Relicensing Study 3.3.1

Conduct Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station

Study Report

Addendum 7 Assessment of Yellow Lampmussels in Reach 4

Northfield Mountain Pumped Storage Project (No. 2485)

and Turners Falls Hydroelectric Project (No. 1889)

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FirstLight

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LIST OF ABBREVIATIONS

CF	Compound Function
cfs	cubic feet per second
cm	centimeters
FERC	Federal Energy Regulatory Commission
FL	FirstLight
ft	feet
ft/s	feet per second
HSI	Habitat Suitability Index
MADFW	Massachusetts Division of Fisheries & Wildlife
NHESP	Natural Heritage and Endangered Species Program
NMFS	National Marine Fisheries Service
PHABSIM	Physical Habitat Simulation
USFWS	United States Fish and Wildlife Service
WUA	Weighted Usable Area

1 INTRODUCTION

On October 14, 2016, then FirstLight Hydro Generating Company (now collectively referred to as FirstLight or FL) filed with the Federal Energy Regulatory Commission (FERC) Study Report No. 3.3.1 Instream Flow Habitat Assessment in the Bypass Reach and below Cabot Station.

Between April 3, 2017 and May 1, 2018, FL filed the following additional addendums to Study No. 3.3.1:

- Addendum 1- Addressed Miscellaneous Comments Provided on the Original Study 3.3.1 filing
- Addendum 2- Instream Flow Study Results for Mussels in Reach 5
- Addendum 3- Yellow Lampmussel Assessment in Reach 3
- Addendum 4- Sea Lamprey Assessment with new Habitat Suitability Index Curves

On October 9, 2018, FL held a Study Report Meeting in which Addendums 1-4 were discussed and filed its meeting summary on October 24, 2018 per FERC regulations. Stakeholder comments on the meeting summary and addendums were due by November 23, 2018. Comments on Study No. 3.3.1 were filed by the United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the Massachusetts Division of Fisheries & Wildlife (MADFW). Some of the comments filed on Study No. 3.3.1 requested additional information. On December 21, 2018, FL filed its response to comments with FERC. In its responsiveness summary, FL provided the following additional information on March 1, 2019 as Addendum 5.

- Persistent habitat maps for Reach 3 and dual flow results for Reach 4 for the new Sea Lamprey Habitat Suitability Index Curves.
- Persistent habitat mapping of juvenile Yellow Lampmussels in Reach 3 over a range of Project Operations.

On January 22, 2019, FERC issued its Study Plan Determination. Relative to Study No. 3.1.1 it states: "*FirstLight should evaluate the 4-variable (depth, substrate, benthic velocity and shear stress) WUA versus flow relationship, conduct a dual flow analysis using the 4-variable WUA and conduct shear stress mapping for adult and juvenile yellow lampmussel at the range of flows modeled in Reach 4 for other species (1,200 to 37,500 cfs)*". FERC stated that the requested information should be filed within 90 days or by April 22, 2019.

FL had proposed to file the dual flow analysis for the new Sea Lamprey Habitat Suitability Index Curves in Reach 4 by March 1, 2019, but in its March 1, 2019 cover letter it indicated that it would be filed on April 22, 2019. Thus, the Reach 4 analysis for Yellow Lampmussel and Sea Lamprey spawning was included in Addendum 6. In addition to the dual flow analysis, FL also conducted a persistent habitat analysis for adult and juvenile Yellow Lampmussel and Sea Lamprey in Reach 4.

On July 3, 2019, FERC requested additional information on Yellow Lampmussel habitat in Reach 4 and stated that FL should file:

- An evaluation of the 4-variable (depth, substrate, benthic velocity, and sheer stress) weighted usable area (WUA) versus flow relationship;
- A dual flow analysis using the 4-variable WUA; and
- A shear stress mapping for adult and juvenile yellow lampmussel at the range of flows modeled in reach 4 for other species (1,200 to 37,500 cfs).

Each of these items are included in this document below.

2 METHODS

2.1 Weighted Usable Area vs. Flow

As part of Study No. 3.3.1 *Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station*, a PHABSIM 1-D model was used to analyze the habitat in Reach 4. The model consists of 12 habitat transects and additional hydraulic transects, which corresponds to transects within the HEC-RAS hydraulic model. Substrate data for these transects were obtained during the field work described in the Study 3.3.1 Report. As part of the analysis conducted for Study 3.3.1, later addendums, and this addendum, habitat versus flow relationships were developed at each incremental station along the transects based on the habitat suitability index (HSI) values for mussels that were developed for Study 3.3.16 – *Habitat Assessment, Surveys, and Modeling of Suitable Habitat for State-listed Mussel Species in the CT River below Cabot Station*. The binary habitat criteria for depth, velocity, and substrate from that study are provided below in Tables 2.1-1 and 2.1-2 for reference. Additionally, suitable shear stress was less than 150 dynes/cm^2 for adult Yellow Lampmussel and 10 dynes/cm^2 for juvenile Yellow Lampmussel, as identified by the MA Natural Heritage and Endangered Species Program (NHESP). Shear stress was calculated similarly to how it was described in detail in Addendum 2.

Table 2.1-1: Binary Habitat Suitability Criteria Developed for Adult Yellow Lampmussel

Parameter		Yellow Lampmussel Adult
Class	**Benthic Velocity Range (ft/s)**	
1	<0.16	1
2	0.16-0.34	1
3	0.35-0.67	1
4	0.68-0.99	1
5	1.00-1.32	1
6	1.33-1.65	1
7	1.66-2.47	1
8	2.48-3.29	0
9	3.30-4.93	0
10	4.94-6.56	0
11	>6.56	0
Class	**Water Depth Range (ft)**	
1	0	0
2	0.03-0.34	0
3	0.35-0.83	1
4	0.84-1.65	1
5	1.66-2.47	1
6	2.48-3.29	1
7	3.30-4.93	1
8	4.94-6.56	1
9	6.57-9.85	1
10	9.86-13.12	1
11	>13.12	1
Class	**Particle Size**	
1	Organic Material	0
2	Clay	0
3	<0.002 in [mud/silt]	1
4	0.002 – 0.08 in. [sand]	1
5	0.08- 1.26 in. [fine gravel]	1
6	1.26 – 2.52 in. [coarse gravel]	1
7	2.52 – 5.90 in. [small cobble]	1
8	5.90 – 9.84 in. [large cobble]	0
9	9.84 – 157.5 in. [boulder]	0
10	Bedrock	0

Table 2.1-2: Binary Habitat Suitability Criteria Developed for Juvenile Yellow Lampmussel

Parameter		Yellow Lampmussel Juvenile
Class	**Benthic Velocity Range (ft/s)**	
1	<0.16	1
2	0.16-0.34	1
3	0.35-0.67	1
4	0.68-0.99	1
5	1.00-1.32	1
6	1.33-1.65	1
7	1.66-2.47	0
8	2.48-3.29	0
9	3.30-4.93	0
10	4.94-6.56	0
11	>6.56	0
Class	**Water Depth Range (ft)**	
1	0	0
2	0.03-0.34	0
3	0.35-0.83	1
4	0.84-1.65	1
5	1.66-2.47	1
6	2.48-3.29	1
7	3.30-4.93	1
8	4.94-6.56	1
9	6.57-9.85	1
10	9.86-13.12	1
11	>13.12	1
Class	**Particle Size**	
1	Organic Material	0
2	Clay	0
3	<0.002 in [mud/silt]	1
4	0.002 – 0.08 in. [sand]	1
5	0.08- 1.26 in. [fine gravel]	1
6	1.26 – 2.52 in. [coarse gravel]	1
7	2.52 – 5.90 in. [small cobble]	1
8	5.90 – 9.84 in. [large cobble]	0
9	9.84 – 157.5 in. [boulder]	0
10	Bedrock	0

2.2 Dual Flow Analysis

A dual flow analysis was conducted for Reach 4 and calculated the habitat CF(I) = 1.0[1] present over paired base flow and higher flows across a range of scenarios, as those that may be expected during a minimum flow/peaking flow hydropower operation. In this analysis, it also includes flows in excess of the Cabot and Station No. 1 hydraulic capacity (about 16,000 cfs[2]) up to 37,500 cfs, which is the upper end of the modeling range in Reach 4. The resulting flow combinations ranged from 1,200 cfs to 37,500 cfs. Dual flow habitat was calculated using the series of rectangular habitat cells for each transect. As streamflow varies, habitat may decrease in some cells, while increase in others provided the cell has suitable substrate. This evaluation was based on the 4-variable (depth, substrate, benthic velocity, and shear stress) versus flow relationships. For immobile target species such as Yellow Lampmussel, an assumption was made that the available habitat is the minimum available in each cell between a given pair of flows. The PHABSIM program calculated these minimum habitat cell values for a dual flow combination and summed them for a particular transect. The habitat for dual flow combinations is equal to, or less than, the minimum of the two steady state flow habitat values calculated for each of the two flows. The dual flow results for each transect in Reach 4 were weighted in the same manner used in Study 3.3.1 and related addendums. The flows used in the Dual Flow Tables are provided below:

- 1,200 cfs;
- 1,600 cfs;
- 2,000 cfs;
- 2,800 cfs;
- 4,000 cfs;
- 5,000 cfs;
- 6,000 cfs;
- 8,000 cfs;
- 10,000 cfs;
- 12,000 cfs;
- 14,000 cfs;
- 15,000 cfs;
- 17,500 cfs;
- 20,000 cfs;
- 25,000 cfs;
- 30,000 cfs; and
- 37,500 cfs.

2.3 Shear Stress Mapping

Based on the binary suitability values for shear stress, as described in Section 2.1, shear stress suitability was plotted for the entire wetted cross-sectional area of transects at all modeled flows in Reach 4 for adult and juvenile Yellow Lampmussel. Figure 2.3-1 provides the location of the cross-sections in Reach 4.

[1] Mussel habitat is binary with suitable habitat designated as 1 and unsuitable as 0.
[2] Cabot and Station No. 1 hydraulic capacities are 13,728 cfs and 2,210 cfs, respectively, or a total of 15,938 cfs ~ 16,000 cfs.

FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

Relicensing Study 3.3.1
Addendum 7

N

0 0.25 0.5 1 Miles

Figure 2.3-1: Reach 4
Transect Locations

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3 RESULTS

3.1 Weighted Usable Area vs. Flow

The WUA vs. Flow relationship for adult and juvenile Yellow Lampmussel developed for Reach 4 is shown in Figure 3.1-1. Peak WUA is at 5,000 cfs for adult Yellow Lampmussel, and 2,800 cfs for juvenile Yellow Lampmussel, above which WUA declines.

3.2 Dual Flow Analysis

Dual flow tables for adult Yellow Lampmussel are shown in Tables 3.2-1 and 3.2-2. Dual flow tables for juvenile Yellow Lampmussel are shown in Tables 3.2-3 and 3.2-4. These tables indicate that substantially lower amounts of habitat is available at higher flows.

3.3 Shear Stress Mapping

Shear stress suitability is shown for adult and juvenile Yellow Lampmussels at each transect in Reach 4 in Figures 3.3.1 through 3.3.24[3]. Shear stress for adult Yellow Lampmussels is typically suitable across most transects and at a wide variety of flows; however, juveniles could be more constrained by shear stress, assuming that other suitability indices (i.e. depth, velocity, and substrate) are not already limiting.

[3] In these figures, the gray areas of the cross-sections are not wetted at the flow value indicated.

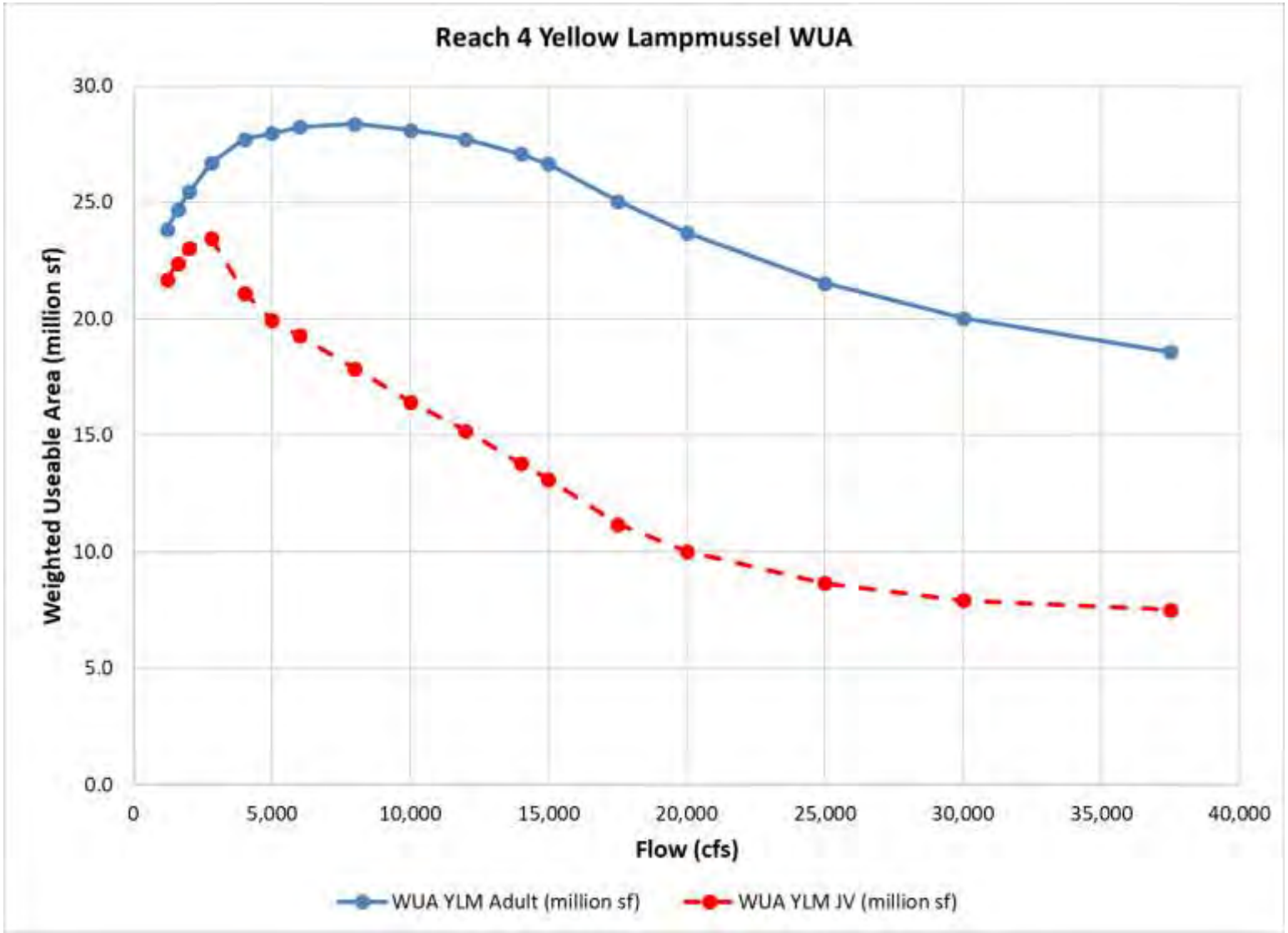

Figure 3.1-1: Weighted Usable Area for Juvenile and Adult Yellow Lampmussel in Reach 4

Table 3.2-1: Adult Yellow Lampmussel Dual Flow Table

Adult Yellow Lampmussel Dual Flow Pairs: Total Reach 4 Suitable Area (million sf) 4 Variable																	
CFS	**1,200**	**1,600**	**2,000**	**2,800**	**4,000**	**5,000**	**6,000**	**8,000**	**10,000**	**12,000**	**14,000**	**15,000**	**17,500**	**20,000**	**25,000**	**30,000**	**37,500**
1,200	23.9	23.9	23.9	23.8	23.8	23.4	23.2	22.8	22.4	21.9	21.2	20.8	19.2	18.0	16.0	14.6	12.7
1,600		24.7	24.7	24.7	24.6	24.3	24.1	23.7	23.2	22.7	22.0	21.5	20.0	18.6	16.5	15.1	13.2
2,000			25.5	25.5	25.4	25.1	24.8	24.4	23.9	23.4	22.7	22.2	20.6	19.2	17.1	15.6	13.6
2,800				26.7	26.6	26.3	26.0	25.7	25.1	24.6	23.8	23.4	21.7	20.3	18.0	16.5	14.5
4,000					27.7	27.4	27.1	26.8	26.2	25.7	24.9	24.5	22.8	21.4	19.1	17.5	15.5
5,000						28.0	27.7	27.3	26.8	26.3	25.5	25.1	23.4	22.0	19.7	18.1	16.1
6,000							28.2	27.9	27.3	26.8	26.0	25.6	23.9	22.5	20.2	18.6	16.6
8,000								28.4	27.8	27.3	26.5	26.1	24.4	23.0	20.7	19.1	17.0
10,000									28.1	27.6	26.8	26.4	24.7	23.3	21.0	19.4	17.3
12,000										27.7	26.9	26.5	24.8	23.4	21.1	19.5	17.4
14,000											27.1	26.6	24.9	23.5	21.2	19.6	17.5
15,000												26.7	25.0	23.5	21.2	19.6	17.5
17,500													25.1	23.6	21.3	19.7	17.6
20,000														23.7	21.4	19.8	17.7
25,000															21.5	19.9	17.8
30,000																20.0	17.9
37,500																	18.6

Table 3.2-2: Adult Yellow Lampmussel Dual Flow Table (Percent Maximum Habitat)

Adult Yellow Lampmussel Dual Flow Pairs: Reach 4 Percent of Maximum Habitat 4 Variable																	
CFS	**1,200**	**1,600**	**2,000**	**2,800**	**4,000**	**5,000**	**6,000**	**8,000**	**10,000**	**12,000**	**14,000**	**15,000**	**17,500**	**20,000**	**25,000**	**30,000**	**37,500**
1,200	84%	84%	84%	84%	84%	83%	82%	80%	79%	77%	75%	73%	68%	63%	56%	51%	45%
1,600		87%	87%	87%	87%	86%	85%	83%	82%	80%	77%	76%	70%	66%	58%	53%	46%
2,000			90%	90%	89%	88%	87%	86%	84%	83%	80%	78%	73%	68%	60%	55%	48%
2,800				94%	94%	93%	92%	90%	88%	87%	84%	82%	77%	72%	64%	58%	51%
4,000					98%	96%	96%	94%	92%	91%	88%	86%	80%	75%	67%	62%	55%
5,000						99%	98%	96%	94%	93%	90%	88%	82%	77%	69%	64%	57%
6,000							100%	98%	96%	94%	92%	90%	84%	79%	71%	66%	58%
8,000								100%	98%	96%	94%	92%	86%	81%	73%	67%	60%
10,000									99%	97%	95%	93%	87%	82%	74%	68%	61%
12,000										98%	95%	93%	87%	82%	74%	69%	61%
14,000											95%	94%	88%	83%	75%	69%	62%
15,000												94%	88%	83%	75%	69%	62%
17,500													88%	83%	75%	69%	62%
20,000														83%	75%	70%	62%
25,000															76%	70%	63%
30,000																71%	63%
37,500																	65%

Table 3.2-3: Juvenile Yellow Lampmussel Dual Flow Table

Juvenile Yellow Lampmussel Dual Flow Pairs: Total Reach 4 Suitable Area (million sf) 4 Variable																	
CFS	**1,200**	**1,600**	**2,000**	**2,800**	**4,000**	**5,000**	**6,000**	**8,000**	**10,000**	**12,000**	**14,000**	**15,000**	**17,500**	**20,000**	**25,000**	**30,000**	**37,500**
1,200	21.7	21.5	21.4	20.4	17.1	15.7	14.7	12.9	11.6	10.5	9.3	8.7	6.9	5.8	4.5	3.8	3.0
1,600		22.4	22.2	21.3	18.0	16.4	15.3	13.5	12.0	10.9	9.7	9.0	7.2	6.1	4.7	4.0	3.2
2,000			23.0	22.1	18.7	17.1	15.9	14.0	12.5	11.2	10.0	9.3	7.5	6.3	4.9	4.2	3.3
2,800				23.5	20.0	18.3	17.1	15.1	13.4	12.1	10.7	10.0	8.1	6.9	5.5	4.6	3.8
4,000					21.1	19.4	18.1	16.1	14.4	13.0	11.6	10.9	8.9	7.7	6.1	5.3	4.3
5,000						19.9	18.7	16.7	14.9	13.6	12.1	11.4	9.4	8.1	6.6	5.7	4.8
6,000							19.3	17.3	15.5	14.1	12.6	11.9	9.9	8.6	7.1	6.2	5.3
8,000								17.9	16.1	14.7	13.2	12.5	10.5	9.2	7.6	6.7	5.6
10,000									16.4	15.1	13.5	12.8	10.8	9.6	7.9	6.9	5.9
12,000										15.2	13.7	12.9	10.9	9.7	8.0	7.0	5.9
14,000											13.8	13.1	11.1	9.8	8.1	7.1	6.0
15,000												13.1	11.1	9.9	8.1	7.2	6.0
17,500													11.2	9.9	8.2	7.3	6.1
20,000														10.0	8.3	7.3	6.1
25,000															8.6	7.7	6.5
30,000																7.9	6.7
37,500																	7.5

Table 3.2-4: Juvenile Yellow Lampmussel Dual Flow Table (Percent Maximum Habitat)

Juvenile Yellow Lampmussel Dual Flow Pairs: Reach 4 Percent of Maximum Habitat 4 Variable																	
CFS	**1,200**	**1,600**	**2,000**	**2,800**	**4,000**	**5,000**	**6,000**	**8,000**	**10,000**	**12,000**	**14,000**	**15,000**	**17,500**	**20,000**	**25,000**	**30,000**	**37,500**
1,200	92%	92%	91%	87%	73%	67%	63%	55%	49%	45%	40%	37%	30%	25%	19%	16%	13%
1,600		95%	95%	91%	77%	70%	65%	57%	51%	46%	41%	38%	31%	26%	20%	17%	14%
2,000			98%	94%	80%	73%	68%	60%	53%	48%	42%	40%	32%	27%	21%	18%	14%
2,800				100%	85%	78%	73%	64%	57%	51%	45%	43%	35%	29%	23%	20%	16%
4,000					90%	83%	77%	69%	61%	56%	49%	46%	38%	33%	26%	22%	19%
5,000						85%	80%	71%	64%	58%	51%	48%	40%	35%	28%	24%	20%
6,000							82%	73%	66%	60%	54%	51%	42%	37%	30%	27%	22%
8,000								76%	69%	63%	56%	53%	45%	39%	32%	28%	24%
10,000									70%	64%	58%	55%	46%	41%	33%	30%	25%
12,000										65%	58%	55%	47%	41%	34%	30%	25%
14,000											59%	56%	47%	42%	34%	30%	25%
15,000												56%	47%	42%	35%	31%	26%
17,500													48%	42%	35%	31%	26%
20,000														43%	35%	31%	26%
25,000															37%	33%	28%
30,000																34%	29%
37,500																	32%

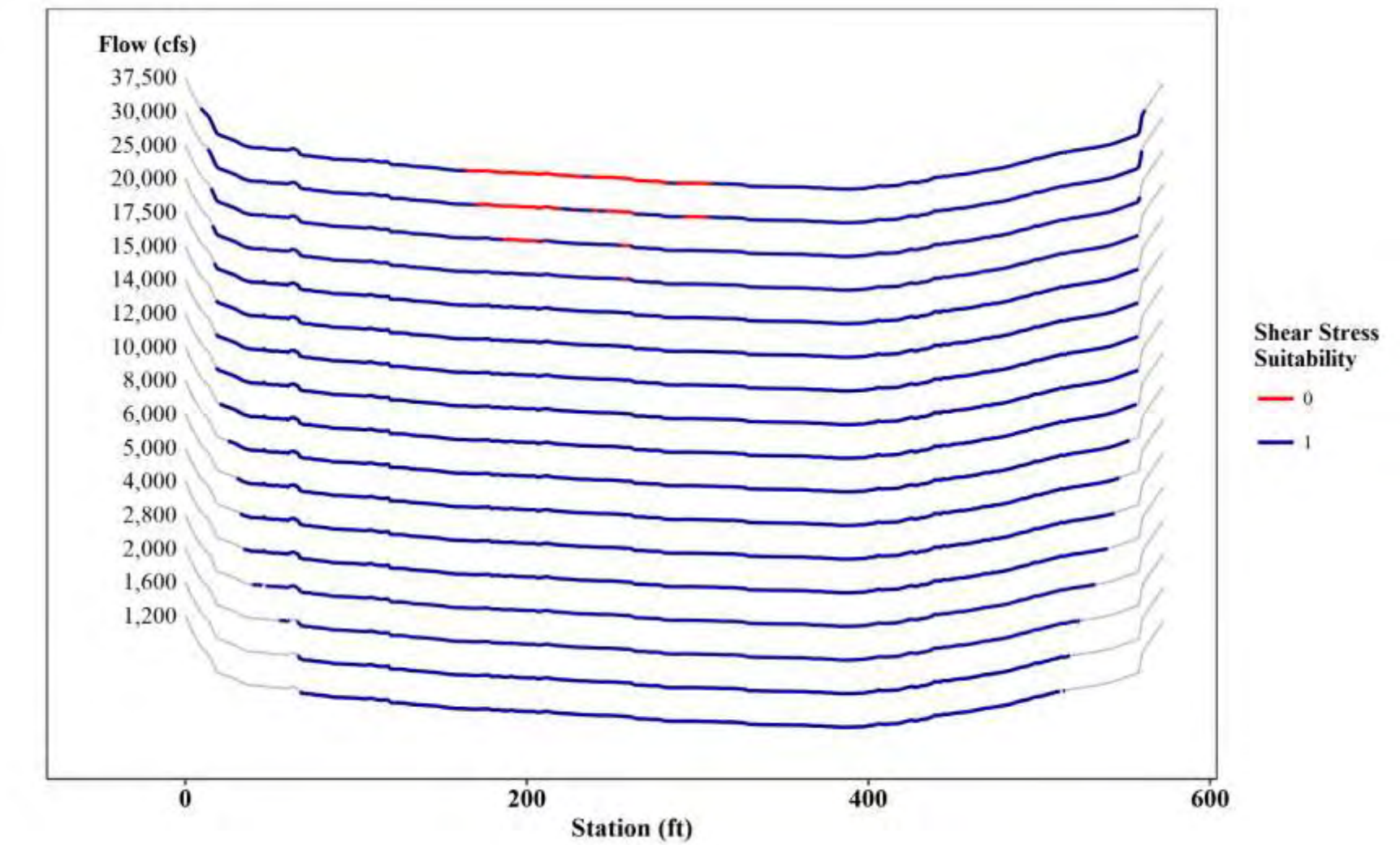

Figure 3.3-1: Shear Stress Mapping at T100 – Adult Yellow Lampmussel

Note: gray portions of the lines are non-wetted areas.

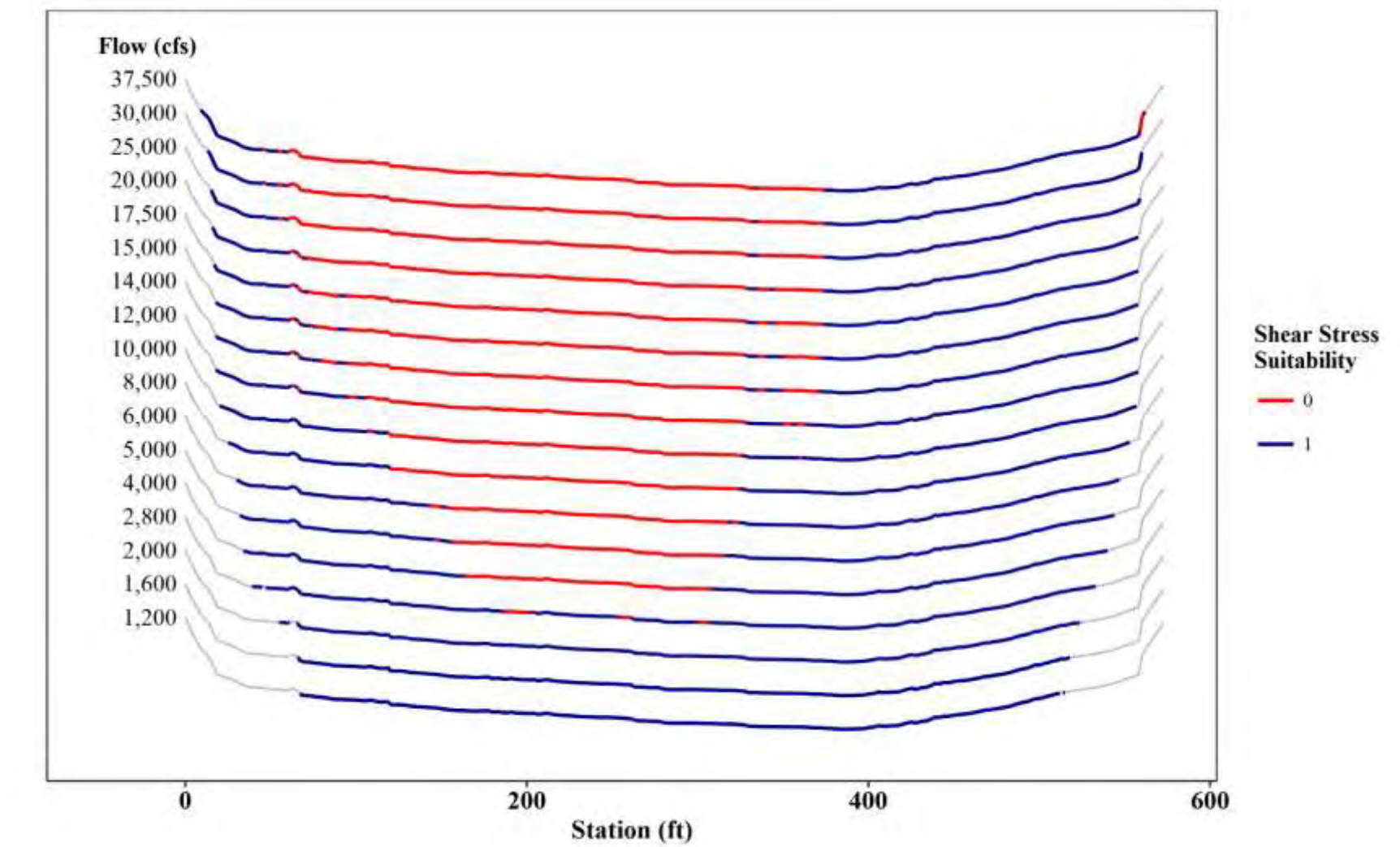

Figure 3.3-2: Shear Stress Mapping at T100 – Juvenile Yellow Lampmussel

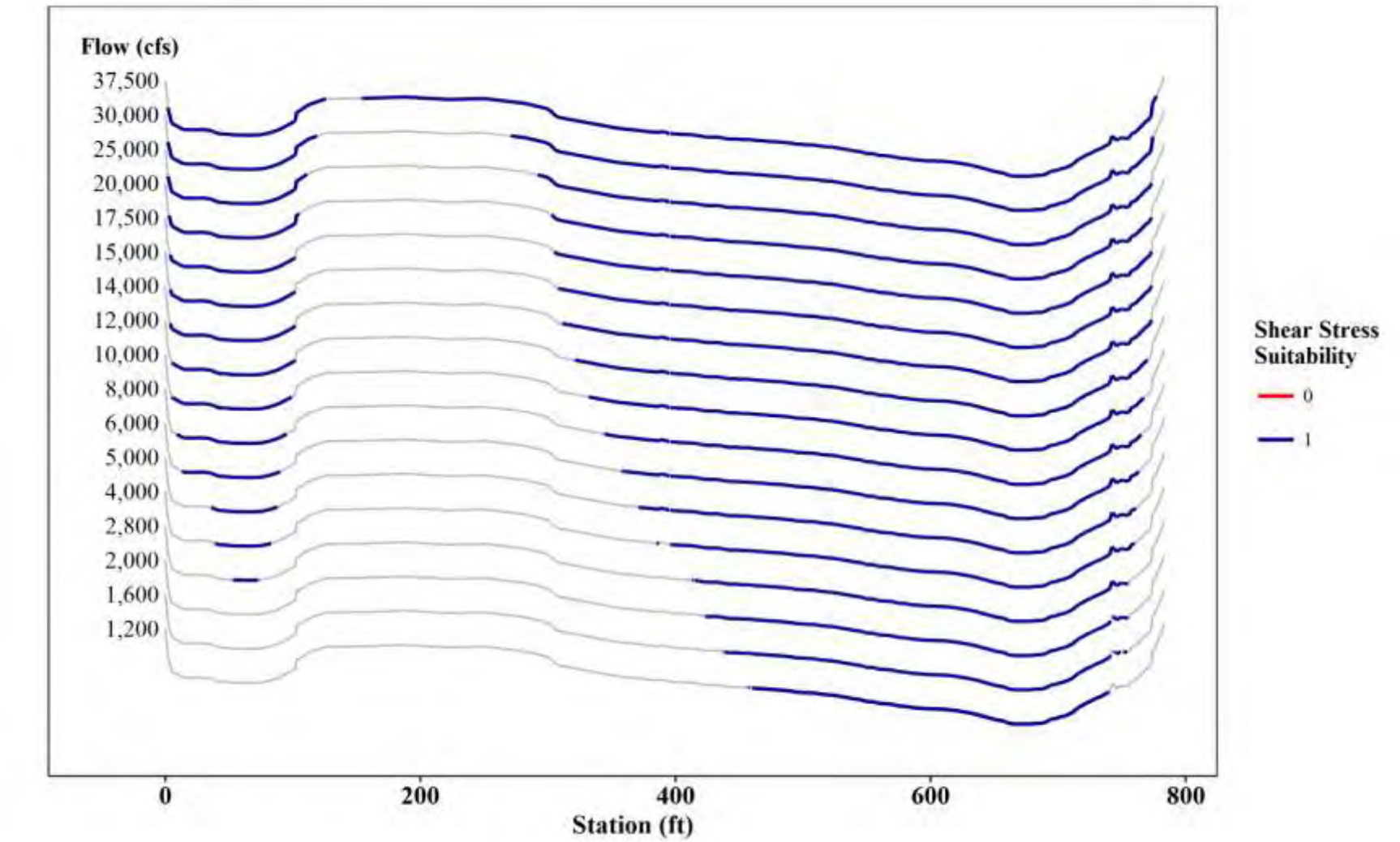

Figure 3.3-3: Shear Stress Mapping at T99 – Adult Yellow Lampmussel

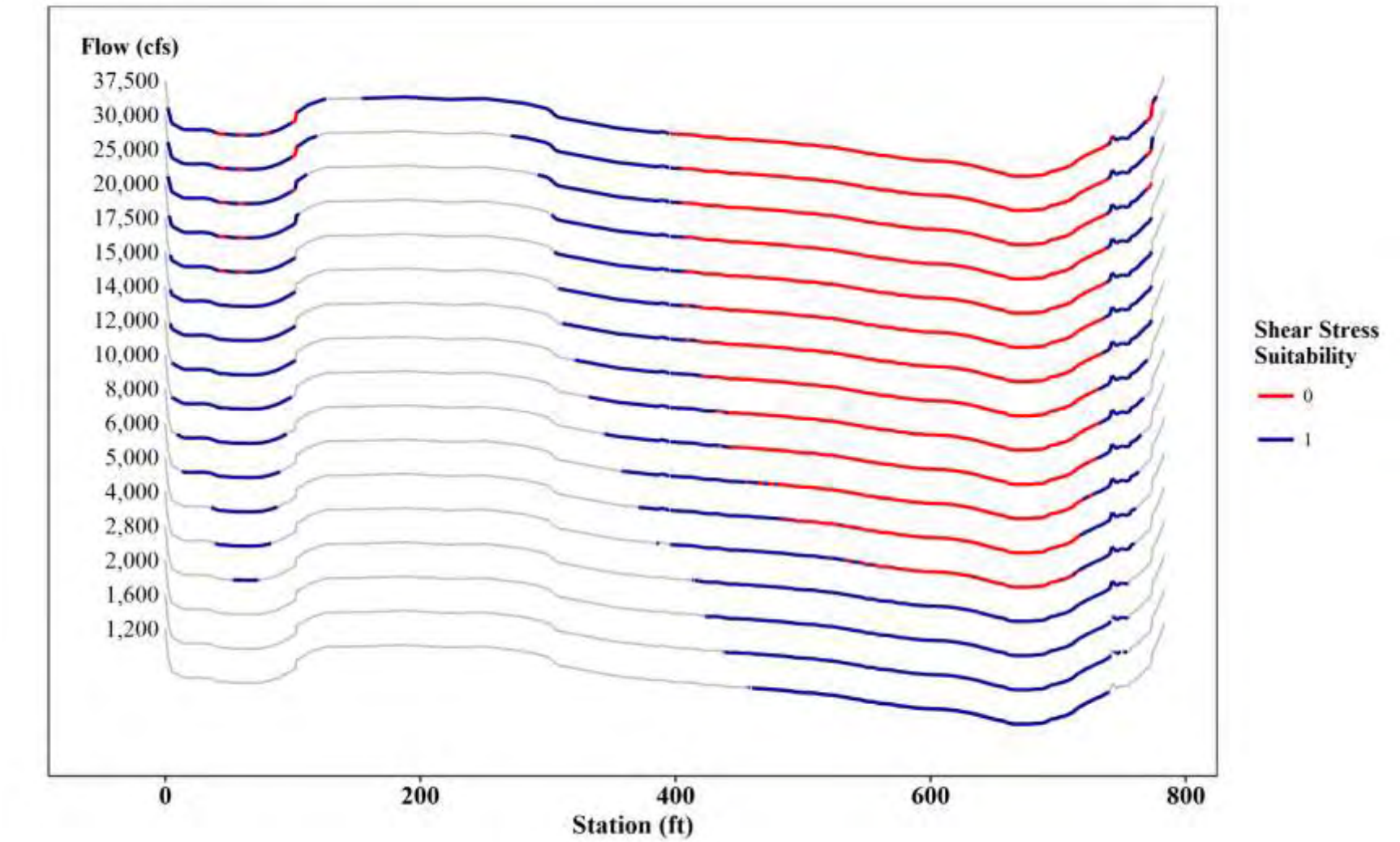

Figure 3.3-4: Shear Stress Mapping at T99 – Juvenile Yellow Lampmussel

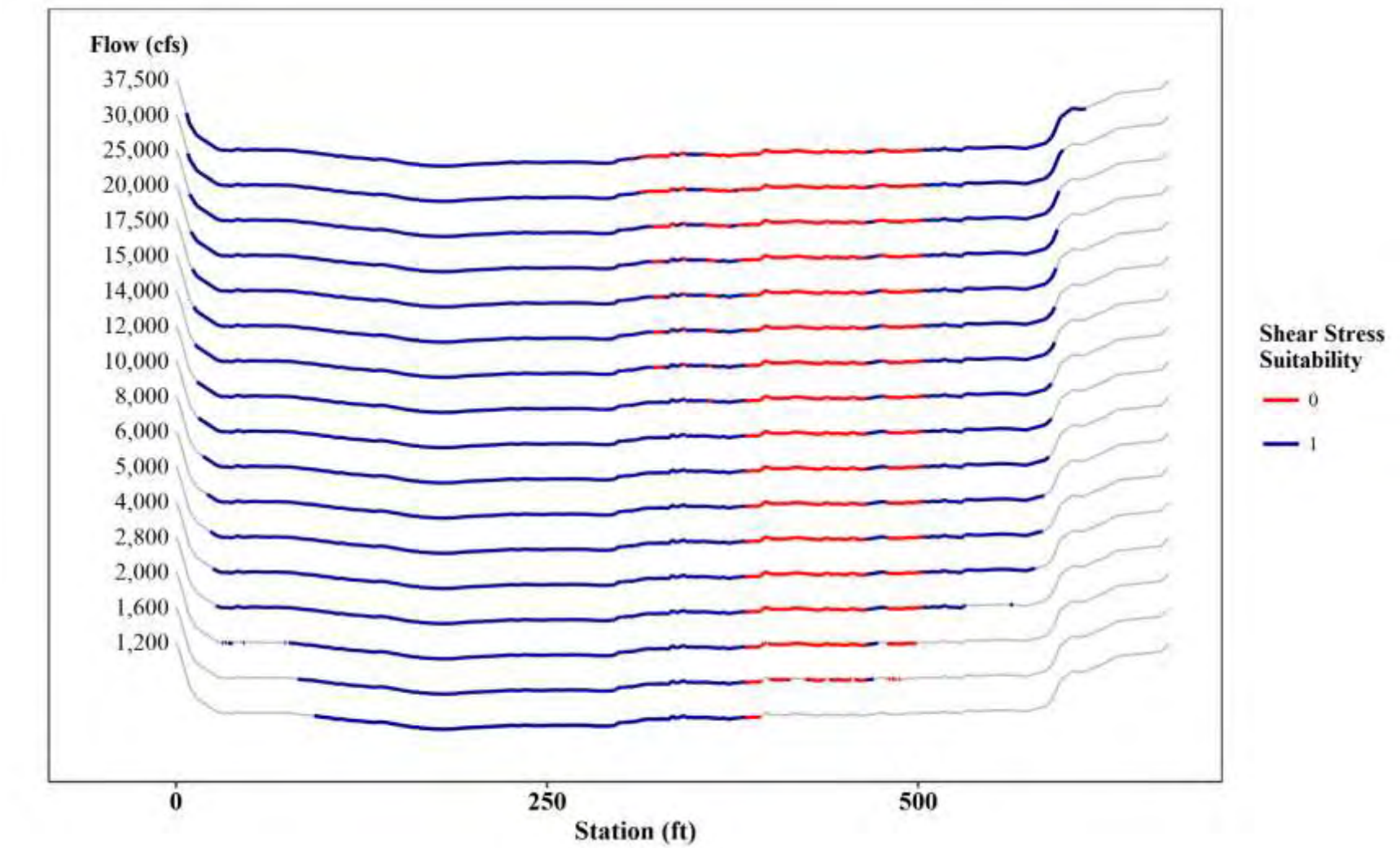

Figure 3.3-5: Shear Stress Mapping at T98 – Adult Yellow Lampmussel

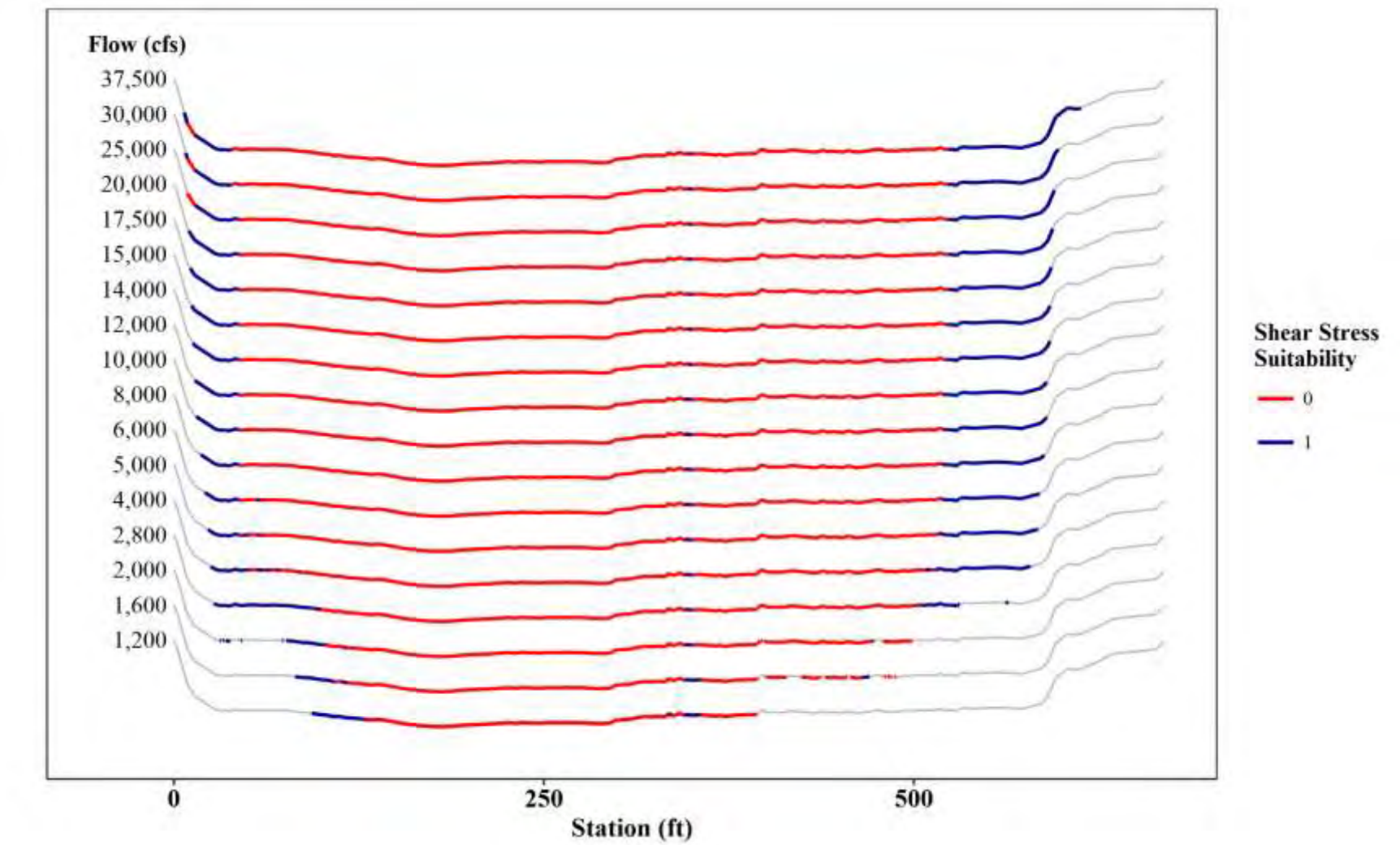

Figure 3.3-6: Shear Stress Mapping at T98 – Juvenile Yellow Lampmussel

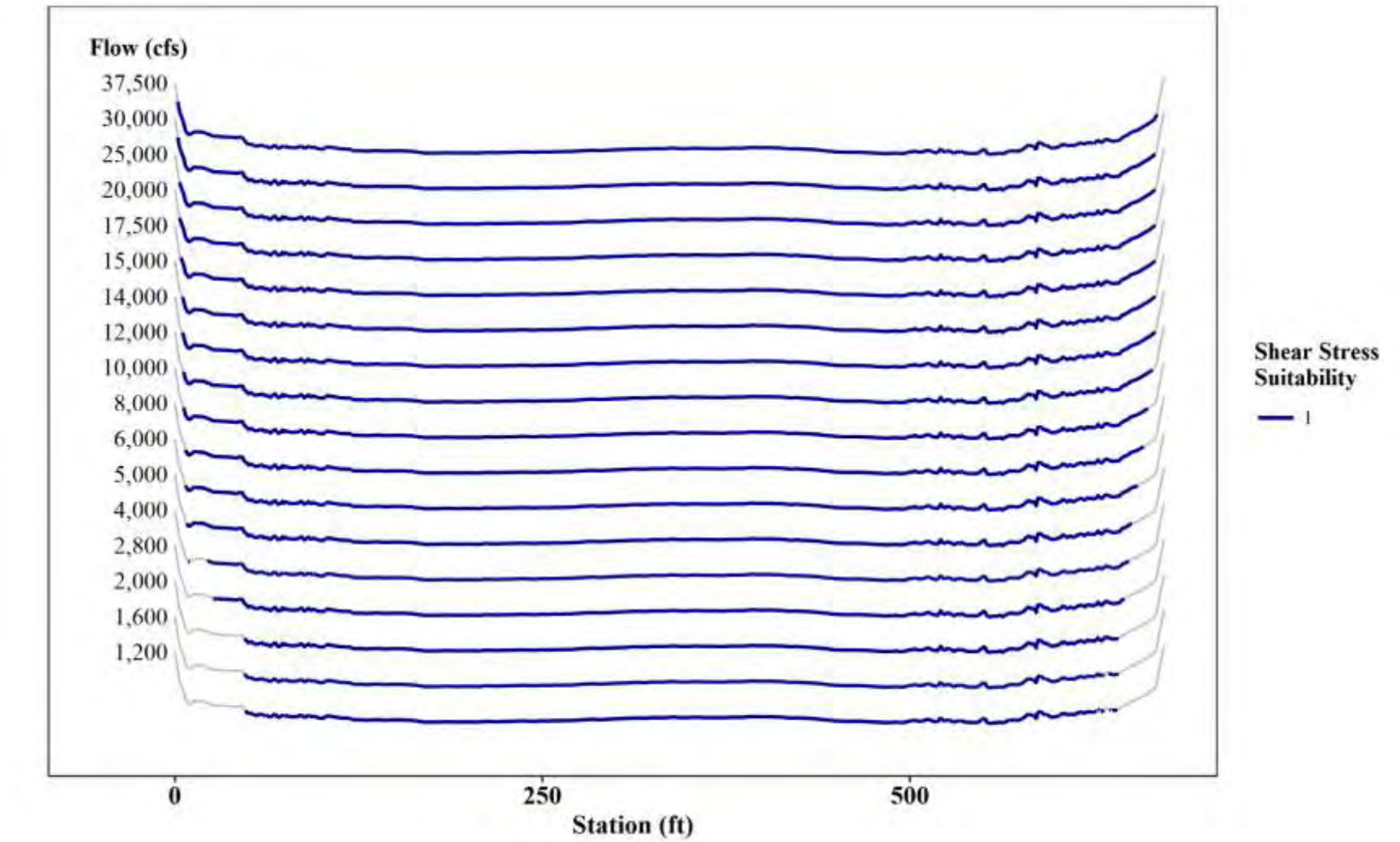

Figure 3.3-7: Shear Stress Mapping at T97 – Adult Yellow Lampmussel

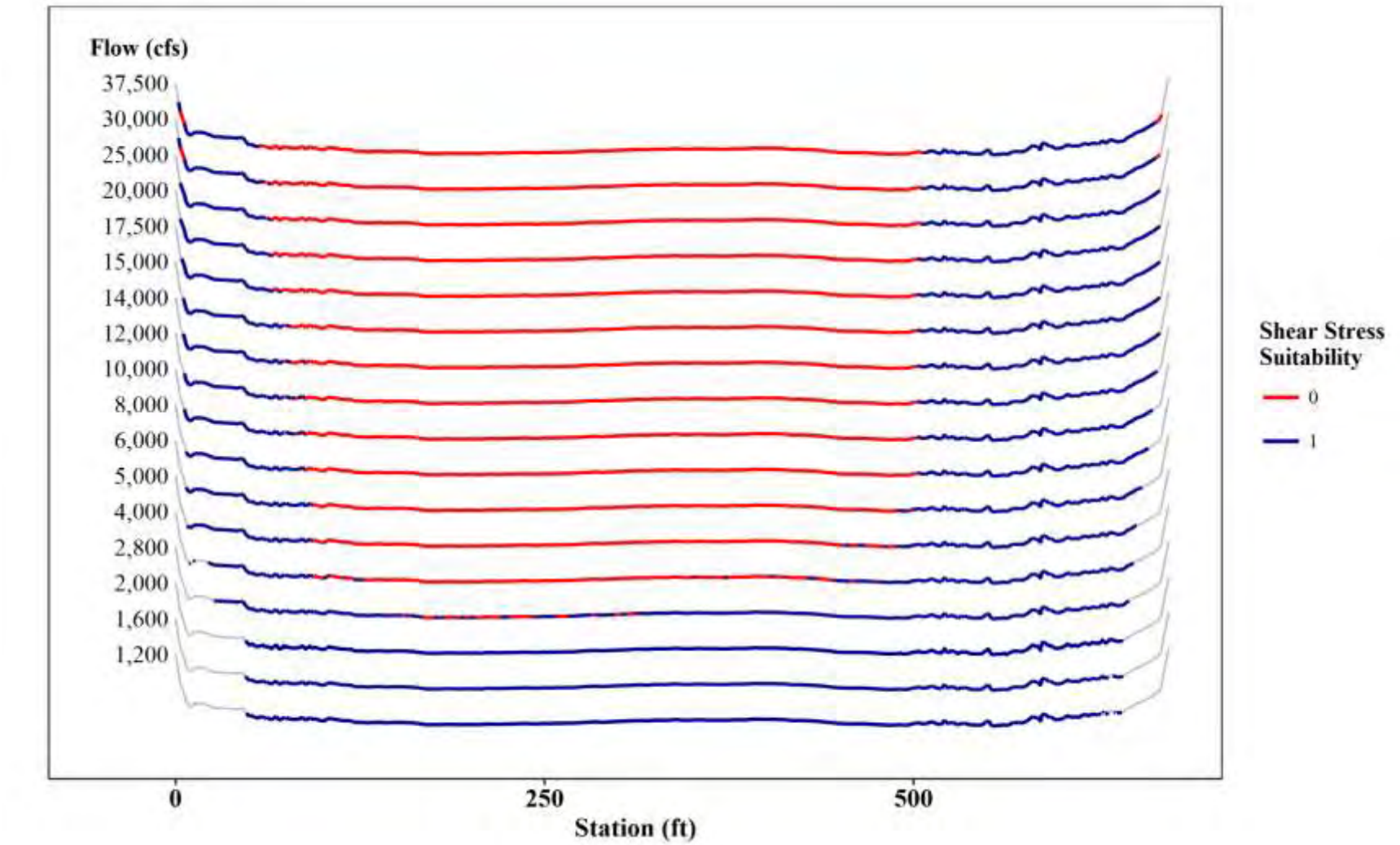

Figure 3.3-8: Shear Stress Mapping at T97 – Juvenile Yellow Lampmussel

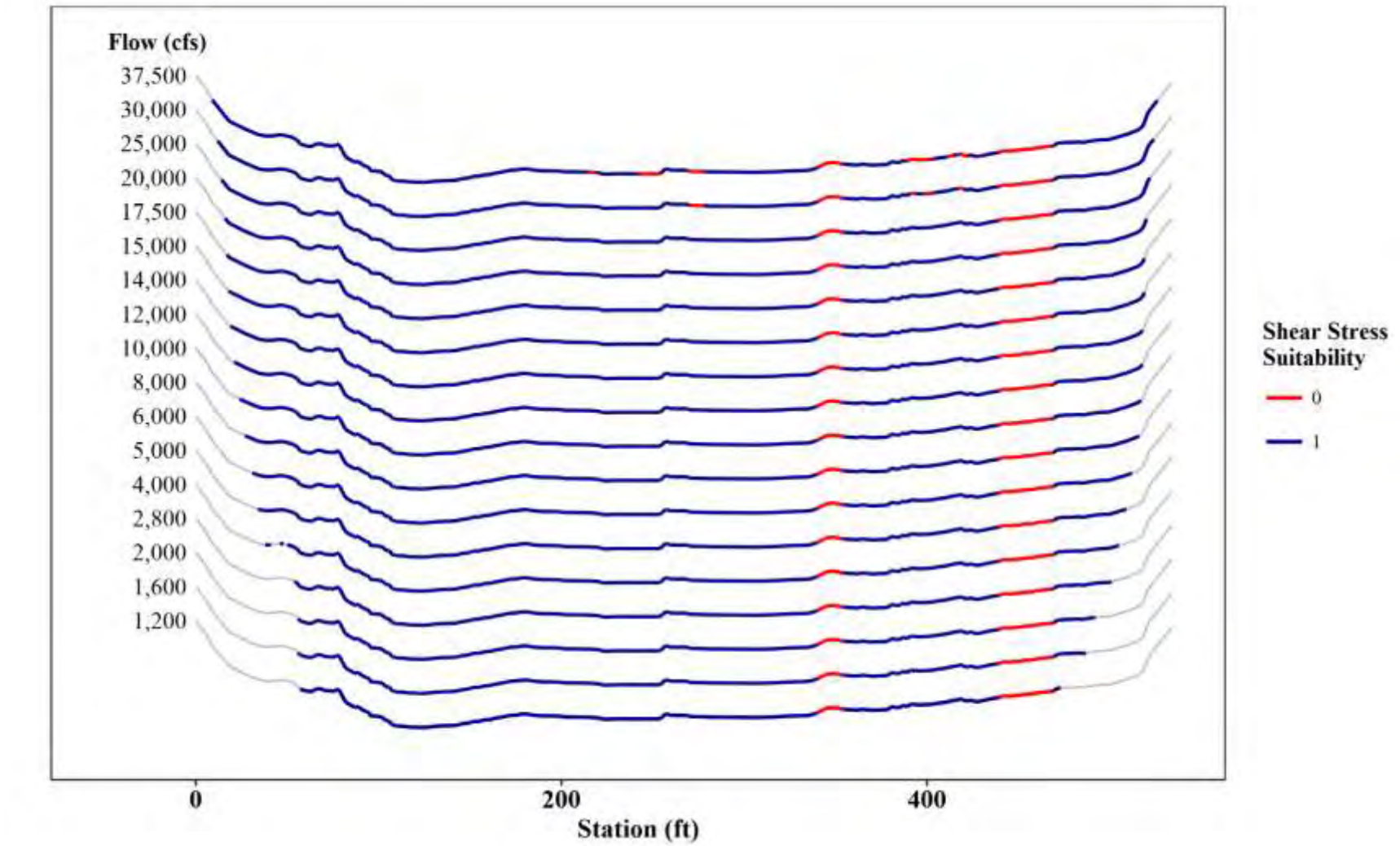

Figure 3.3-9: Shear Stress Mapping at T96 – Adult Yellow Lampmussel

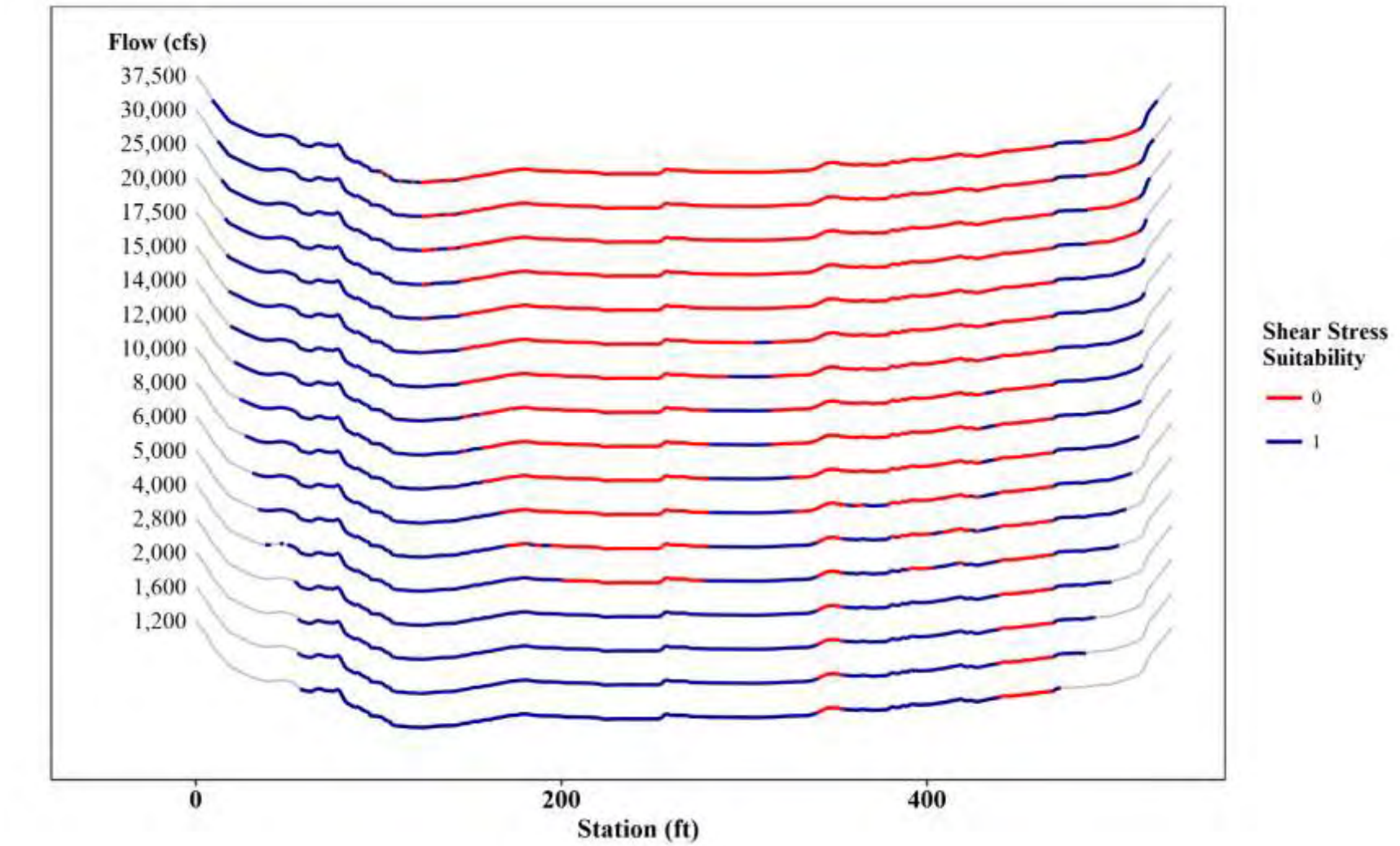

Figure 3.3-10: Shear Stress Mapping at T96 – Juvenile Yellow Lampmussel

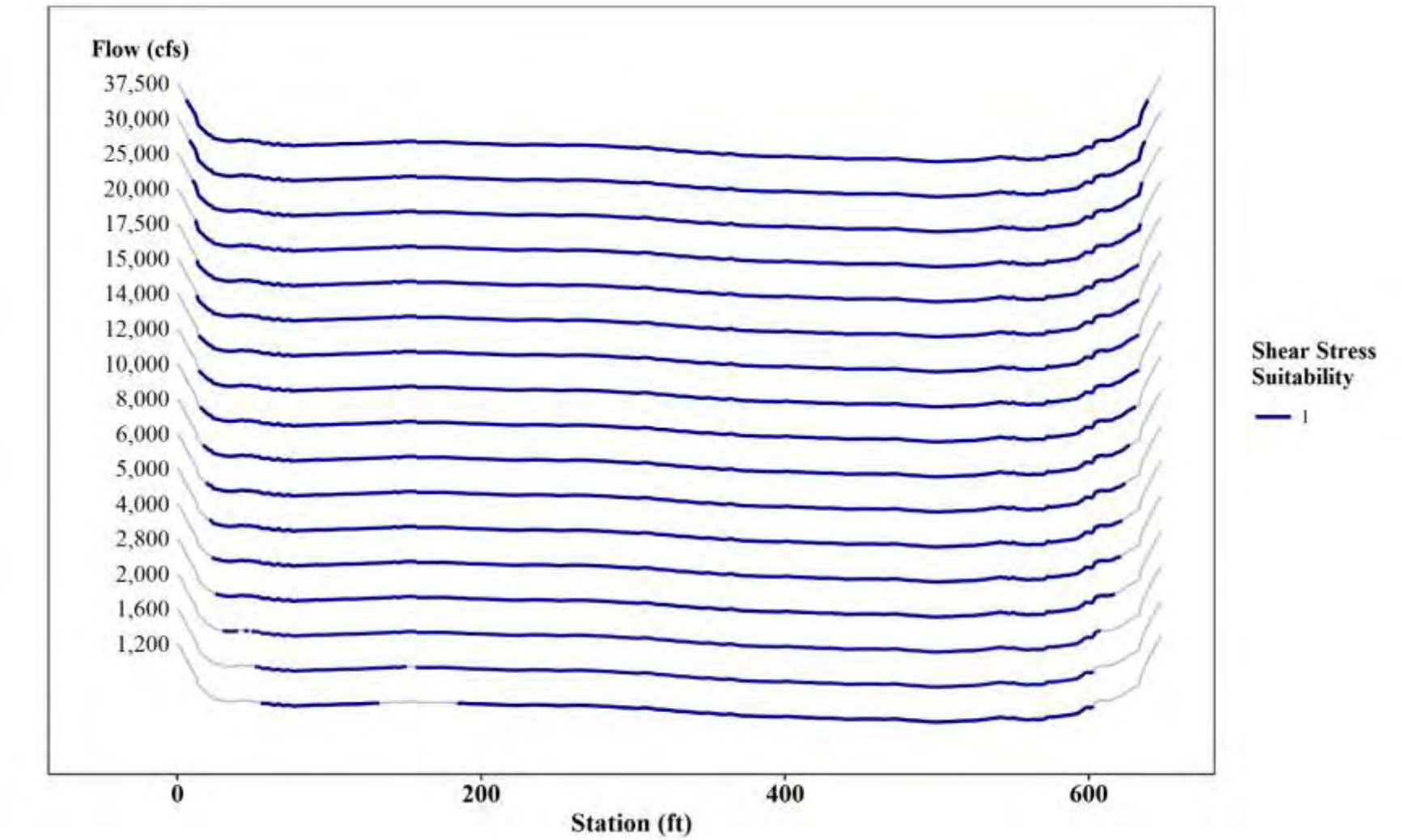

Figure 3.3-11: Shear Stress Mapping at T95 – Adult Yellow Lampmussel

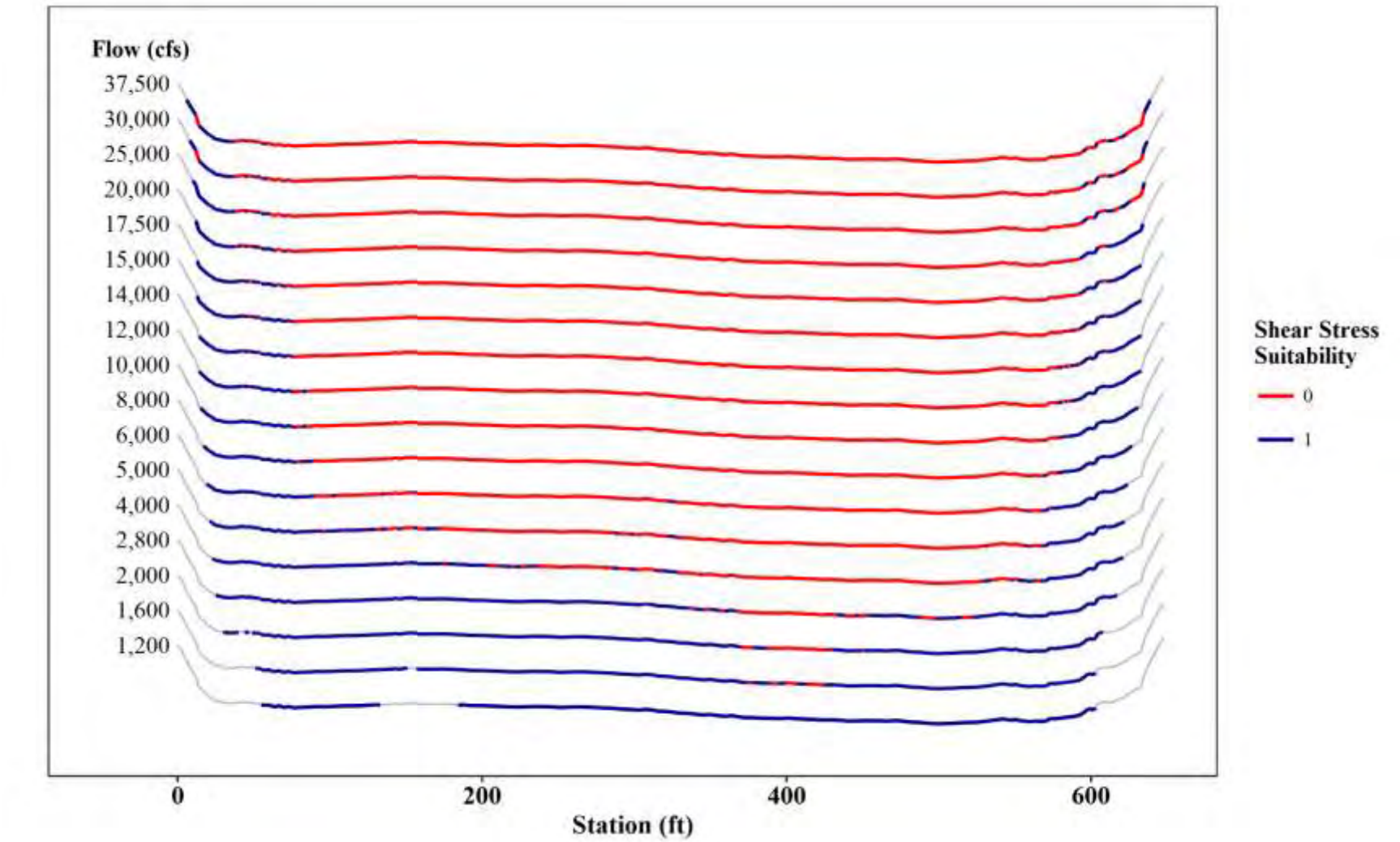

Figure 3.3-12: Shear Stress Mapping at T95 – Juvenile Yellow Lampmussel

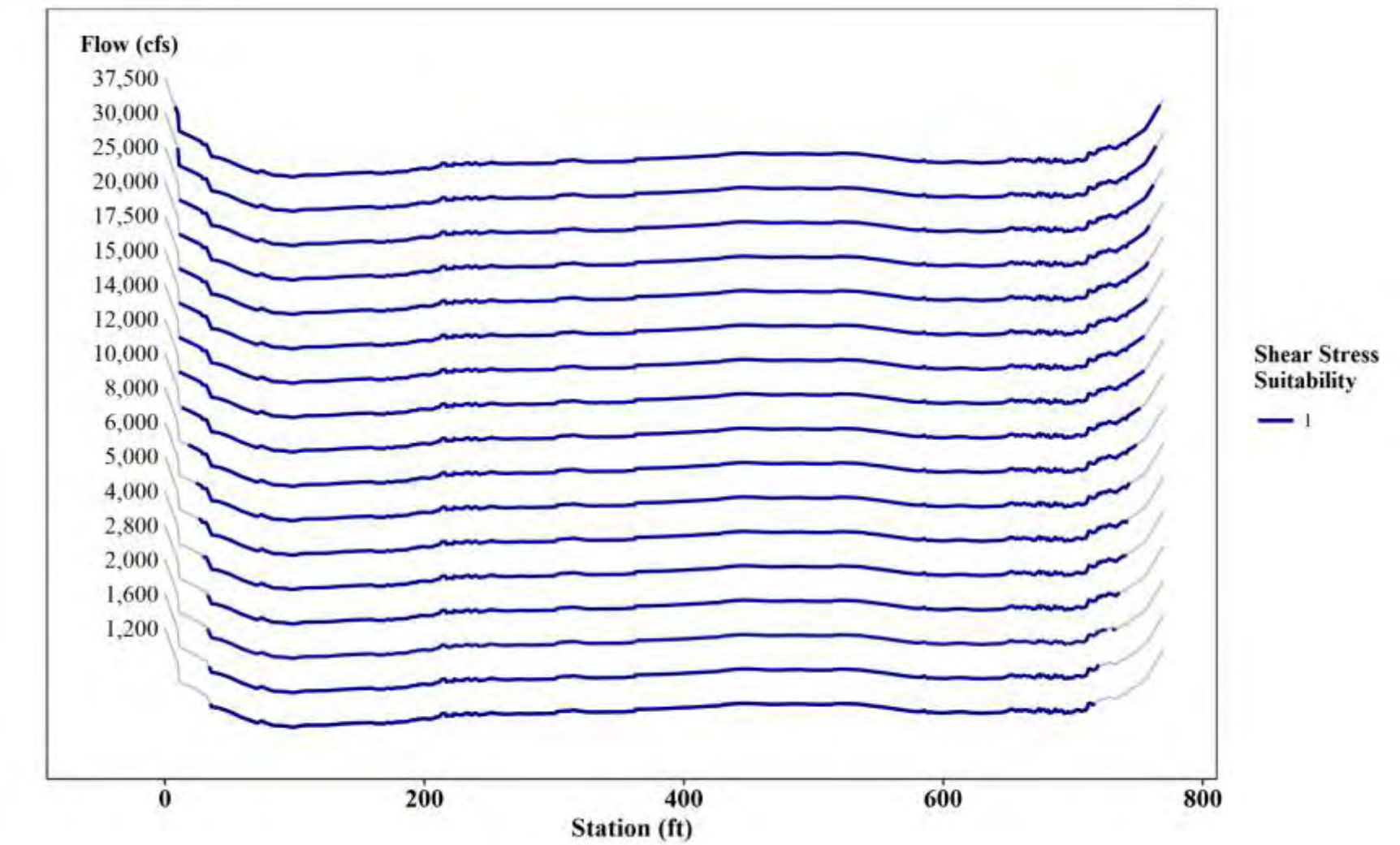

Figure 3.3-13: Shear Stress Mapping at T92 – Adult Yellow Lampmussel

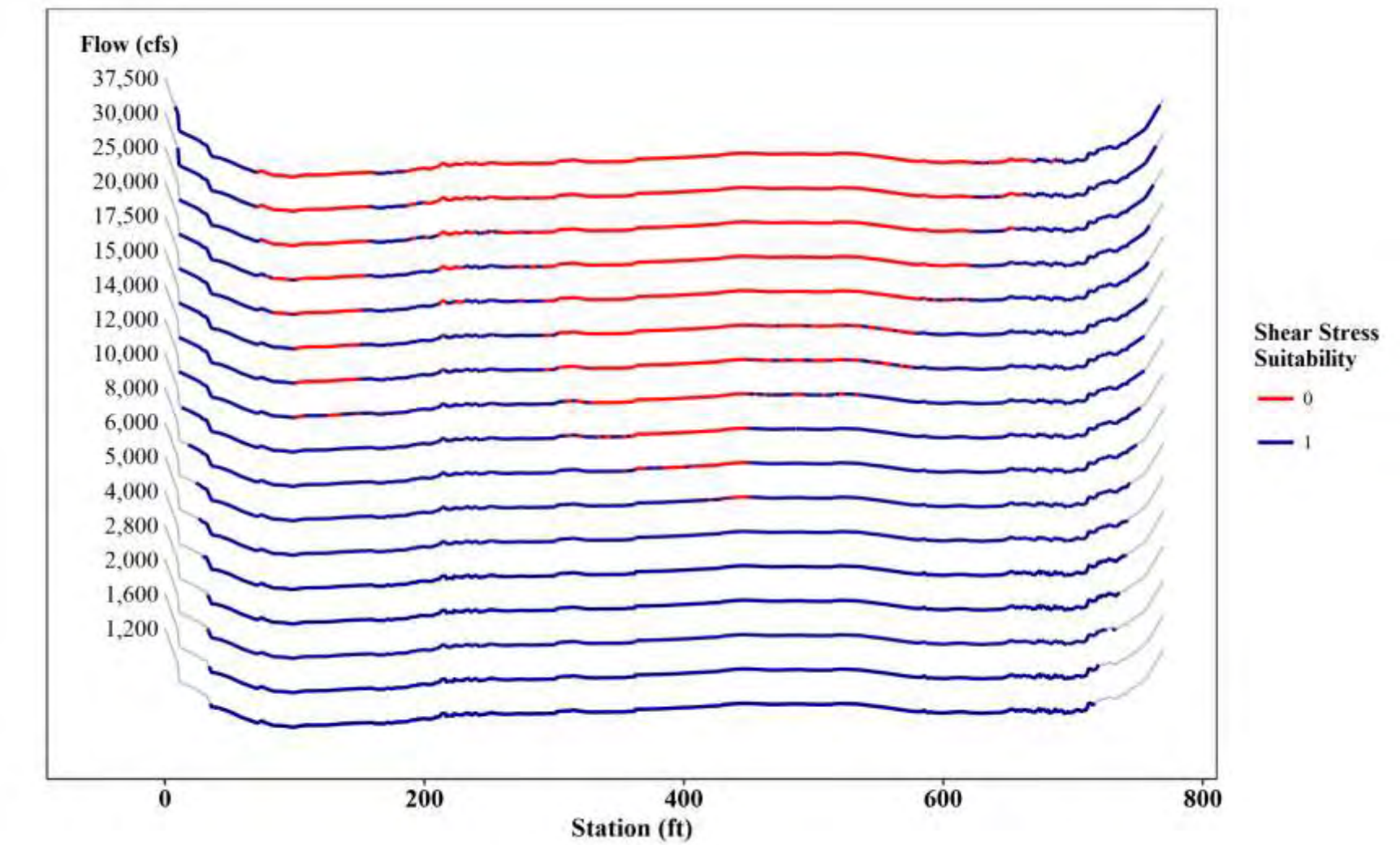

Figure 3.3-14: Shear Stress Mapping at T92 – Juvenile Yellow Lampmussel

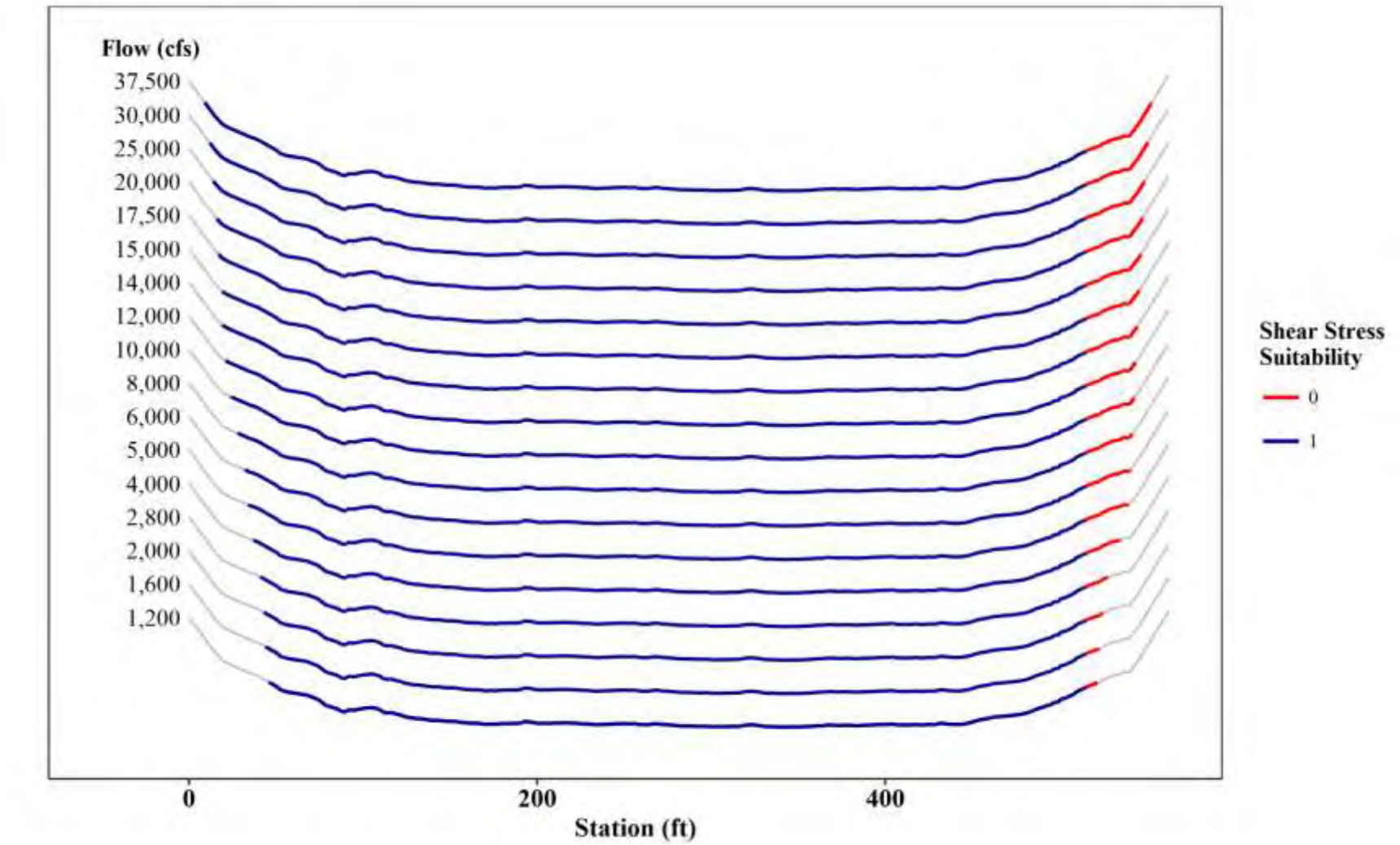

Figure 3.3-15: Shear Stress Mapping at T91 – Adult Yellow Lampmussel

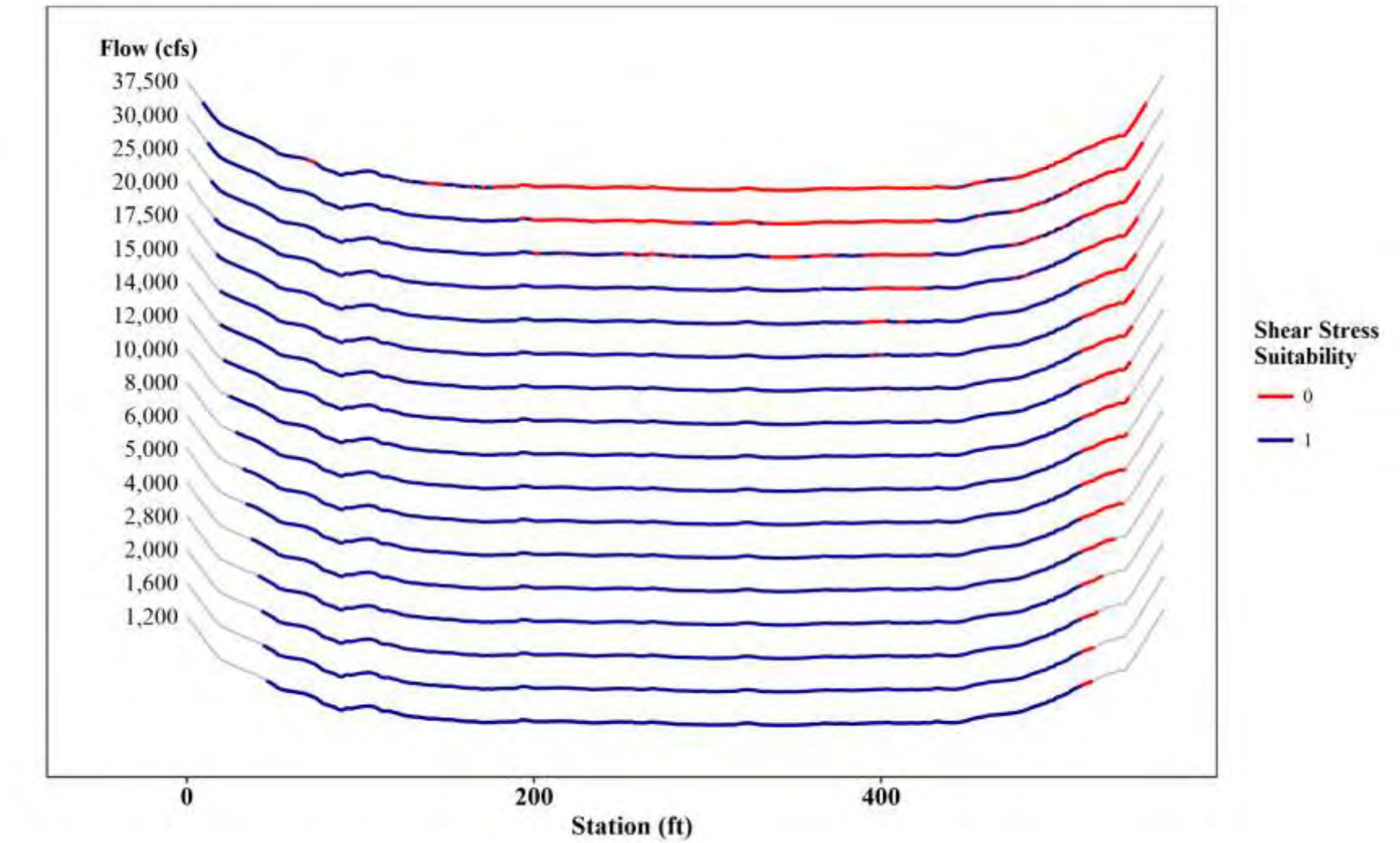

Figure 3.3-16: Shear Stress Mapping at T91 – Juvenile Yellow Lampmussel

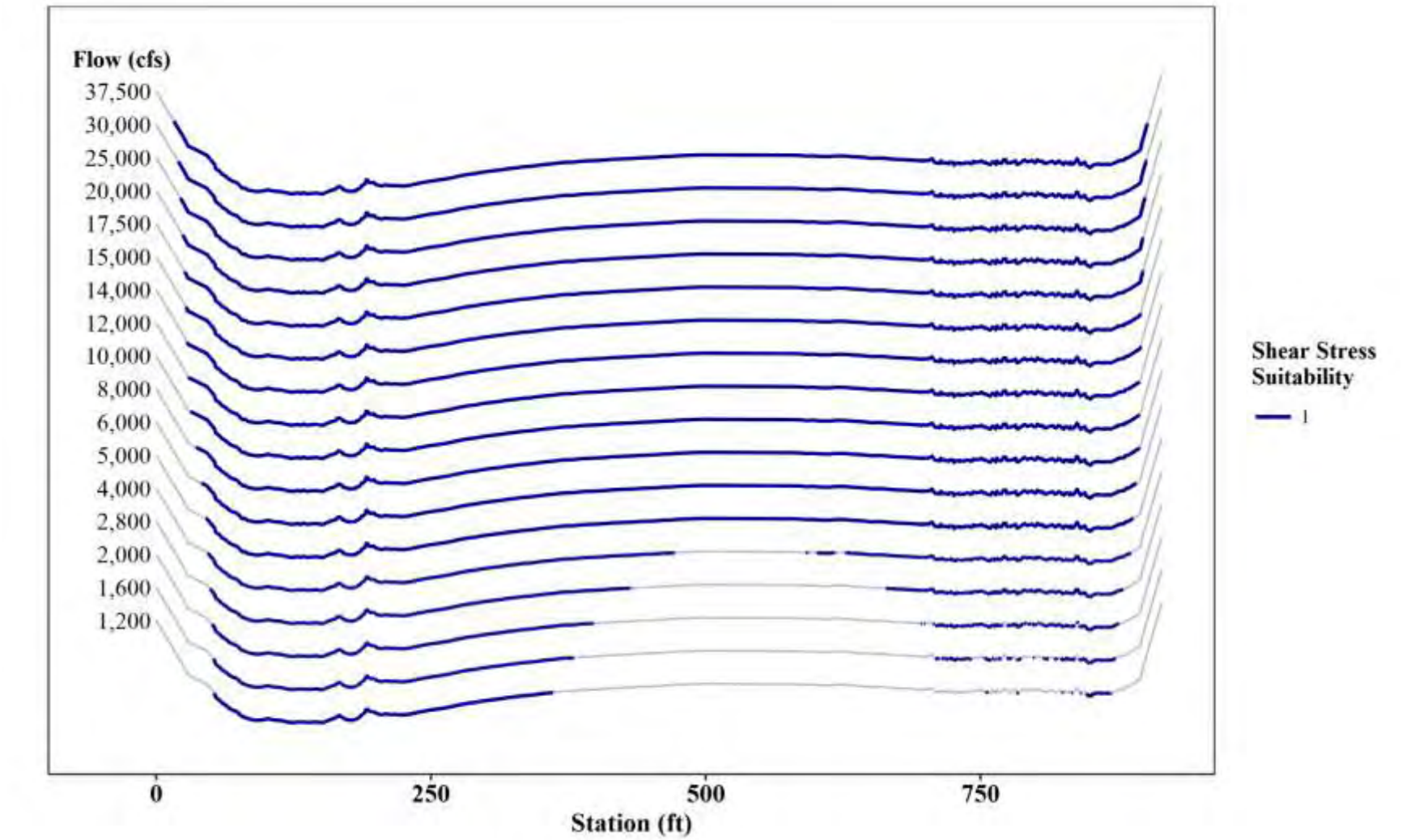

Figure 3.3-17: Shear Stress Mapping at T90 – Adult Yellow Lampmussel

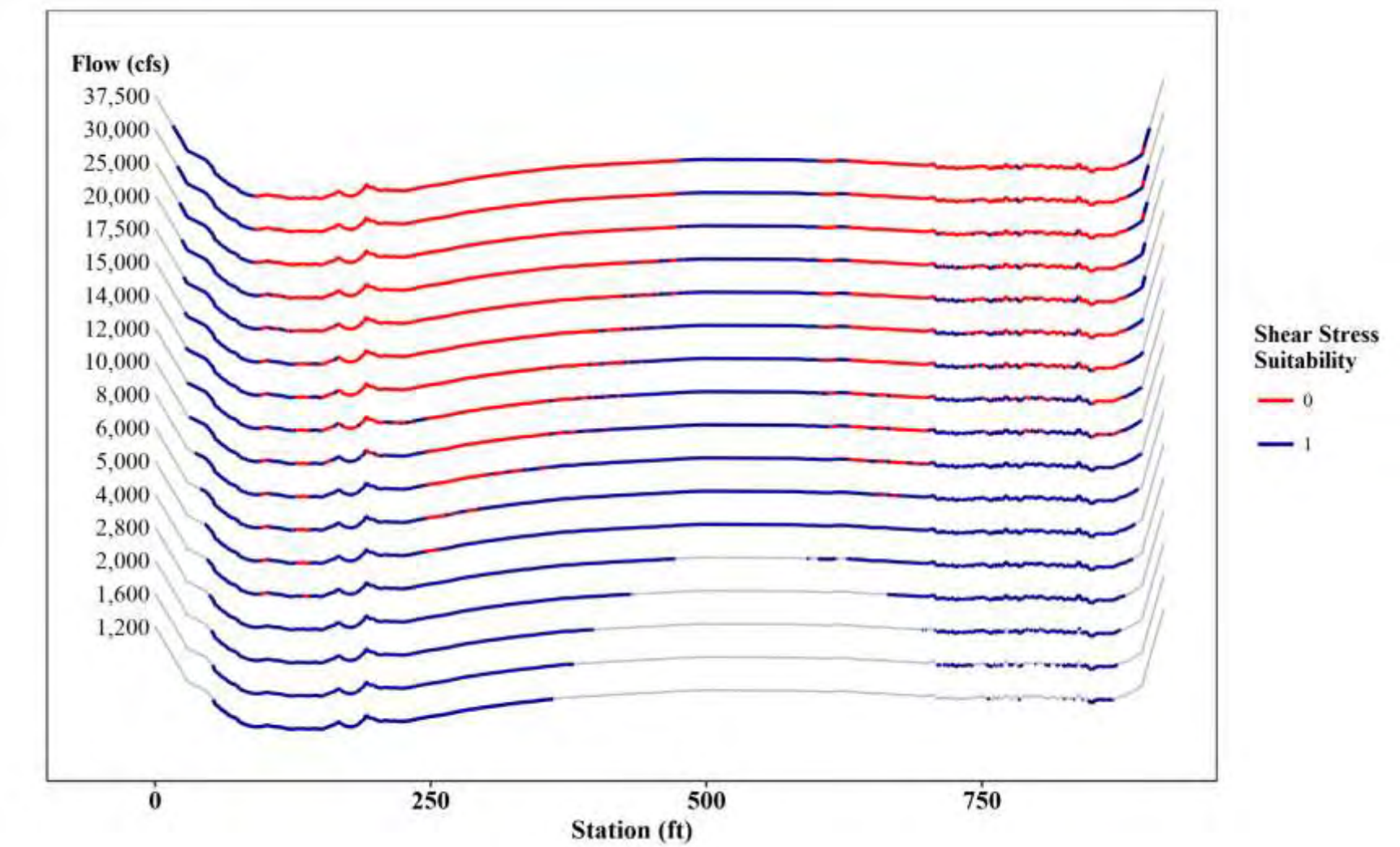

Figure 3.3-18: Shear Stress Mapping at T90 – Juvenile Yellow Lampmussel

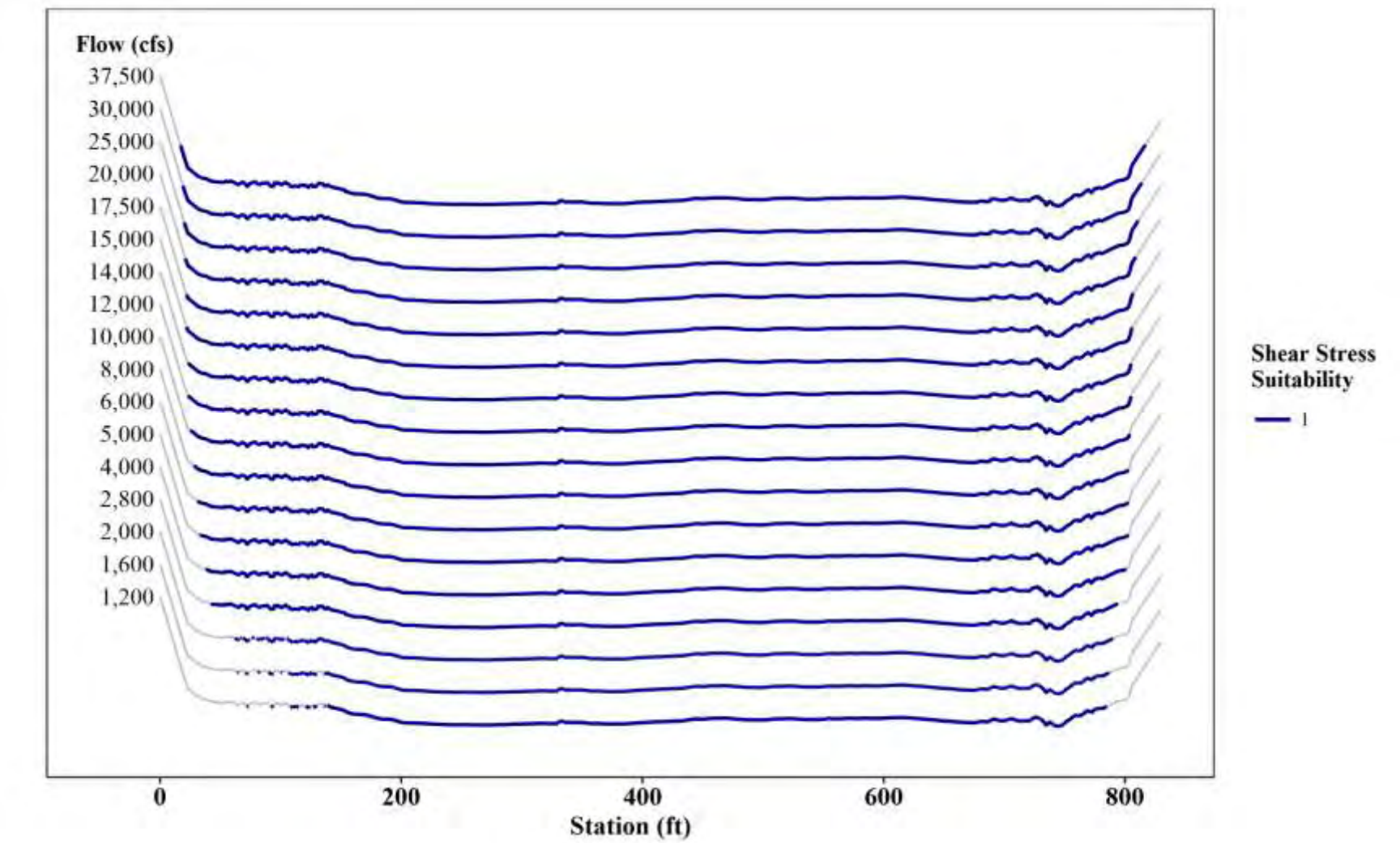

Figure 3.3-19: Shear Stress Mapping at T89 – Adult Yellow Lampmussel

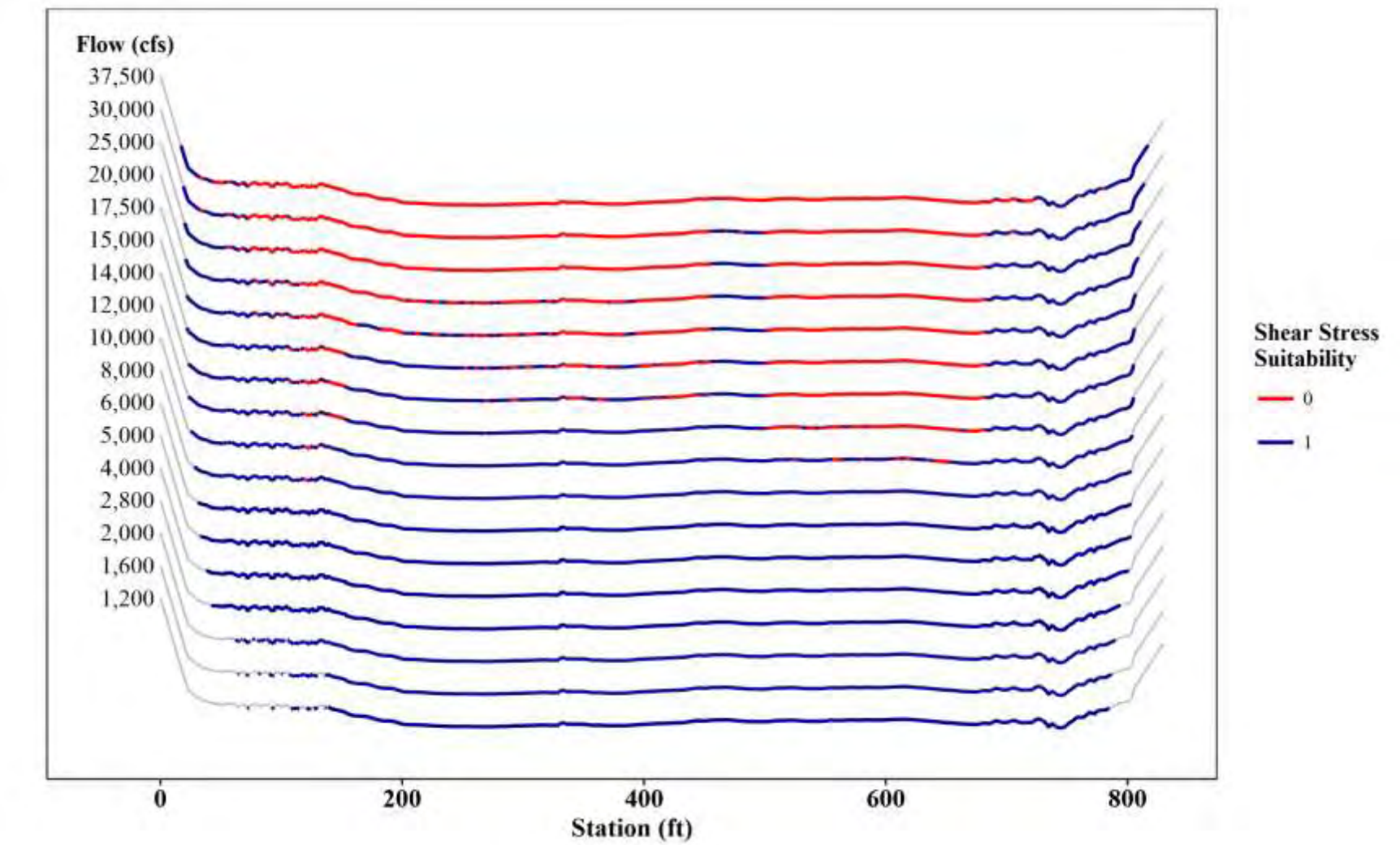

Figure 3.3-20: Shear Stress Mapping at T89 – Juvenile Yellow Lampmussel

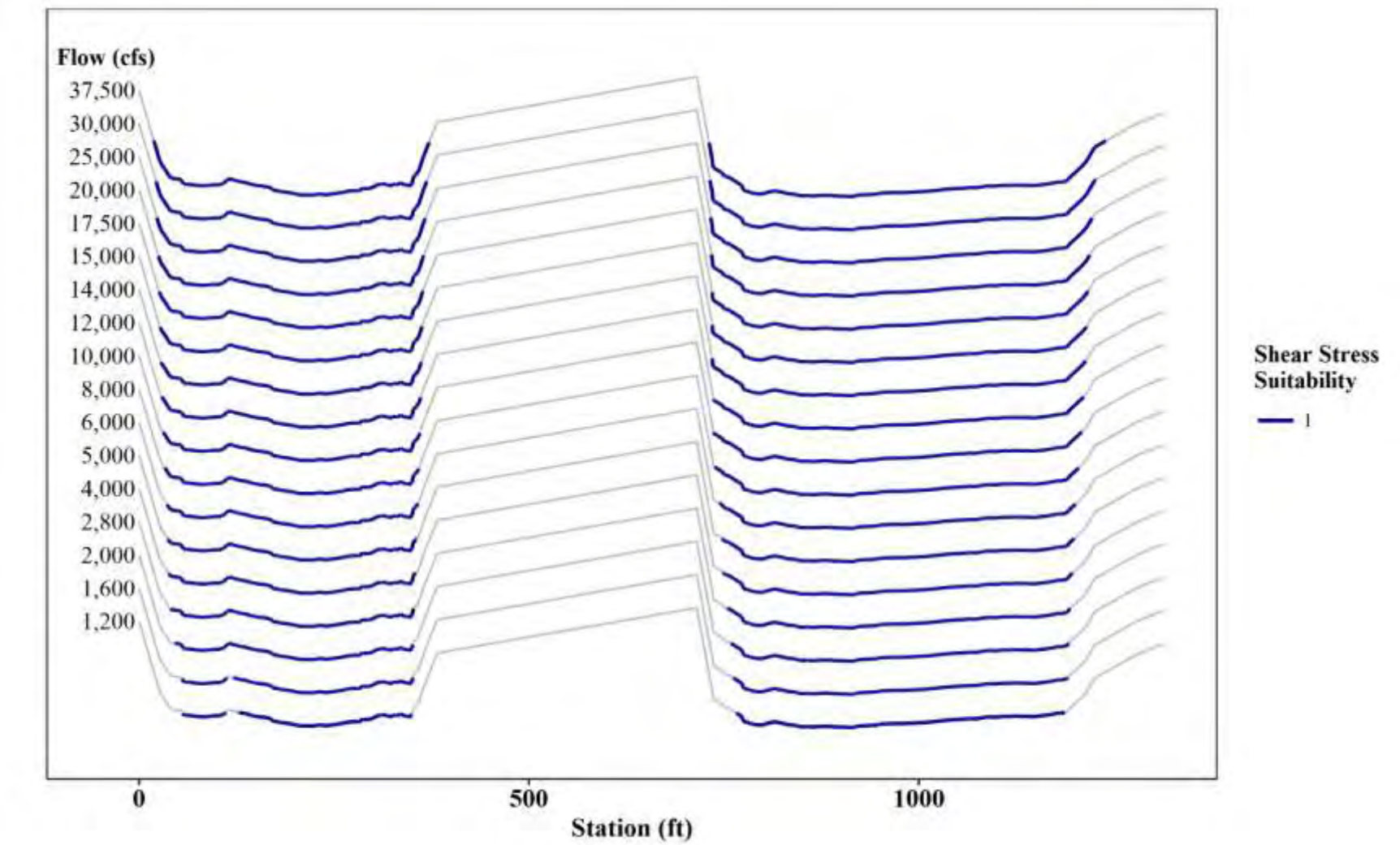

Figure 3.3-21: Shear Stress Mapping at T88 – Adult Yellow Lampmussel

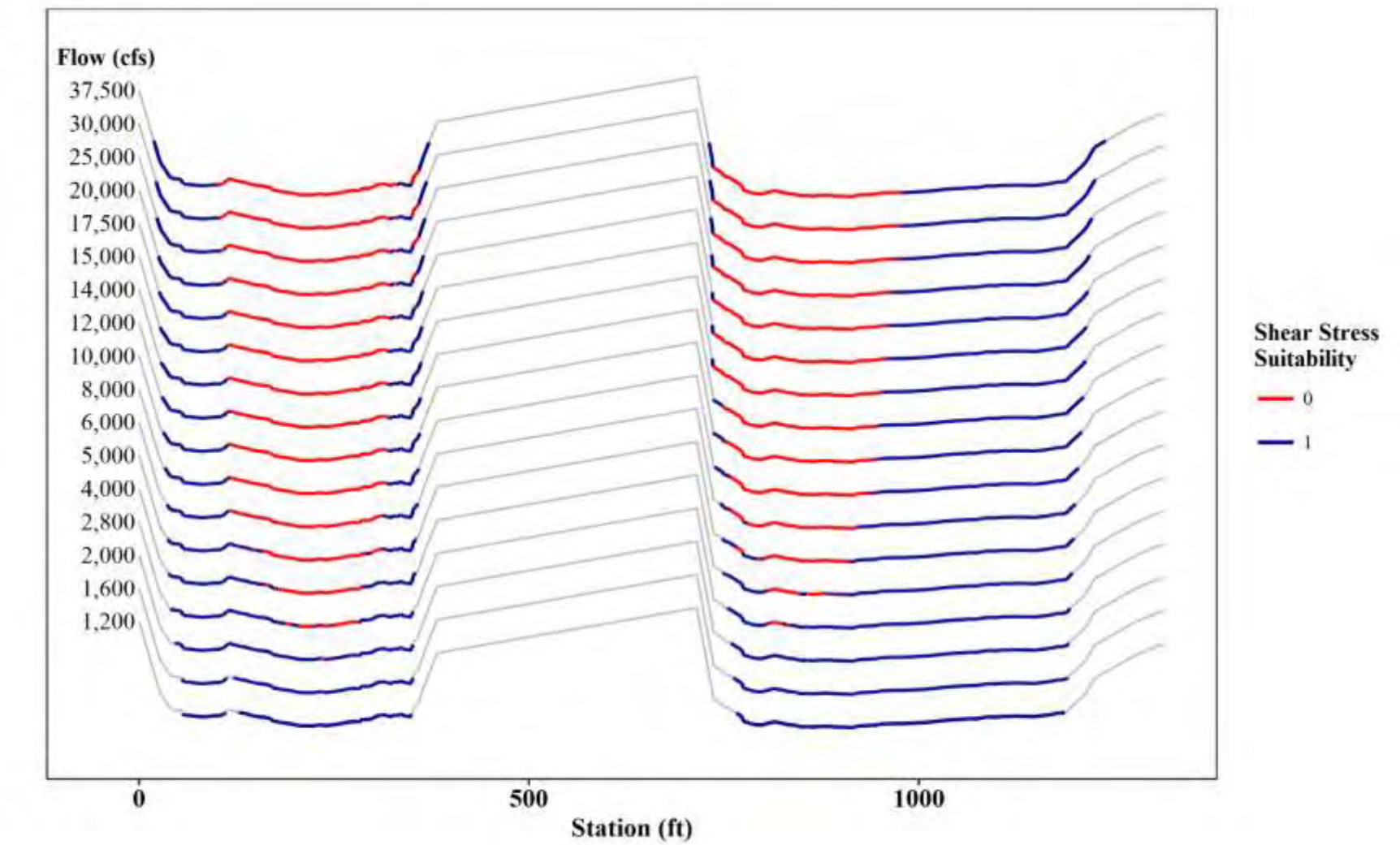

Figure 3.3-22: Shear Stress Mapping at T88 – Juvenile Yellow Lampmussel

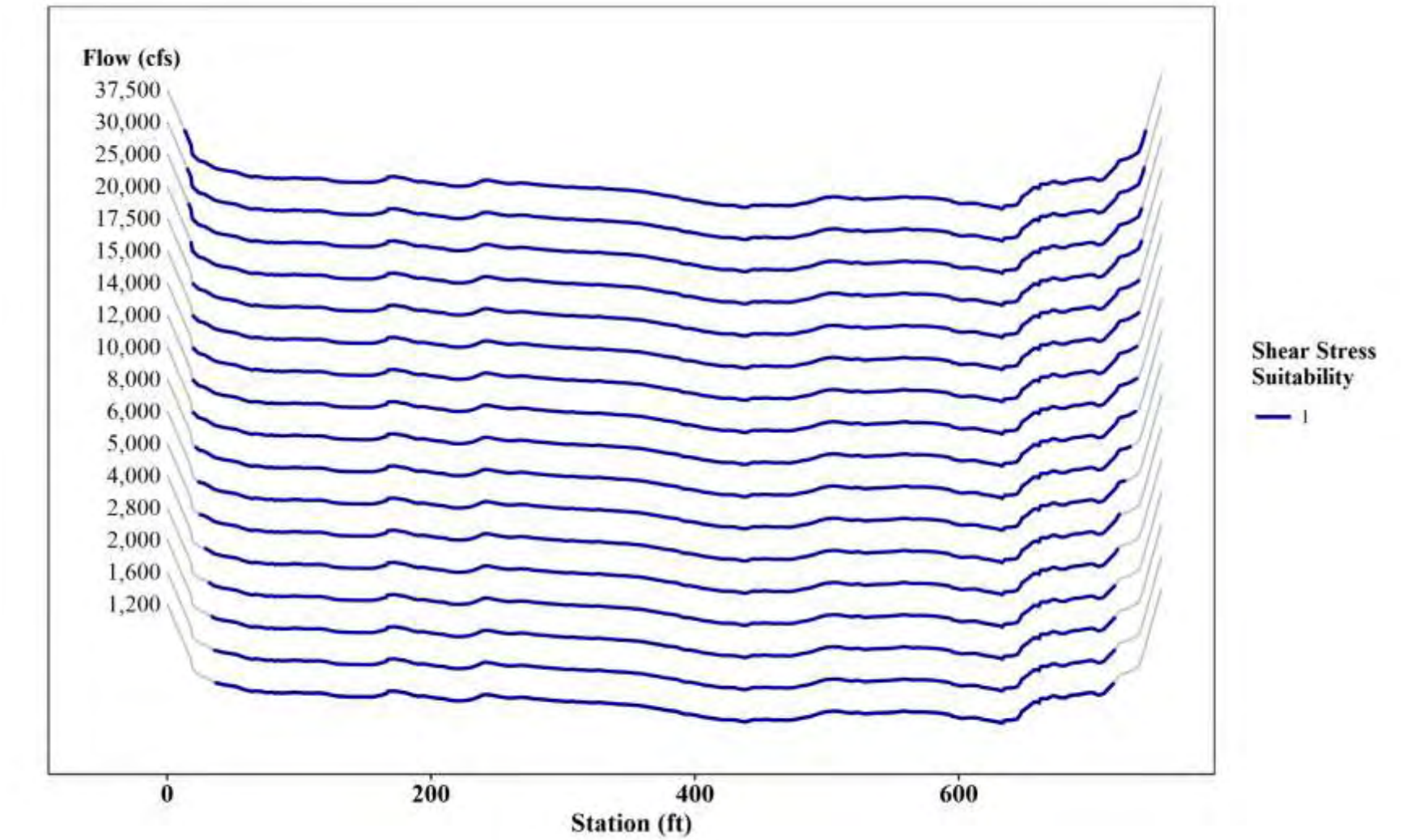

Figure 3.3-23: Shear Stress Mapping at T87 – Adult Yellow Lampmussel

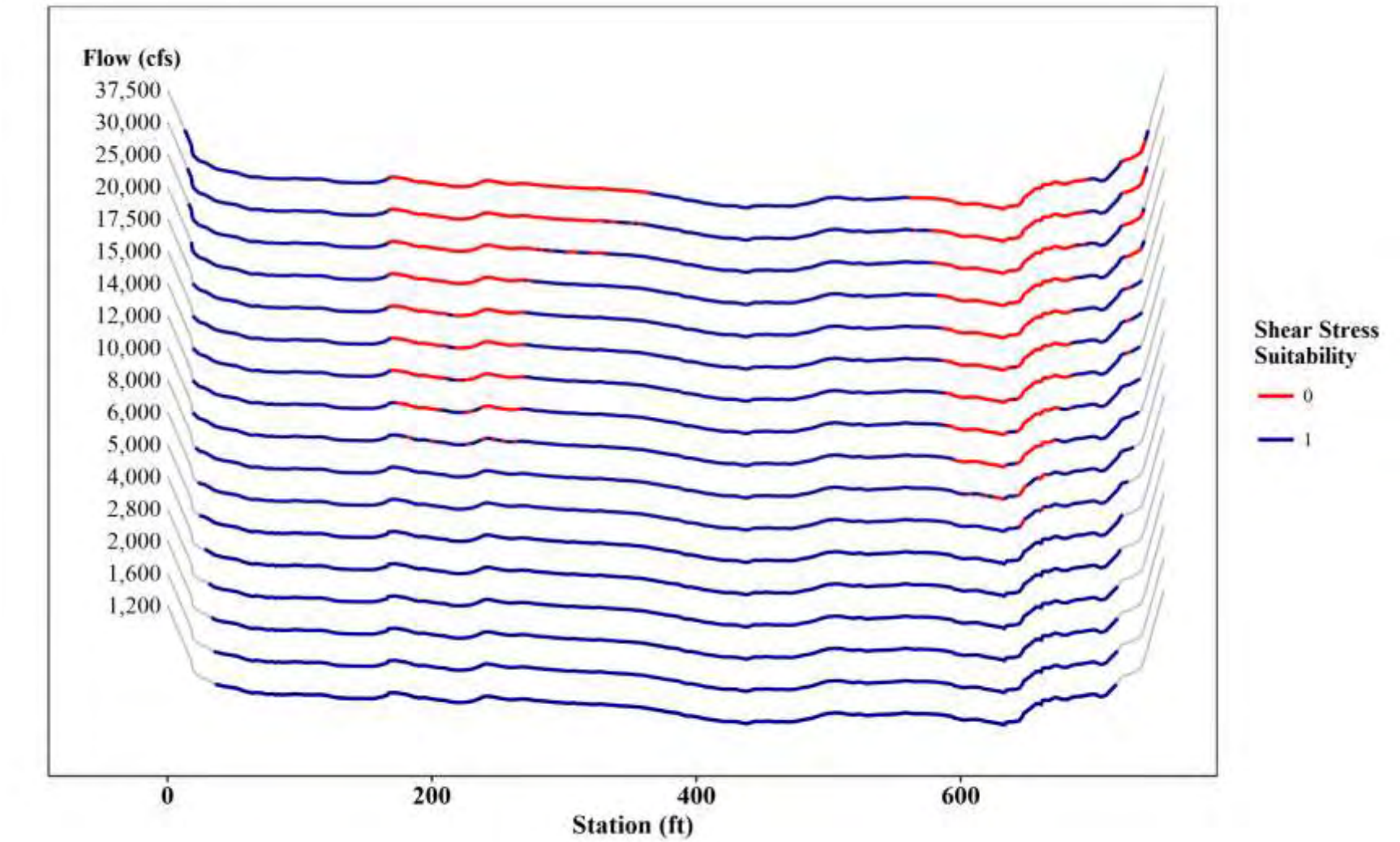

Figure 3.3-24: Shear Stress Mapping at T87 – Juvenile Yellow Lampmussel

4 DISCUSSION

This addendum provides all information requested by FERC on July 3, 2019, including:

- An evaluation of the 4-variable WUA versus flow relationship for Yellow Lampmussel in Reach 4;
- A dual flow analysis for Yellow Lampmussel using the 4-variable WUA in Reach 4; and
- Shear stress mapping for adult and juvenile Yellow Lampmussel at the range of flows modeled in Reach 4 for other species (1,200 to 37,500 cfs).

FL provided these analyses as requested by FERC in their July 3, 2019 filing. However, for an immobile species such as Yellow Lampmussel, a persistent habitat analysis as provided for Reach 4 on April 1, 2019 in Addendum 6[4], is much more appropriate. In Addendum 6, persistent habitat was analyzed spatially at each transect by overlaying station cells from the PHABSIM model for all unique flows and associated suitable habitat that occurred for each cohort[5]. In the persistent habitat analyses, any areas that did not contain suitable habitat during any flow that was experienced were assigned an unsuitable value for persistent habitat for that cohort. Therefore, persistent habitat analysis is much more detailed and suitable since it accounts for the varying flows, especially high flows above the control of FL (16,000 cfs) that a species such as Yellow Lampmussels encounters. The WUA versus flow figure and dual flow tables provided here in Addendum 7 is based only on the total WUA for each flow or in the case of the dual flow table, two flows, not how the location of the suitable habitat changes at different flows. It should also be noted that, though shear stress mapping was performed and provided in this addendum, habitat suitability for mussels also depends on depth, benthic velocity and substrate.

[4] Relicensing Study 3.3.1 Addendum 6 Assessment of Sea Lamprey (new spawning HSI curves) and Yellow Lampmussels in Reach 4.

[5] Cohorts for Yellow Lampmussels are described in Section 2.2 of Addendum 6.