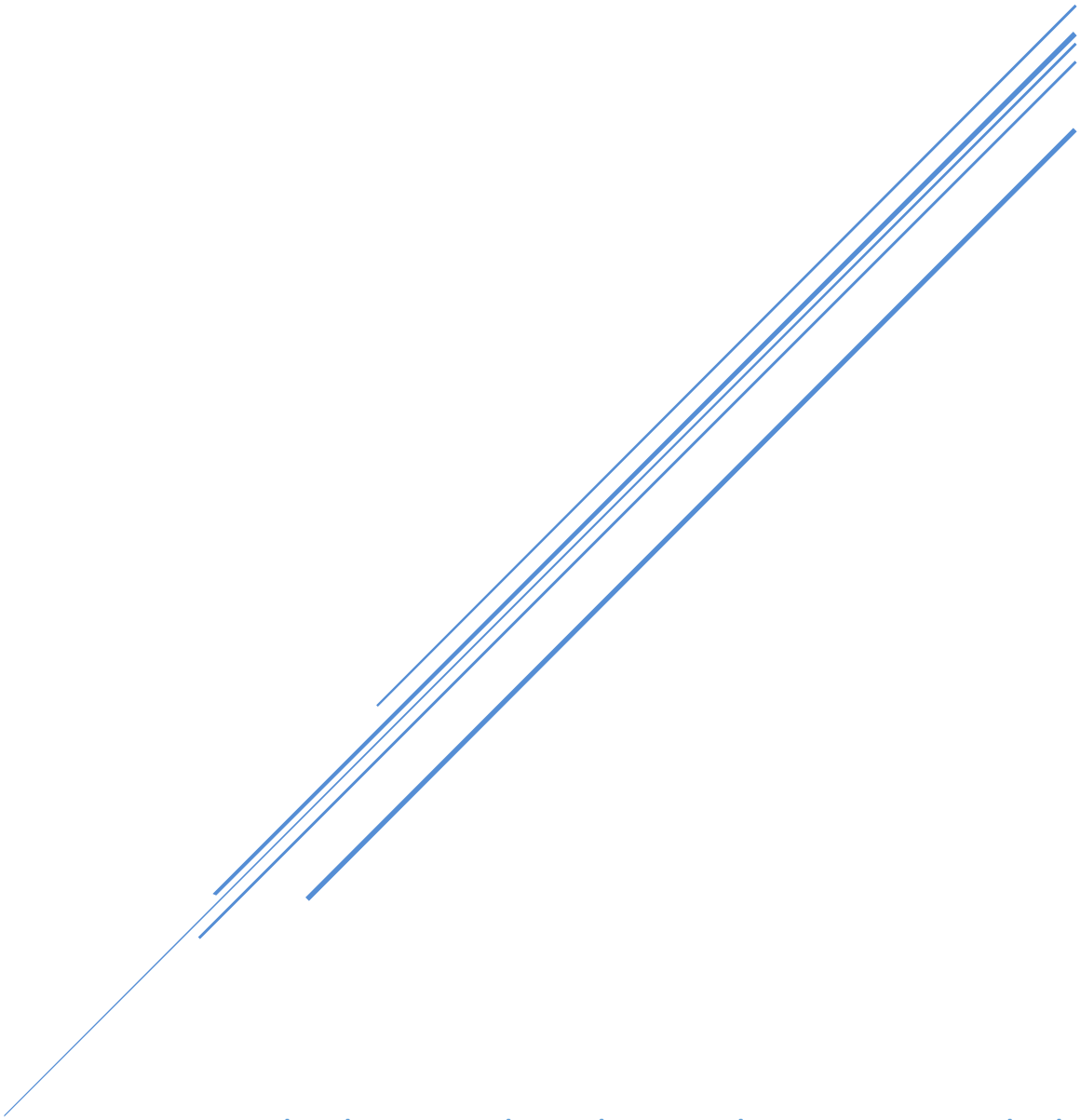
APPENDIX 4G

Flow Rating Curves



Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

4G – Flow Rating Curves

PREPARED FOR:

1050 Loveland Boulevard
Port Charlotte, Florida 33980

PREPARED BY:

IN CONJUNCTION WITH:

Lower Charlotte Harbor Flatwoods Hydrologic Modeling/Planning Project

Technical Memorandum – Task 4g Data Collection: Flow Rating Curves

To: Jennifer Hecker, Nicole Iadevaia, and Sarina Weiss
From: Roger Copp and Kirk Martin, P.G., Water Science Associates
Date December 26, 2021
Re: Flow Rating Curves

BACKGROUND

Water Science Associates was contracted by the Coastal & Heartland National Estuary Partnership (CHNEP) to develop a hydrologic restoration plan for the Lower Charlotte Harbor Flatwoods that will promote sheet flow enhancement and restore wetland hydroperiods in Babcock Webb and Yucca Pens Wildlife Management Area (WMA) and improve the timing and magnitude of flows to tidal creeks west of Yucca Pens WMA.

Project tasks include:

1. Compilation of existing hydrologic data,
2. Installation of new surface and groundwater monitoring stations and rain gages,
3. Evaluation of vegetation indicators of wetland health,
4. Maintenance of the monitoring stations and downloading measured data,
5. Development of an existing conditions hydrologic model of the study area,
6. Evaluation of alternative management scenarios, and
7. Development of a Lower Charlotte Harbor Flatwoods Strategic Hydrological Restoration Planning Tool and Report.

The Task 1 - Data Discovery Memorandum and the Task 2 deliverables including the Groundwater Monitoring Plan, the Flow Monitoring Plan, and the Monitoring Equipment Acquisition and Installation Memoranda have been submitted to CHNEP. Groundwater and rainfall monitoring station locations were selected to complement existing monitoring stations and to address objectives identified during meetings of the Charlotte Harbor Flatwoods Initiative. The monitoring station locations were selected to provide water level data to define watershed boundaries on the eastern and northern portions of the study area, conveyances from Babcock Webb to Yucca Pens, and groundwater levels in Yucca Pens. Task 3 includes ecologic monitoring to determine average wet season water depths at more than 50 locations in Babcock Webb and Yucca Pens and Historical Hydroperiod Mapping. Dry season field work for Task 3 was completed in April and May 2020. Wet season field work was completed in November 2020 to measure water depths at the locations inventoried in the 2020 dry season. Task 3 memoranda describing dry and wet season conditions have been submitted to CHNEP.

Task 4 activities include maintenance of the monitoring stations and downloading on a quarterly basis for six quarters and processing collected data at the flow monitoring stations to create time series of flow data. This memorandum summarizes the methodology used to create the flow time series data.

DESCRIPTION OF DELIVERABLE REQUIREMENTS

The requirement for Task 4g is to describe the process of creating flow time series data from water level and flow measurements collected at the flow monitoring stations. In addition, the Scope of Work stipulates that this memorandum provide a description of the timing and duration of inundation within the WMAs.

DATA COLLECTION

The Flow Monitoring Plan described the location of the flow monitoring stations and flow monitoring activities, and the location of the installed stations is presented in **Figure 1**. The stations were all installed in May 2020 and were operational as of May 15, 2020. Flows were measured at three locations on Yucca Pens Creek as shown in **Figure 2**.

The flow measurements were made using standard USGS stream gaging techniques by personnel taking multiple velocity and depth measurements across the width of the streams/creeks. The flow monitoring equipment used at each station depended on the width and depth of the stream section. For narrow streams, a pygmy or Sontek FlowTracker meter with a top setting wading rod was used. For larger streams (Zemel Canal and the South Branch of Alligator Creek), a Teledyne RDI Stream Pro Acoustic Doppler Current Profiler was used.

The tidal flow monitoring station equipment includes a Sontek SL side-looking velocity meter that uses ultrasonic Doppler technology to measure incoming and outgoing water velocities, a KPSI pressure transducer to record water levels, a Campbell Scientific CR300 data logger, and a Sierra Wireless Cellular IP model kit. The Sontek SL side-looking velocity meter provides a measurement of water velocities at multiple locations across the stream channel but is not necessarily an accurate method of the determining average velocity for the stream channel. Accordingly, the monitoring team also conducted velocity measurements in Yucca Pens Creek with a Teledyne RDI Stream Pro Acoustic Doppler Current Profiler at multiple locations and multiple dates as described in detail below in the Results section.

Field staff discovered that roadway construction crews were planning to demolish the Winegourd Creek monitoring station in September 2020, therefore the field staff removed the monitoring equipment from that station. Development of a stage/discharge relationship for Winegourd Creek was not possible as this station was visited four times prior to abandonment, and flow measurements were taken on two of the four site visits, with no flow observed on the remaining two site visits.

The water level monitoring equipment from Winegourd Creek was installed at a new monitoring station on Yucca Pens Creek at Burnt Store Road. This station provides reliable flow measurements upstream of the Yucca Pens Creek tidal flow monitoring station. The addition of the Yucca Pens Creek flow monitoring station at Burnt Store Road provides valuable information that increases reliability of the flow monitoring program in Yucca Pens Creek. Moving this station also solved challenges encountered during siting of the Yucca Pens Creek tidal flow monitoring station (described below). Establishing a reliable stage/discharge relationship has proven to be difficult at the tidal monitoring station for several reasons, as explained below:

- The station location was mandated by the landowner. An upstream location still within tidal influence was preferable due to the cross-section dimensions, however permission for the first alternative explored could not be obtained to utilize that location. An additional upstream location (Yucca Pens Creek at Burnt Store Road) was established that still provides necessary information to assist the analysis.
- The tidal flow monitoring station is difficult to access during the wet season due to the presence of water levels above the ground surface at the tidal flow monitoring station.
- The cross-section is very wide at this location with much of the flow occurring outside of the main channel. Velocities are very low in the over-bank due to vegetation resistance.

The original flow monitoring station established for Zemel Canal at Burnt Store Road was found to be tidally influenced which inhibited the ability to develop an accurate relationship between canal stage and flow. Accordingly, that station was moved upstream approximately 4,100 feet to a location that is not subjected to tidal influences. The location of the upstream Zemel Canal monitoring station is also shown in **Figure 1**.

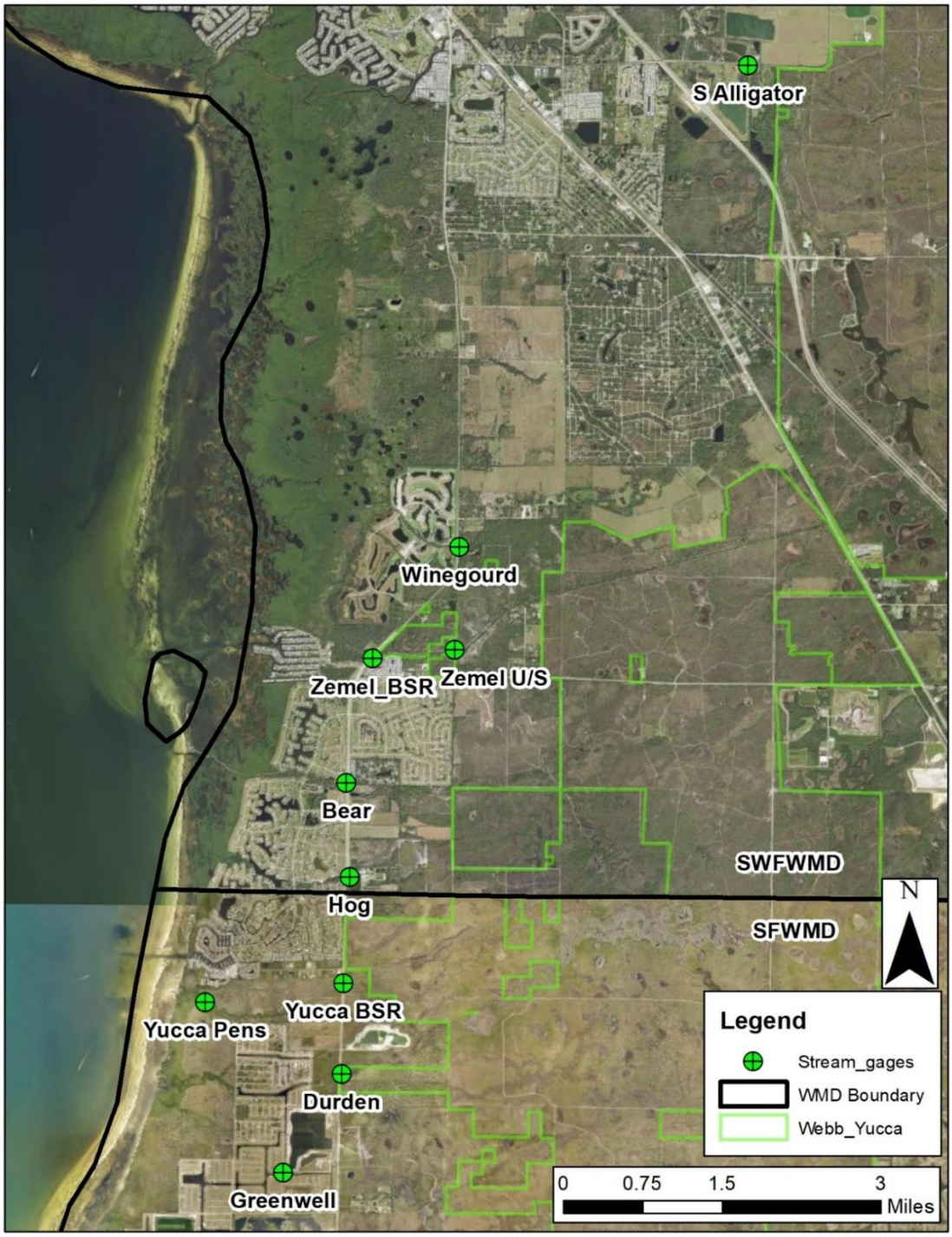


Figure 1 - Flow Monitoring Stations

Figure 2 - Detailed View of Yucca Pens Flow Monitoring Stations

RESULTS FOR NON-TIDAL STATIONS

Graphs of recorded flows and corresponding water elevations for the freshwater flow monitoring stations are presented in **Figures 3 – 9.** These flow and water level measurements were used along with the data logger time series data to calculate flow time series files at each of the flow monitoring stations. A listing of the flow measurements across a range of water depths at all stations is presented in

A summary of flow measurements at the Yucca Pens tidal station and nearby stations is presented in **Table 2**. As shown in **Figure 2**, the Yucca Pens tidal constriction is located 1,800 feet upstream of the tidal flow monitoring station, and the Yucca Pens Creek flow station is located 5,600 feet upstream of the constriction. The flow measurements in the Yucca Pens stations indicate that flows measured on June 10 and November 12, 2020 are relatively similar at Burnt Store Road, the constriction, and at the tidal flow monitoring station.

The flow measurements on May 21, August 10, and September 15 differed between locations due to the timing of the flow measurements with respect to rising and falling tides. **Figure 10** illustrates the timing of the May 21 flow measurements relative to the changes in tide levels at the tidal flow monitoring station. The flow at the tidal station were higher than at the constriction because the tidal station monitoring was conducted while the tide was still rising, while the measurement at the upstream constriction was conducted close to slack tide. **Figure 11** illustrates the timing of the August 10 flow measurements with respect to tidal fluctuations. The larger measured flow at the tidal monitoring station was performed while the tide was still falling, while the flows at the constriction was lower since that measurement was conducted close to slack tide. The flow measurements for September 15 presented in **Figure 12** indicate negative flow measurements at the tidal station on a rising tide and positive flow measurements at the constriction and Burnt Store Road stations on a falling tide. The similar flows between stations on June 10 and November 12 suggest that the flow measurements at Burnt Store Road are a reasonable estimate of net discharges to tide from Yucca Pens Creek. For graphs below: Tidal G. Q – Tidal Gage flow, cfs (cubic feet per second). YP Constr. Q – YP Constriction flow, cfs, BSR Q – Burnt Store Road flow, cfs (refer to Figure 2 for locations of these stations).

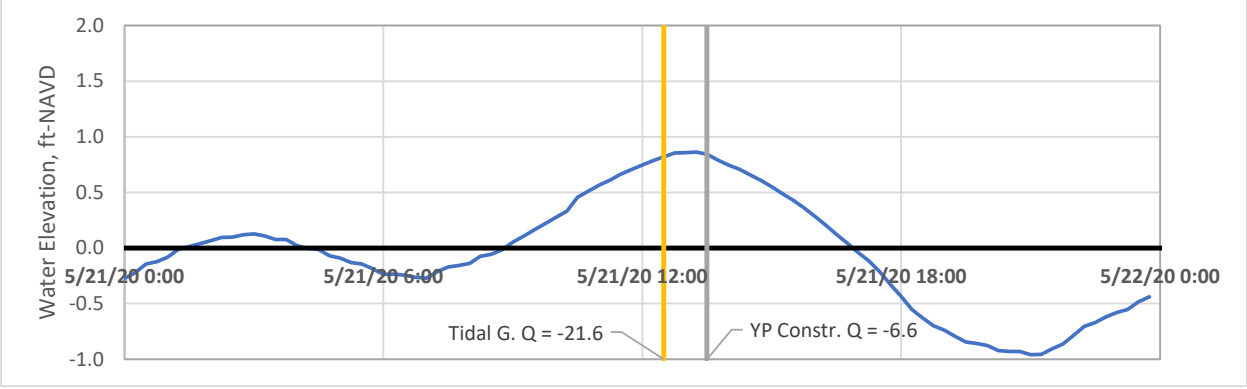


Figure 10 - Yucca Pens Tidal Flow Measurements on May 21, 2020

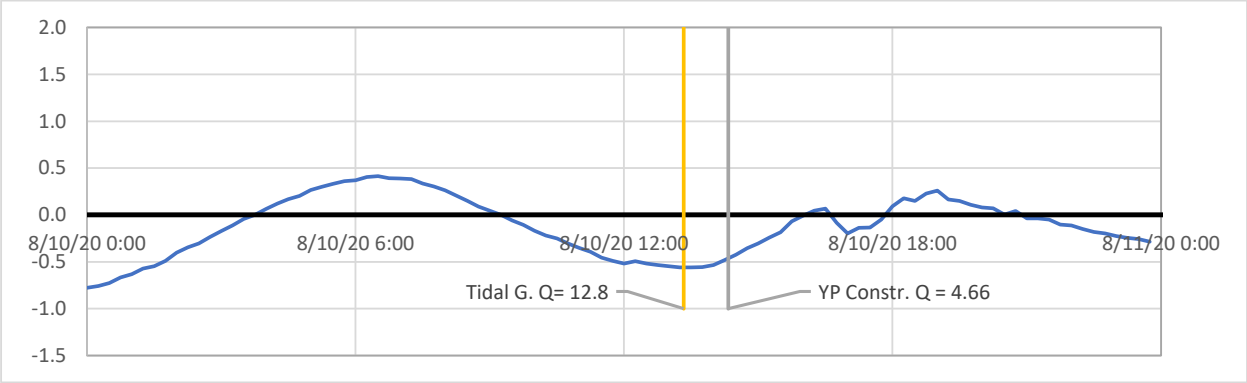


Figure 11 - Yucca Pens Tidal Flow Measurements on August 10, 2020

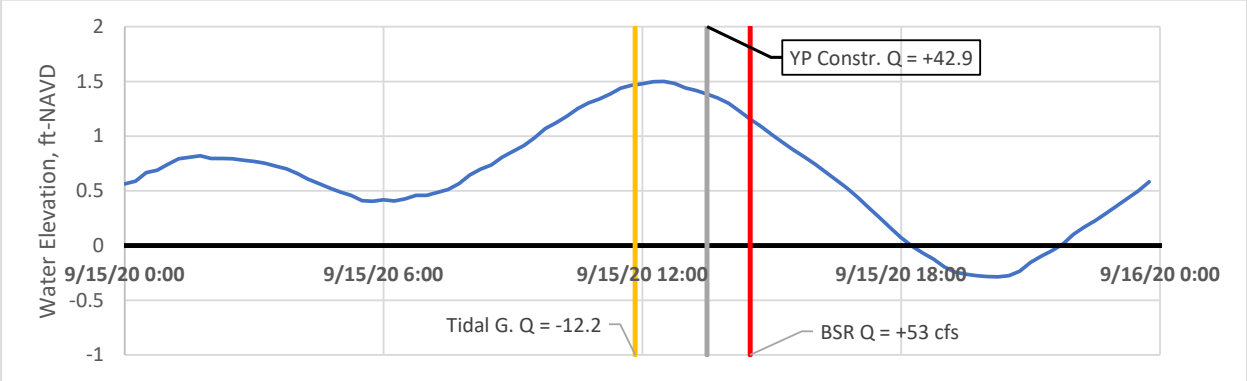
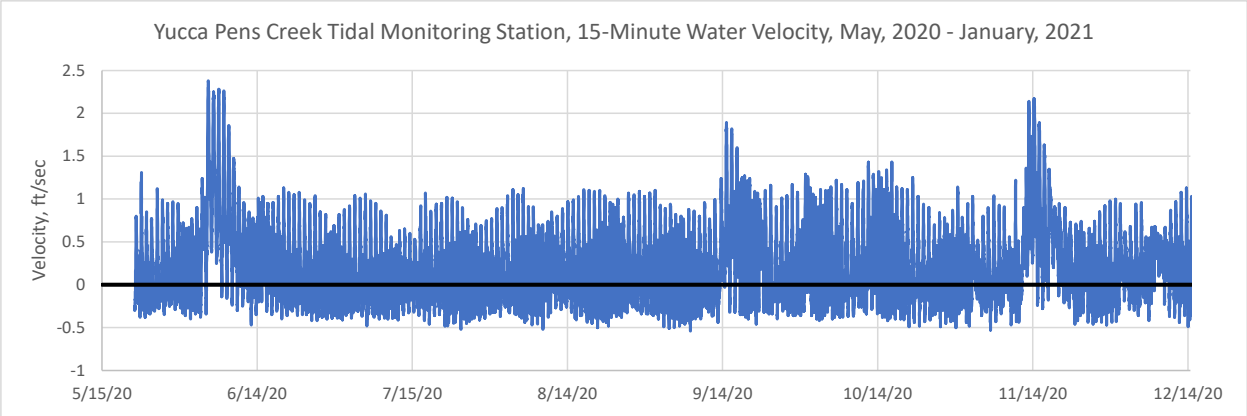
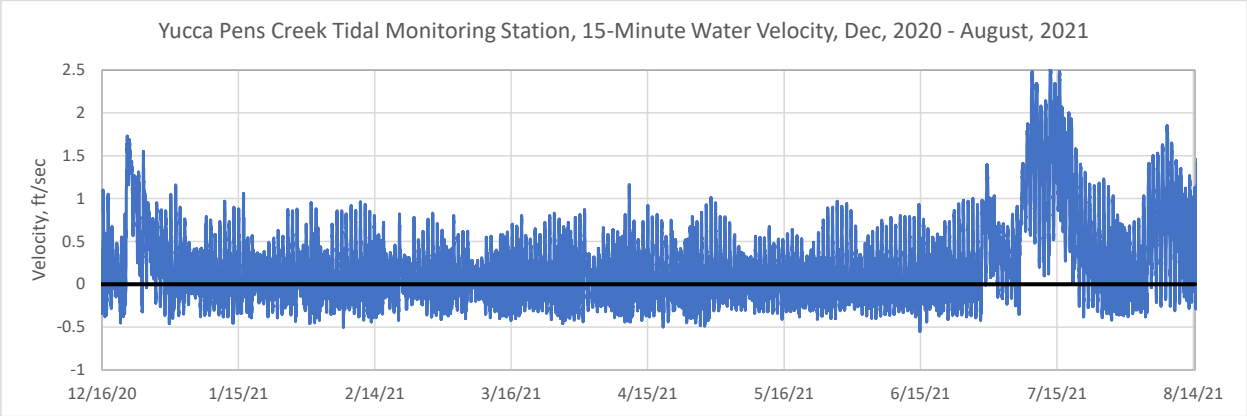


Figure 12 - Yucca Pens Creek Tidal Flow Measurement on Sept. 15, 2020

The recorded tidal velocities shown in **Figure 13** provide insight to the forces associated with the tidal fluctuations. Velocities range from 1 to -0.5 ft/sec during periods of low runoff. Outgoing velocities increase above 2 ft/sec during the summer runoff period with incoming velocities slightly less (ranging from -0.3 to -0.4 ft/sec) during the summer runoff period. Wet season tidal ranges during runoff events in 2020 ranged from +2.3 to +0.3 ft/sec. A large runoff event was experienced in mid-July 2021, where tidal velocities ranged from +2.5 to +0.3 ft/sec over a 10-day period. The highest outgoing velocities at the tidal monitoring station were experienced during the same period as the highest recorded water levels at the Yucca Pens Creek monitoring station on Burnt Store Road.





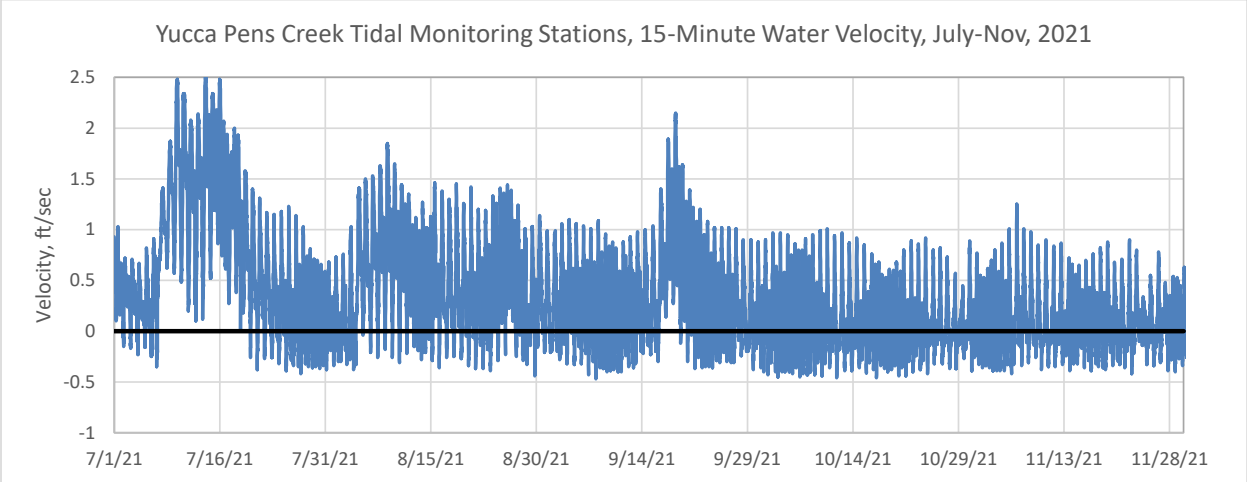


Figure 13 - Tidal Velocities at the Yucca Pens Tidal Monitoring Station

Table 1. The ADCP (Acoustic Doppler Current Profiler) measurement rating is calculated using the data collection and processing software (Winriver) by RDI instruments. For measurements taken with a pygmy meter, the rating is based on stream gaging standards established by USGS. The field equipment used to measure channel velocity is also documented in **Table 1**. Sample field records and computer output from field measurements are presented in **Appendix A**. The last page of **Appendix A** provides an example of the Winriver output with the flow measurement accuracy highlighted. The flow measurement rating (excellent, good, fair, poor) is based on the professional experience of the flow measurement team.

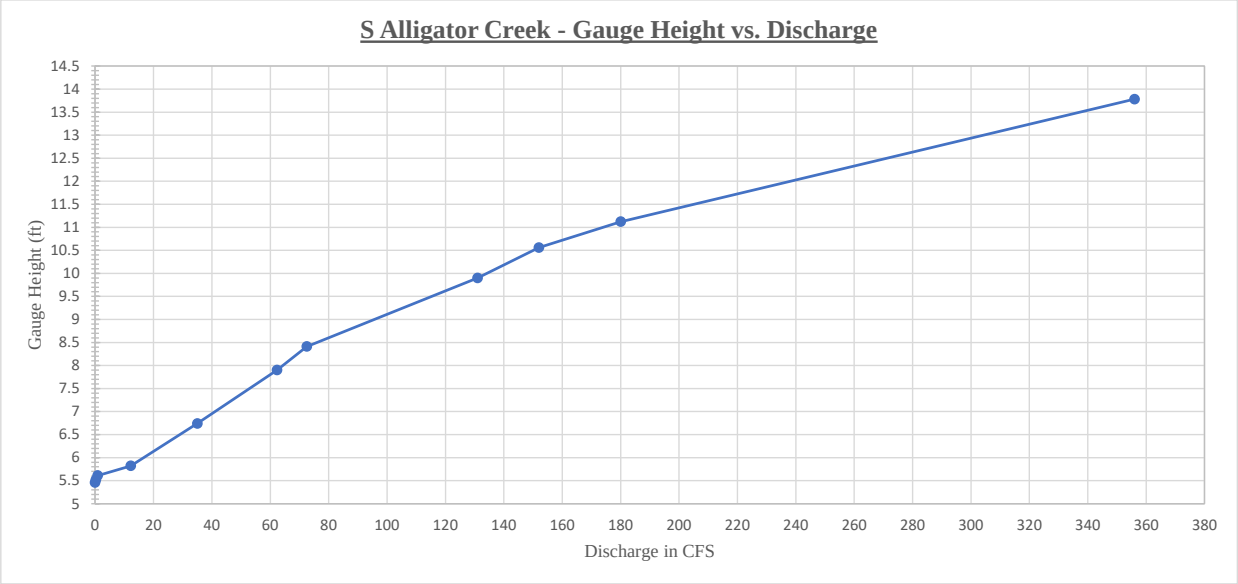


Figure 3 - Stage/Discharge Measurements for South Alligator Creek at South Jones Loop Road

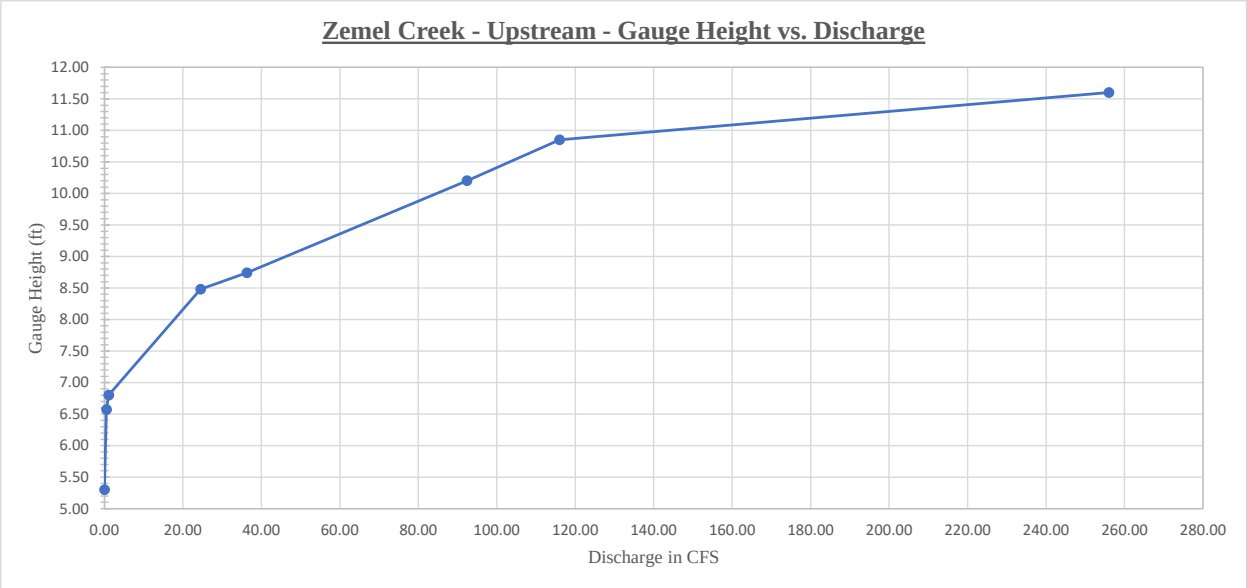


Figure 4 - Stage/Discharge Measurements for Zemel Creek at Station Upstream of Burnt Store Road

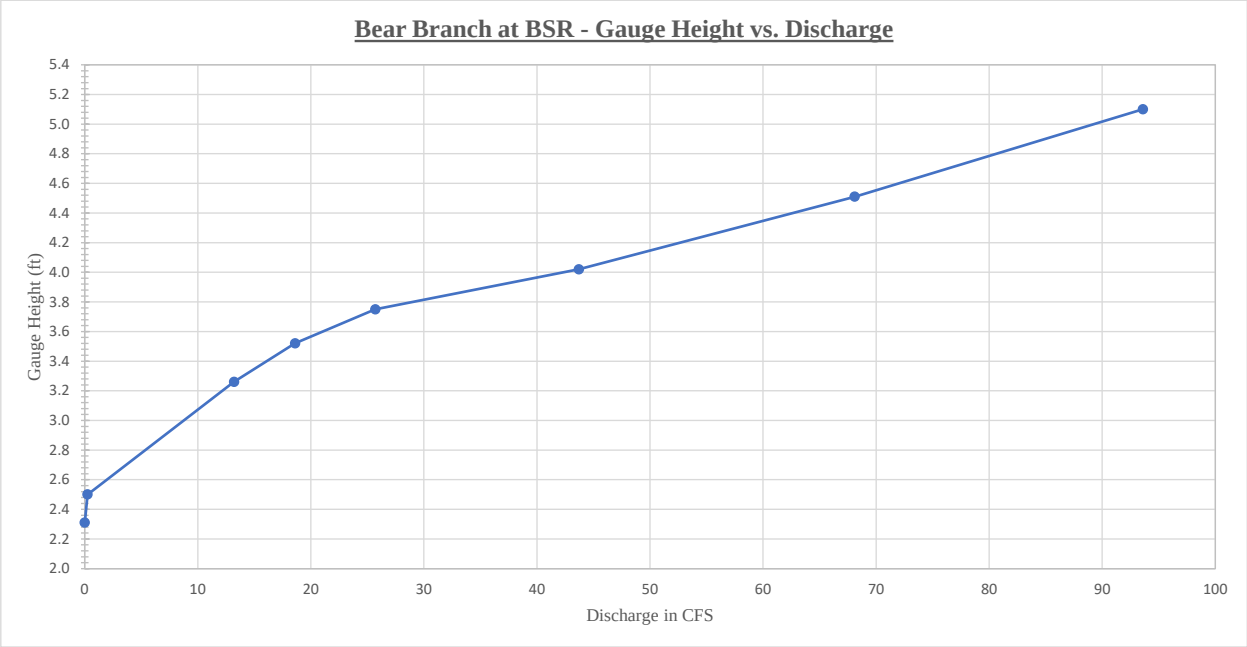


Figure 5 - Stage/Discharge Measurements for Bear Branch at Burnt Store Road

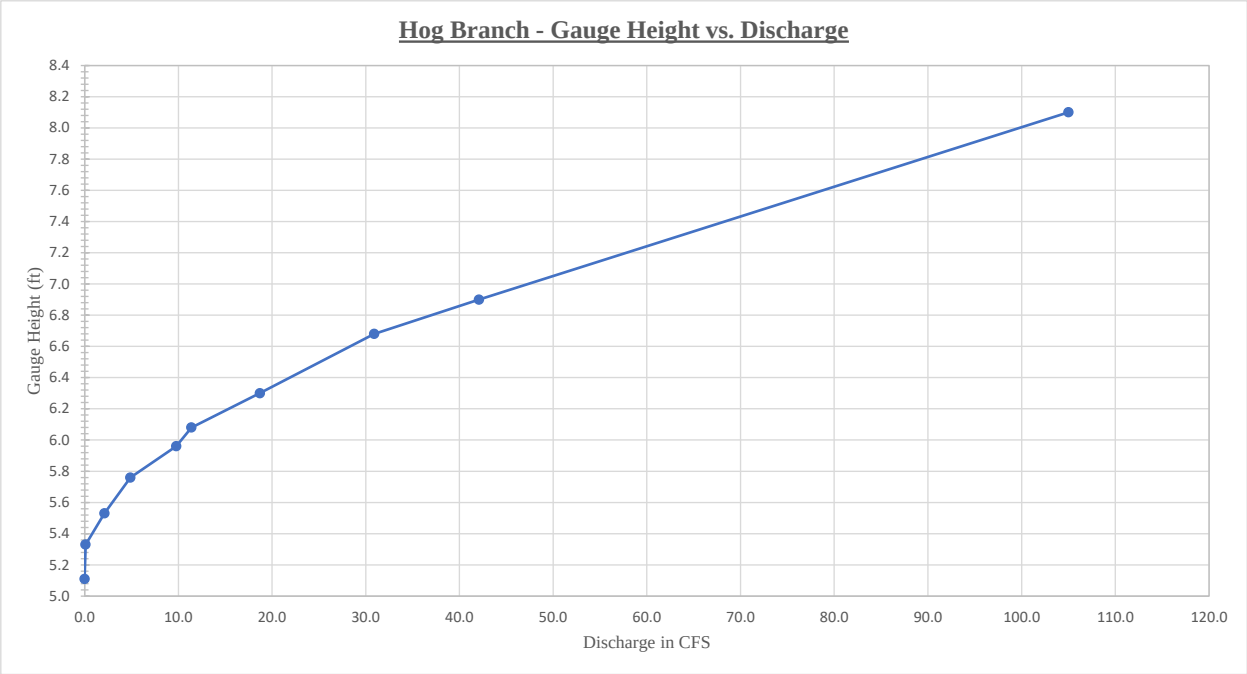


Figure 6 - Stage/Discharge Measurements for Hog Branch at Burnt Store Road

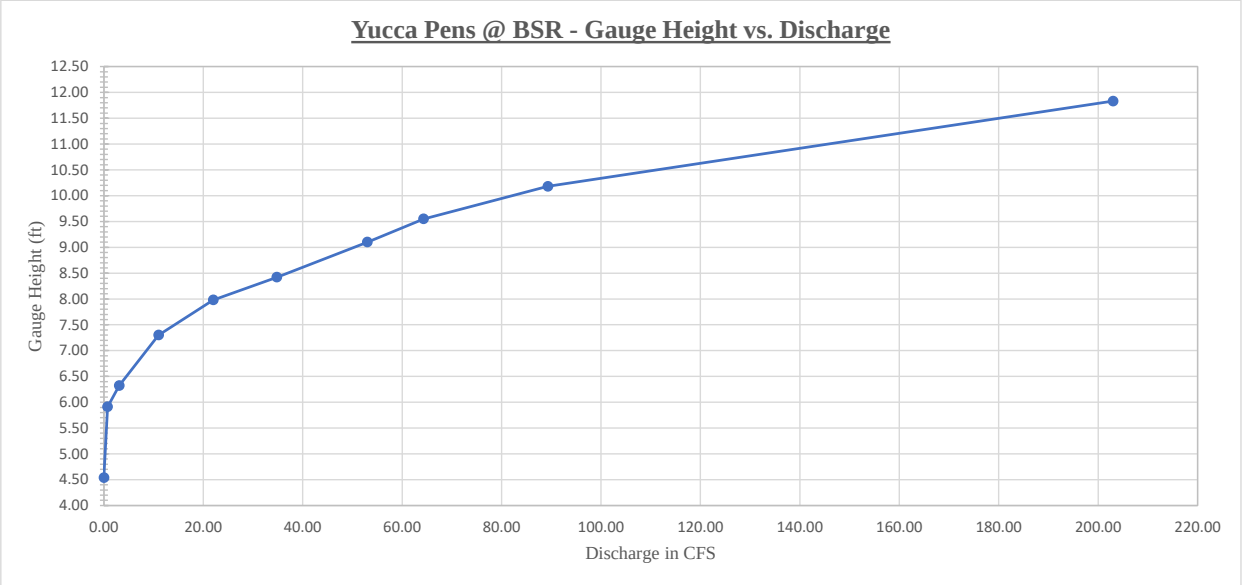


Figure 7 - Stage/Discharge Measurements for Yucca Pens Creek at Burnt Store Road

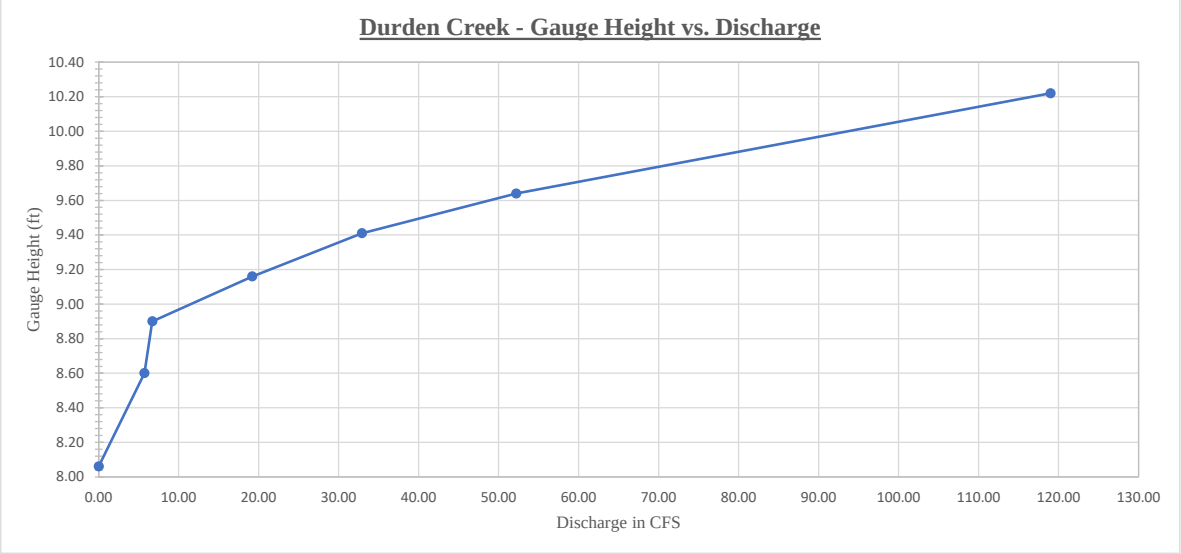


Figure 8 - Stage/Discharge Measurements for Durden Creek at Burnt Store Road

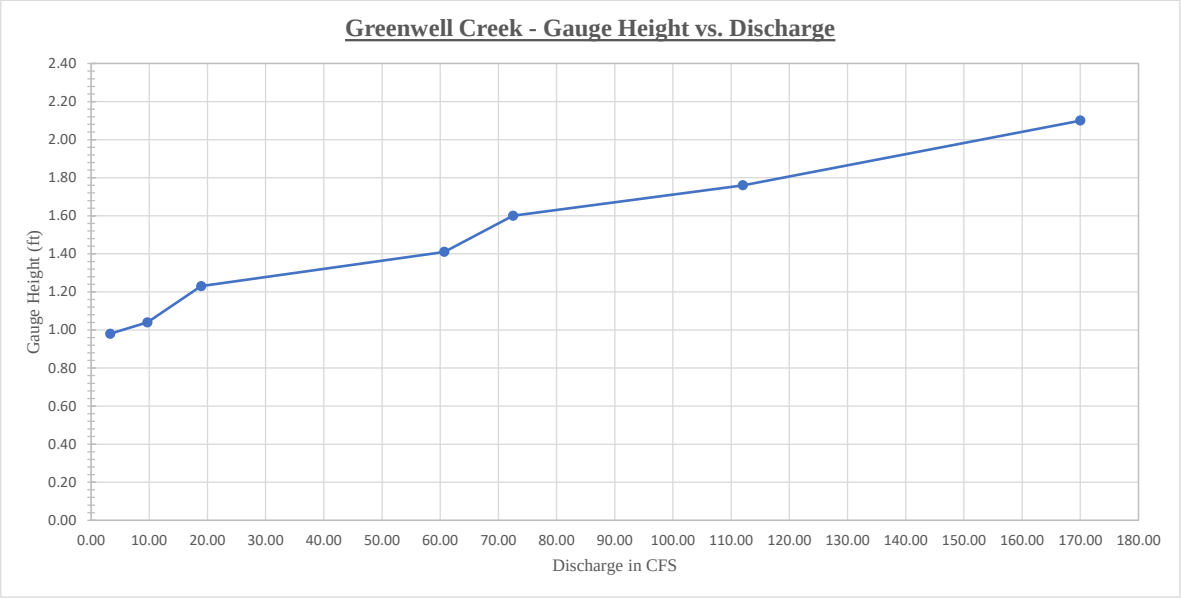


Figure 9 - Stage/Discharge Measurement for Greenwell Branch at NW 36th Avenue, Cape Coral

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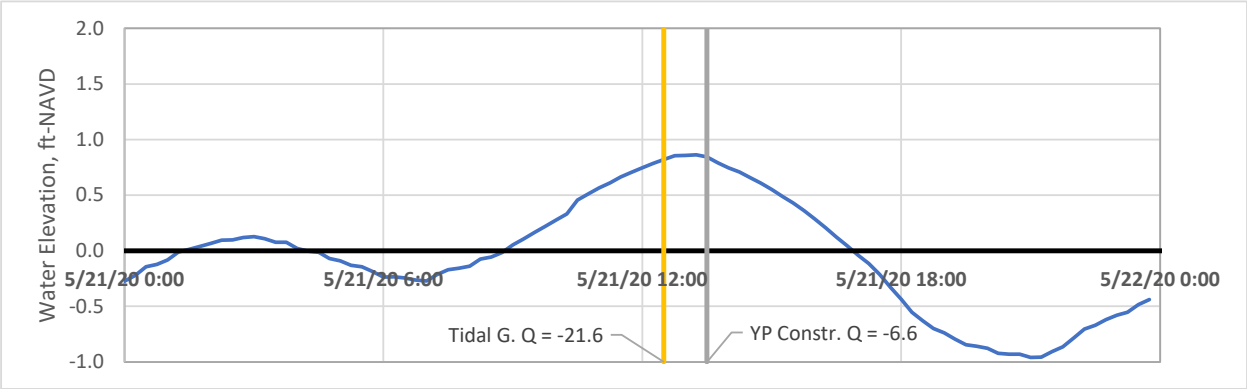
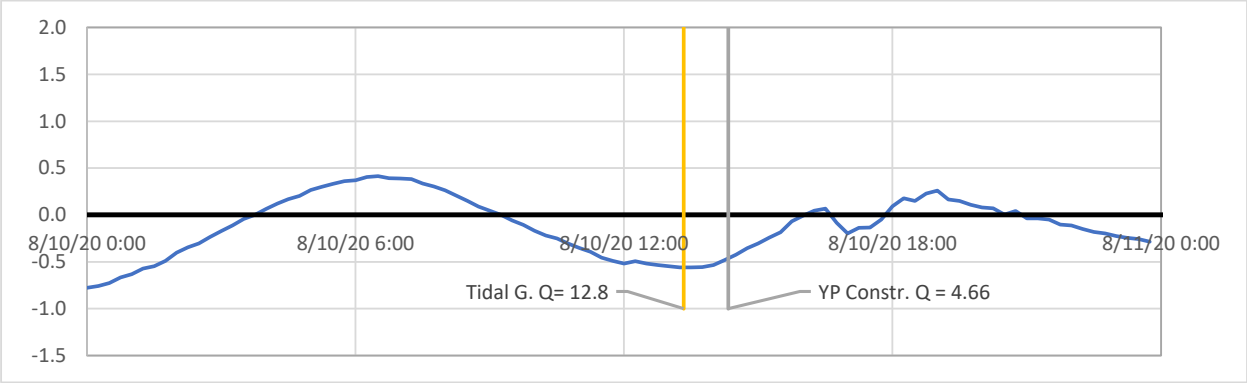


Figure 10 - Yucca Pens Tidal Flow Measurements on May 21, 2020



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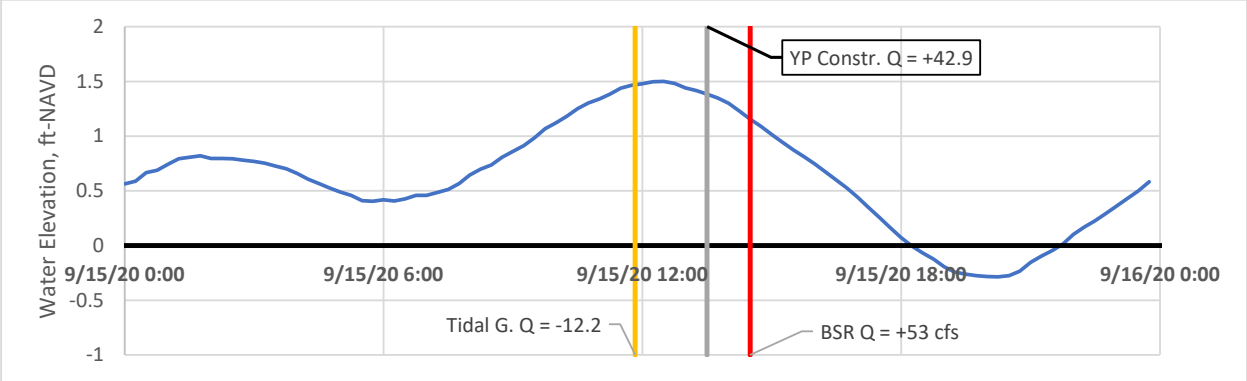

Figure 12 - Yucca Pens Creek Tidal Flow Measurement on Sept. 15, 2020

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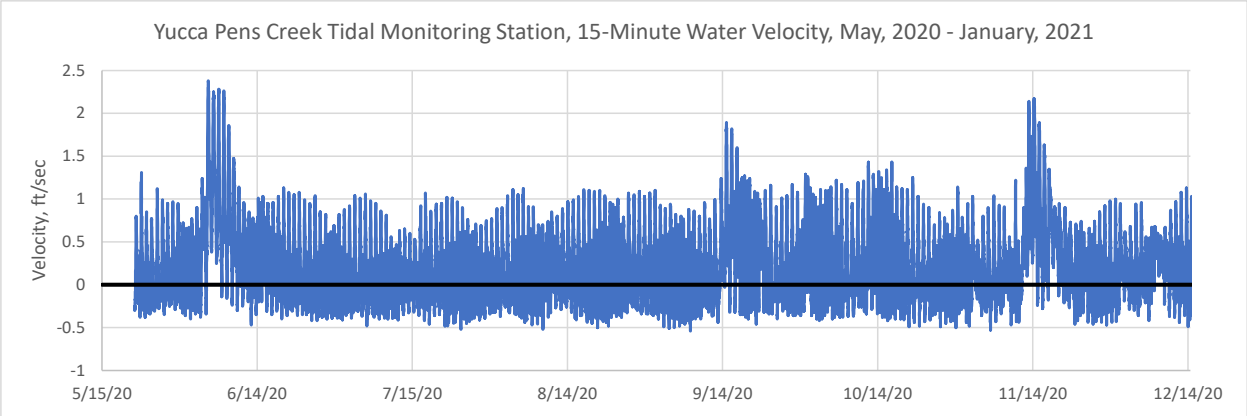
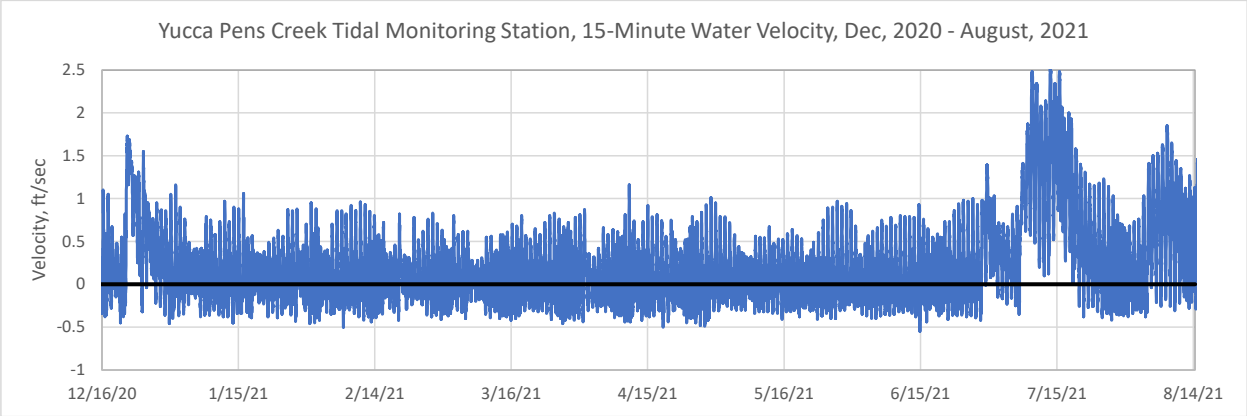




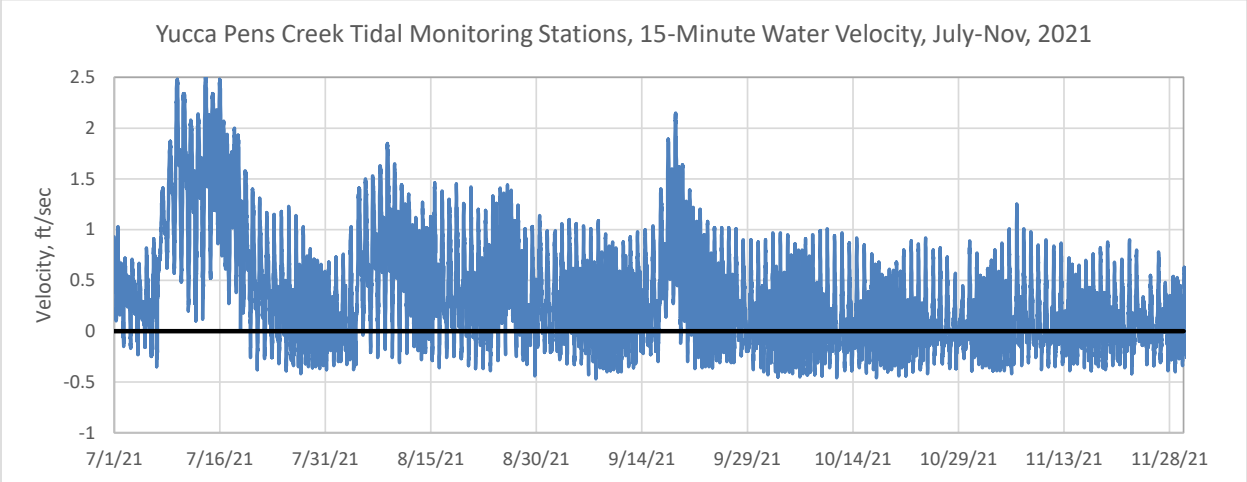


Figure 13 - Tidal Velocities at the Yucca Pens Tidal Monitoring Station

Table 1 - Discharge Measurement Summary

S. Alligator Creek	Meas. #	Date:	Stage	Discharge (cfs)	Meter	Rated:	Remarks:
	1a	5/21/2020	5.46	0.00	Observation	G	PZF - Point of Zero Flow
	1b	5/21/2020	5.52	0.244	Price - Pygmy	F	Very low velocities
	2	6/10/2020	5.82	12.20	Price - Pygmy	G	Box culverts mostly clear
	3	8/24/2020	7.90	62.30	ADCP	E	Box culverts mostly clear
	4	8/28/2020	6.74	35.00	ADCP	G	Box culverts mostly clear
	5	9/14/2020	8.41	72.50	ADCP	G	Box culverts mostly clear
	6	9/30/2020	10.56	152.00	ADCP	E	Box culverts mostly clear
	7	11/12/2020	11.12	180.00	ADCP	E	Box culverts mostly clear
	8	11/13/2020	9.90	131.00	ADCP	E	Box culverts mostly clear
	9	3/10/2021	5.61	0.84	Price - Pygmy	G	Box culverts mostly clear
	10	7/8/2021	13.78	356.00	ADCP	G	Box culverts mostly clear - Est. 30 cfs through ByPass Culvert W of Main Channel
	11	10/14/2021	6.14	24.4	Price - Pygmy	G	Box culverts mostly clear (PZF = 5.24)
Zemel_Upstream	1	10/20/2020	8.48	24.50	ADCP	G	Re-located Gauge Upstream where it is not tidally influenced
	2	11/10/2020	8.74	36.30	ADCP	G	Channel Mostly Clear - Mod. Veg on LEW / REW
	2b	11/10/2020	5.30	0.00	Observation	F	Estimated PZF
	3	11/12/2020	10.85	116.00	ADCP	E	Mod. Veg. LEW / REW
	4	11/13/2020	10.20	92.40	ADCP	G	Mod. Veg. LEW / REW
	5	3/10/2021	6.80	1.07	Price - Pygmy	G-F	Channel Mostly Clear - Mod. Veg on LEW / REW
	6	5/11/2021	6.57	0.50	Price - Pygmy	G	Channel Mostly Clear - Mod. Veg on LEW / REW
	7	7/8/2021	11.60	256.00	ADCP	E	O.S. Destroyed by Hurricane Elsa. Disch Meas. at BSR Box Culverts - Clear - O.S. estimated from Logger Data
Bear Branch	Meas. #	Date:	Stage	Discharge (cfs)		Rated:	Remarks:
	1a	5/21/2020	2.31	0.00	Observation	G	PZF - Point of Zero Flow
	1b	5/21/2020	2.68	0.145	Price - Pygmy	F-P	Low Velocities
	2	6/9/2020	3.52	18.60	Price - Pygmy	G	Mod - High Velocities
	3	9/14/2020	3.75	25.70	ADCP	G	ADCP Meas. @ Upstr. Side of Culverts (600' Dstr.)
	4	10/2/2020	3.26	13.20	ADCP	G	Culverts Dstr. Clear
	5	11/12/2020	4.51	68.10	ADCP	E	Culverts Dstr. Clear
	6	11/13/2020	4.02	43.70	ADCP	E	Culverts Dstr. Clear
	7	5/11/2021	2.50	0.25	Price - Pygmy	F	Low Velocities
	8	7/8/2021	5.10	93.60	ADCP	G	Culverts Dstr. Clear

Discharge Measurement Rating: (Excellent (+/- 2%) / Good (+/- 5%) Fair (+/- 8%) Poor (> 8%))

Table 1 – Discharge Measurement Summary, continued

Hog Branch	Meas. #	Date:	Stage	Discharge (cfs)		Rated:	Remarks:
	1a	5/21/2020	5.11	0.00	Observation	E	PZF - Point of Zero Flow
	1b	5/21/2020	5.33	0.095	Price - Pygmy	F-P	Low Velocities - Light/Mod Veg. in Box Culvert
	2	6/9/2020	5.96	9.77	Price - Pygmy	G-F	Low-Mod. Velocities
	3	8/28/2020	5.53	2.11	Price - Pygmy	G	Low-Mod. Velocities
	4	9/14/2020	6.30	18.70	ADCP	G	Light/Mod. Moss & Algae on Box Culvert Lip
	5	9/30/2020	6.08	11.40	ADCP	F	Light/Mod. Moss & Algae on Box Culvert Lip
	6	10/2/2020	5.76	4.88	Price - Pygmy	G	Light/Mod. Moss & Algae on Box Culvert Lip
	7	11/12/2020	6.90	42.10	ADCP	E	Light/Mod. Moss & Algae on Box Culvert Lip
	8	11/13/2020	6.68	30.90	ADCP	G	Light/Mod. Moss & Algae on Box Culvert Lip
	9	7/8/2021	8.10	105.00	ADCP	G	Culvert Clear
Yucca Pens @ BSR	1	6/10/2020	7.98	22.00	ADCP	P	Positive Flow - Incoming Tide @ Gauging Station - No Tidal Fluctuation observed @ Burnt Store Rd.
	2	7/21/2020	5.91	0.72	Price - Pygmy	F	Positive Flow - Outgoing Tide @ Gauging Station - No Tidal Fluctuation observed @ Burnt Store Rd.
	3	8/10/2020	6.32	3.07	Price - Pygmy	F	Positive Flow - Transistional Flow @ Gauging Station from Outgoing to Incoming - No Tidal Fluctuation observed @ Burnt Store Rd.
	4	9/15/2020	9.10	53.00	ADCP	G	Positive Flow - No Tidal Fluctuation Observed
	5	9/16/2020	9.55	64.30	ADCP	G	Positive Flow - No Tidal Fluctuation Observed
	6	9/30/2020	8.42	34.80	ADCP	G	Positive Flow - No Tidal Fluctuation Observed
	7	10/2/2020	7.30	11.00	ADCP	G	Positive Flow - No Tidal Fluctuation Observed
	8	11/10/2020	4.54	0.00	Observation	G	PZF 10' (+/-) Upstr. of Fenceline on Western BSR Easement
	9	11/12/2020	10.18	89.30	ADCP	G	Positive Flow - No Tidal Fluctuation Observed
	10	3/10/2021	5.50	<0.10	Observation	G	Est. / Observation
	11	7/8/2021	11.83	203.00	ADCP	E	Culverts Clear

Discharge Measurement Rating: (Excellent (+/- 2%) / Good (+/- 5%) Fair (+/- 8%) Poor (> 8%))

Table 1 – Discharge Measurement Summary, continued

Durden Creek	Meas. #	Date:	Stage	Discharge (cfs)		Rated:	Remarks:
	1	6/9/2020	9.16	19.20	ADCP	P	Culverts Totally Submerged - Eddy on LEW
	2	7/21/2020	8.60	5.72	ADCP	p	Culverts Totally Submerged - Eddy on LEW
	3	8/28/2020	8.90	6.70	ADCP	P	Culverts Totally Submerged
	4a	9/9/2020	8.06	0.00	Observation	G	PZF @ Western Easement Fenceline
	4	9/14/2020	9.64	52.20	ADCP	G	Culverts Totally Submerged
	5	9/16/2020	9.41	32.90	ADCP	F	Culverts Totally Submerged
	6	7/8/2021	10.22	119.00	ADCP	E	Culverts Totally Submerged
Greenwell Branch	Meas. #	Date:	Stage	Discharge (cfs)		Rated:	Remarks:
	1	6/9/2020	1.23	18.90	ADCP	G	Culverts Clear
	2a	7/21/2020	0.98	3.26	ADCP	P	Culverts Clear
	2b	7/21/2020	0.98	0.33	Price - Pygmy	F	Pygmy Meter Meas. - Greenwell @ Burnt Store Rd.
	3	8/10/2020	1.04	9.67	ADCP	G	Culverts Clear
	4	9/14/2020	1.76	112.00	ADCP	E	Culverts Clear
	5	9/16/2020	1.41	60.70	ADCP	G	Culverts Clear
	6	11/12/2020	1.60	72.50	ADCP	E	Culverts Clear
	7	7/8/2021	2.10	170.00	ADCP	E	Culverts Clear

Discharge Measurement Rating: (Excellent (+/- 2%) / Good (+/- 5%) Fair (+/- 8%) Poor (> 8%))

Table 2 – Discharge Measurements in the Yucca Pens Creek stations at Burnt Store Road and the Tidal Flow Monitoring Station

Yucca Pens	Meas. #	Date:	Stage	Discharge (cfs)	Rated:	Remarks:
Gauging Station	1a	5/21/2020	0.60	-21.60	G	Negative flow - Incoming Tide (IT) @ Gauging Station (GS) - LEW is undefined due to Mangroves (Estimated)
Upstr. @ Constriction	1b	5/21/2020	0.74	-6.56	F	Negative flow - Incoming Tide @ GS & U/S Constriction
Gauging Station	2a	6/10/2020	0.42	16.60	P	Positive Flow - Incoming Tide @ Gauging Station
Upstr. @ Constriction	2b	6/10/2020	0.59	22.10	G	Pos Flow - IT @ GS - No Tidal Fluctuation @ Constriction
Yucca Pens @ BSR	1	6/10/2020	7.98	22.00	P	Positive Flow - IT @ GS - No Tidal Fluctuation @ BSR
Gauging Station	4a	8/10/2020	-0.54	12.80	G	Positive Flow - Outgoing Tide (OT) @ GS
Upstr. @ Constriction	4b	8/10/2020	-0.62	4.66	P	Positive Flow - OT @ GS - Tidal Fluct @ Constriction
Yucca Pens @ BSR	3	8/10/2020	6.32	3.07	F	Positive Flow - OT @ GS - Tidal Fluct @ Constriction
Gauging Station	5a	9/15/2020	1.31	-12.20	P	Neg Q - IT @ GS - LEW is undefined, Mangroves (Est)
Upstr. @ Constriction	5b	9/15/2020	0.14	42.90	G	Positive Flow with Incoming Tide
Yucca Pens @ BSR	4	9/15/2020	9.10	53.00	G	Positive Flow - No Tidal Fluctuation Observed
Upstr. @ Constriction	6	11/12/2020	0.37	88.50	G	Positive Flow with Outgoing Tide
Yucca Pens @ BSR	9	11/12/2020	10.18	89.30	G	Positive Flow - No Tidal Fluctuation Observed

Abbreviations: IT: Incoming Tide; OT: Outgoing Tide; GS: Gaging Station; U/S: upstream; BSR: Burnt Store Road; LEW: Left Edge of Water; Est: Estimated

METHODOLOGY TO ESTIMATE FLOWS FROM STAGE/DISCHARGE RELATIONSHIPS

Review of **Figures 3-9** indicate that the measured flow and stage points align well and create relatively smooth curves. Accordingly, the method to find the flow (Q) for a given stage (H) consisted simply of the following steps:

1. For a given stage recording in the stage time series record, find the stage/discharge points that are higher and lower than the given stage
2. Use the equation of the line between the two measured points in the stage/discharge relationship to interpolate the flow value for the given stage in the time series of recorded water elevations (i.e., linear interpolation method)
3. If the given stage is greater than the highest measured stage, then the line equation from the two greatest measured stages is used (i.e., linear extrapolation method)

The basic steps to calculate a flow for each measured stage is listed below.

Measured Stage Values: H , (H[0] and H[1] is the selected interval, lowest and highest respectively)
Measured Flow Values: Q , (Q[0] and Q[1] is the selected interval, lowest and highest respectively)
Given Stage Value: h
Calculated Flow Value: q
Number of Measured Values: n
Calculated Slope: m

The first step is reading in the measured stages and Flows from the Discharge Data worksheet.
Then the script goes line by line through the given stage data (Stage data worksheet), looks for the interval of measured stages that contains the given stage, then calculates the new flow value based on the interval found. This falls into 3 cases.

1. The interval is found, then the two measured stage and flow points are used alongside the given stage value to linear interpolate the new flow value
    a. m = (Q[1] – Q[0]) / (H[1] – H[0])
    b. q = Q[0] + ((h – H[0]) * m)
2. The given stage value is less than the lowest measured stage value. Linear extrapolation is used with the two lowest measured stage and flow values. Extrapolated values floored at zero
    a. m = (Q[0] - Q[1]) / (H[0] - H[1]) find slope using two lowest stage and flow values
    b. q = Q[0] + ((h - H[0]) * m) extrapolate from lowest flow values using given stage, lowest stage and slope.
    c. If q < 0, q = 0
3. The given stage value is greater than the highest measured stage value. Linear extrapolation is used with the two highest measured stage and flow values.
    a. m = (Q[1] - Q[0]) / (H[1] - H[0]) find slope using two highest flow values
    b. q = Q[1] + ((h - H[1]) * m)

These calculated flow values were then saved in the Stage data worksheet on the same row, in the adjacent cell to the given stage data from which they were calculated.

Recorded water levels and the estimated flows at the flow monitoring stations are presented in **Appendix B**. Note that the period of record for Yucca Pens Creek at Burnt Store Road is shorter than for other stations since this station was established using equipment that was originally installed at Winegourd Creek. The Winegourd Creek station was abandoned due to construction in September 2020 associated with the widening of Burnt Store Road.

DURATION OF INUNDATION

Simulated hydroperiods for calendar years 2020 and 2021 for the study area are presented in **Figure 14**. The simulated hydroperiods from the 100% calibration were calculated for the 12/21/21 simulation (annotated in graphs as year/month/day, "20211221") as part of the final calibration work. Hydroperiods are greatest in the South Walk-In Area of southwestern

Babcock Webb WMA and are below optimum conditions in Yucca Pens. Hydroperiods in Yucca Pens are rarely greater than 5 months which is less than optimum, especially for the cypress strands of Yucca Pens. The southern portion of Yucca Pens has hydroperiod less than one month, and the western cypress strands of Yucca Pens have hydroperiods ranging from 2 – 5 months. The simulated hydroperiods are consistent with the findings of the Task 3 ecologic investigations. Conversely, hydroperiods in Babcock Webb are above nine months in much of the South Walk-In Area.

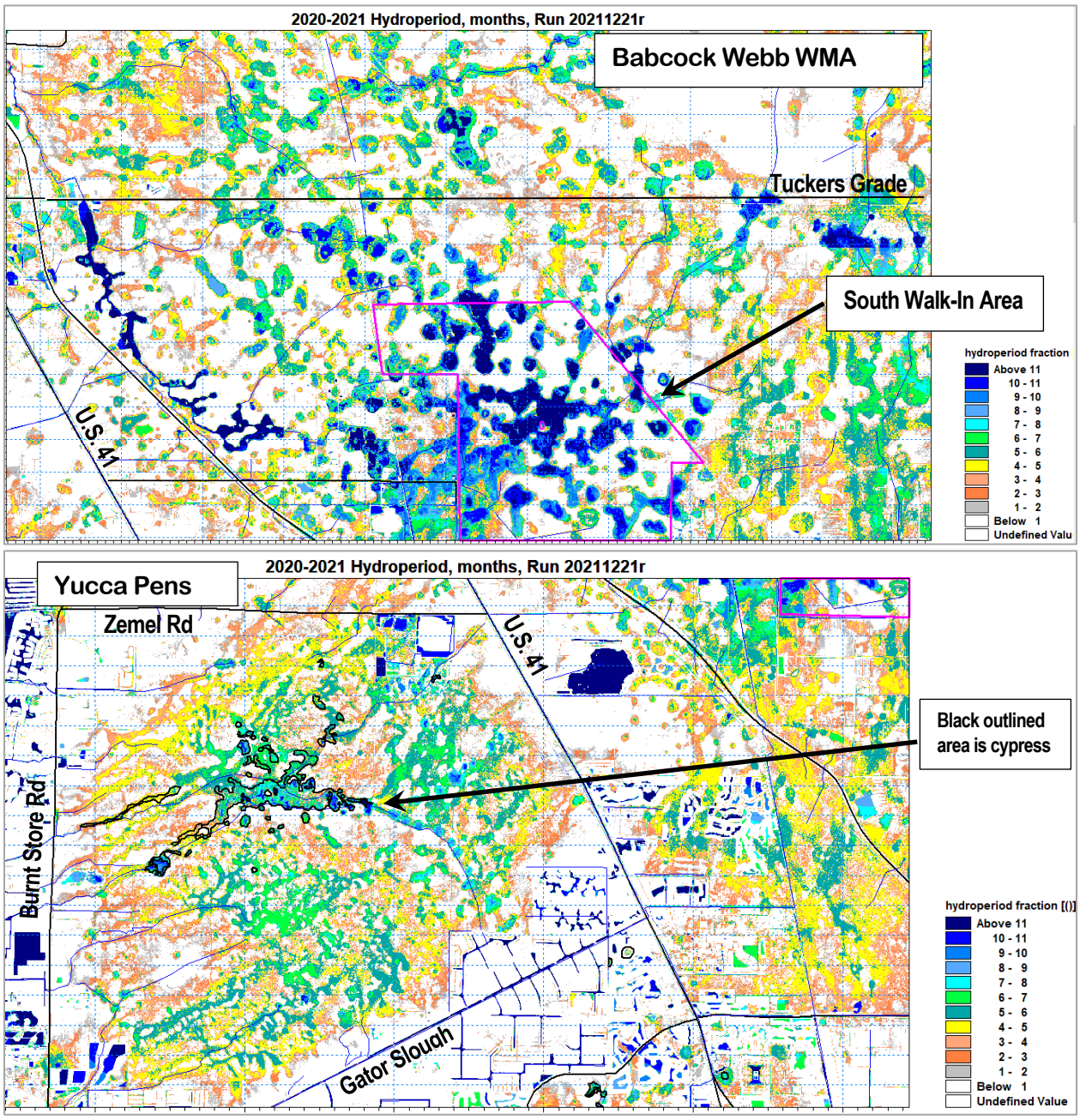


Figure 14 – Simulated Yucca Pens Hydroperiod, 2020-2021, 1221r simulation

All of the flow monitoring stations were ephemeral. Positive flows ceased in Alligator Creek in early February, and in Yucca Pens Creek in December. Positive flows ended in January for Bear Branch, Hog Branch, Yucca Pens Creek, Durden Creek, and Greenwell Branch. Restoration of hydroperiods in Yucca Pens would have a positive effect on extending the duration of dry season discharges to tidal creeks west of Yucca Pens.

Restoration of hydroperiods in both Babcock Webb and Yucca Pens will have a positive effect on restoration of vegetative communities, which will be beneficial for wildlife. Work associated with subsequent tasks will focus on restoration measures that restore wetland hydroperiods, and this restoration is expected to have a positive effect on discharges to tidal nurseries.

APPENDIX A

Sample Field Records from Flow Measurements

Bear Branch Flow Measurement Field Log, 6/9/20

HYDROGAGE, INC.

Hydrometric Services - Lakeland, Florida
(863) 816-5871

Meas. No. 2
Comp. by JCH
Checked by WHH

DISCHARGE MEASUREMENT NOTES

Sta. No. _____
Bear Creek / Bear Branch
Date 6/9, 2020 Party WHH, JCH
Width 24.75 Area 20.3 Vel. .916 G.H. 3.52 Disch. 18.6
Method 6 No. secs. 32 G. H. change 0 in .50 hrs. Susp. Rod
Method coef. ____ Hor. angle coef. ____ Susp. coef. ____ Meter No. Roy 2020

GAGE READINGS				
Time		Recorder	Inside	Outside
1200				3.52
1205	SM			
1245	FM			
1250				3.52
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Type of meter Pygmy
Date rated 6/99 for rod., other.
Meter _____ ft. above bottom of weight
Spin before meas. 66 sec after 66
Meas. plots ____ % diff. from rating ____
Wading, cable, ice, boat, upstr., downstr., side
bridge 50 feet, mile, above, below
gage, and 50' dstr of SG
Check-bar, found _____
changed to _____ at _____
Correct _____
Levels obtained _____

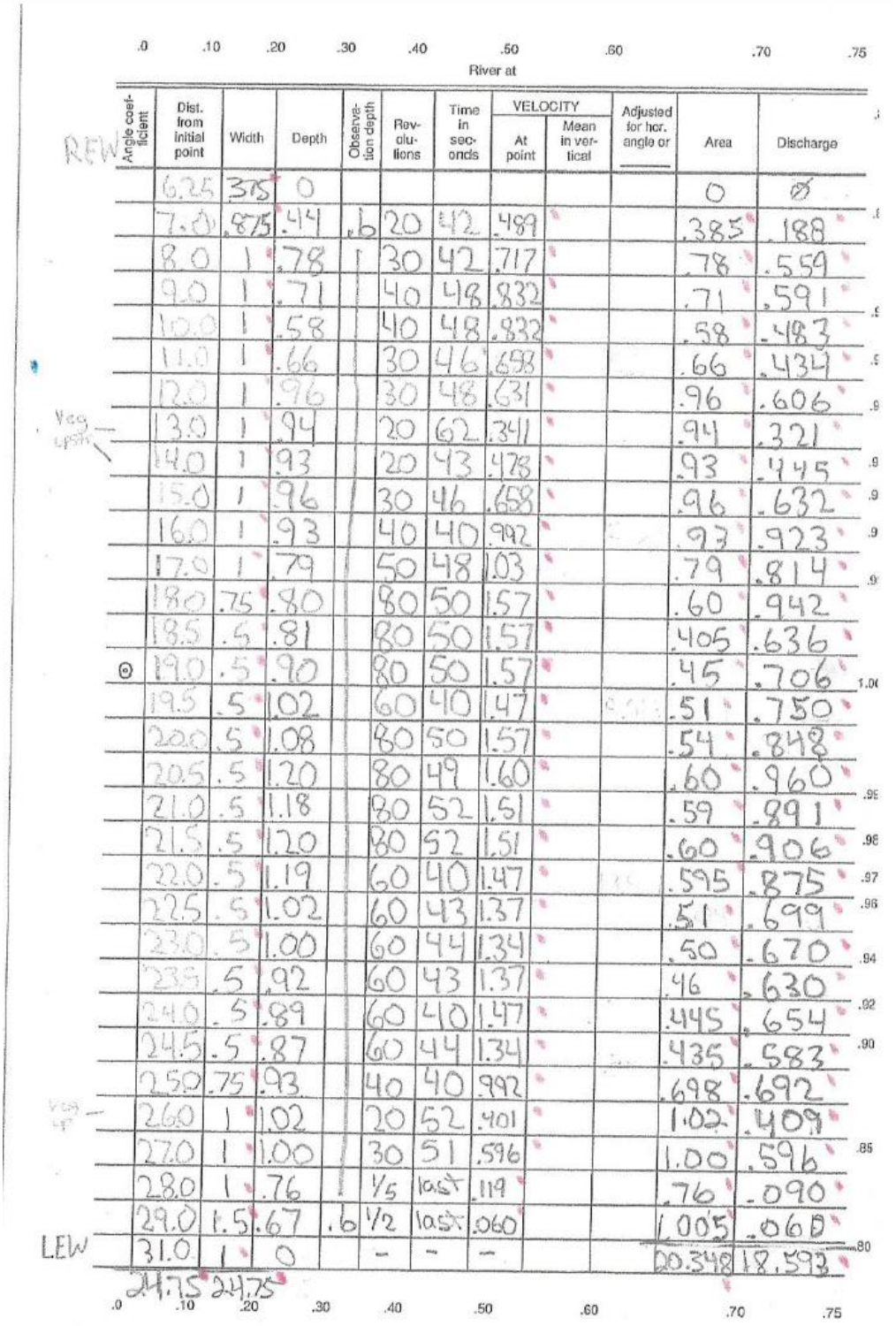
Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section Firm Sand
Flow Uniform - mod. high Weather Sunny, Cloudy
Other _____ Air ____ °F@ ____
Gage OK Water ____ °F@ ____
____ Record removed No Intake flushed U L ____
Observer _____

Control light Vegetation - Natural channel mostly clear
Remarks _____

G.H. of zero flow _____

9/99 HDG 2726

Bear Branch Flow Measurement Field Log, 6/9/20, continued



River at

	Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	VELOCITY: At point	VELOCITY: Mean in vertical	Adjusted for hor. angle or	Area	Discharge
REW		6.25	375	0							0	Ø
		7.0	.875	.44	.6	20	42	.489			.385	.188
		8.0	1	.78		30	42	.717			.78	.559
		9.0	1	.71		40	48	.832			.71	.591
		10.0	1	.58		40	48	.832			.58	.483
		11.0	1	.66		30	46	.658			.66	.434
		12.0	1	.96		30	48	.631			.96	.606
Veg		13.0	1	.94		20	62	.341			.94	.321
upstr		14.0	1	.93		20	43	.478			.93	.445
		15.0	1	.96		30	46	.658			.96	.632
		16.0	1	.93		40	40	.992			.93	.923
		17.0	1	.79		50	48	1.03			.79	.814
		18.0	.75	.80		80	50	1.57			.60	.942
		18.5	.5	.81		80	50	1.57			.405	.636
⊙		19.0	.5	.90		80	50	1.57			.45	.706
		19.5	.5	1.02		60	40	1.47			.51	.750
		20.0	.5	1.08		80	50	1.57			.54	.848
		20.5	.5	1.20		80	49	1.60			.60	.960
		21.0	.5	1.18		80	52	1.51			.59	.891
		21.5	.5	1.20		80	52	1.51			.60	.906
		22.0	.5	1.19		60	40	1.47			.595	.875
		22.5	.5	1.02		60	43	1.37			.51	.699
		23.0	.5	1.00		60	44	1.34			.50	.670
		23.5	.5	.92		60	43	1.37			.46	.630
		24.0	.5	.89		60	40	1.47			.445	.654
		24.5	.5	.87		60	44	1.34			.435	.583
		25.0	.75	.93		40	40	.992			.698	.692
Veg		26.0	1	1.02		20	52	.401			1.02	.409
up		27.0	1	1.00		30	51	.596			1.00	.596
		28.0	1	.76		1/5	last	.119			.76	.090
		29.0	1.5	.67	.6	1/2	last	.060			1.005	.060
LEW		31.0	1	0		-	-	-			20.348	18.593

24.75 24.75

Acoustic Doppler Current Profiler Sample Output, Yucca Pens Creek Tidal Station, 6/21/20

Station Number:
Station Name: Yucca Pens

Meas. No: 1
Date: 05/21/2020

Party: WHH JCH	Width: 36.2 ft	Processed by: WHH
Boat/Motor:	Area: 87.0 ft²	Mean Velocity: -0.249 ft/s
Gage Height: 0.60 ft	G.H.Change: 0.100 ft	Discharge: -21.6 ft³/s

Area Method: Avg. Course	ADCP Depth: 0.150 ft	Index Vel.: 0.00 ft/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj.Mean Vel: 0.00 ft/s	Qm Rating: G
MagVar Method: None (0.0°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 ft²	Diff.: 0.000%
Depth: Composite (VB)	Top Est: Power (0.1667)	Control1: 7-Light Debris	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.90 ft/s	Type/Freq.: StreamPro / 2000 kHz	
WT 3-Beam Solution: YES	Max. Depth: 4.13 ft	Serial #: 118	Firmware: 31.11
BT Error Vel.: 0.33 ft/s	Mean Depth: 2.40 ft	Bin Size: 4 cm	Blank: 50 cm
WT Error Vel.: 1.41 ft/s	% Meas.: 61.88	BT Mode: 0	BT Pings: 1
BT Up Vel.: 1.00 ft/s	Water Temp.: 80.0 °F	WT Mode: 12	WT Pings: 6
WT Up Vel.: 1.00 ft/s	ADCP Temp.: 86.6 °F		
Use Weighted Mean Depth: YES			

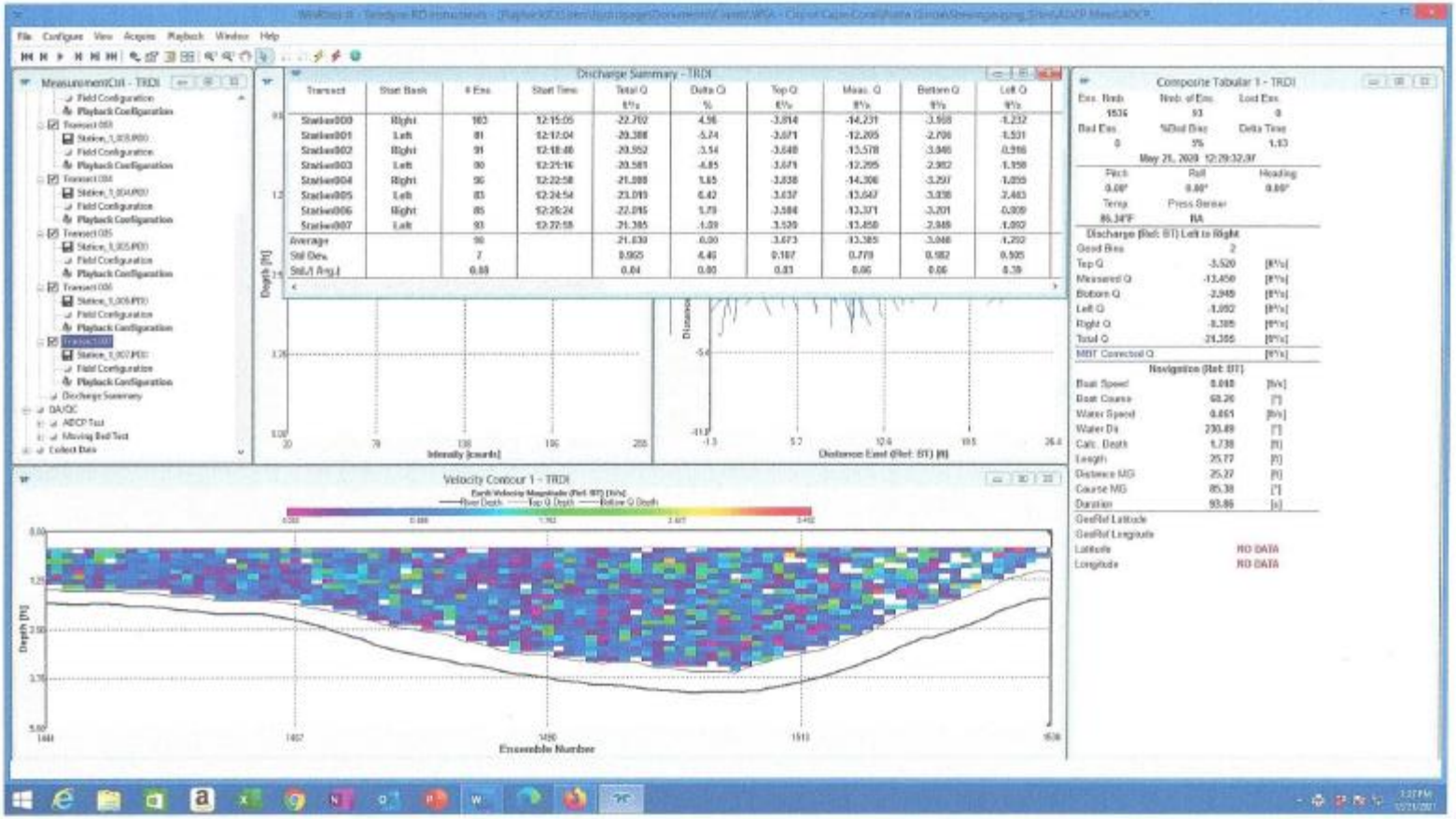
Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: 5' Downstream of Station

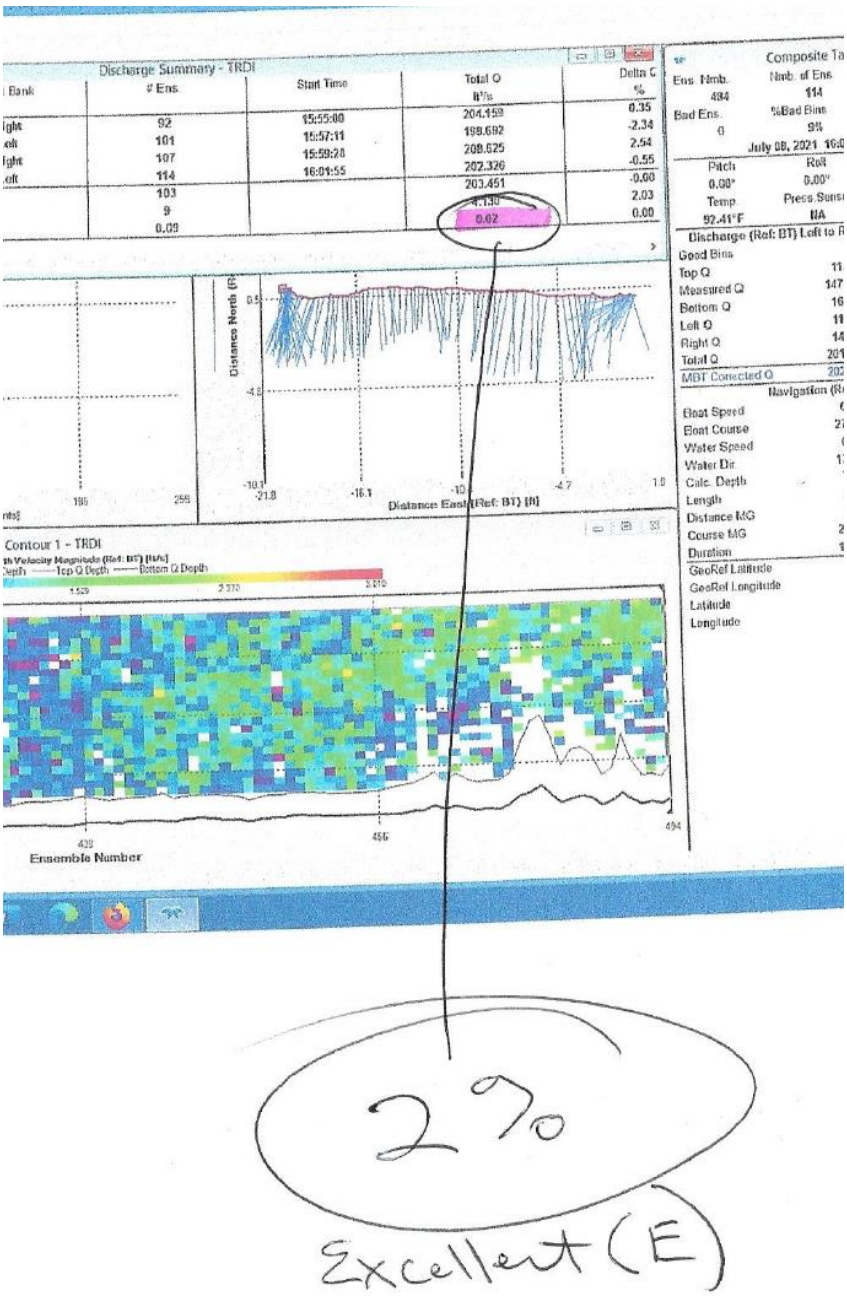
Project Name: Station_1.mmt
Software: 2.18

Tr.#		Edge Distance L	Edge Distance R	#Ens.	Discharge Top	Discharge Middle	Discharge Bottom	Discharge Left	Discharge Right	Discharge Total	Width	Area	Time Start	Time End	Mean Vel. Boat	Mean Vel. Water	% Bad Ens.	% Bad Bins	
000	R	10	1	103	-3.81	-14.2	-3.18	-1.24	-0.247	-22.7	36	86	12:15	12:16	0.25	-0.26	0	7	#
001	*L*	*10*	*1*	*81*	*-3.67*	*-12.2*	*-2.72*	*-1.52*	*-0.283*	*-20.4*	*36*	*86*	*12:17*	*12:18*	*0.31*	*-0.24*	*0*	*6*	
002	R	10	1	91	-3.64	-13.6	-3.04	-0.918	0.247	-20.9	36	87	12:18	12:20	0.28	-0.24	0	5	
003	L	10	1	90	-3.67	-12.3	-2.97	-1.17	-0.459	-20.6	36	87	12:21	12:22	0.28	-0.24	0	6	
004	R	10	1	96	-3.85	-14.3	-3.28	-1.06	0.494	-22.0	36	87	12:22	12:24	0.27	-0.25	0	5	
005	*L*	*10*	*1*	*83*	*-3.64*	*-13.6*	*-3.04*	*-2.44*	*-0.247*	*-23.0*	*36*	*88*	*12:24*	*12:26*	*0.31*	*-0.26*	*0*	*5*	
006	R	10	1	85	-3.57	-13.4	-3.21	-0.918	-0.953	-22.0	36	87	12:26	12:27	0.30	-0.25	1	3	
007	L	10	1	93	-3.53	-13.5	-2.97	-1.09	-0.388	-21.4	36	87	12:27	12:29	0.28	-0.25	0	5	
Mean		10	1	90	-3.67	-13.4	-3.05	-1.29	-0.230	-21.6	36	87	**Total**	00:14	0.28	-0.25	0	5	
SDev		0	0	7	0.110	0.776	0.178	0.500	0.440	0.968	0.1	0.7			0.02	0.01			
SD/M		0.00	0.00	0.08	0.03	0.06	0.06	0.39	1.92	0.04	0.00	0.01			0.08	0.04			

Remarks: Incoming tide. LEW undefined due to Mangroves - Estimated.
Staff Gauge Readings: 0.52 @ 1200; 0.57@ 1214; 0.62 @ 1230

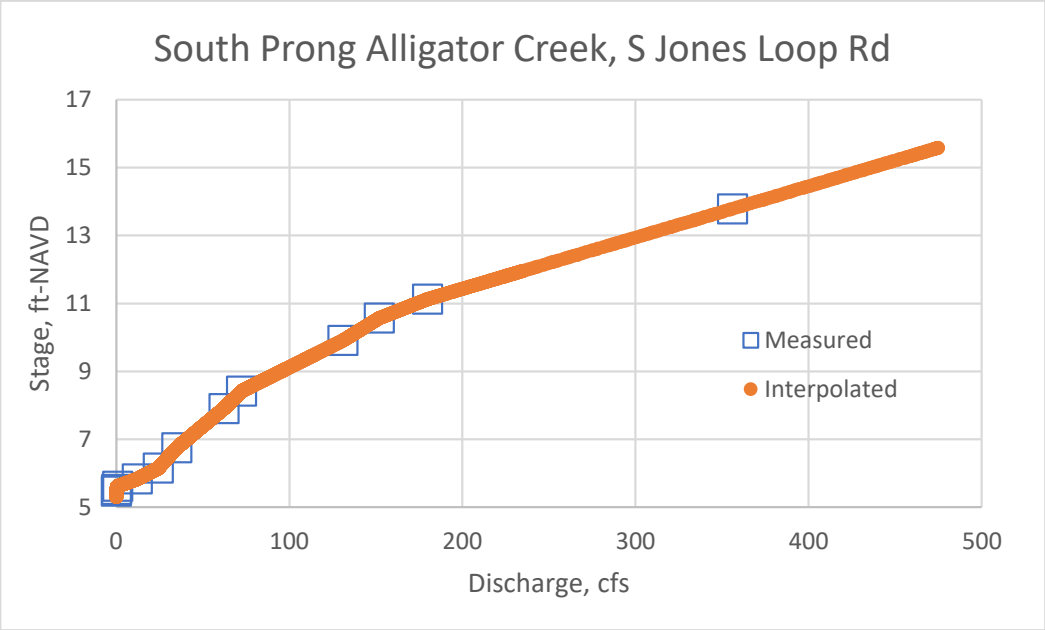
- transect has been subsectioned
Discharge for transects in *italics* have a total Q more than 5% from the mean


Discharge Summary - TRDI
Composite Tabular 1 - TRDI
Velocity Contour 1 - TRDI
Ensemble Number
Depth [ft]
Intensity [counts]
Distance East (Ref: BT) [ft]


Discharge Summary - TRDI
Bank
Ens.
Start Time
Total Q
Delta Q
92
101
107
114
103
9
0.09
15:55:00
15:57:11
15:59:28
16:01:55
204.159
198.682
209.625
202.326
203.451
0.02
0.35
-2.34
2.54
-0.55
-0.00
2.03
0.00
Composite Ta
Ens. Numb.
484
Numb. of Ens
114
Bad Ens.
0
%Bad Bins
9%
July 08, 2021
Pitch
0.00°
Roll
0.00°
Temp
92.41°F
Press.Sens
NA
Discharge (Ref: BT) Left to R
Good Bins
Top Q
Measured Q
Bottom Q
Left Q
Right Q
Total Q
MBT Corrected Q
Navigation (R
Boat Speed
Boat Course
Water Speed
Water Dir
Calc. Depth
Length
Distance MG
Course MG
Duration
GeoRef Latitude
GeoRef Longitude
Latitude
Longitude
Distance North (ft)
Distance East (Ref: BT) (ft)
Contour 1 - TRDI
Top Q Depth
Bottom Q Depth
Ensemble Number
270
Excellent (E)

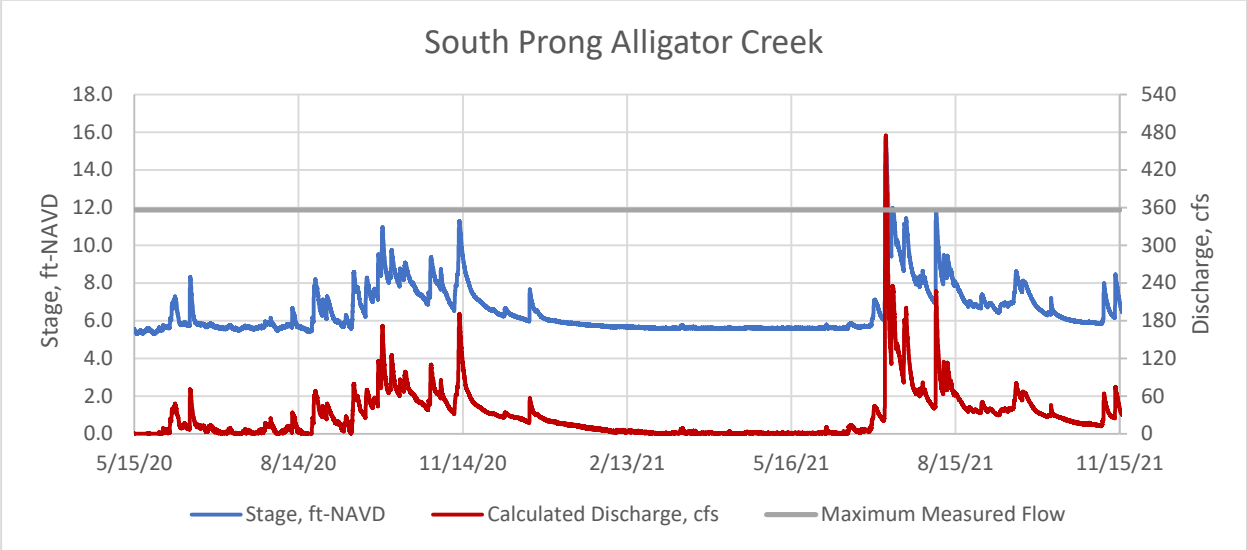
APPENDIX B

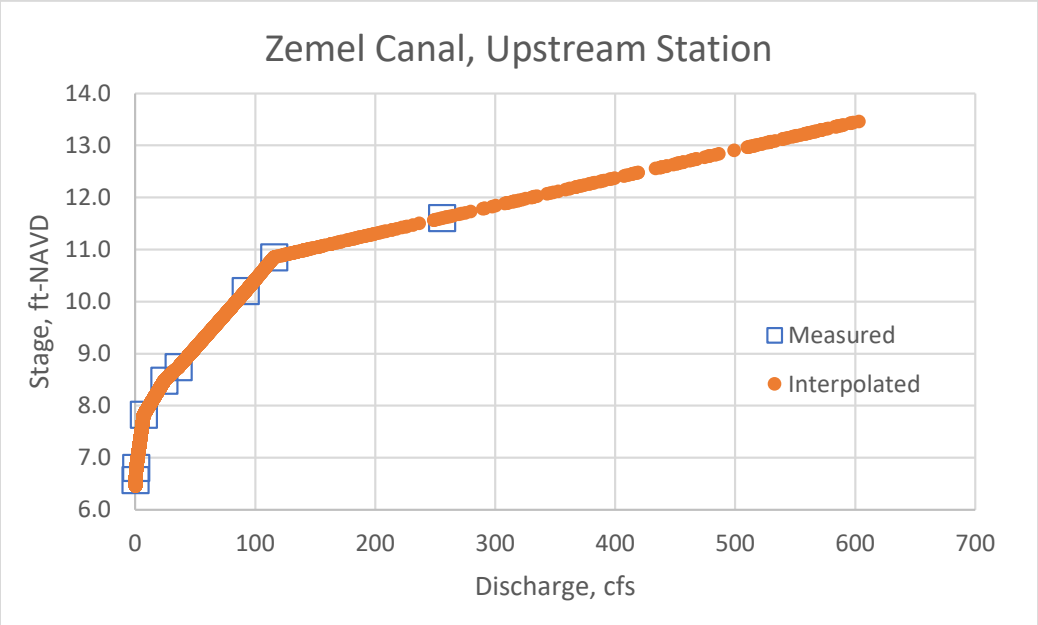
Stage/Discharge Relationships and Time Series of Stages and Estimated Flows



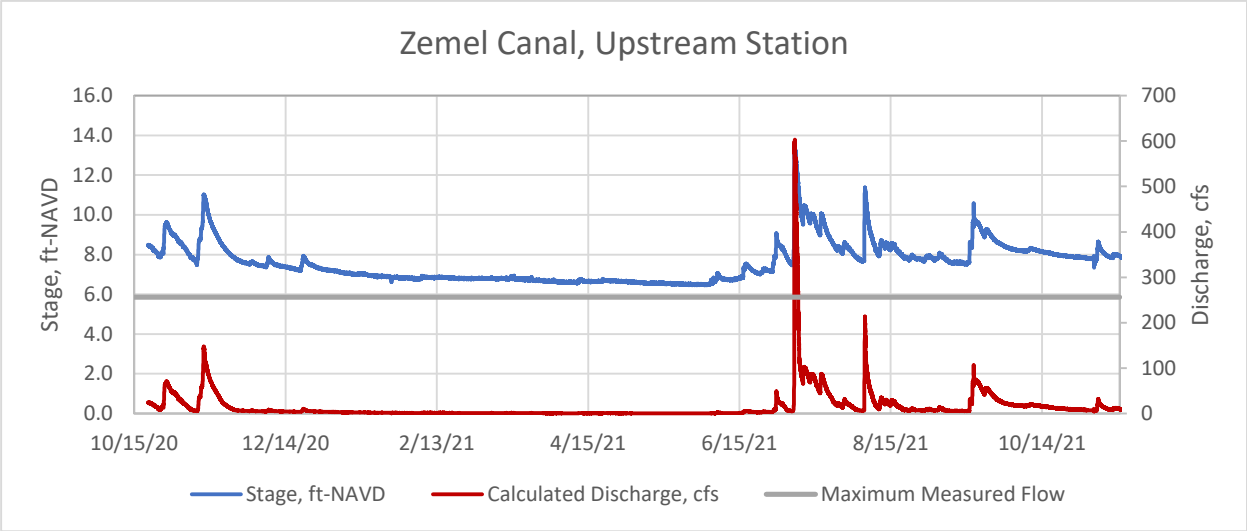
Note: the **Interpolated** values shown above are the calculated flows based on the flow calculation method described above in section METHODOLOGY TO ESTIMATE FLOWS FROM STAGE/DISCHARGE RELATIONSHIPS.

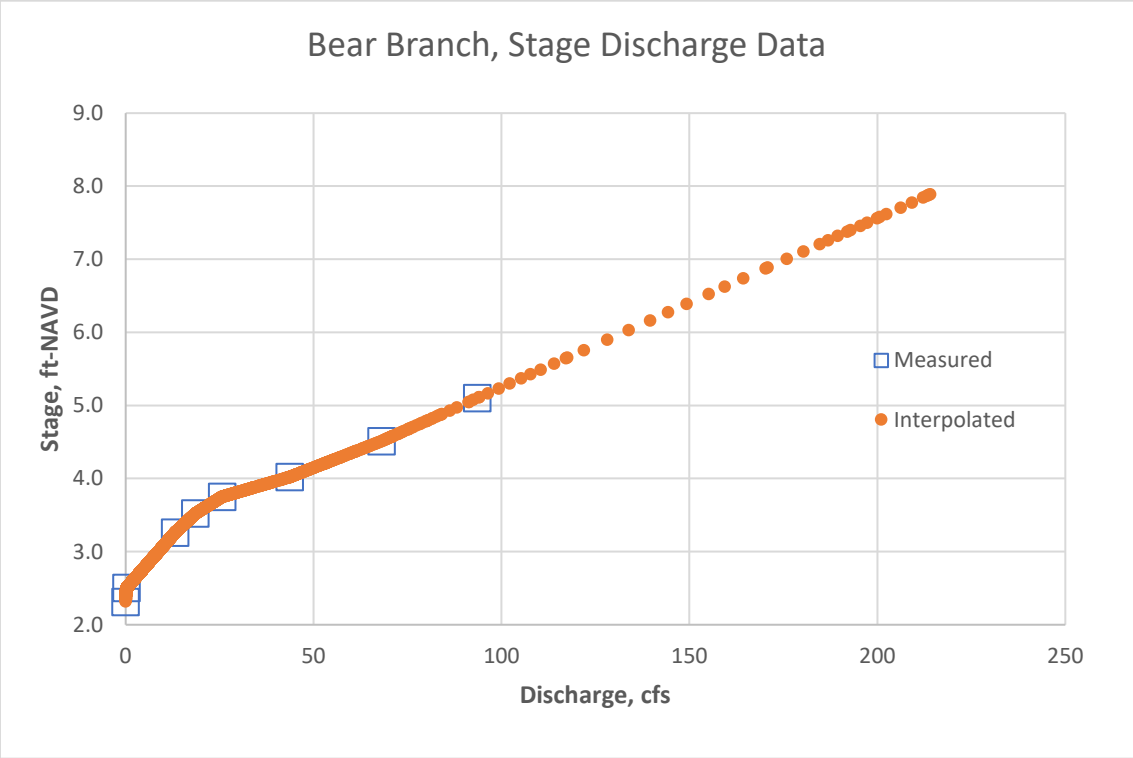
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). Water level measurements ranged from 5.5 ft-NAVD to 11.1 ft-NAVD. Water levels ranged from 5.5 in mid to late May were less than the measured water levels range from 5.8 to 15.6 ft-NAVD. Flows are calculated using the stage/discharge relationship shown above (see METHODOLOGY TO ESTIMATE FLOWS FROM STAGE/DISCHARGE RELATIONSHIPS for a description of how the flows were calculated using the stage/discharge relationship). Flow is less than 10 cfs from January 21, 2021 due to normal flow reductions in the dry season when rainfall is limited. Flows are less than 2 cfs from late February to early-June, 2021.



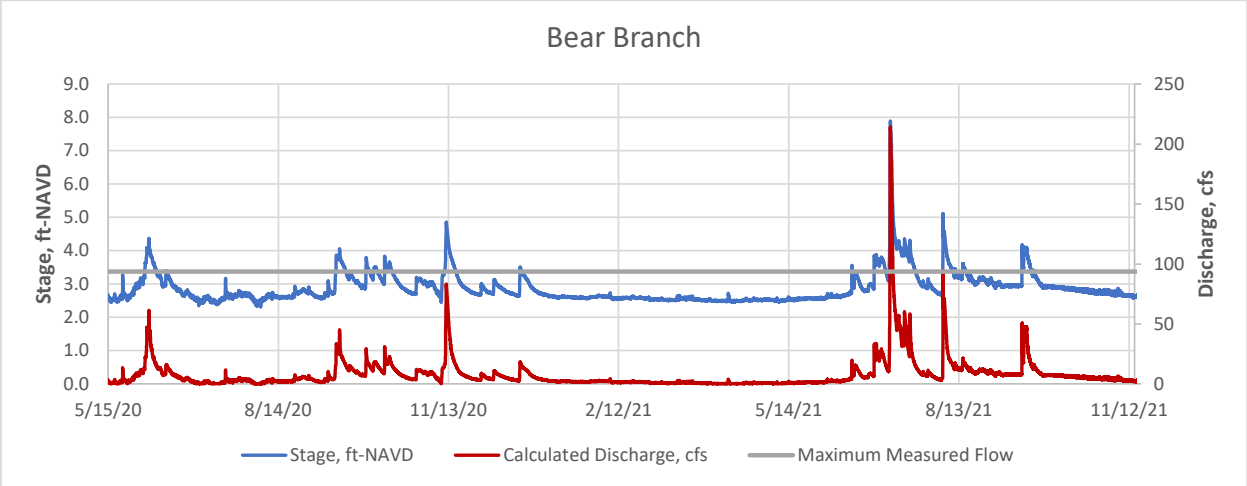


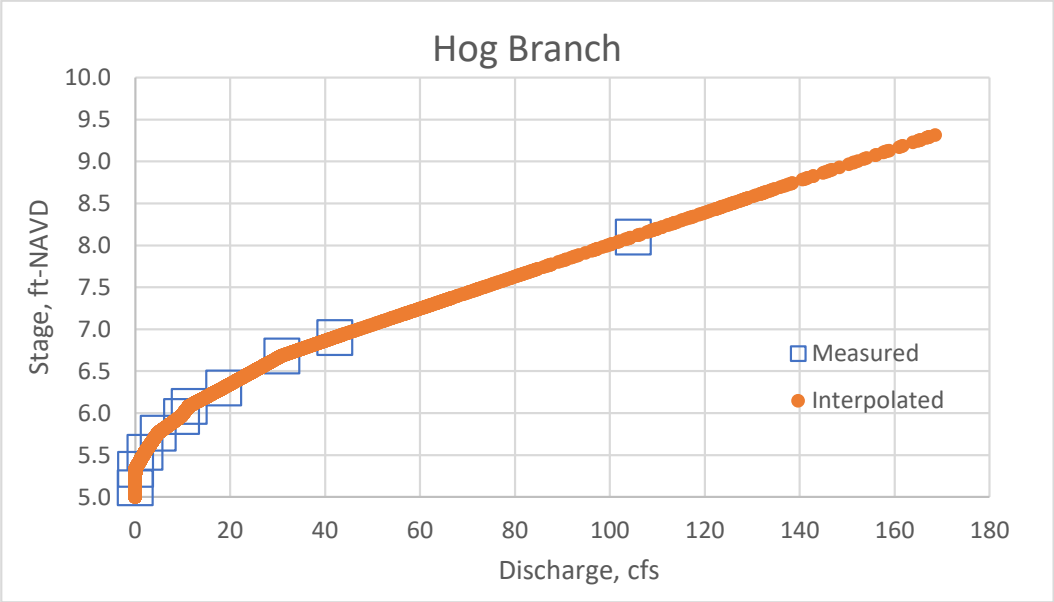
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). The measured water levels range from 5.3 to 11.85 ft-NAVD, with 5.3 ft-NAVD equal to the bottom of the canal bed. Flows are calculated using the stage/discharge relationship shown above (see METHODOLOGY TO ESTIMATE FLOWS FROM STAGE/DISCHARGE RELATIONSHIPS for a description of how the flows were calculated using the stage/discharge relationship). Flow is less than 10 cfs from November 23, 2020 due to normal flow reductions in the dry season when rainfall is limited. Flows are less than 1 cfs from early February to mid-June, 2021.



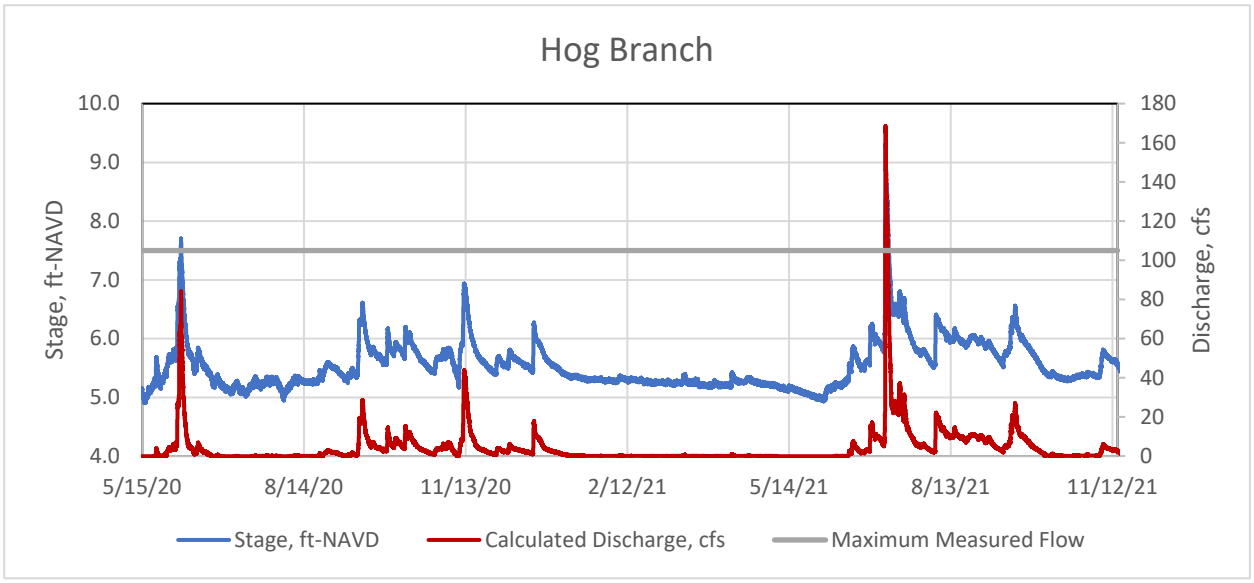


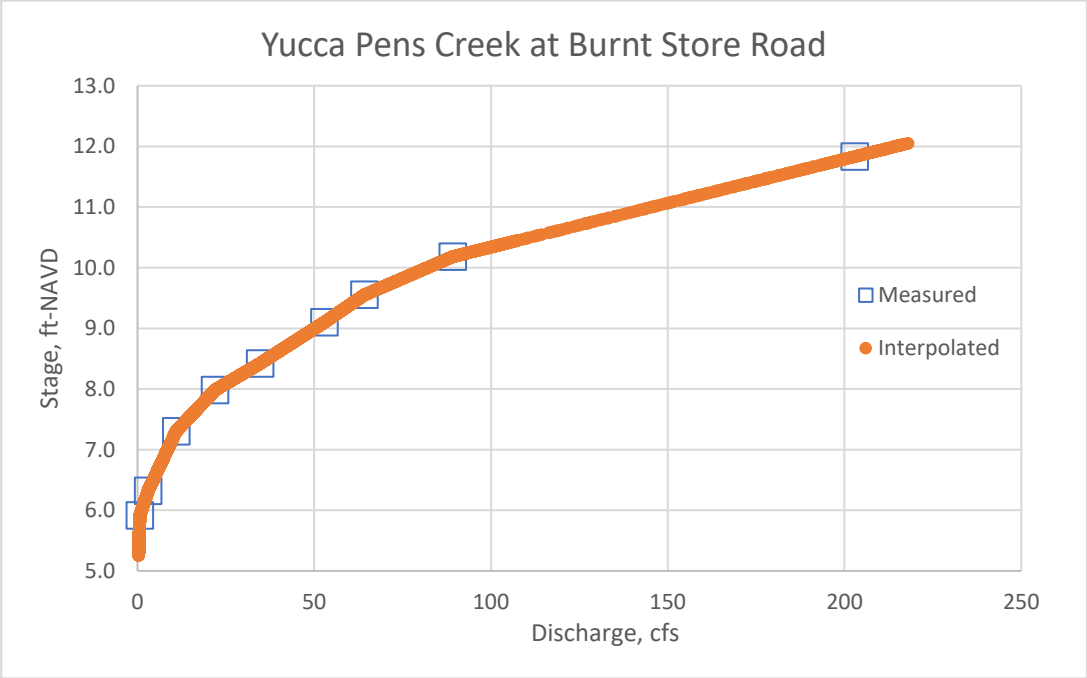
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). The flow drops to zero when water levels are below 2.31 ft-NAVD, which is the point where water no longer flows under Burnt Store Road. Flows were below 1 cfs for short portions of May 2020, the first half of July 2020, a few days in early August 2020, and most of March through mid-May, 2021. The data suggest that additional recharge in the headwaters of the Bear Branch watershed would be beneficial. Wet season water levels do not vary as much as nearby Hog Branch and Yucca Pens Creek, but more than in Durden Creek.



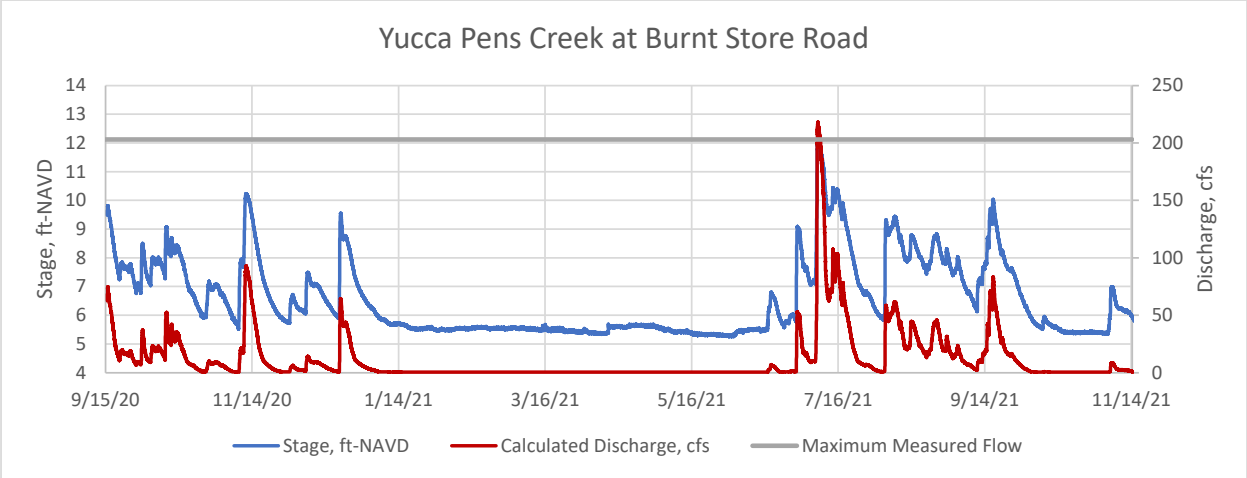


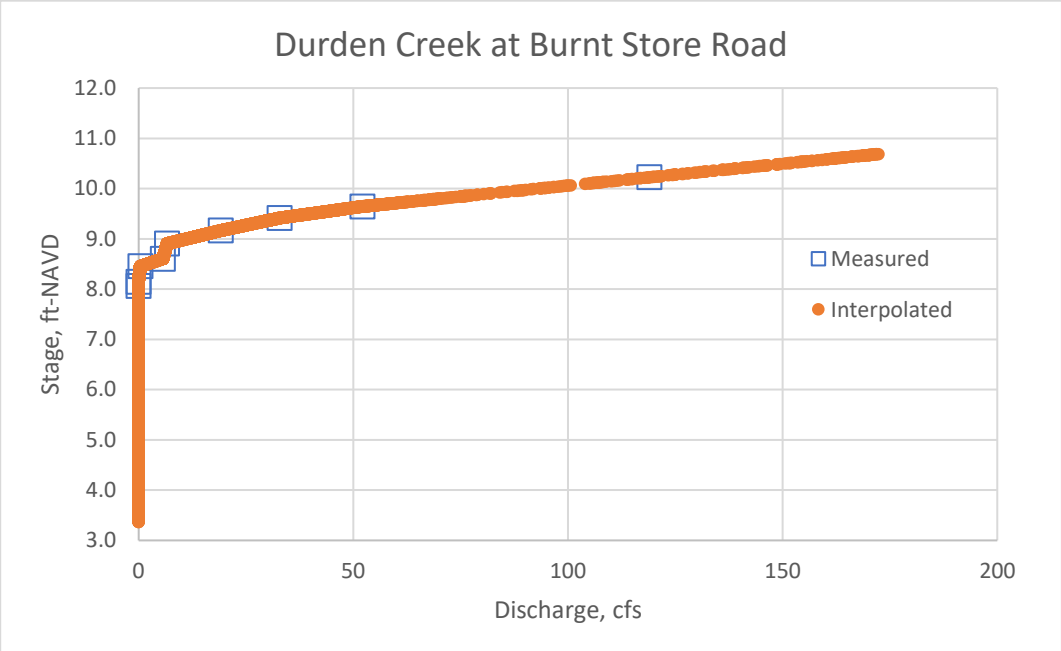
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). The minimum measured flow is when the water level is 5.11 ft-NAVD because that is the invert elevation of the Hog Branch culverts under Burnt Store Road. Water levels drop below the culvert invert elevation due to groundwater seepage from the Hog Branch channel upstream of Burnt Store Road. The flows are less than 1 cfs during most of May 2020, from June 21, 2020 to late August, 2020, from January 6, 2021 through mid-June, 2021. Flows again dropped below 1 cfs in early October, 2021 until rainfall in early November 2021 resulted in a slight increase in flows. The data suggest that additional recharge in the headwaters of the Hog Branch watershed would be beneficial.



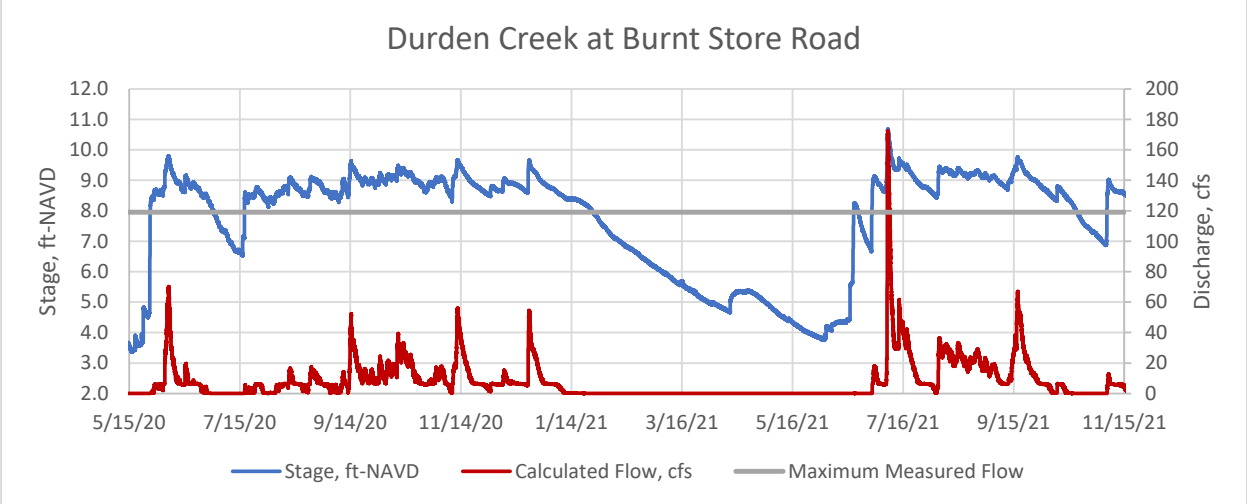


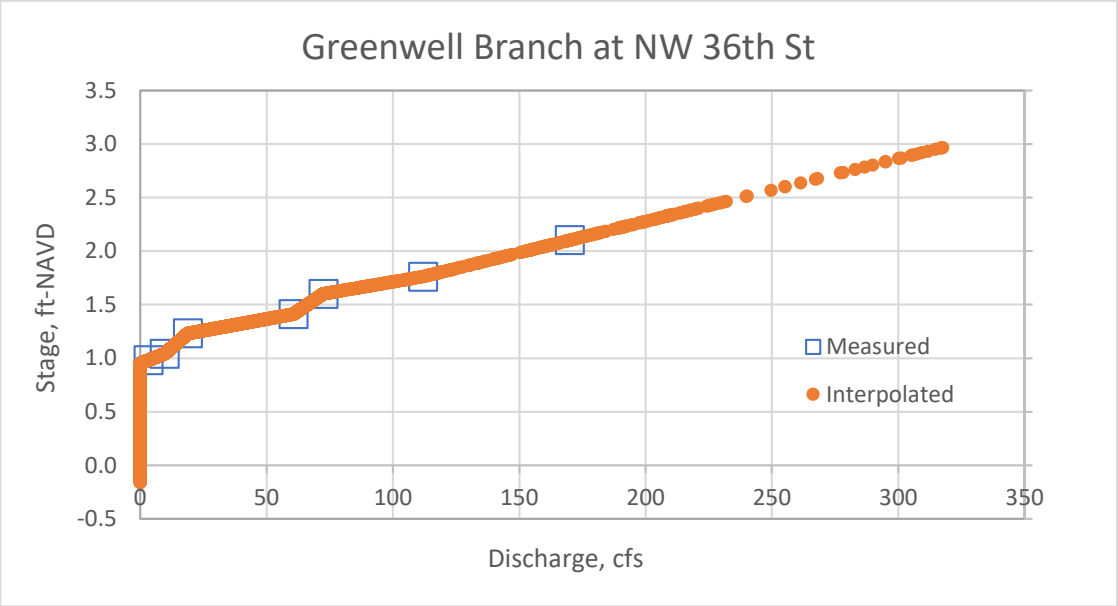
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). The minimum measured flow is when the water level is 4.54 ft-NAVD because that is the invert elevation of the Yucca Pens Creek culverts under Burnt Store Road (BSR). The stage and flow time series for this station begin in September, 2020 because this station was activated after the Winegourd flow monitoring station was abandoned due to construction on BSR in the vicinity of Winegourd Creek. Water levels at Yucca Pens Creek at BSR drop below the culvert invert elevation due to groundwater seepage from the Yucca Pens Creek channel upstream of Burnt Store Road. The flows are less than 1 cfs for a few days in early November 2020 and then again for a few days in late November 2020. Flows increase due to late season 2020 rainfall and stay above 1 cfs until January 6, 2021. Flows remain below 1 cfs for most of the dry season of 2021 until June 26, 2021 when flows increase in due to the onset of the wet season.



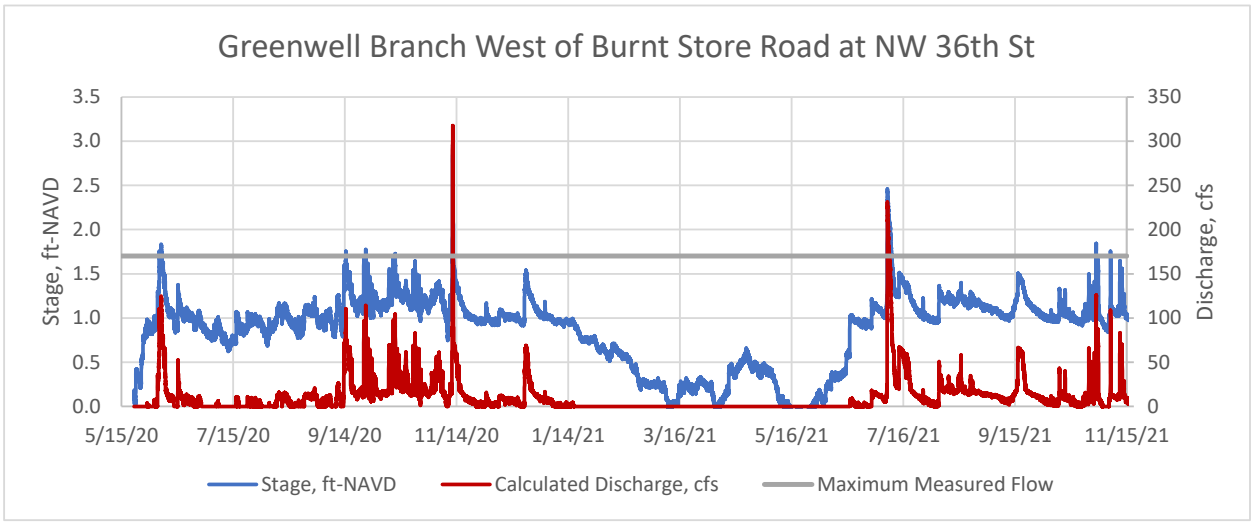


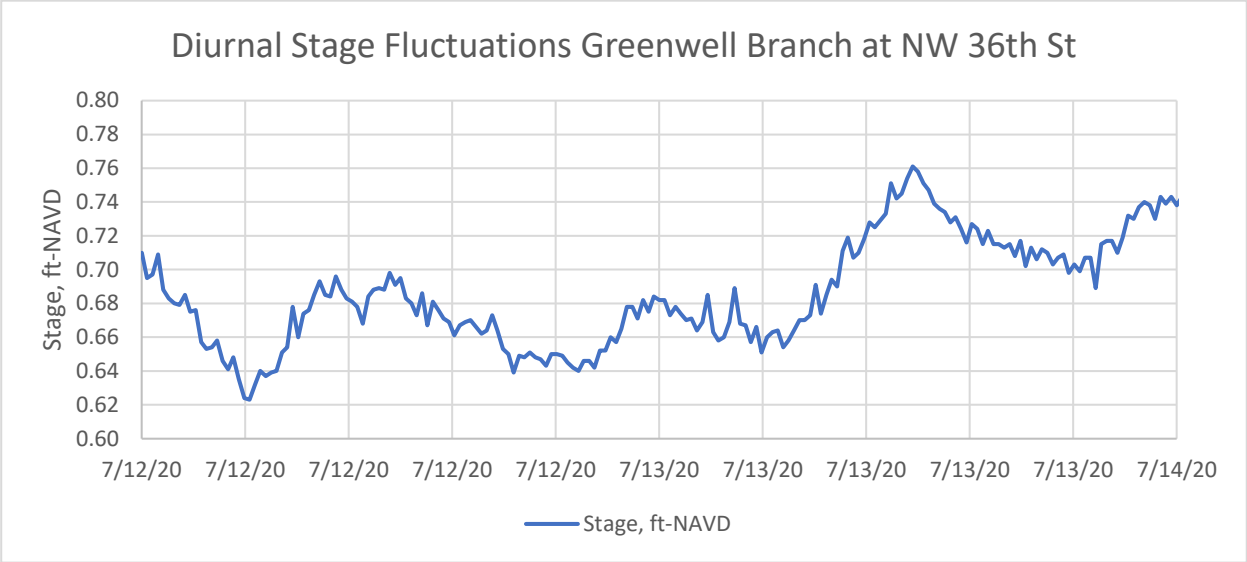
The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). The minimum measured flow is when the water level is 8.06 ft-NAVD because that is the elevation where Durden Creek no longer has positive flow through the culverts under Burnt Store Road (BSR). Water levels drop below the culvert invert elevation due to groundwater seepage from the Durden Creek channel upstream of BSR. Water levels drop to less than 4 ft-NAVD, which is significantly lower than the invert elevation of the culverts under BSR. The reason for this is unclear, but may be due to more pervious aquifer conditions in the vicinity of Durden Creek at BSR. The flows are less than 1 cfs for most of May 2020 and from late June through July 20, 2020. Runoff continues through the remainder of 2020 into early 2021, and drop below 1 cfs from January 9 to June 28, 2021 when flows increase due to the onset of the wet season. Flows drop below 1 cfs again from October 14 – November 5, 2021. Wet season water levels vary the least in Durden Creek relative to the other flow monitoring stations, most likely due to the cypress wetlands and marshes in Yucca Pens east of the FWC western boundary.





The graph below shows measured water levels (blue line, vertical scale on left) and calculated flows (red line, vertical scale on right). Positive flows cease when the water level is below 0.98 ft-NAVD. This monitoring station is located in a man-made canal in northern Cape Coral at NW 36th Street, and the invert elevation of the three culverts is approximately -3.4 ft-NAVD. The measured stages vary approximately 0.1 feet on a daily basis (see diurnal stage graph below), which suggests minor tidal influence. Flows are less than 1 cfs in 2020 from mid-May to early June, June 12 – 14, June 23 – 25, June 27 – July 24, July 30 – August 7, August 16 – 22, and September 6 – 9. Flows in 2021 are less than 1 cfs from January 9 – July 28 and November 1 – 5.




Diurnal Stage Fluctuations Greenwell Branch at NW 36th St
Stage, ft-NAVD
0.80
0.78
0.76
0.74
0.72
0.70
0.68
0.66
0.64
0.62
0.60
7/12/20
7/12/20
7/12/20
7/12/20
7/12/20
7/13/20
7/13/20
7/13/20
7/13/20
7/13/20
7/14/20
Stage, ft-NAVD