Charlie Creek

Physical Habitat Modeling using System for Environmental Flows Analysis (SEFA)

Final Report

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1. Introduction

The Southwest Florida Water Management District (SWFWMD or District) is developing the technical documentation for establishing Minimum Flows and Levels (MFLs) for Charlie Creek, located in Hardee County, Florida (Figure 1). HSW Consulting, LLC. (HSW) is assisting the District with the instream physical habitat analysis in support of the MFLs development. The objective of this analysis is to characterize the potential effects of flow reductions from a baseline condition on a suitability index for instream habitat in Charlie Creek. HSW collected physical habitat data (depth, velocity, and substrate) for five sites and developed a physical habitat index using the System for Environmental Flow Analysis (SEFA).

Included in this report are an overview of the project goal (Section 1); a description of the geometric and hydraulic data collection and processing (Section 2 and Section 3); and habitat modeling and analysis approach and results (Section 4).

The SEFA data collection effort was completed in an area of Charlie Creek between two available stream flow gauges. The United States Geological Survey (USGS) maintains two long-term stream flow gauges on Charlie Creek (02296260 Charlie Creek near Crewsville; 02296500 Charlie Creek near Gardner) that define the project boundary area (Figure 1). These two gages are referred to as Crewsville gage and Gardner gage in the remainder of the report. Five sites were selected by HSW for data collection between the gages (Figure 1) and are described further in Section 2. Hog Heaven and White Marsh C are located about 1.5 miles and 2 miles upstream of Gardner gage. White Marsh B and White Marsh A sites are located about 2 and 3 miles upstream of Gardner gage. Grass Valley Ranch site is located about 1.5 miles downstream of Crewsville gage.

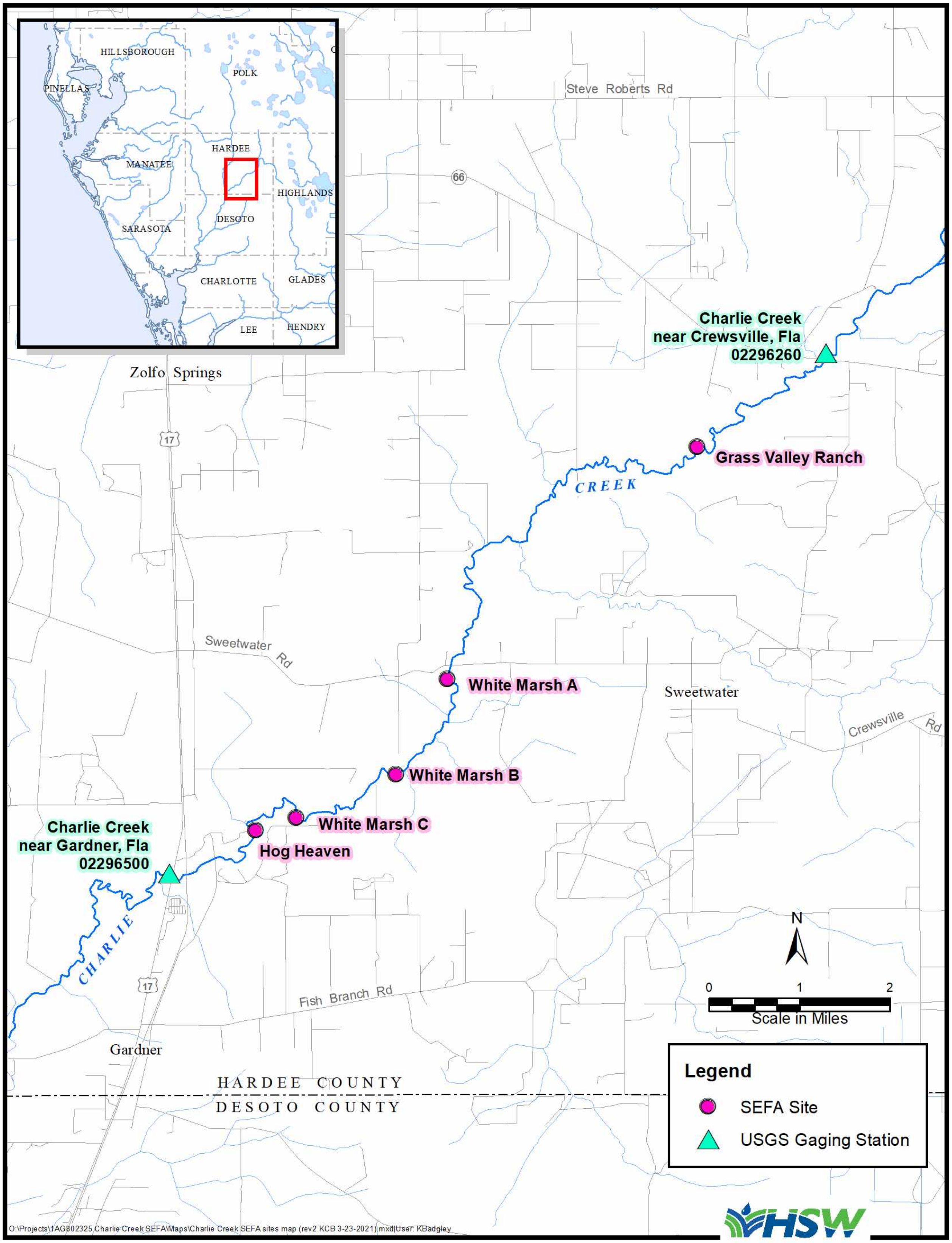

Figure 1. Selected Sites on Charlie Creek

2. Site Selection/Data Collection

Charlie Creek is generally characterized by sandy banks that appear prone to erosion during higher flows. The substrate is mostly sand, although an area of rocky substrate is known to exist at the upstream end of the study area. Brown and Caldwell, Inc. completed the Charlie Creek reconnaissance on April 24, 2018 and May 3, 2018 for site selection. The field methodology used by the District was followed for selecting the sites (Hood, 2006).

Five sites were chosen based on physical characteristics, ease of access, and diversity of habitat area (Figure 1). Each site contained one or more mesohabitats and represents a section of the river where the mesohabitat was homogeneous across the channel. The selected sites for SEFA data collection are representative of the accessible portions of Charlie Creek. The transect locations at each site and corresponding photographs are included in Appendix A.

Three transects were selected at each site and marked with a headpin and tailpin (i.e., rebar driven in the ground) at the right bank and left bank (looking downstream), respectively. An eyebolt was installed as a temporary benchmark (TBM) at each site. The surface water elevation and bank elevations at each transect were referenced to the TBM. These TBMs were later surveyed by a professional surveyor and the elevations (NAVD88) provided by the surveyor were used for SEFA models Substrate, cover, depth, and velocity data were collected along each transect at each site. The measurements were made during low, medium, and high flow conditions at the five sites at a total of 15 transects that included riffles, runs, and pools, and that had a variety of substrates and cover types (Table 2 and Appendix A).

The objective of the data collection was to provide the necessary channel habitat and hydraulic data for habitat modeling over a range of flows that encompasses most historically observed instream flows. Low, medium, and high flow target ranges (Table 1) were determined using the following exceedance rates (Hood, 2006).

- Low: 80-100 percent exceedance rate
- Medium: 35-65 percent exceedance rate
- High: 0-30 percent exceedance rate

Table 1. Targeted flow ranges for SEFA data collection

Flow Description	**Flow range targeted for data collection**	
	02296260 Charlie Creek near Crewsville (cfs)	**02296500 Charlie Creek near Gardner (cfs)**
Low	0.5-2	1-10
Medium	7-60	25-105
High	80-300	200-500

Data Collection

Field data collection procedures were in accordance with SWFWMD PHABSIM (Physical Habitat Simulation) data collection guidance document (Hood, 2006). HSW used OTT MF Pro Flow Meter

(Manual flow measurement) and/or SonTek M9 Acoustic Doppler Current Profiler (ADCP) for data collection. The OTT MF Pro Flow Meter is a top setting wading rod specifically used to measure flow in small streams or rivers that are wadable. A minimum of 20 stations were selected for flow measurement at each transect (Hood, 2006).

Velocities were measured at 0.6 times the depth when depths were less than 1.5 ft. For depths more than or equal to 1.5 ft, velocity was measured at 0.2 and 0.8 times the depth (Figure 2). These two velocities were averaged to represent the average velocity in the vertical. The use of 0.6 and 0.2/0.8 methods assume that the velocity profile is logarithmic. Velocities closer to the river bottom are expected to be lower than velocities farther from the river bottom due to increased friction near the river bottom. If the velocity at 0.8 depth was greater than the velocity at 0.2 depth or if the velocity at 0.2 depth was greater than or equal to twice the velocity at 0.8 depth, then the velocity profile was considered abnormal and the three-point method was used (Figure 2). The three-point method was computed by averaging the velocity measured at 0.2 and 0.8 depths and then averaging that result with a third velocity measured at 0.6 depth.

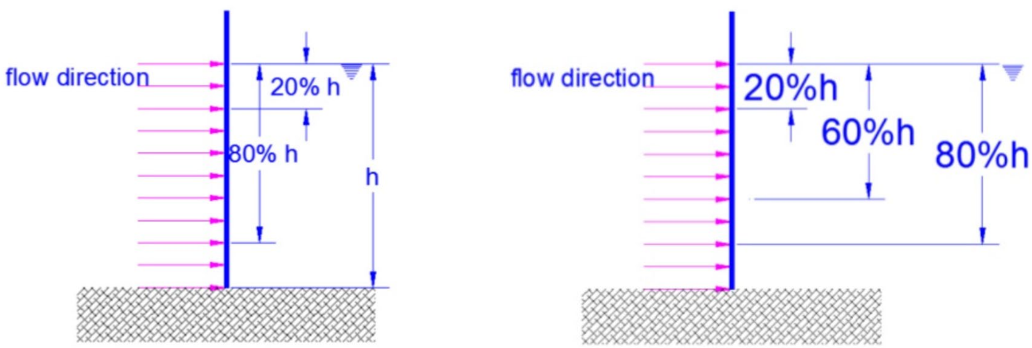

Figure 2. Two-point and three-point USGS methods.

The depths and widths were used to calculate the cross-sectional area associated with each vertical (depth × width). The calculated area and the average velocity within that interval were multiplied to determine the flow through that interval. The flows through the intervals are added to calculate the total flow through the transect.

Discharge measurements were performed using the ADCP when the wading rod measurements were impractical due to high depths. After completion of compass calibration, velocity and depth data were collected using the ADCP moving-boat discharge method. Discharge measurements using ADCP consisted of reciprocal passes (at least 4 passes) having a total measurement time of 720 seconds or greater. The ADCP was tethered and the passes were completed by moving the ADCP along a tagline between headpin and tailpin at each transect (Figure 3). An even number of passes with reciprocal courses were completed at each transect to minimize directional biases in measured discharges.

Figure 3. Moving boat discharge measurements on Charlie Creek.

Low flow data were collected during March-April 2020, medium flow during July 2020 and January 2021, and high flow during August 2020 (Table 2).

Table 2. Summary of the measured flows and stages at the selected sites

Site ID (Latitude Longitude) Upstream to downstream	Transect type Upstream to downstream	Low flow		Medium flow		High flow	
		Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)
Grass Valley Ranch (GVR) (27.44498 -81.7016)	Pool	0.32	42.22	37	43.65	166.3	46.63
	Run	0.37	42.22	39.5	43.66	171.1	46.63
	Shoal	0.38	42.23	39.4	43.67	174.8	46.57
White Marsh A (WMA) (24.40761 -81. 7467)	Pool	1.34	31.55	91.4	33.61	299.6	36.18
	Run	2.57	31.54	93.3	33.60	303.3	36.12
	Shoal	2.98	31.51	94.3	33.57	310.8	36.12
White Marsh B (WMB) (27.39188 -81.7558)	Pool	2.94	28.14	107.5	30.30	321.6	32.99
	Run	3.10	28.13	109.5	30.30	323	32.98
	Shoal	3.53	28.11	109.6	30.30	317	32.94
White Marsh C (WMC) (27.38525 -81.7742)	Run	3.53	26.17	34.9	27.16	290.4	30.05
	Pool	2.08	26.14	36.6	27.02	287	30.04
	Shoal	3.54	26.10	34.4	26.89	299.5	29.99
Hog Heaven (27.38233 -81.7815)	Run	3.07	25.81	33.2	26.71	305.4	29.24
	Shoal	3.30	25.80	34.1	26.70	302.6	29.23
	Pool	4.47	25.78	35.9	26.69	305.1	29.23

3. ADCP2RHBX

SEFA input file requires depths and depth averaged velocities for each offset along the transects for the survey flow condition. In this study, medium flow was selected as the survey flow condition. For the survey flow, SEFA uses the measured depths and velocities at each offset and calculates flow using the velocity-area method. SEFA uses flow/stage values from low/high flow conditions and estimated flow/measured stage from medium flow condition to establish the rating curves at each transect. Data collected using OTT MF Pro Flow Meter provided the depths and depth-averaged velocities for each offset at a transect. However, data collected using ADCP was processed further using ADCP2RHBX software to estimate the depths and depth-averaged velocities for each offset.

For medium flow, ADCP was used for data collection at all transects at WMA and WMB and at WMC pool transect. Data collection at all other transects was completed using OTT MF Pro Flow Meter. ADCP continuously measures water depth and velocities as the ADCP moves across the stream at a transect. The raw ADCP files (.rivr) contain data related to the course followed across the river and the depth/velocity information. Some of the relevant parameters measured by ADCP are DMG (Distance Measured Good, ft), Depth, Depth averaged water speed, and other information (Table 3 and Figure 4).

Table 3. ADCP output parameters

Parameter	**Description**
DMG (Distance Measured Good, ft)	DMG is the straight line distance traveled by ADCP from the starting location as measured by bottom tracking
Depth (ft)	Water depth measured by ADCP
Mean Speed (Depth, ft/sec)	Depth-averaged water speed
Direction (deg)	Direction of depth-averaged water velocity vector
Boat Direction (deg)	Direction of boat movement (Direction of transect tagline)
Heading or Orientation of the Instrument (deg)	Direction of the instrument

ADCP2RHBX software was used to read the data generated by the ADCP from each pass and estimate the depth and depth averaged velocity at each offset. Using ADCP2RHBX and multi pass ADCP data, depths and velocities from each ADCP pass at a transect were averaged to generate the multi pass average depths and average velocities at equally spaced intervals (1 ft spacing) for the medium flow condition. ADCP2RHBX program uses depth-averaged mean speed (ft/s) from the ADCP output for averaging the velocities from multiple passes. However, this speed does not account for direction and needs to be projected perpendicular to the cross-section to generate a depth-average streamwise velocity. The equation below is used to estimate the streamwise velocity for each ADCP pass (Figure 2).

Streamwise velocity = Mean Speed (ft/sec) × $\sin{(\theta_{WT} - \theta_{BT})}$

The averaging options used for all the ADCP transects at the five sites are as below:

- Offset distance – 1 ft

- Distance to average Depth – 1ft
- Distance to average streamwise velocity – 1ft

Since an averaging distance of 1 ft is specified, depth and streamwise velocity values 0.5 ft either side the offset point are averaged. For example, depth and velocities between 0.5 ft and 1.5 ft are averaged and assigned to the offset point of 1 ft. The depths and estimated streamwise velocities from each ADCP pass at a transect were averaged to generate the multi pass average depths and average streamwise velocities at equally spaced intervals (1 ft spacing) for the medium flow condition.

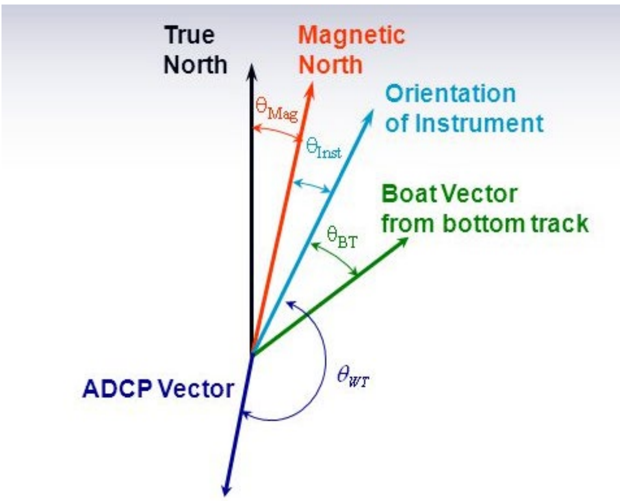

Figure 4. ADCP velocity vector projection.

4. Modeling and Analysis

SEFA (System for Environmental Flow Analysis) (Aquatic Habitat Analysts, Inc., 2012) is a program that simulates relationships between streamflow and a measure of physical habitat for selected fish or other aquatic life forms by guilds, species, and/or life stages. SEFA software utilizes hydraulic, instream habitat, and time series models to develop flow recommendations based on habitat suitability criteria for the evaluated aquatic organisms. The hydraulic characteristics and stage-discharge relationships within a stream sub-reach are key components of a SEFA model. The program allows for the alteration of flows to estimate their effects on the suitability of habitat (reported as area weighted suitability) for organisms of interest in the study system (Jowett, Payne, & Milhouse, SEFA: System for environmental flow analysis , 2014). The ability of SEFA modeling to evaluate relationships between streamflow and physical habitat for aquatic organisms is directly applicable to MFL evaluations.

Water velocity, depth, and channel substrate are variables that characterize the physical habitat suitability of a location for aquatic organisms. The response functions needed to evaluate habitat suitability are the relationships between stream discharge and the combination of depth, water velocity, and inundated substrate type. SEFA calculates Area Weighted Suitability (AWS), which is a measure of suitable habitat available to aquatic life forms within the evaluated sub-reach under specified discharge conditions. The program translates an input time series of daily discharge (or other time increment) into a time series of daily AWS (by guild, species, and life stage) and then calculates statistics for each AWS frequency distribution. The output function of the SEFA program is the relation between stream discharge and AWS.

Instream Habitat Model

Hydraulic modeling within SEFA characterizes the physical attributes within the stream (i.e., depth, velocity) over a prescribed range of discharges. Inputs to SEFA include physical habitat data, micro-scale fish habitat-suitability criteria, hydraulic data, and stage-discharge ratings. The three sets of stage and discharge measured at a site were used to establish a rating for each transect in the SEFA program. The rating curves were calculated using SEFA default settings.

Habitat Suitability Curves

Habitat Suitability Curves (HSCs) provided by the District are the biological basis of physical habitat modeling and represent the functional relationship between a selected physical habitat variable and a suitability index representing the viability of the selected species/life stage. The suitability index varies between 0 (unsuitable) and 1 (most suitable) and provides a probability measure on how suitable a habitat is for a target species. Thirty-one habitat suitability curves of various species and life stages were incorporated into the instream habitat models (Table 4, Appendix B). The velocity, depth, and substrate criteria for each species and life stage were utilized to calculate the AWS. The library of suitability curves utilizes an index of substrate/cover types numbered 1-18 (Appendix B).

Table 4. Habitat Suitability Curves used in the analysis

Species or Group	**Life stage**
Redbreast Sunfish	Adult, Juvenile, Spawning, Fry
Habitat Guilds	Shallow/Slow, Shallow/Fast, Deep/Slow, Deep/Fast
Channel Catfish	Adult, Juvenile, Spawning, Fry
Darters	Generic, Blackbanded
Macroinvertebrates	Ephemeroptera, Plecoptera, Trichoptera, EPT Total
Largemouth Bass	Adult, Juvenile, Spawning, Fry
Bluegill	Adult, Juvenile, Spawning, Fry
Spotted Sunfish	Adult, Juvenile, Spawning, Fry
Cyprinidae	Adult

Seasonality

Many fish species in the Charlie Creek system spawn during the three to five months of spring and summer that coincide with several environmental factors that influence spawning (e.g., water temperature). Some species, such as catfish, spawn during extended periods spanning six to eight months (Table 5). Spawning and fry habitats are needed for critical life-cycle stages for fish, and seasonality of spawning and fry are considered for the habitat analysis in Section 4.

Table 5. Seasonality of fish spawning and fry

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Largemouth bass - Spawning												
Channel catfish - Spawning												
Bluegill - Spawning												
Redbreast Sunfish - Spawning												
Spotted Sunfish – Spawning												
Largemouth bass - fry												
Channel catfish - fry												
Bluegill – fry												
Redbreast Sunfish - fry												
Spotted Sunfish - fry												

*Grey cell indicates the months Area Weighted Suitability (AWS) was evaluated for the species life stages.

Reference: (HSW Engineering Inc., 2018)

4.1 Hydraulic Model

Hydraulic modeling within the physical habitat models includes developing the rating curves and simulating velocity profiles at each of the cross sections. Rating curves were developed for all five sites (Figure 1) and are used to evaluate potential changes in habitat associated with variation in flow in Charlie Creek.

Rating Equation

$$Q = a \times (H - SZF)^\wedge\beta \text{.... (1)}$$

Where:

$Q =$ Discharge

$H =$ Stage or water surface elevation

$SZF =$ Stage of zero flow

$\alpha, \beta =$ Regression constants

A log-log linear regression technique (STGQ) for Equation 1 was used to develop the rating curves for the five sites (Appendix C). The three-measured stage/discharge data (Low, Medium, and High) at each cross section were used (Table 2) to develop the log-log rating curve for each cross section. The SEFA default method that fits the curve through the survey flow and the best least square fit to the other stage-discharge pairs was used.

The SZF is the water level that is associated with zero flow. Typically, the SZF is the higher of the two levels: (1) the cross-section minimum, (2) the highest point on the thalweg downstream from the cross-section. However, in some situations, the SZF (as it is used on the rating curve equation) may not relate to either the minimum cross-section level or the level of the downstream control and is estimated as the constant that produces the best fit to a set of stage/discharge measurements. In this study, best fit SZF constants estimated by SEFA were used for rating curves. The mean error of Q (%) is the average percentage absolute error in predicted and rating calibration discharges as a percentage of the rating calibration discharges. Except for the Pool transect at GVR, the Shoal at WMA, and the Run transect at Hog Heaven, the Mean error of Q (%) is less than 3 percent (Table 6).

Table 6. Log-log regression estimates for the transects.

Site ID	**Transect type (Upstream to downstream)**	α	β	**SZF**	**Mean error of Q (%)**
Grass Valley Ranch (GVR)	Pool	24.903	1.074	42.204	11.405
	Run	23.663	1.305	42.179	1.303
	Shoal	22.167	1.423	42.172	1.931
White Marsh A (WMA)	Pool	27.294	1.579	31.45	2.842
	Run	23.129	1.624	31.24	1.237
	Shoal	33.024	1.295	31.352	8.93
White Marsh B (WMB)	Pool	32.451	1.408	27.959	0.797
	Run	29.197	1.511	27.901	2.292
	Shoal	29.979	1.465	27.877	0.767
White Marsh C (WMC)	Run	18.338	1.889	25.754	0.6
	Pool	34.2	1.541	25.975	1.94
	Shoal	32.569	1.575	25.853	1.16
Hog Heaven	Run	25.335	1.741	25.542	11.928
	Shoal	18.795	2.067	25.366	0.992
	Pool	15.776	2.142	25.222	0.767

The critical flow rating is the stage/discharge relationship that would exist when the water level at the transect was not influenced by downstream conditions. In natural rivers, the rating curves cannot cross the critical flow rating. The difference between the rating curve and the critical flow rating depends on how close the flow is to the critical flow. For all the five sites on Charlie Creek, the rating curves do not cross the critical flow ratings (Appendix C). SEFA models for each of the five sites are developed separately and are then combined for habitat analysis within the software.

Velocity Distribution Factors

Velocity Distribution Factors (VDFs) are the ratios of actual measured streamwise velocities to velocities calculated assuming uniform flow conditions.

$VDF = V_{cell}/V$ (or N/N_{cell})

Where V_{cell} is the measured streamwise velocity at a cell, V is the predicted velocity at the cell assuming constant N across the transect. N is Manning's roughness coefficient.

The velocity at any point i is predicted using the equation

$V_i = VDF_i \times R_i^{(2/3\text{-beta})} \times (Q/AR^{2/3})$

Where VDF_i is the VDF for point I, Q is the discharge, A is the area, and R is the hydraulic radius at transects.

VDFs are calculated from the streamwise velocities that were measured across each cross-section during the survey flow (medium flow) and are fitted automatically. When a flow is simulated, calculated water velocities are multiplied by the velocity distribution factor to estimate a simulated water velocity. This process will reproduce the measured velocities across the transect when the survey flow is simulated. VDFs at the edge of water and above the survey water level are assumed to be the same as the nearest measurement point in the water. The survey flow condition is greater than the highest flow simulated in this study and hence all the VDFs used in the models were estimated using the measured streamwise velocities.

Usually, roughness increases as the flow depth or hydraulic depth decreases. A beta value is used within SEFA to estimate the change in roughness (Manning's N and VDF) with discharge. A beta value of zero assumes that roughness does not vary with discharge. A default value of zero is assigned in SEFA but a value of -0.3 is recommended (Jowett, Payne, & Milhous, 2020) and is used for all the transects in this study.

4.2 Flow Reduction Assessment

The baseline daily flow data for the Charlie Creek Gardner gauge for water years (WYs) 1950 to 2019 were provided by the District (Figure 5). For most flowing systems in the District, the annual flow regime is characterized by low (Block 1, B1), medium (Block 2, B2), and high flows (Block 3) for the purpose of developing MFLs. For the Gardner gauge, the District characterized flows less than 24 cfs as Block 1 flows and flows between 24 and 79 cfs were characterized as Block 2 flows, regardless of calendar date.

The flow of 80 cfs at Gardner gauge exceeded about 44% of the time (WY 1950-2019). The flow associated with 44% exceedance at Crewsville gauge is about 41 cfs. Monthly average flows at Gardner gage were plotted against the monthly average flows at Crewsville gage. On average, a flow of 80 cfs at Gardner gauge is associated with a flow of about 40 cfs at Crewsville gauge (Figure 5).

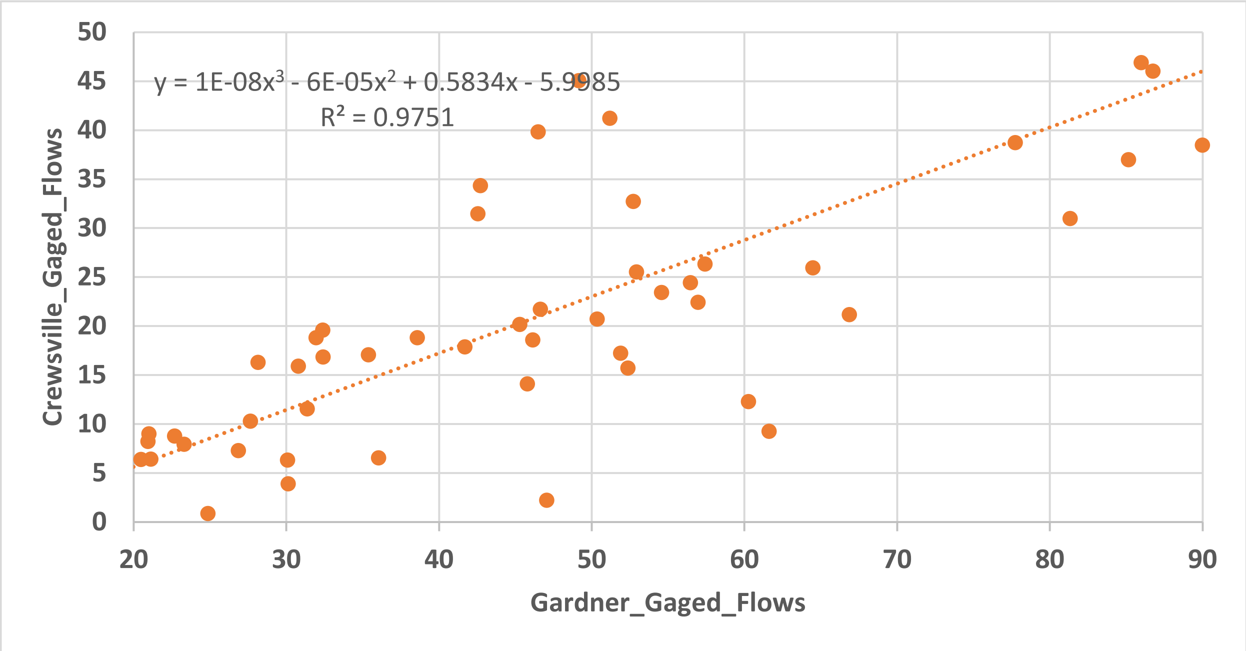

Figure 5. Gardner vs. Crewsville flows

Individual SEFA models were developed for each of the SEFA sites and AWS vs. flow relationship for the entire reach was developed by combining each of the site rhbx files within SEFA. A maximum flow of 86 cfs and flow increment of 1 cfs is used for all the sites except for GVR site. A maximum flow of 43 cfs and a flow increment of 0.5 cfs is used for GVR site (Figure 6).

For the relevant species and life stages, daily AWS values were calculated for the baseline flow record (Block 1 and Block 2) and for various flow reduction (constant relative flow reduction) scenarios within Block 1 and Block 2 for the period of record (WY 1950-2019). Flow reduction scenarios were analyzed for all species and life stages and the species and life stages associated with a 15% decrease in mean and median AWS from the baseline flow were deemed critical species (Table 7 and Table 8).

For Block 1 flow reduction, a 17% flow reduction is associated with 15% decrease in average AWS for Spotted Sunfish-adult and a 13.6% flow reduction is associated with 15% decrease in median AWS for Spotted Sunfish-adult (Table 7). Similarly, for Block 2 flows, a 14.5% flow reduction is associated with 15% decrease in average AWS for Habitat Guilds-DF and a 13.6% flow reduction is associated with 15% decrease in median AWS for Habitat Guilds-DF (Table 8).

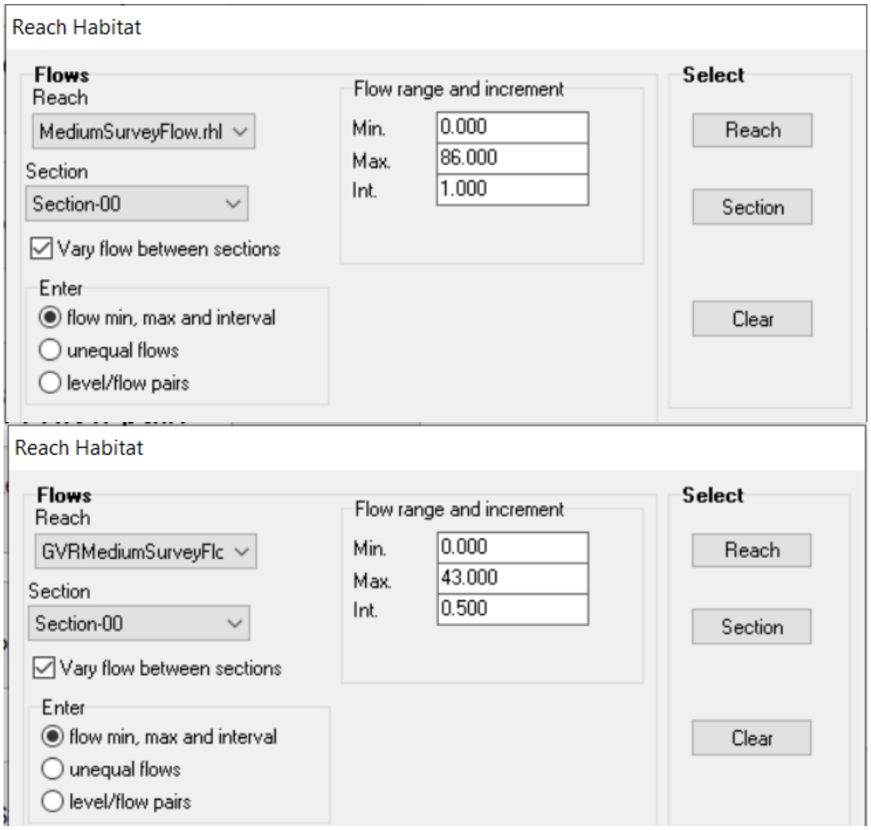

Figure 6. Flow range and increment for time-series analysis

For Block 1 flows, Spotted Sunfish-adult has the steepest slope at median AWS (Slope of AWS vs. flow relationship) relative to the other species and is the most sensitive to flow reduction (Figure 7). Similarly, Habitat Guilds - DF has the steepest slope at median AWS and is most sensitive to flow reduction for Block 2 flows. Largemouth Bass-adult has a negative slope, i.e., the AWS increases with flow reduction on average. Species-life stages that have a negative AWS vs. flow slope resulted in increase in AWS (positive change) with flow reduction and species-life stages that have a flatter slope are less sensitive to flow reduction (Table 7 and Table 8).

Table 7. SEFA flow reduction analysis for Block 1

Species/Life Stage	Block 1 Maximum allowable flow reduction (%)	
	Average AWS	**Median AWS**
Redbreast Sunfish-adult	33.8	36.5
Redbreast Sunfish-juvenile	>40	>40
Redbreast Sunfish-spawning	>40	>40
Habitat Guilds-SS	Positive change	Positive change
Habitat Guilds-DS	33	35.5
Channel Catfish-adult	>40	>40
Channel Catfish-juvenile	20.6	16.8
Channel Catfish-fry	20.8	16.6
Generic Darters-adult	22.3	18.9
Blackbanded Darter-adult	29.5	26.6
Ephemeroptera	31.5	28
Plecoptera	37.3	>40
Tricoptera	30	29.1
Largemouth Bass-adult	Positive change	Positive change
Largemouth Bass-juvenile	>40	>40
Largemouth Bass-spawning	Positive change	Positive change
Bluegill -juvenile	>40	>40
Bluegill -spawning	>40	>40
Bluegill -fry	Positive change	Positive change
Spotted Sunfish-adult	**17**	**13.6**
Spotted Sunfish-juvenile	20.6	16.9
Spotted Sunfish-spawning	20.8	17.8
Spotted Sunfish-fry	24.9	17.8
Cyprinidae -adult	37.8	31.5
Redbreast Sunfish-fry, Habitat Guilds (SF, DF), Channel Catfish-spawning, EPT Total, Hydropsychidae -Total, Tvetenia vitracies-larvae, Largemouth Bass-fry, and Bluegill -adult are excluded from analysis because average AWS is less than 1 ft^2/ft AWS under unimpacted conditions.		

Table 8. SEFA flow reduction analysis for Block 2

Species/Life Stage	Block 2 Maximum allowable flow reduction (%)	
	Average AWS	Median AWS
Redbreast Sunfish-adult	34	31.6
Redbreast Sunfish-juvenile	Positive change	Positive change
Redbreast Sunfish-spawning	Positive change	Positive change
Redbreast Sunfish-fry	25.5	25.5
Habitat Guilds-SS	Positive change	Positive change
Habitat Guilds-DS	34	32
Habitat Guilds-DF	**14.5**	**13.6**
Channel Catfish-adult	35	35
Channel Catfish-juvenile	Positive change	Positive change
Channel Catfish-spawning	15.1	14.1
Channel Catfish-fry	>40	>40
Generic Darters-adult	>40	>40
Blackbanded Darter-adult	>40	>40
Ephemeroptera	>40	>40
Plecoptera	28.7	27.4
Tricoptera	>40	>40
EPT Total	16.9	16.2
Largemouth Bass-adult	Positive change	Positive change
Largemouth Bass-juvenile	Positive change	Positive change
Largemouth Bass-spawning	>40	>40
Bluegill -juvenile	Positive change	Positive change
Bluegill -spawning	Positive change	Positive change
Spotted Sunfish-adult	32.4	29.7
Spotted Sunfish-juvenile	Positive change	Positive change
Spotted Sunfish-spawning	Positive change	Positive change
Spotted Sunfish-fry	Positive change	Positive change
Cyprinidae -adult	Positive change	Positive change

Habitat Guilds (SF), Hydropsychidae -Total, Tvetenia vitracies-larvae, Largemouth Bass-fry, Bluegill -fry and Bluegill -adult are excluded from analysis because average AWS is less than 1 ft^2/ft AWS under unimpacted conditions.

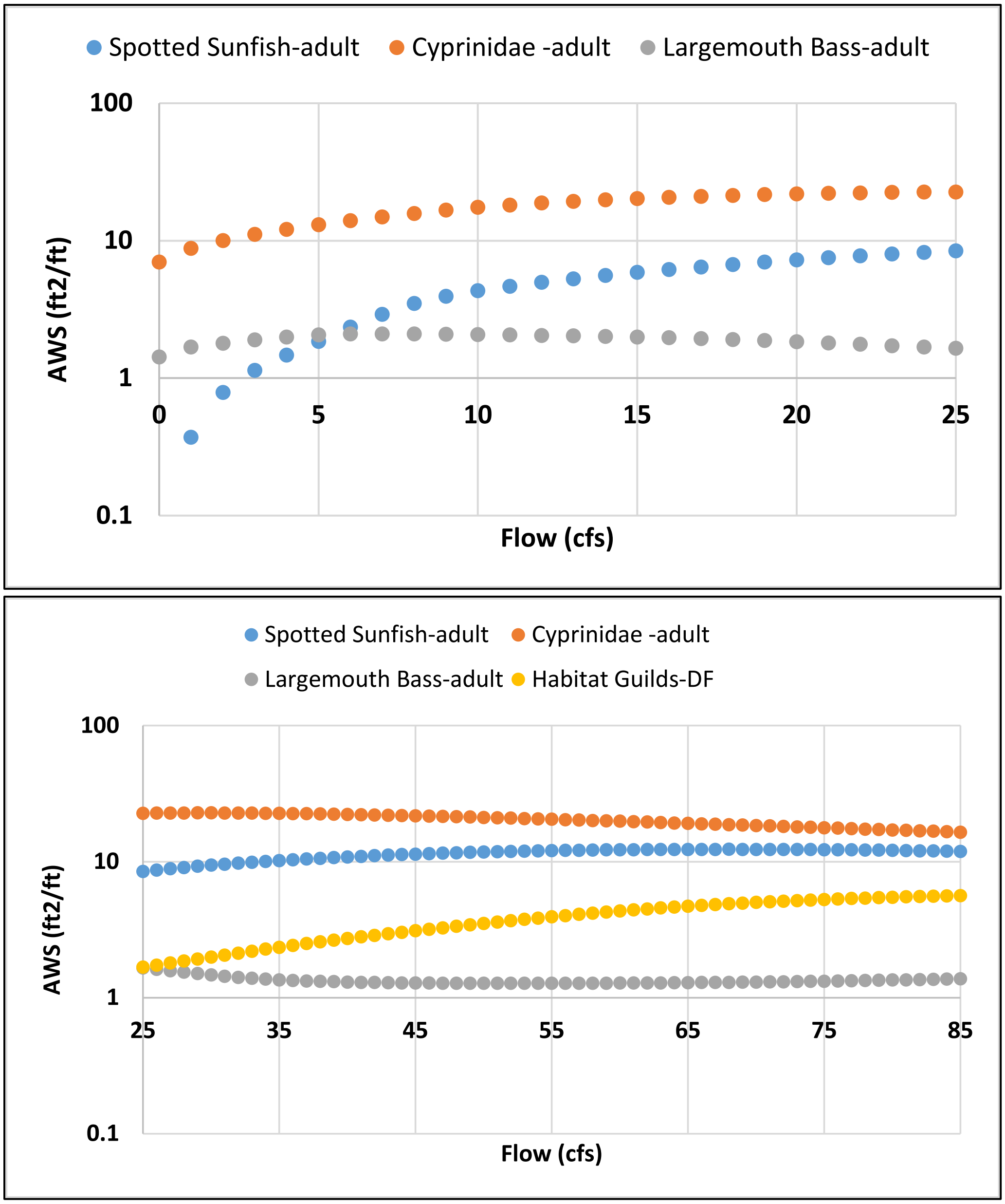

Figure 7. AWS vs. flow relationship for selected species

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Appendix A

Site Name: **White Marsh A (WMA),** **Latitude/Longitude:** **24.40761/-81.7467**

Figure 1. **Site WMA Overview (Top-Looking downstream, Bottom-Looking upstream), Date: 03/26/2020.**

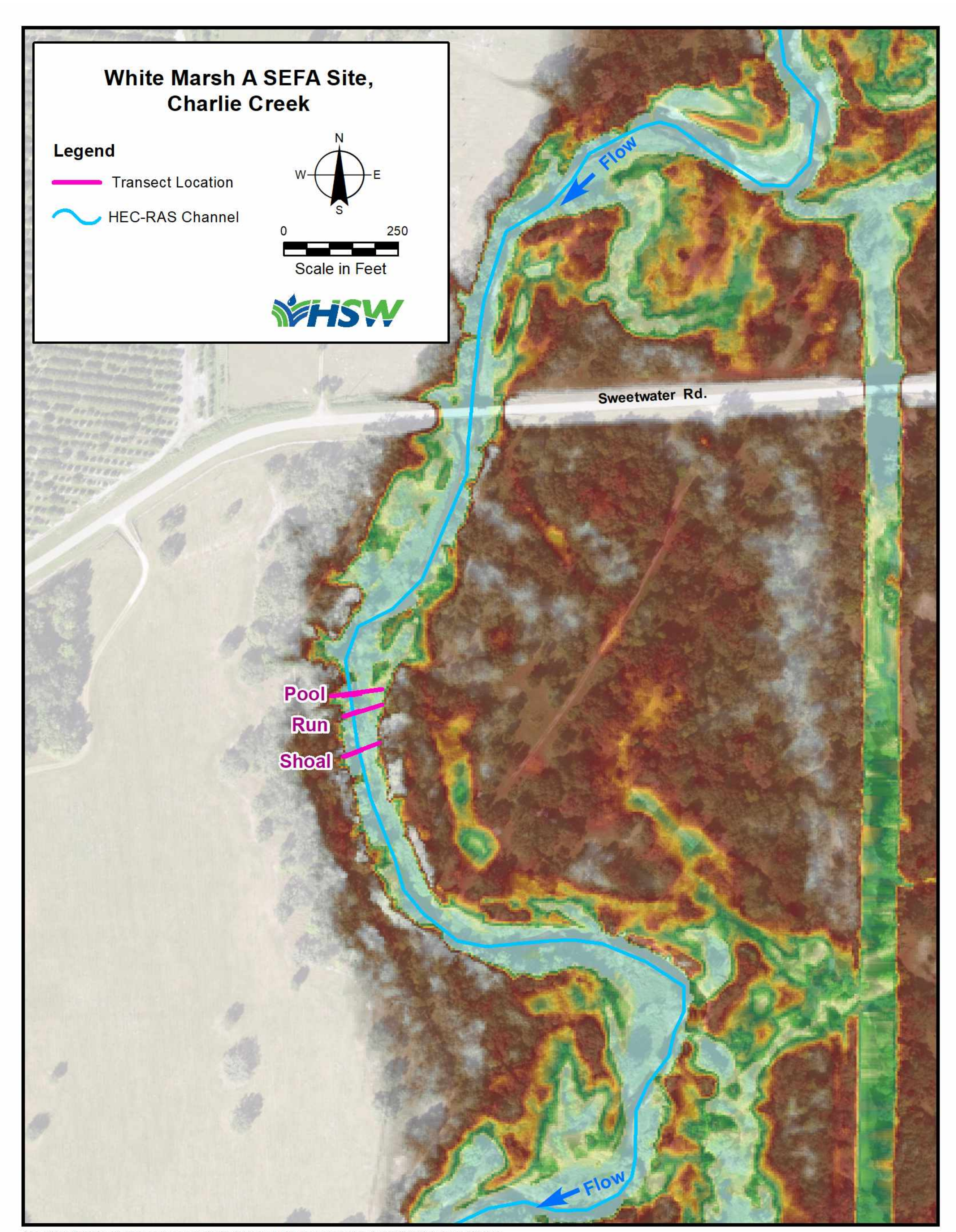


Figure 2. WMA Site transects

Site Name: **White Marsh B (WMB), Latitude/Longitude: 27.39188/-81.7558**

Figure 3. **Site WMB Overview (Top-Looking downstream, Bottom-Looking upstream), Date: 03/25/2020.**

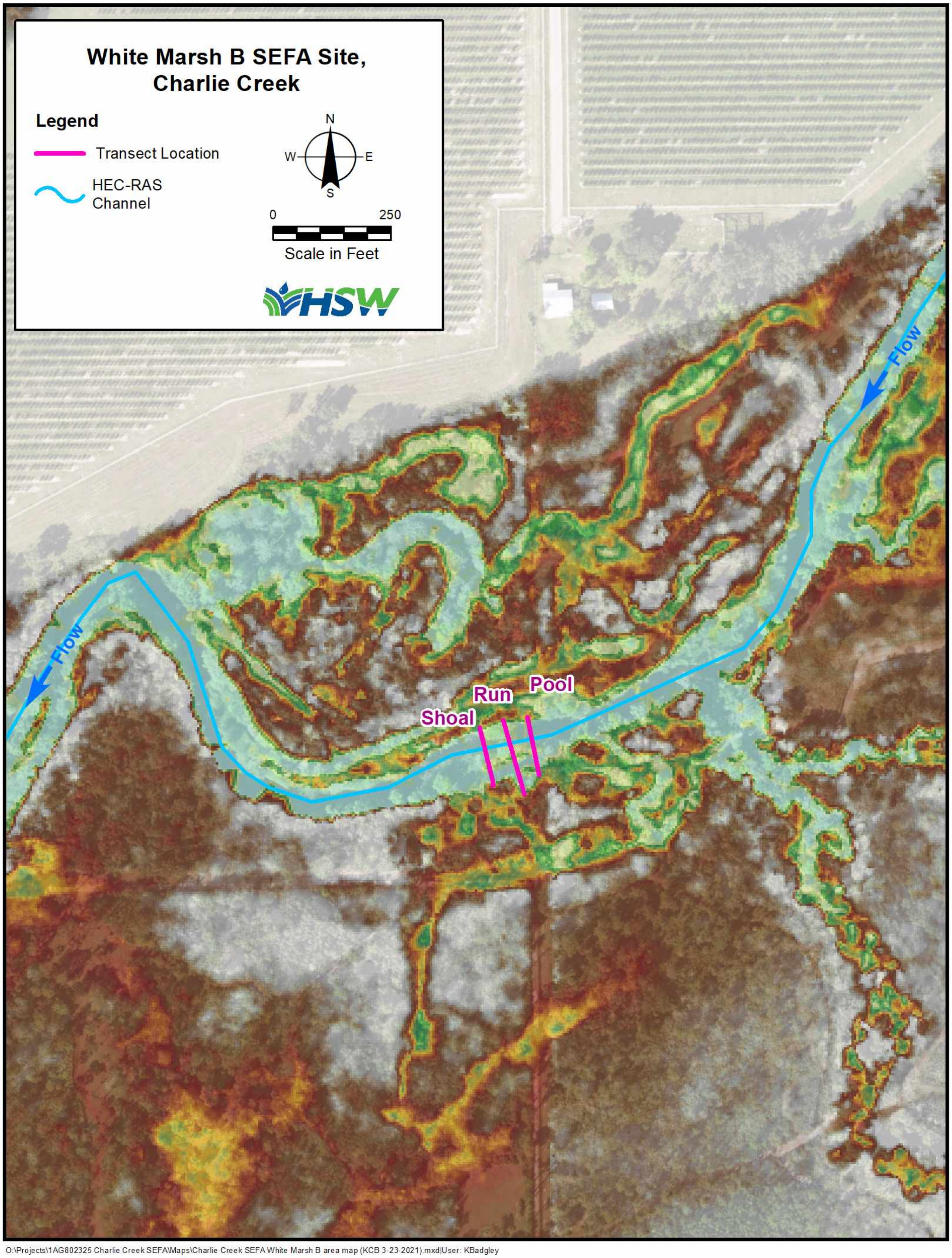
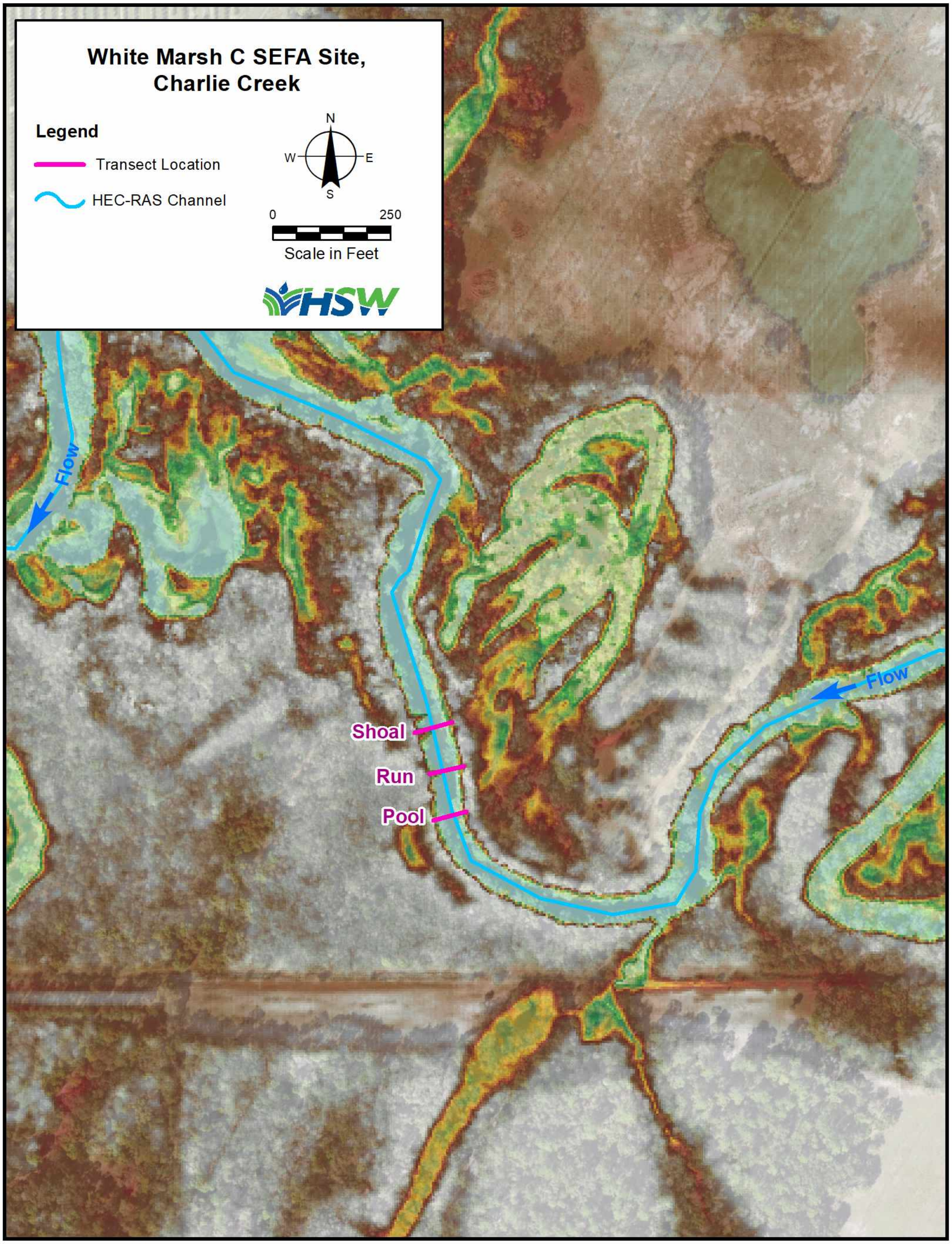


Figure 4. Site WMB Site transects

Site Name: **White Marsh (WMC) , Latitude/Longitude: 27.38525/-81.7742**

Figure 5. Site WMC Overview (Top-Looking downstream, Bottom-Looking upstream), Date: 03/25/2020.



O:\Projects\1AG802325 Charlie Creek SEFA\Maps\Charlie Creek SEFA White Marsh C area map (KCB 3-23-2021).mxd|User: KBadgley

Figure 6. WMC Site transects

Site Name: Grass Valley Ranch (GVR), **Latitude/Longitude:** 27.44498/-81.7016

Figure 7. Site GVR Overview (Top-Looking downstream, Bottom-Looking upstream), Date: 03/27/2020.

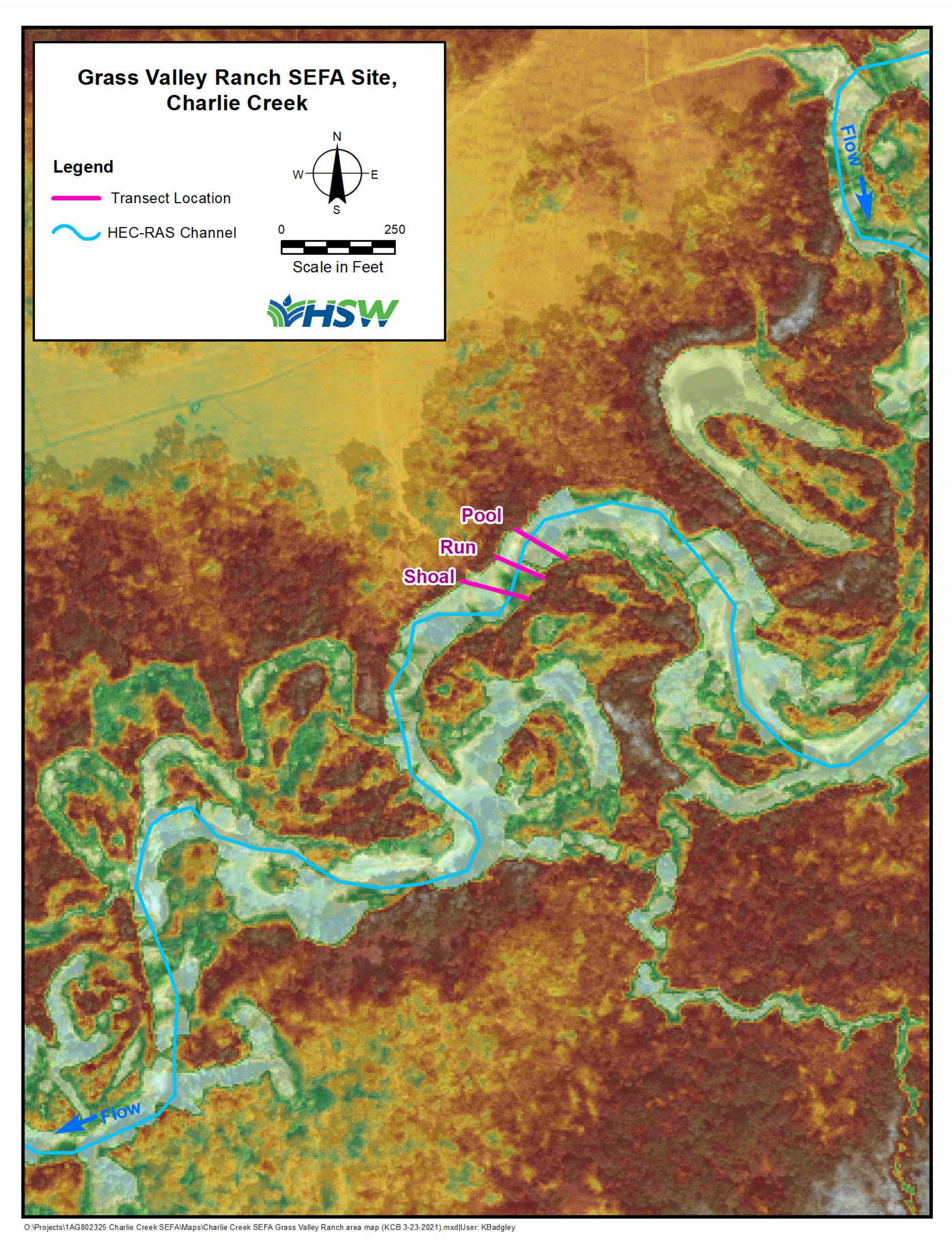


Figure 8. GVR Site transects

Site Name: **Hog Heaven,** **Latitude, Longitude:** **27.38233, -81.7815**

Figure 9. **Site Hog Heaven Overview (Top-Looking downstream, Bottom-Looking upstream), Date: 03/27/2020.**

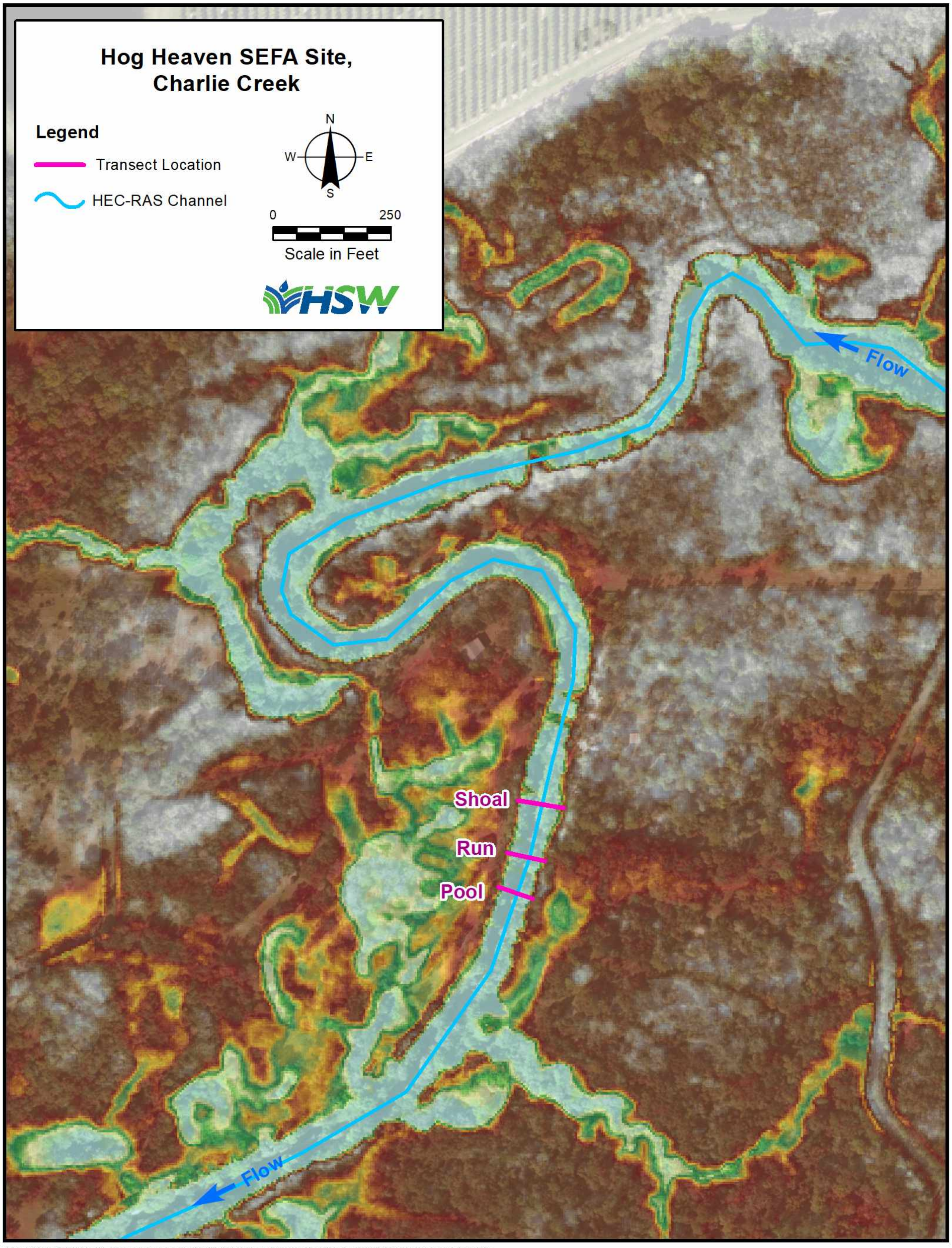
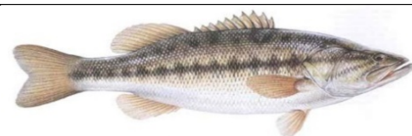


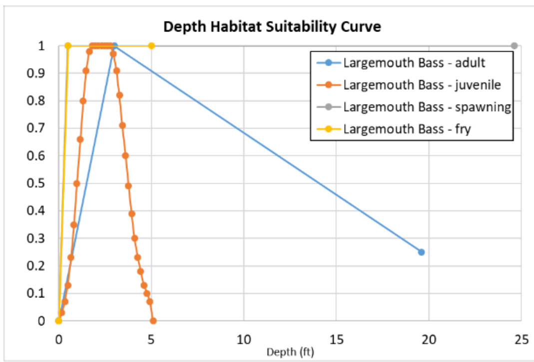
Figure 10. Hog Heaven Site transects

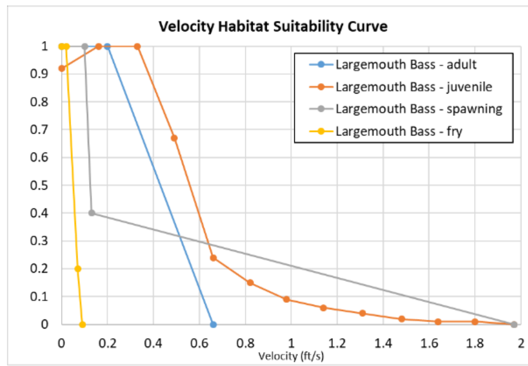
Appendix B

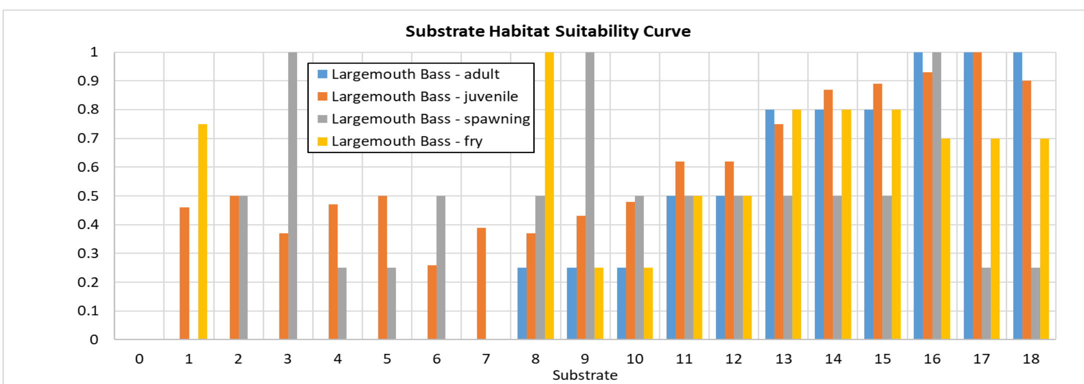
LARGEMOUTH BASS (ADULT/JUVENILE/SPAWNING/FRY)
MICROPTERUS SALMOIDES



Physical Habitat



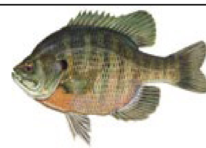




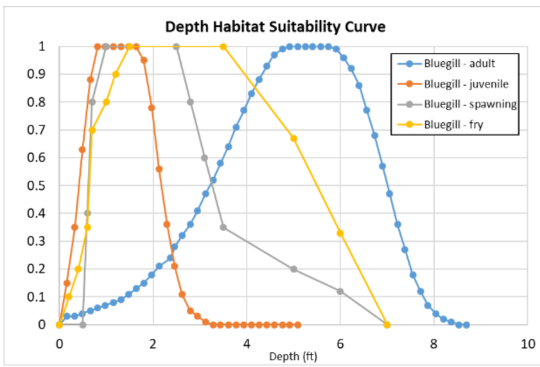
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

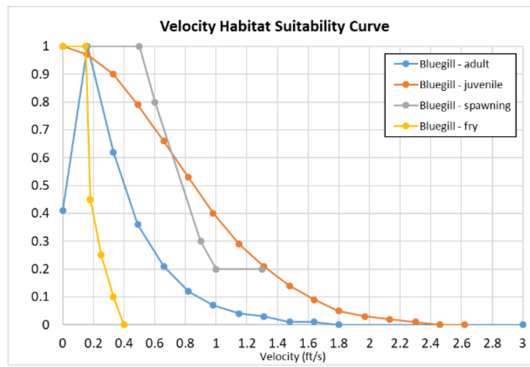
Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

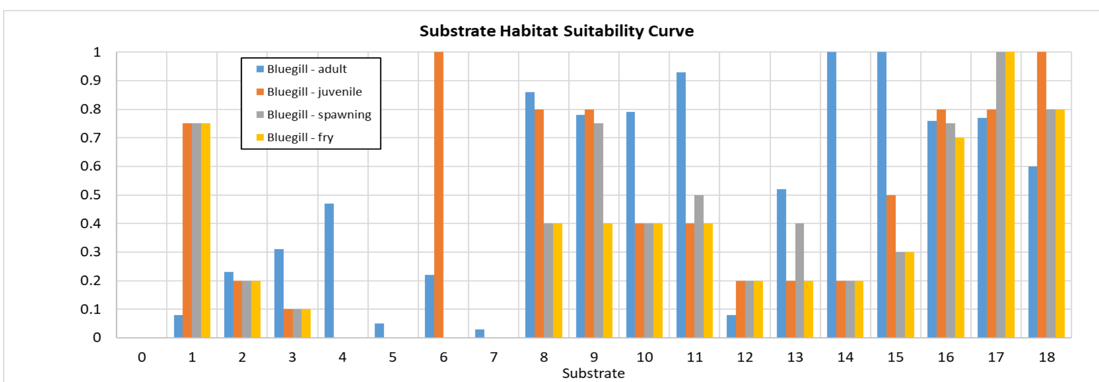
BLUEGILL (ADULT/JUVENILE/SPAWNING/FRY)
LEPOMIS MACROCHIRUS



Physical Habitat





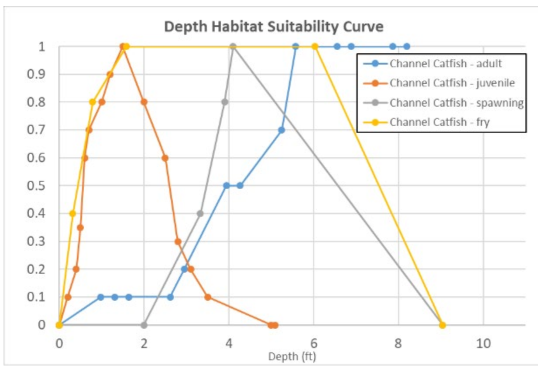


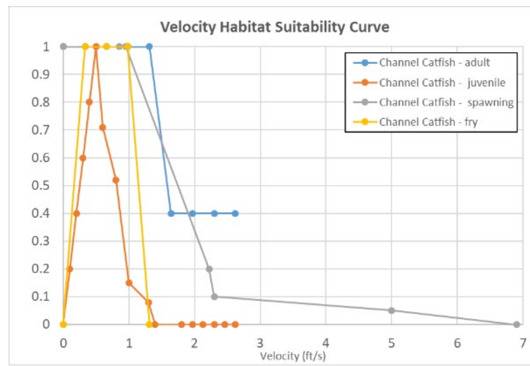
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

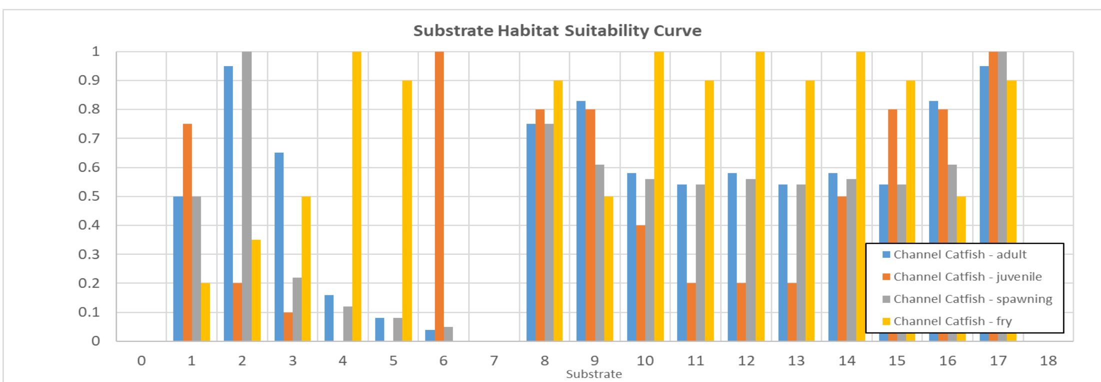
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

CHANNEL CATFISH (ADULT/JUVENILE/SPAWNING/FRY)
ICTALURUS PUNCTATUS

Physical Habitat





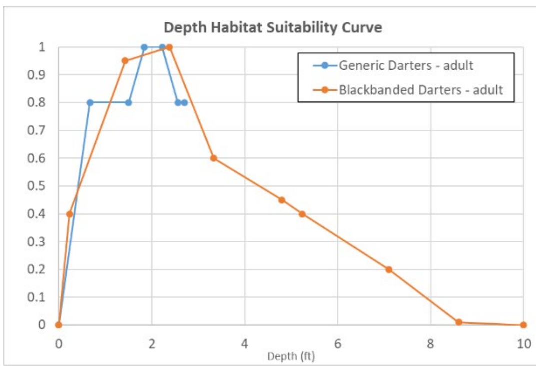


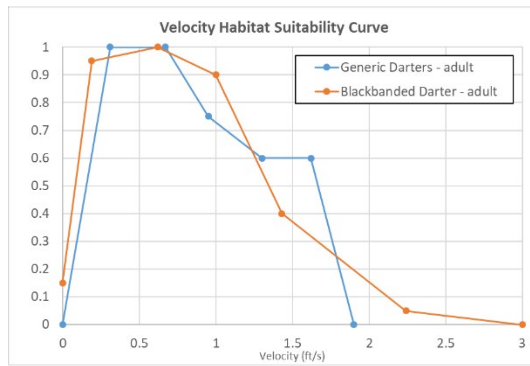
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

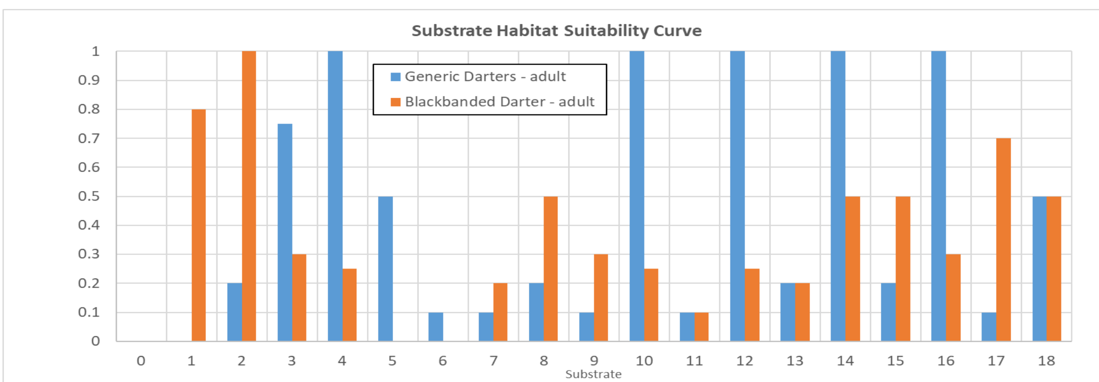
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

DARTERS (GENERIC/BLACKBANDED)
PERCINA NIGROFASCIATA

Physical Habitat





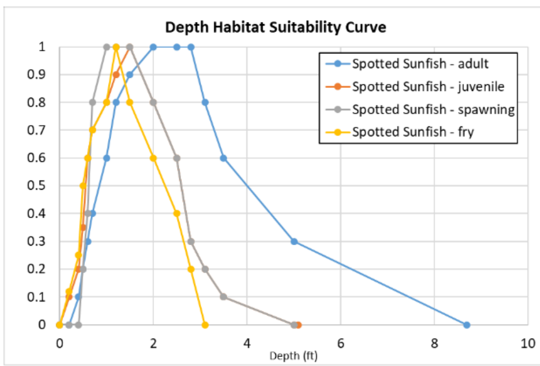


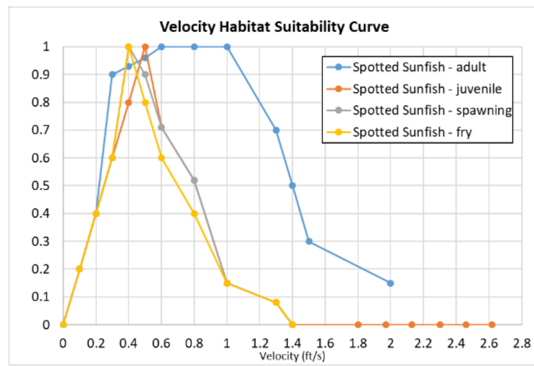
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

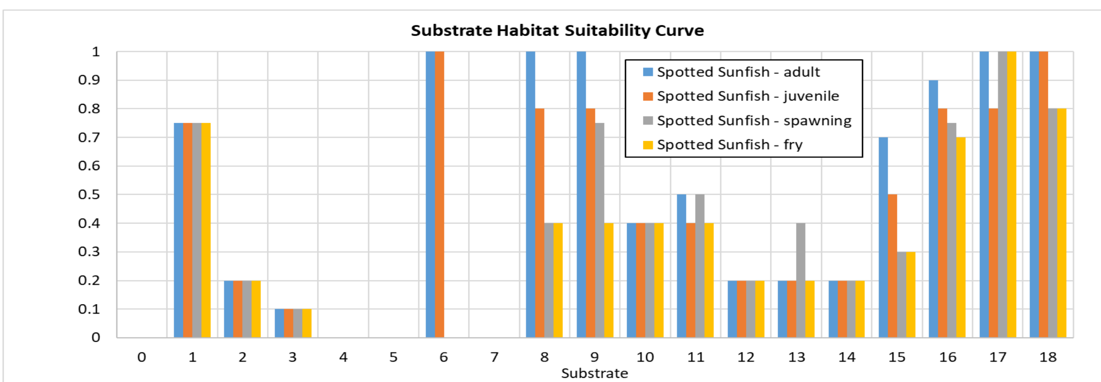
HSCs Source: USFWS “Bluebook” series (1970s,1980s) with habitat values modified by Dr. J. Gore

SPOTTED SUNFISH (ADULT/JUVENILE/SPAWNING/FRY)
LEPOMIS PUNCTATUS

Physical Habitat





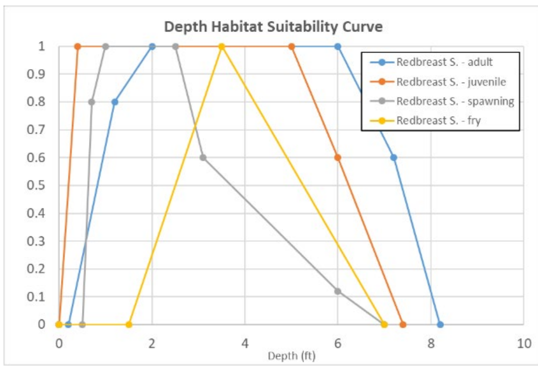


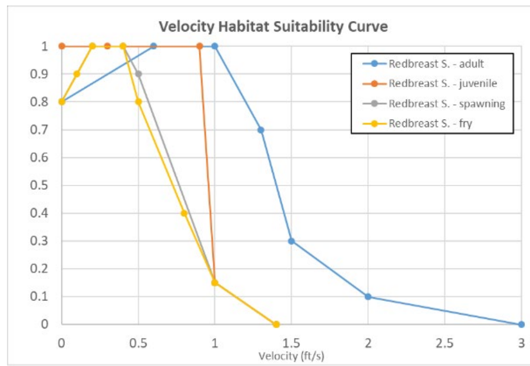
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

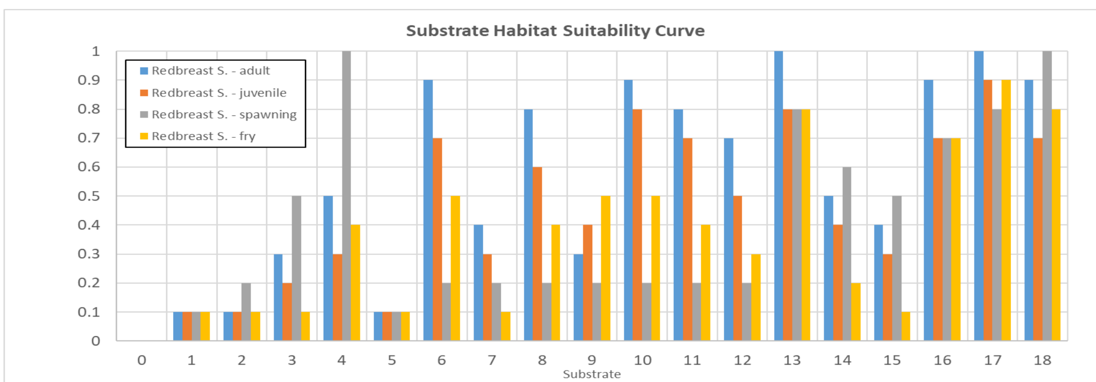
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

REDBREAST SUNFISH (ADULT/JUVENILE/SPAWNING/FRY)
LEPOMIS AURITUS

Physical Habitat





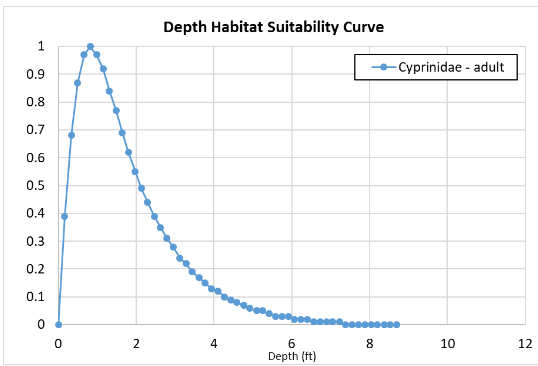


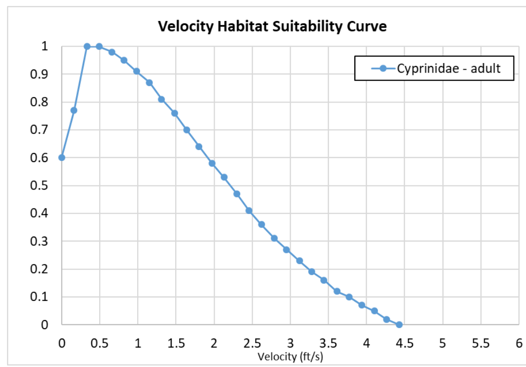
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

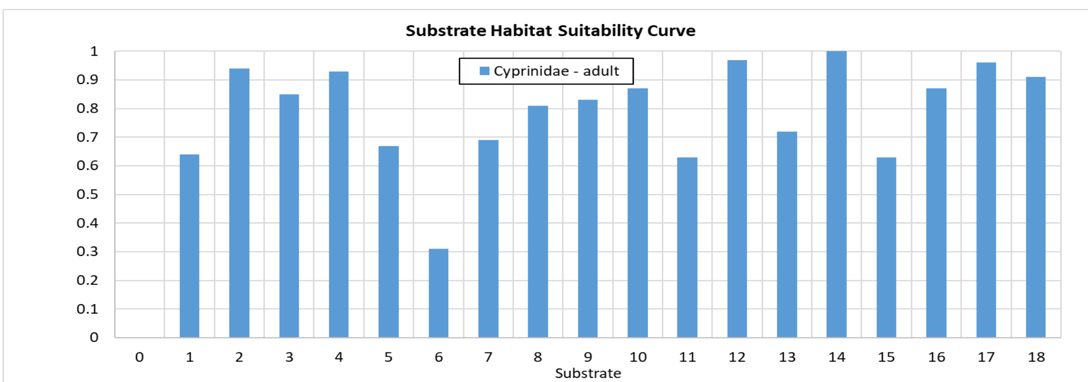
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

CYPRINIDAE – ADULT

Physical Habitat





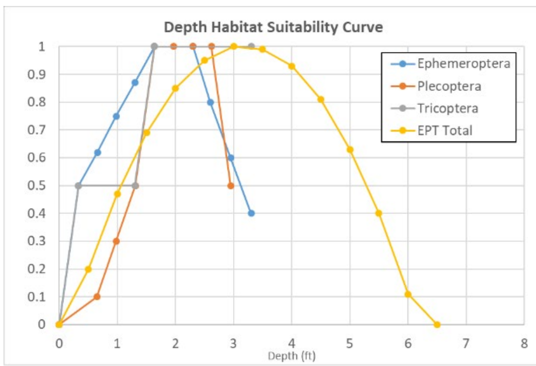


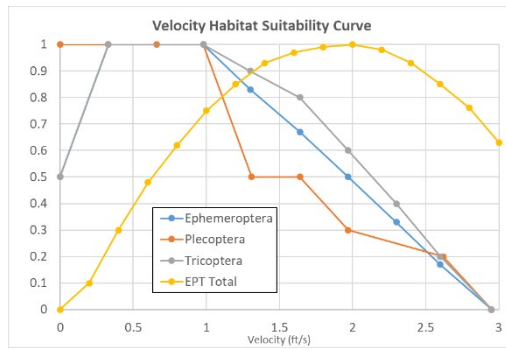
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

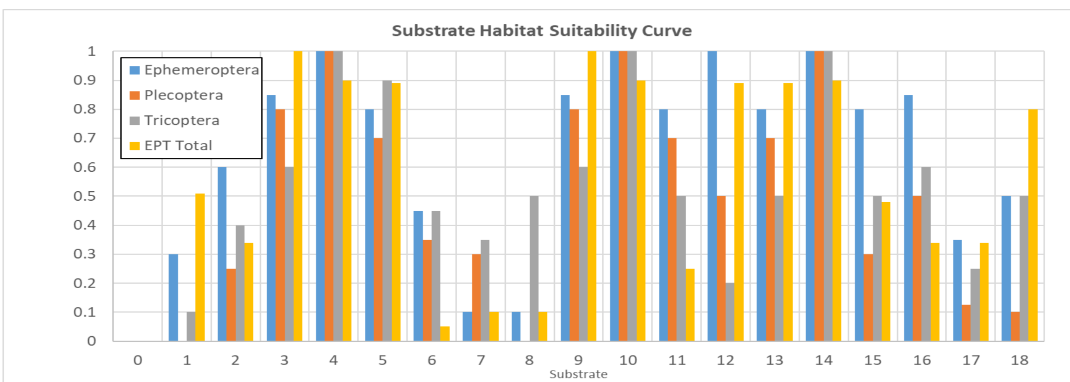
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

EPHEMEROPTERA / PLECOPTERA / TRICHOPTERA / EPT TOTAL
BENTHIC MACROINVERTEBRATE COMMUNITY

Physical Habitat







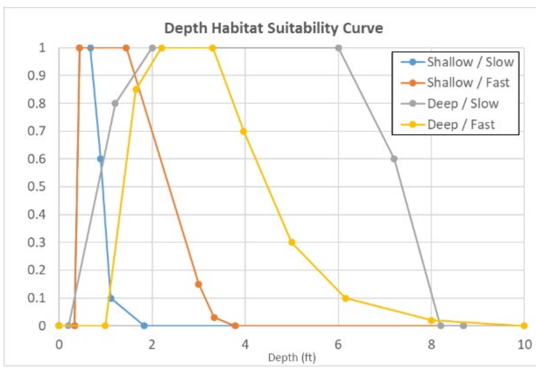
Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

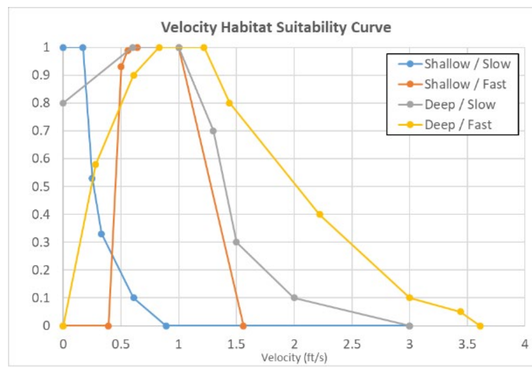
HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

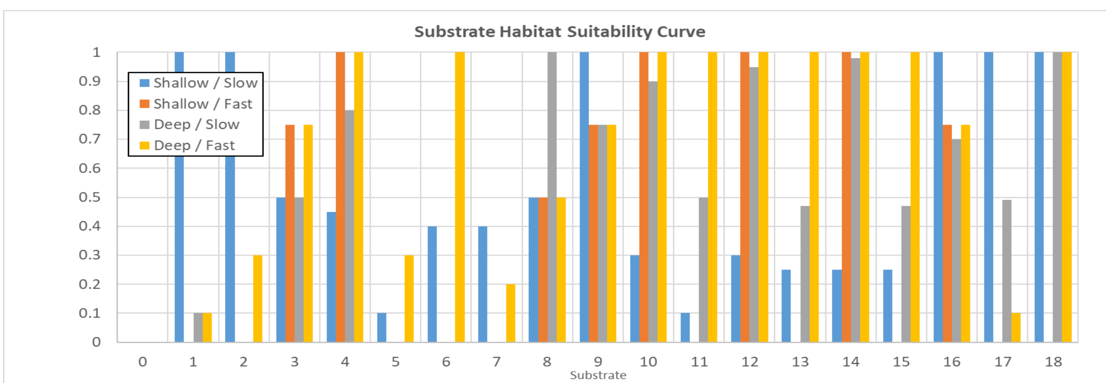
HABITAT GUILDS

(SHALLOW SLOW / SHALLOW FAST / DEEP SLOW / DEEP FAST)

Physical Habitat







Substrate Coding			
1	No cover and silt or terrestrial vegetation	10	Overhead vegetation and cobble
2	No cover and sand	11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris
3	No cover and gravel	12	Instream cover and cobble
4	No cover and cobble	13	Instream cover and small boulder, boulder, angles bedrock, or woody debris
5	No cover and small boulder	14	Proximal instream cover and cobble
6	No cover and boulder, angles bedrock or woody debris	15	Proximal instream cover and small boulder, boulder, angles bedrock, or woody debris
7	No cover and mud or flat bedrock	16	Instream cover or proximal instream cover and gravel
8	Overhead vegetation and terrestrial vegetation	17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
9	Overhead vegetation and gravel	18	Aquatic vegetation - macrophytes

HSCs Source: USFWS "Bluebook" series (1970s,1980s) with habitat values modified by Dr. J. Gore

Appendix C

Grass Valley Ranch (GVR) Site Rating Curves

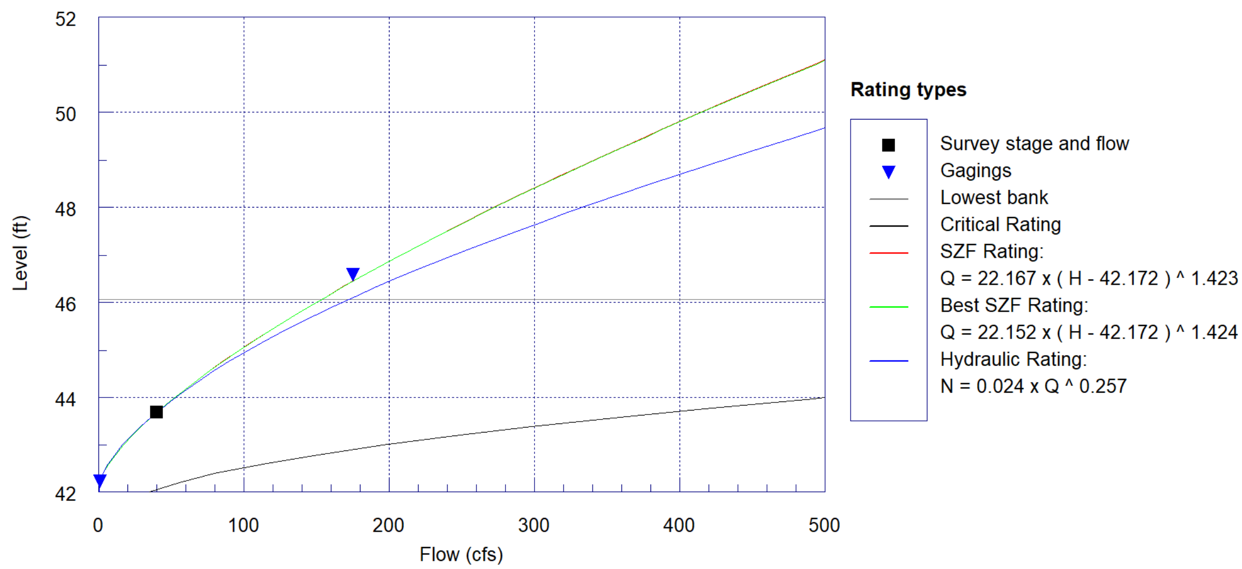


Figure a. Shoal Transect Rating Curve

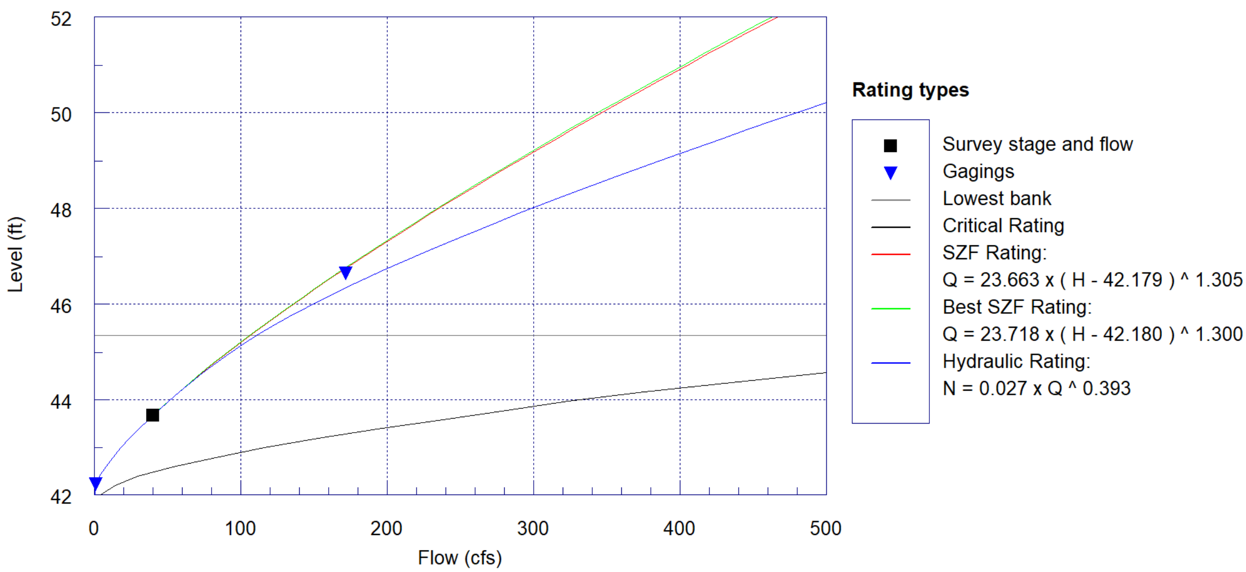


Figure b. Run Transect Rating Curve

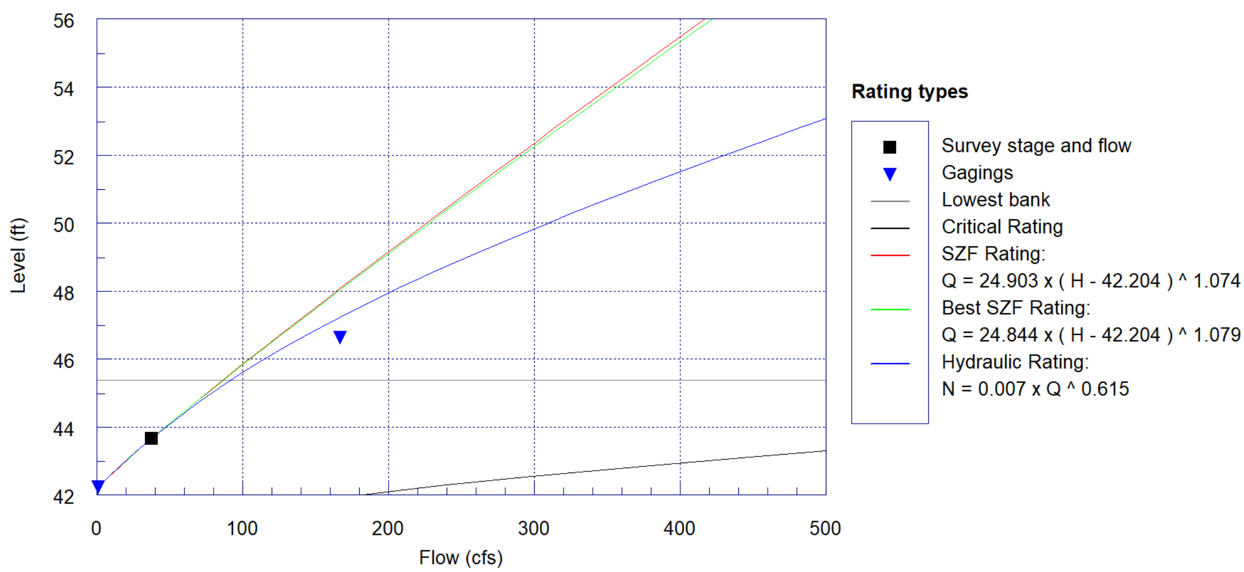


Figure c. Pool Transect Rating Curve

White Marsh A (WMA) Site Rating Curves

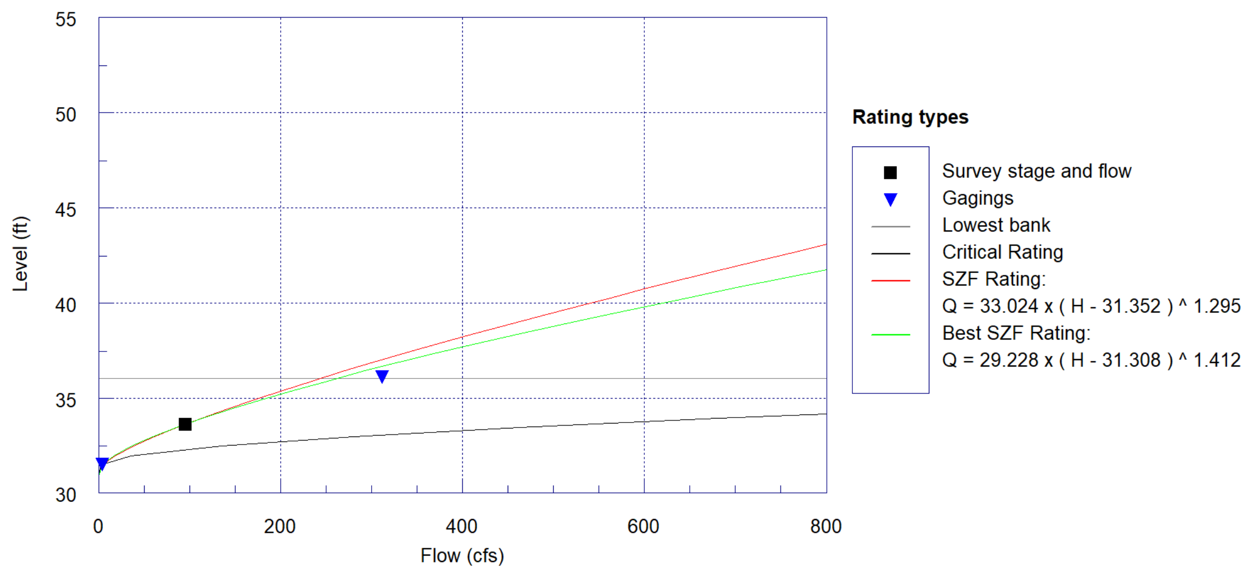


Figure d. Shoal Transect Rating Curve

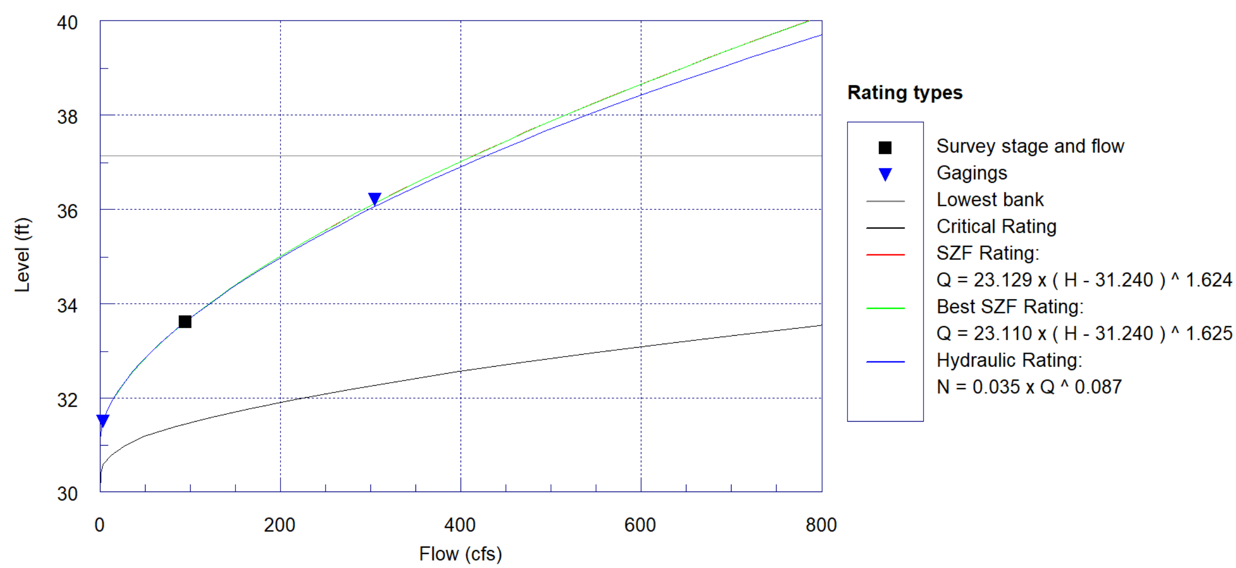


Figure e. Run Transect Rating Curve

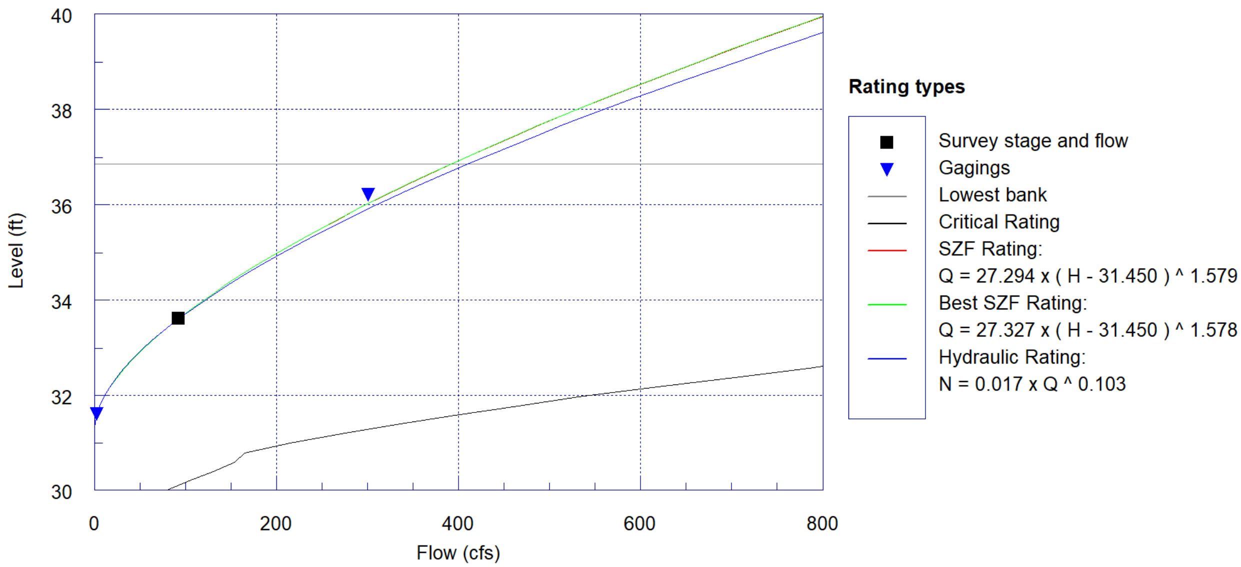


Figure f. Pool Transect Rating Curve

White Marsh B (WMB) Site Rating Curves

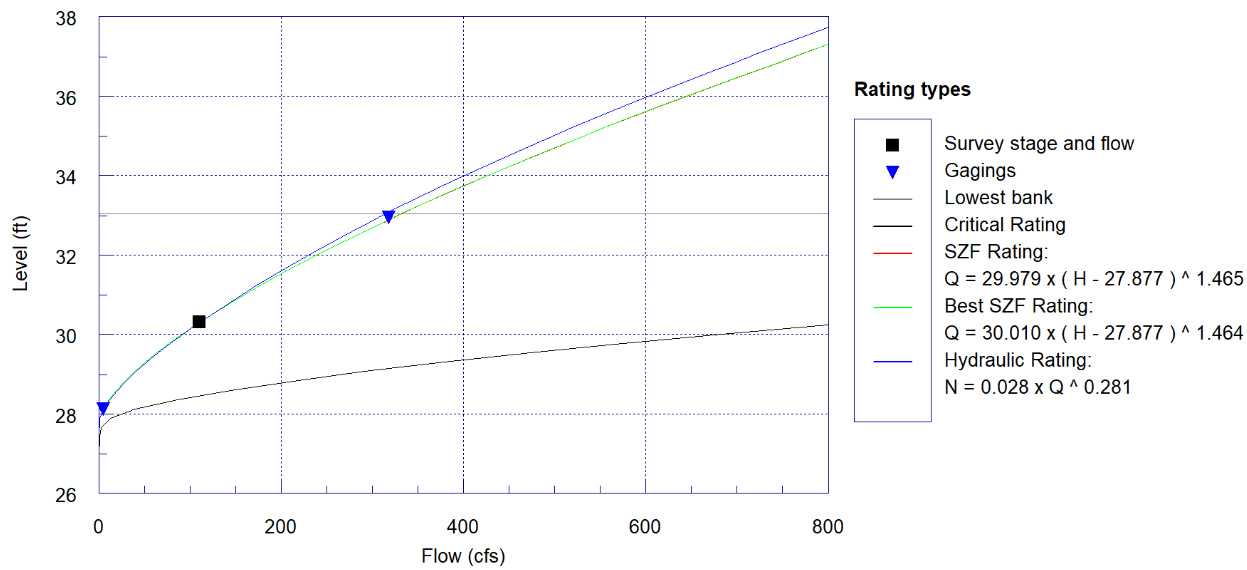


Figure g. Shoal Transect Rating Curve

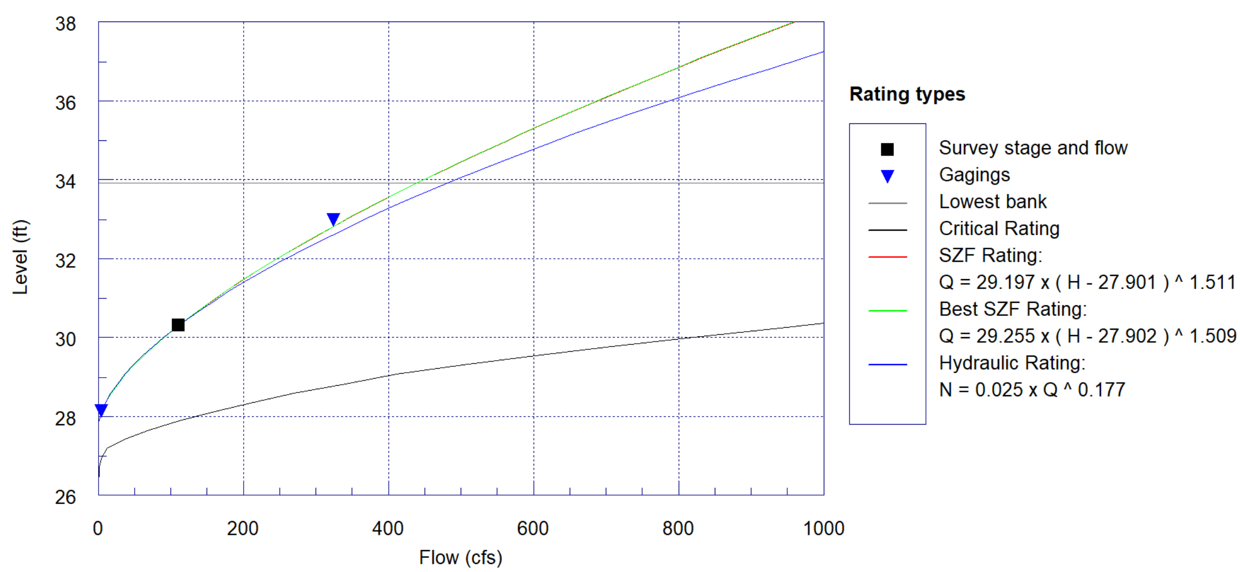


Figure h. Run Transect Rating Curve

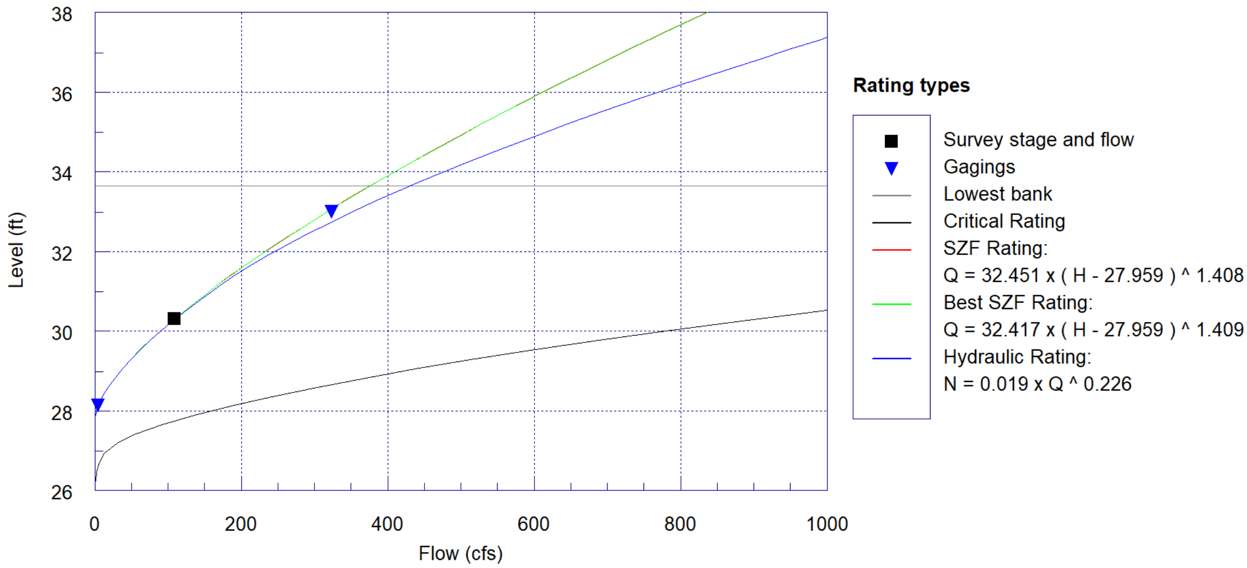


Figure i. Pool Transect Rating Curve

White Marsh C (WMC) Site Rating Curves

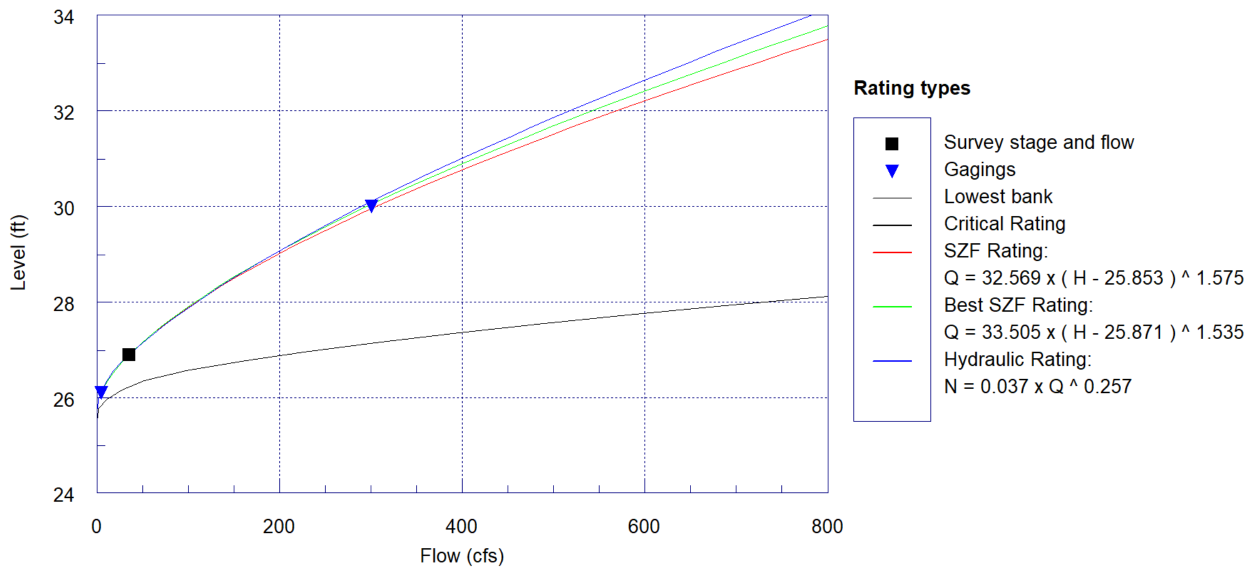


Figure j. Shoal Transect Rating Curve

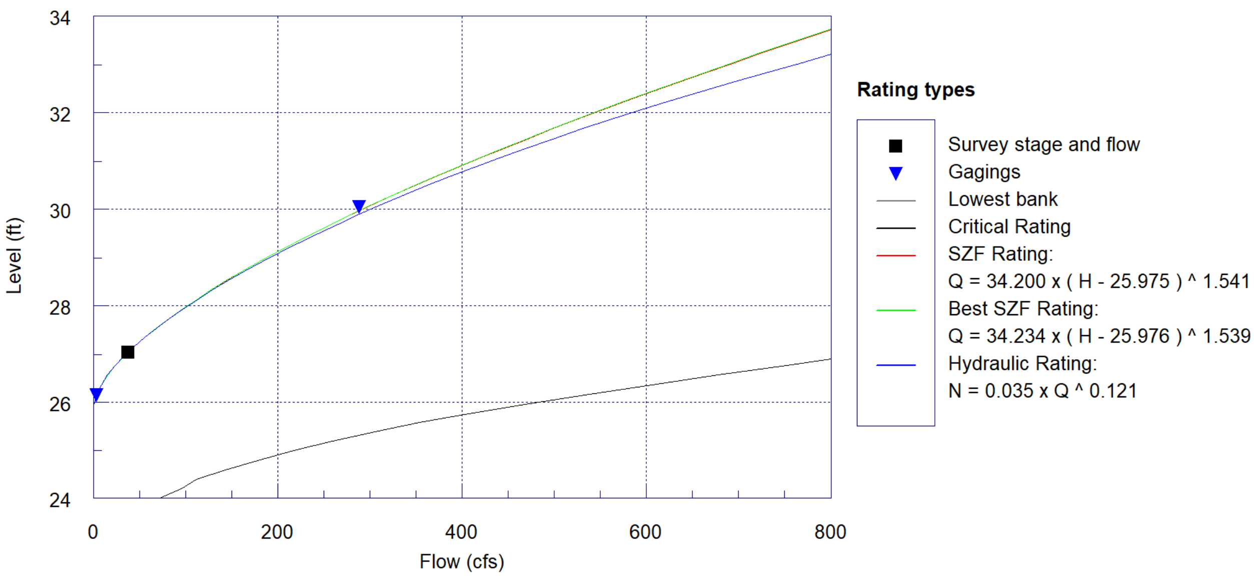


Figure k. Run Transect Rating Curve

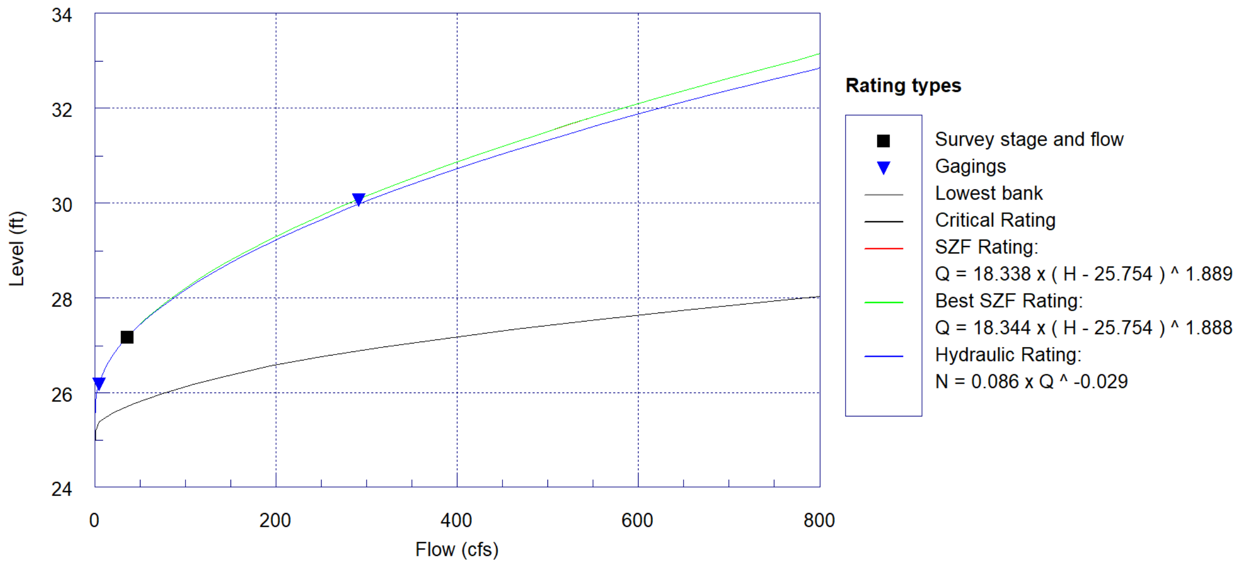


Figure l. Pool Transect Rating Curve

Hog Heaven Site Rating Curves

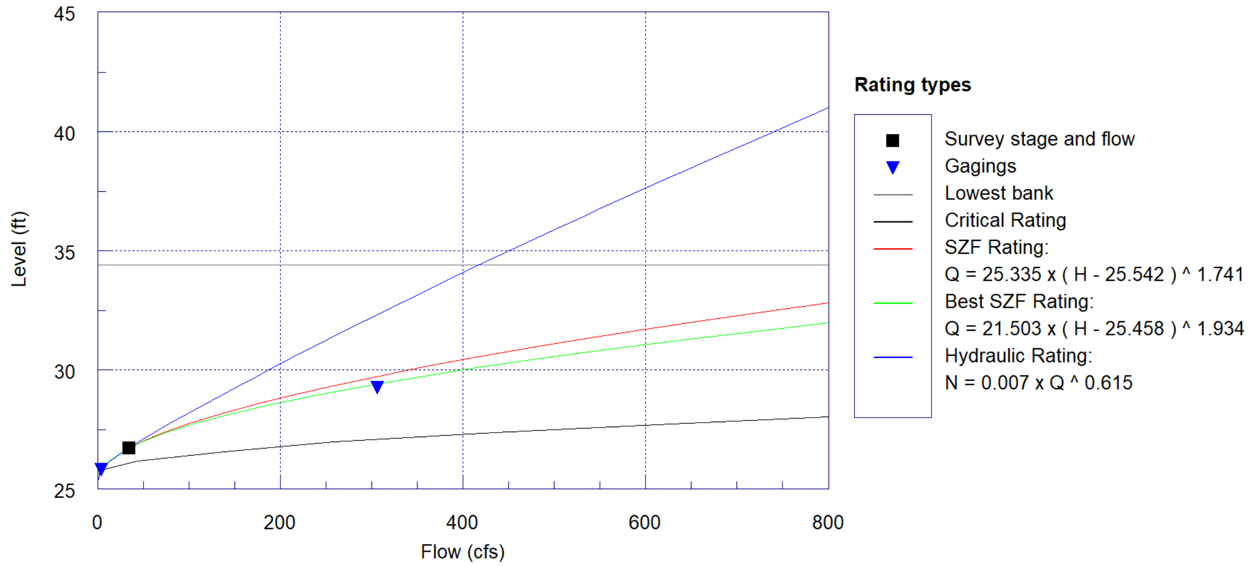


Figure m. Run Transect Rating Curve

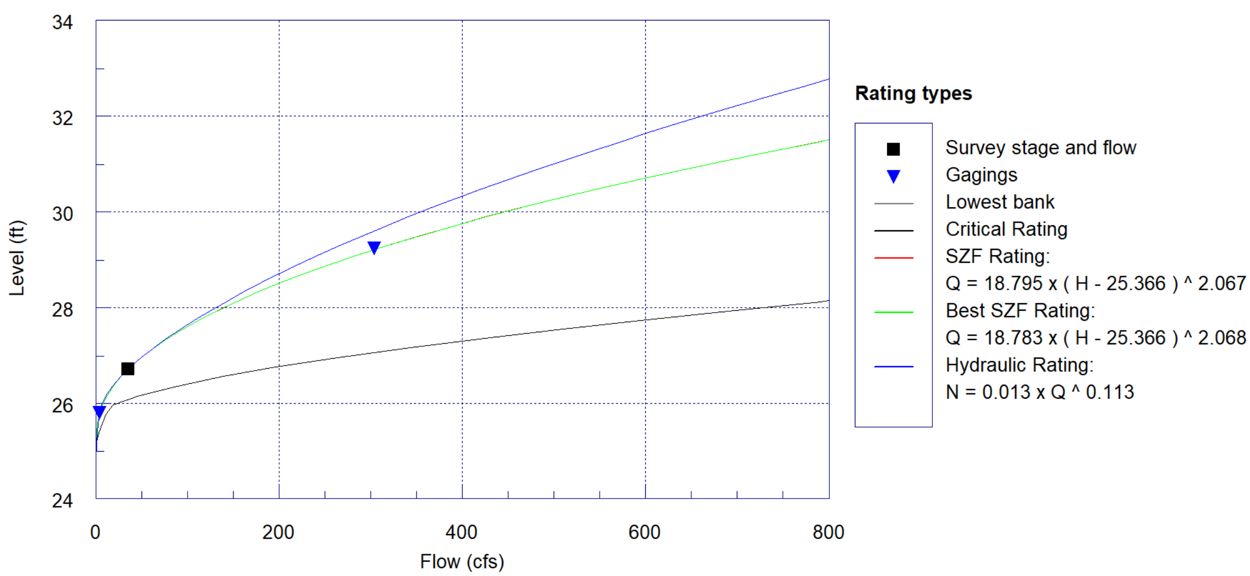


Figure n. Shoal Transect Rating Curve

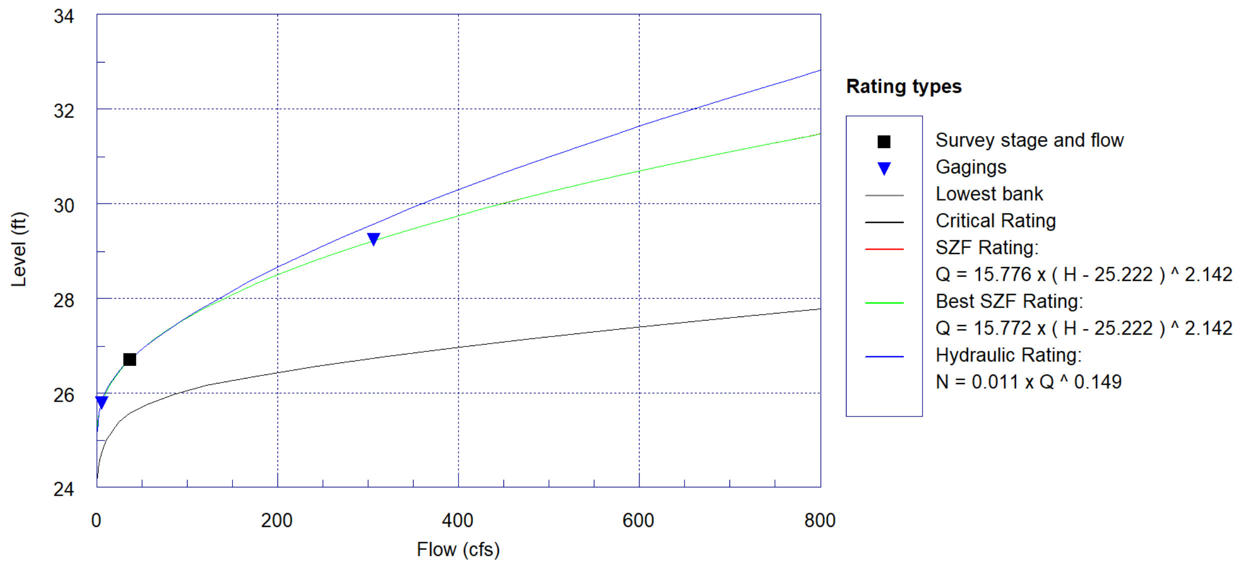


Figure o. Pool Transect Rating Curve