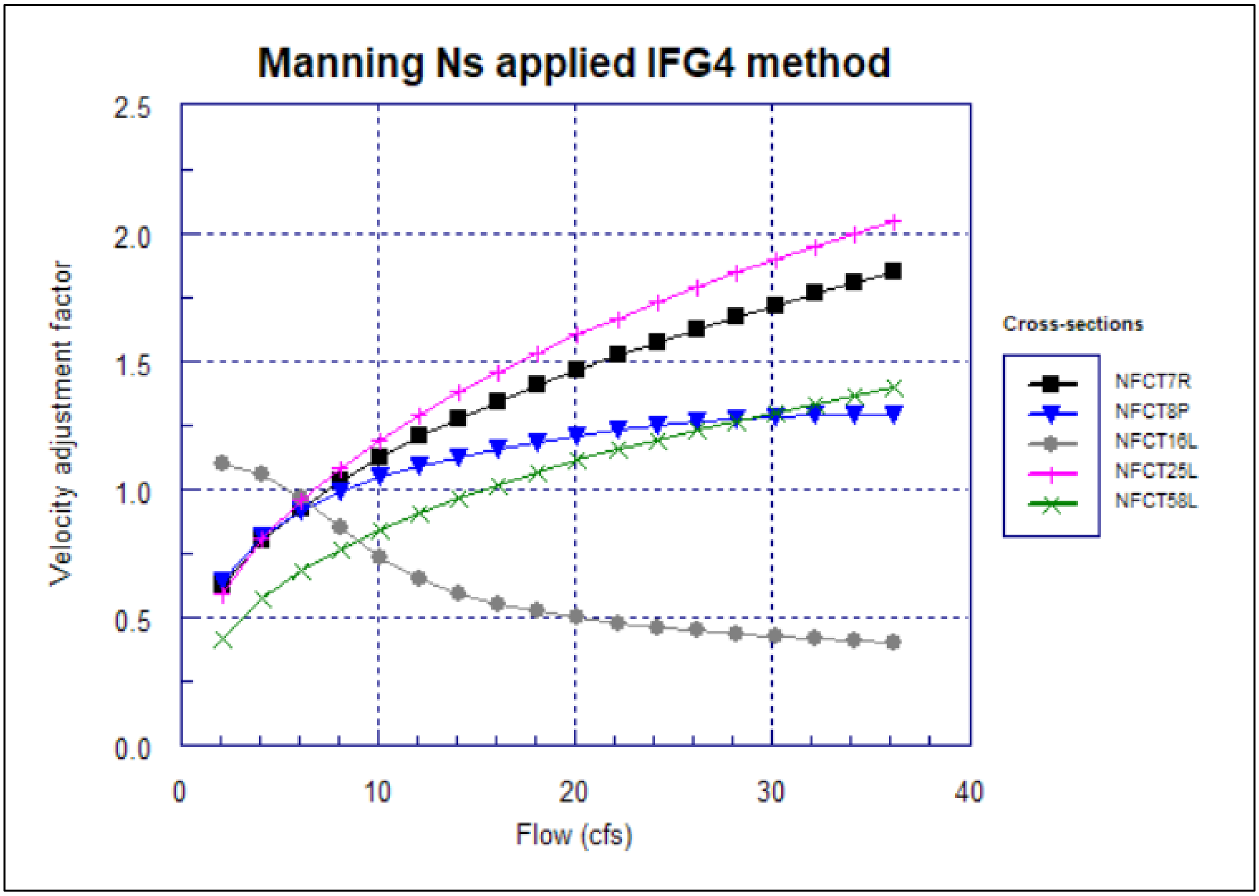

Figure F-9. Velocity simulation VAFs by discharge in North Fork China Creek.

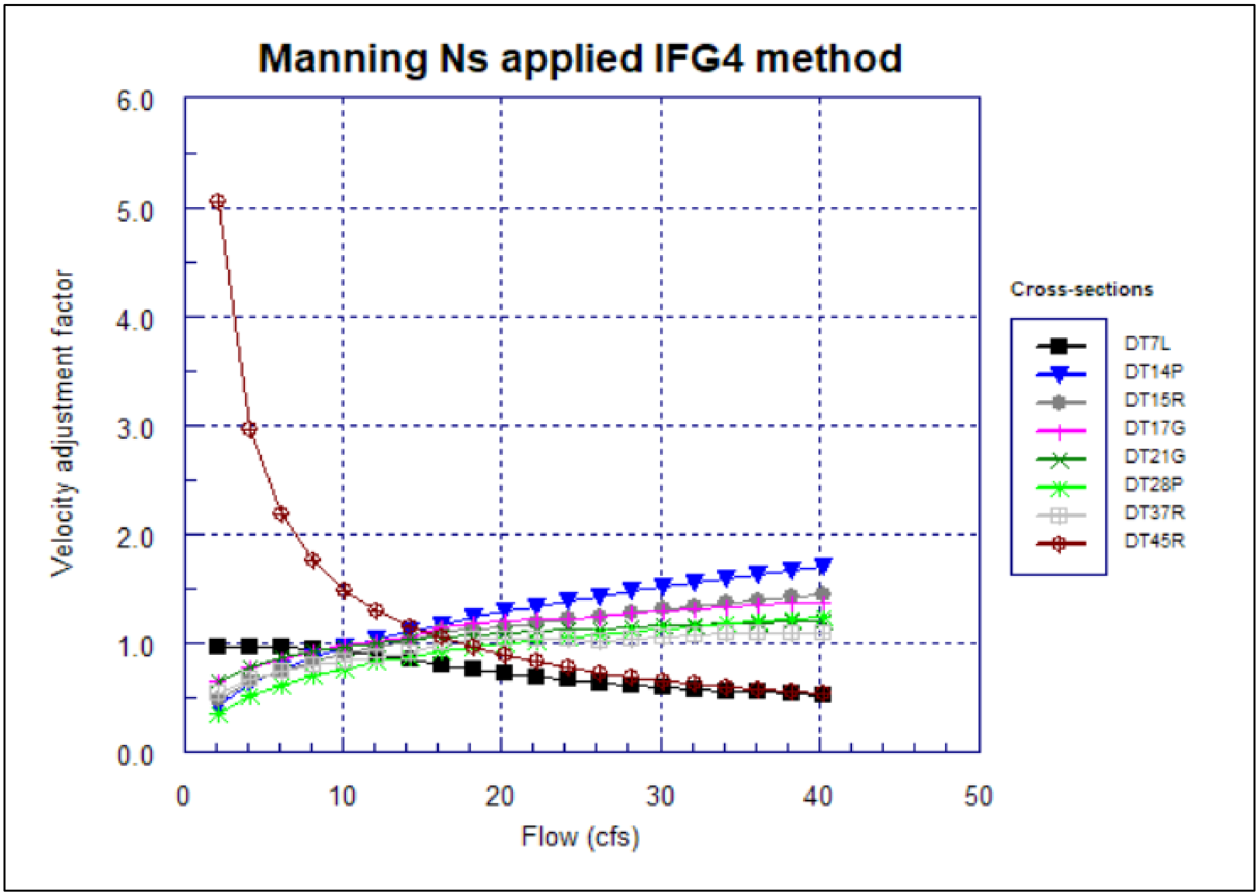

Figure F-10. Velocity simulation VAFs by discharge in Dinner Creek.

APPENDIX G: SELECTED VELOCITY DISTRIBUTION FACTOR PROFILES

This appendix presents the graphical Velocity Distribution Factor (VDF) results for modifications made to six of the total 75 transects used to estimate flow-habitat relationships in Redwood Creek. VDFs were only modified to improve velocity profile prediction or to minimize the exaggeration of negative velocities measured near stream margins.

Each of the figures contains a layered plot with the transect length coordinates (Offset (ft)) on the x-axis, water level (ft) and velocity on the upper y-axis, and the Manning N value or VDF for each transect velocity profile point on the lower y-axis. The upper plot shows the transect and velocity profiles. The survey flow water level is indicted by a solid blue fill. The lower plot is the profile of the unmodified Manning N value or VDF, for the transect being evaluated.

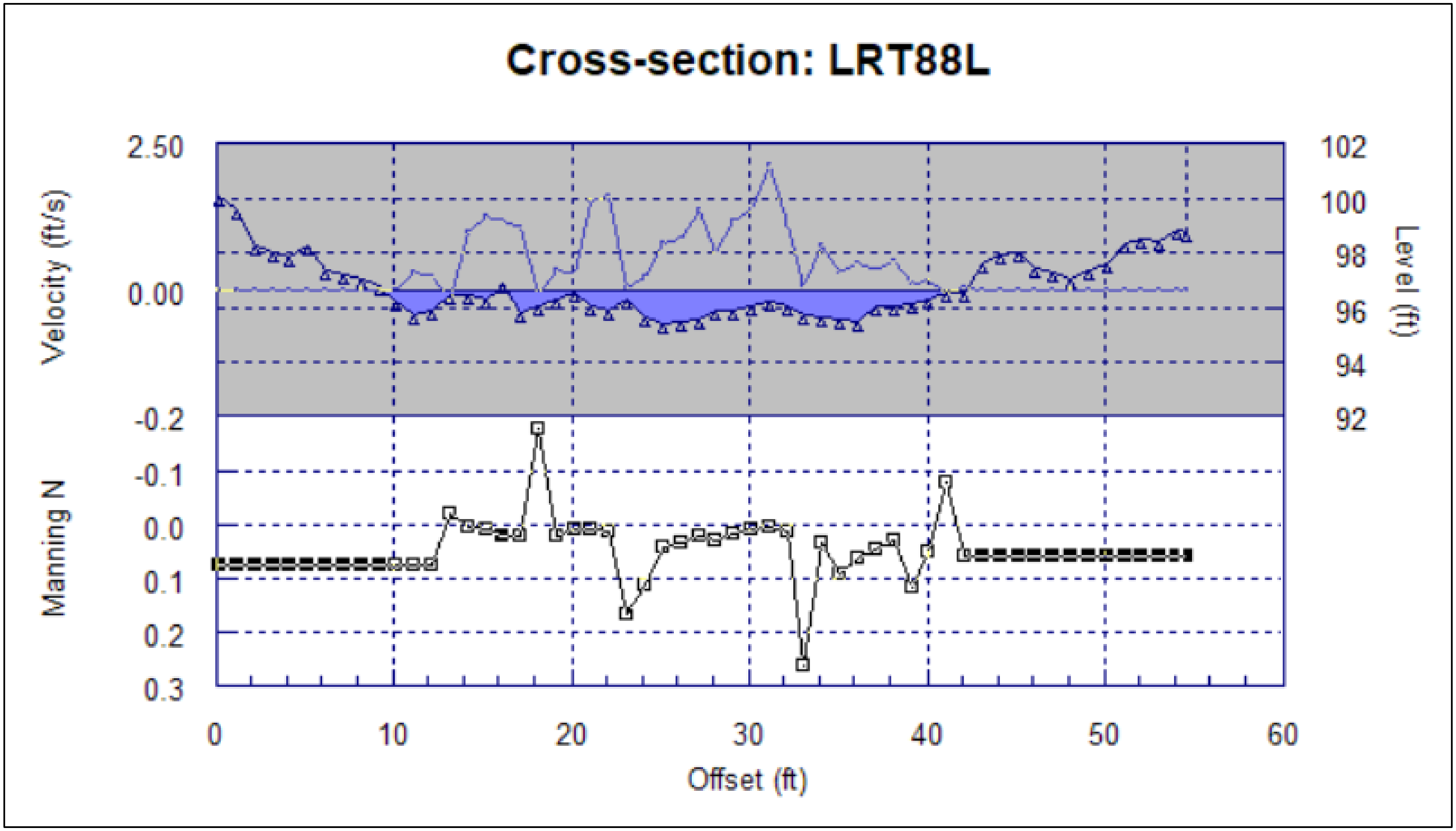

Figure G-1. Lower Redwood Creek cross section LRT88L before VDF modification.

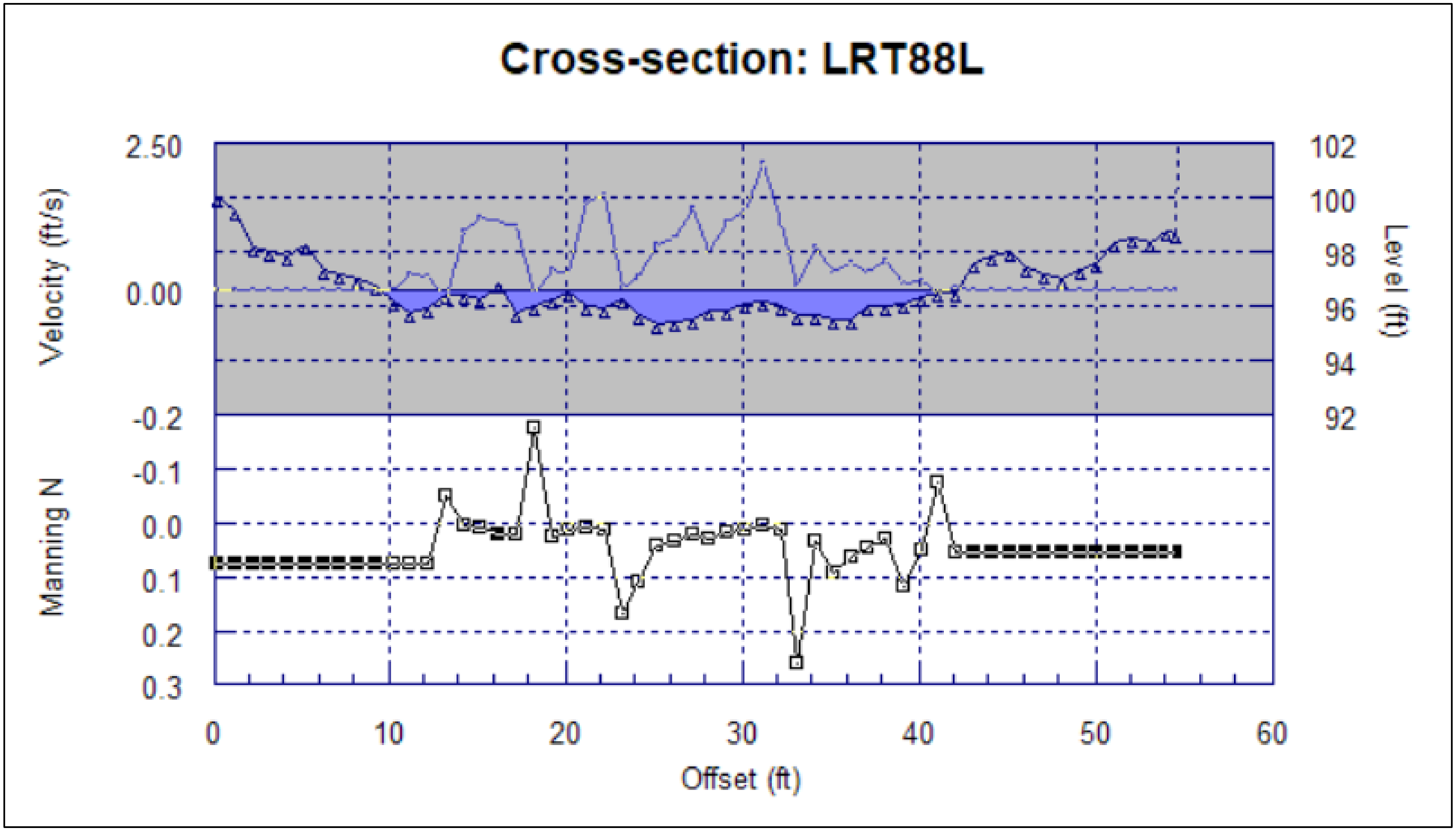

Figure G-2. Lower Redwood Creek cross section LRT88L after VDF modification.

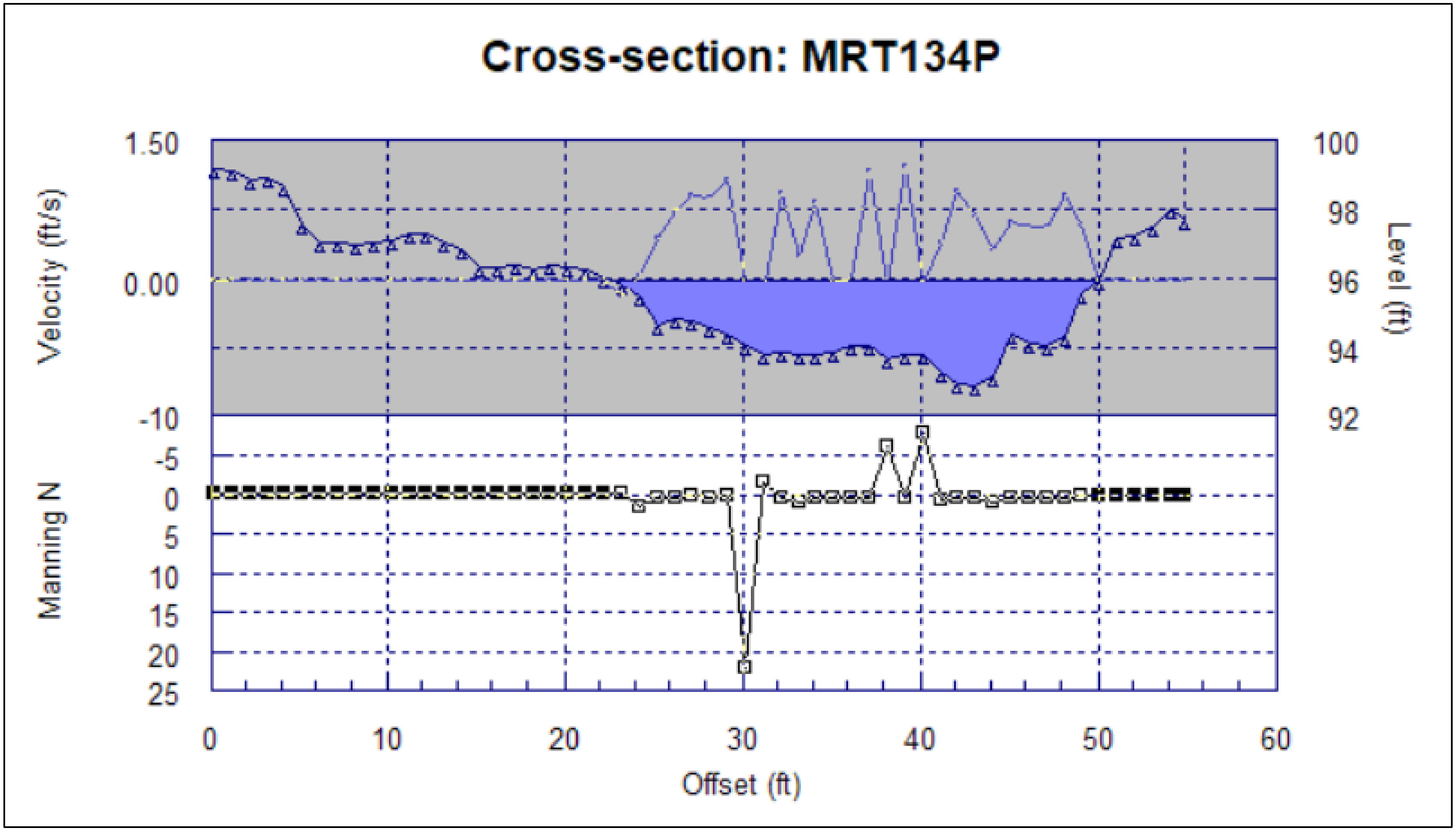

Figure G-3. Middle Redwood Creek cross section MRT134P before VDF modification.

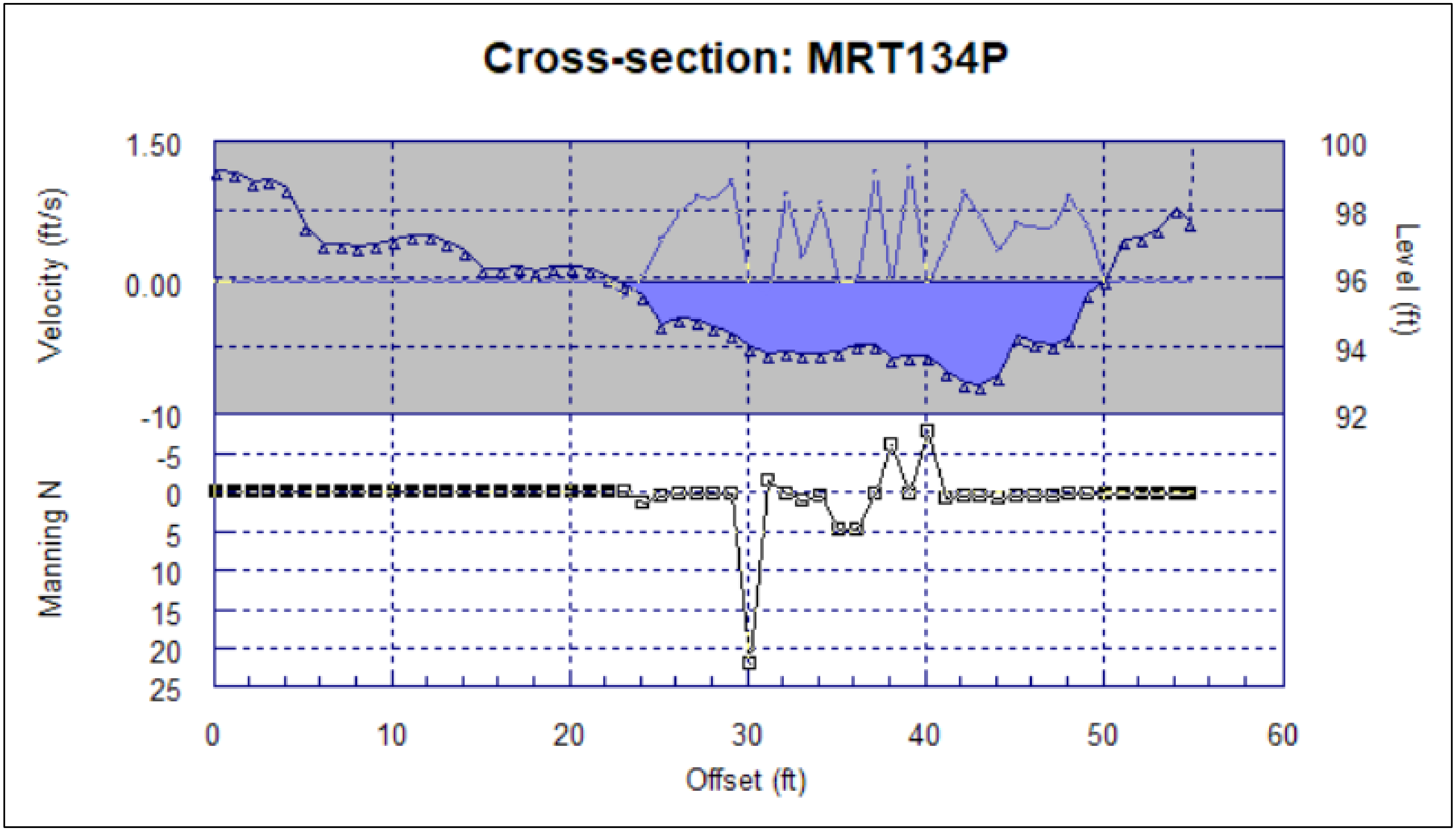

Figure G-4. Middle Redwood Creek cross section MRT134P after VDF modification.

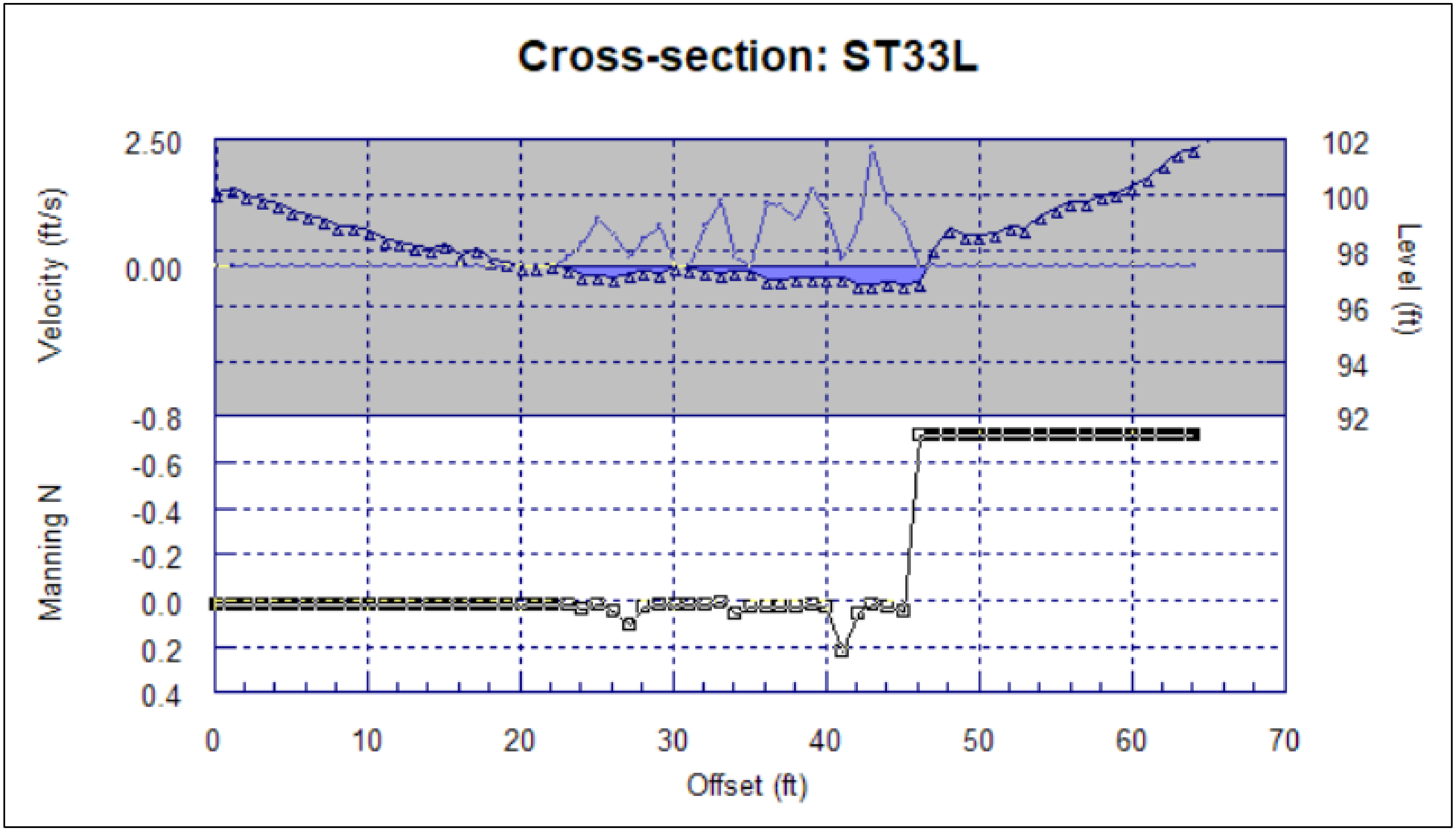

Figure G-5. Seely Creek cross section ST33L before VDF modification.

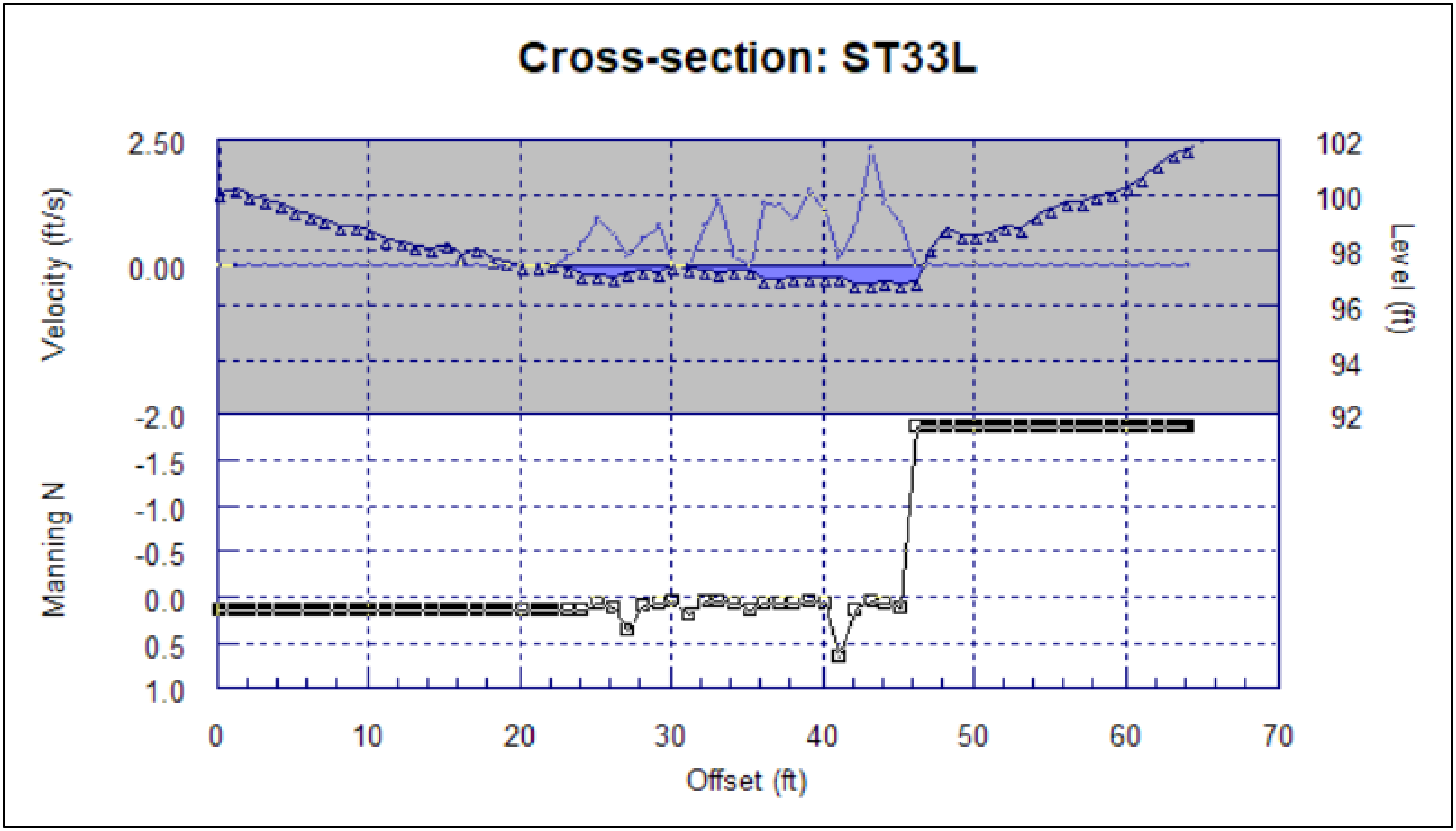

Figure G-6. Seely Creek cross section ST33L after VDF modification.

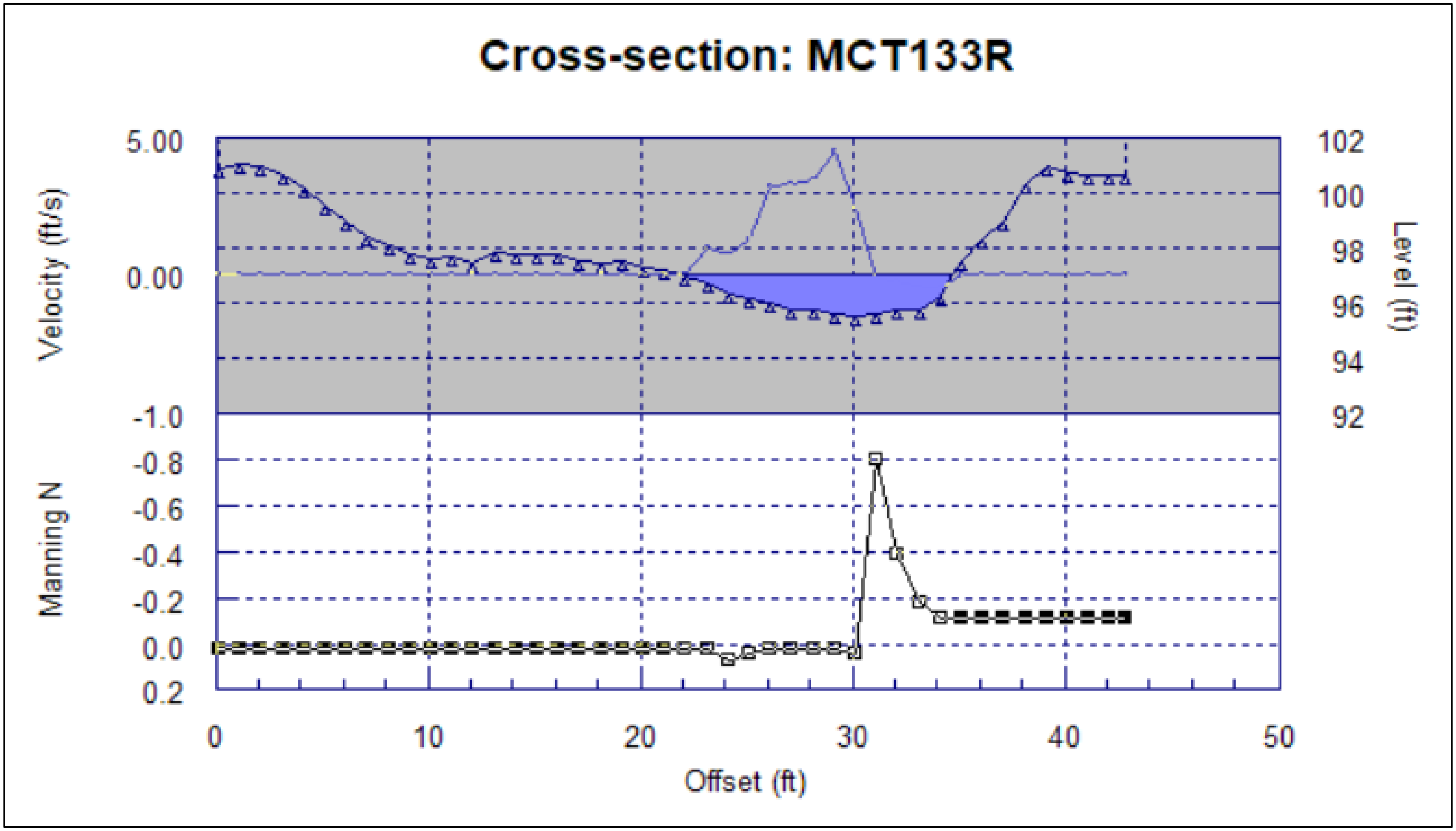

Figure G-7. Miller Creek cross section MCT133R before VDF modification.

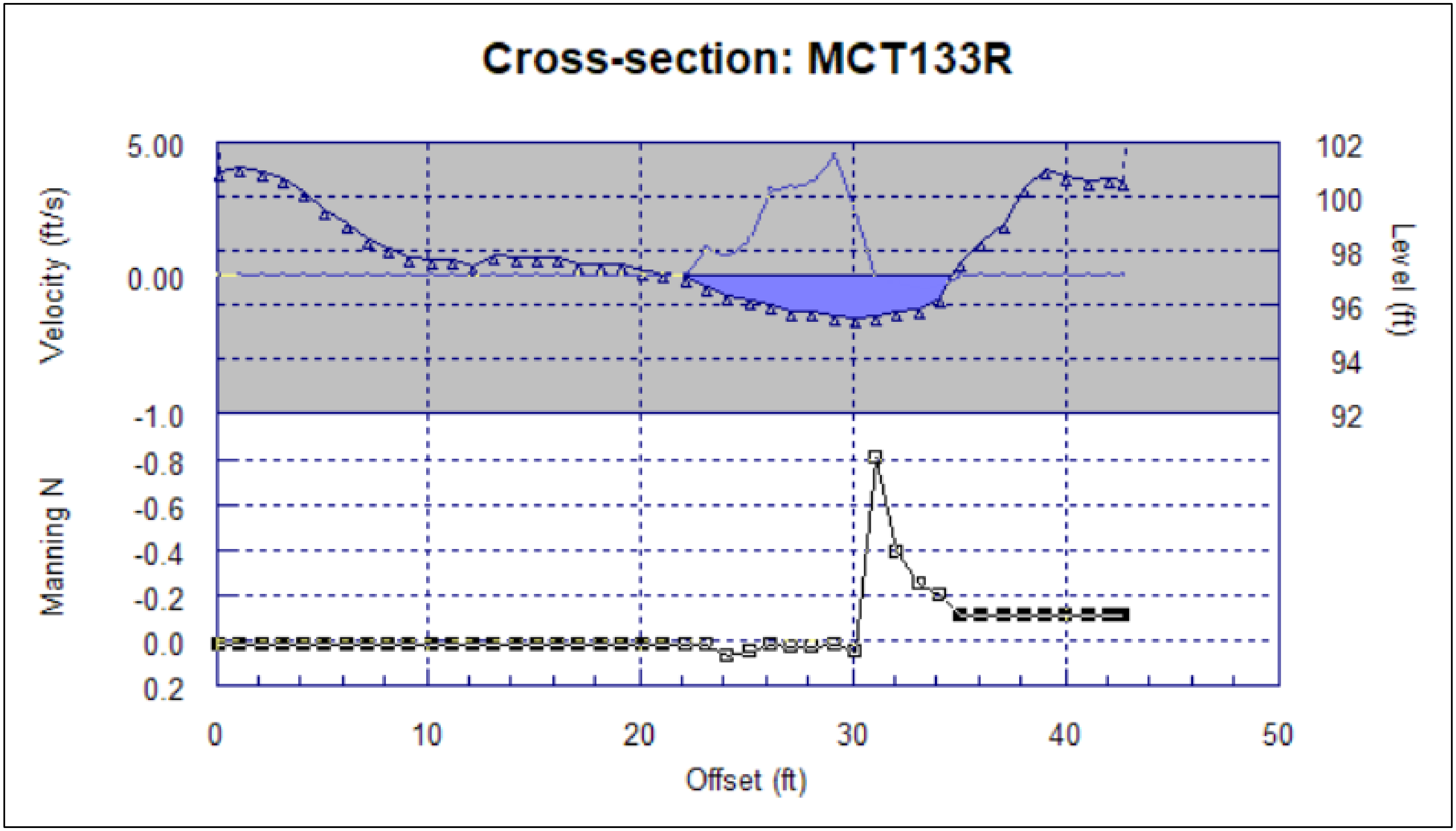

Figure G-8. Miller Creek cross section MCT133R after VDF modification.

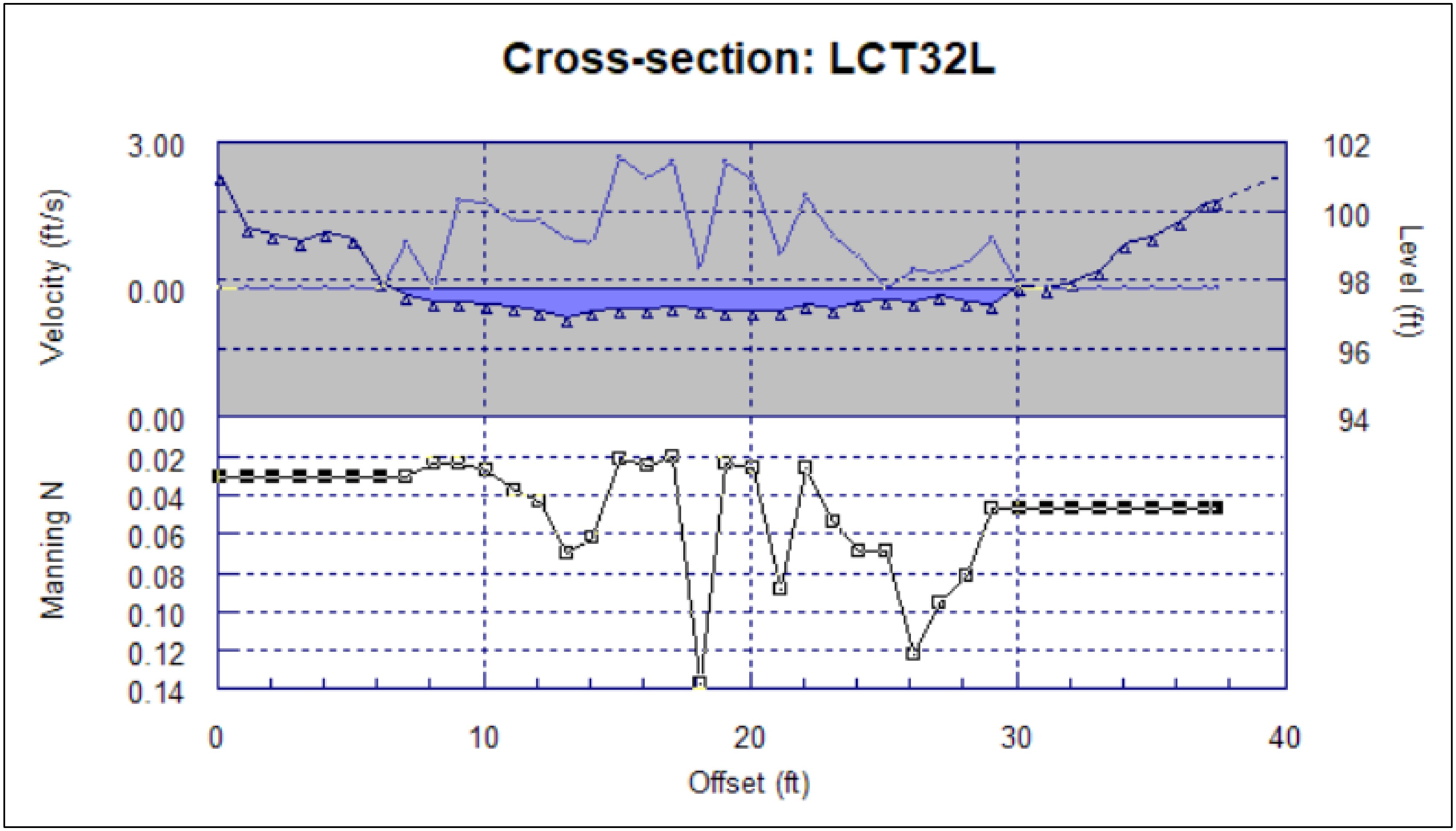

Figure G-9. Lower China Creek cross section LCT32L before VDF modification.

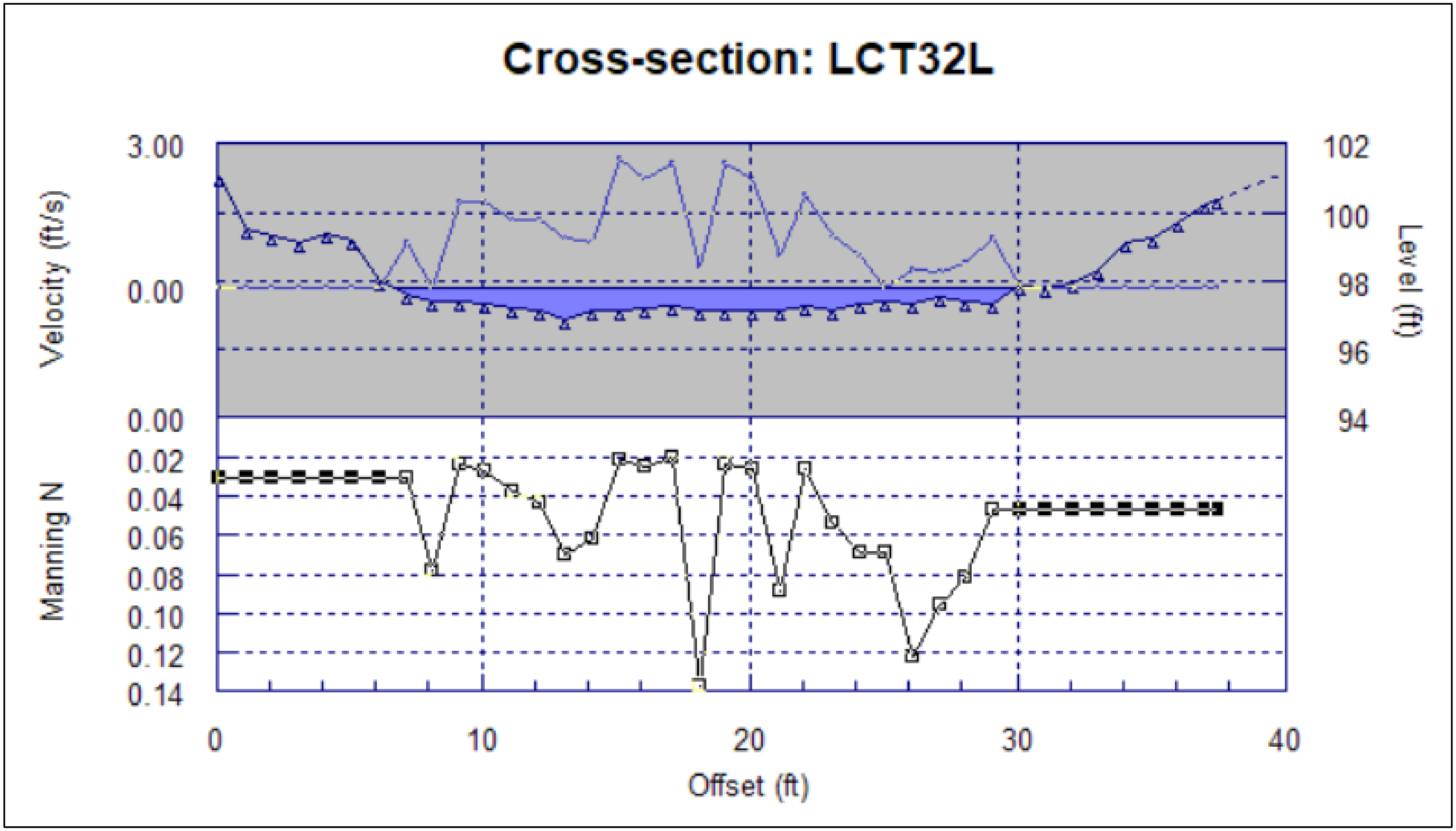

Figure G-10. Lower China Creek cross section LCT32L after VDF modification.

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