WEST CHANNEL WATER QUALITY SECOND YEAR STUDY REPORT

PARR HYDROELECTRIC PROJECT

FERC NO. 1894

Prepared for:

South Carolina Electric & Gas Company
Cayce, South Carolina

Prepared by:

Kleinschmidt

Lexington, South Carolina
www.KleinschmidtGroup.com

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SOUTH CAROLINA ELECTRIC & GAS COMPANY

1.0 INTRODUCTION

South Carolina Electric & Gas Company (SCE&G) is the Licensee for the Parr Hydroelectric Project (FERC No. 1894) (Project). SCE&G is currently seeking a new license from the Federal Energy Regulatory Commission (FERC), as their current license is set to expire on June 30, 2020. The Project consists of two developments, the Parr Shoals Development and the Fairfield Pumped Storage Development. Parr Reservoir, located in Fairfield and Newberry counties, South Carolina, is a 4,400-acre impoundment formed by the Broad River and the Parr Shoals Dam (Parr Dam) and serves as the lower reservoir for the Fairfield Pumped Storage Development. Monticello Reservoir is a 6,800-acre impoundment formed by a series of four earthen dams, and serves as the upper reservoir for the pumped storage development. While the stretch of the Broad River downstream of the Parr Dam is not included in the Project Boundary Line (PBL), Project operations do influence this area.

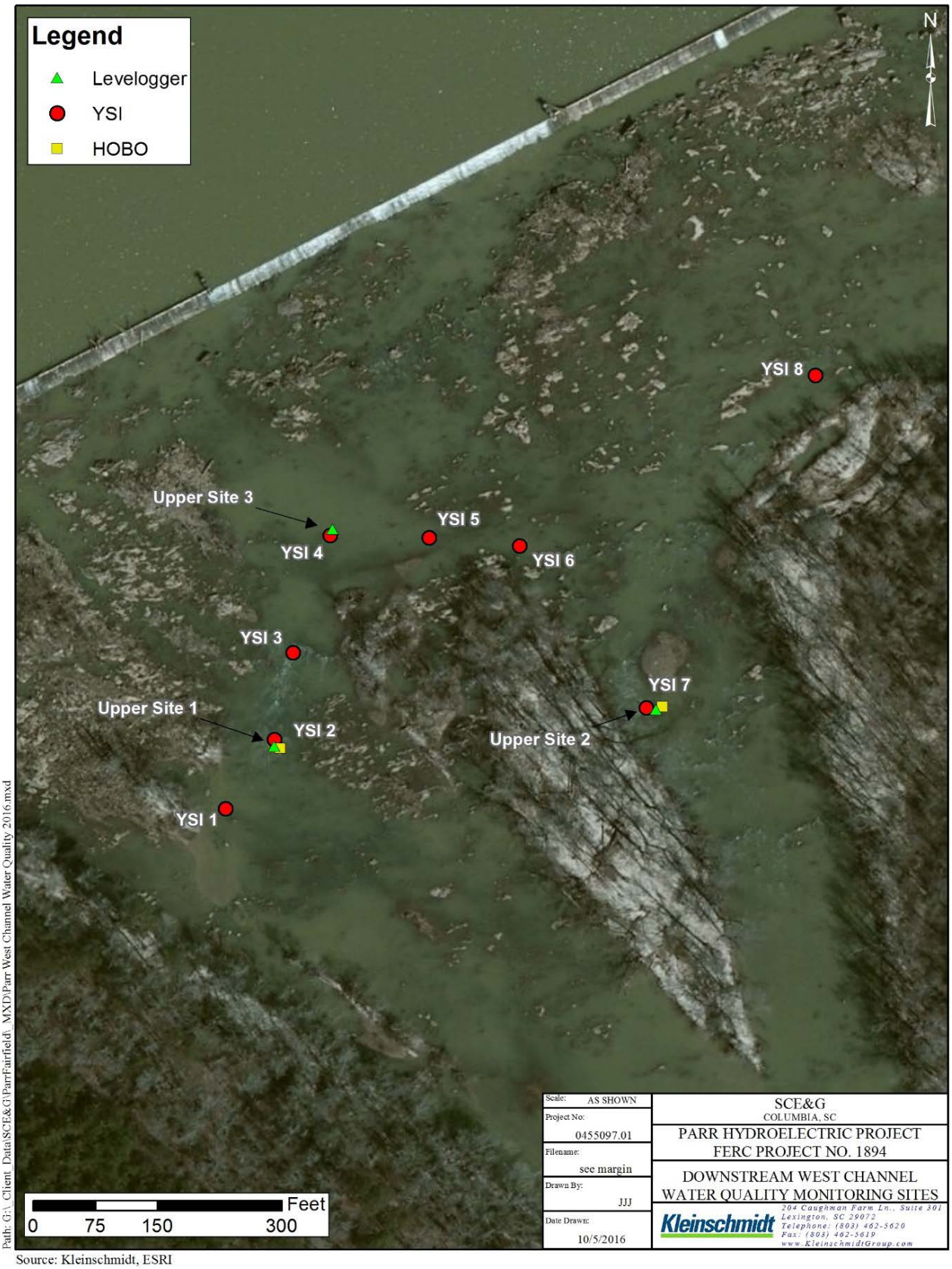
The Project is currently involved in a relicensing process which involves cooperation between SCE&G and a variety of stakeholders including state and federal resource agencies, state and local government, non-governmental organizations (NGO), and interested individuals. SCE&G has established several Technical Working Committees (TWCs) comprised of members from the interested stakeholders. A Water Quality TWC was formed to address potential water quality issues associated with the Project. During issues scoping, the TWC identified the west channel area of the Broad River downstream of the Parr Dam as a potential area for a water quality study. The TWC specifically expressed concern about low dissolved oxygen (DO) levels in this area of the Broad River during the warmer summer and fall months.

SCE&G performed initial sampling in the west channel during 2015 and presented that data to the Water Quality TWC. The TWC recommended that SCE&G perform additional collections

during 2016 to verify some of the high water temperatures and low dissolved oxygen readings recorded during late summer of 2015. SCE&G performed collections of water temperature and DO during August 2016 to verify baseline conditions and to evaluate how discrete spillway releases or pulses through the spillway gates affect water quality in the west channel. The results of this study will be used to develop measures for improving water quality in the west channel during future operations in the new license.

2.0 STUDY AREA

The Broad River immediately downstream of the Parr Dam is naturally divided by Hampton Island, creating an eastern and western channel along the length of the island, which is approximately 1.25 miles long. Water temperature and DO were continuously monitored at four sites along the western channel: two locations just downstream of the Parr Dam (Upper Site 1 and Upper Site 2), one location midway down Hampton Island near the Highway 213 bridge (Middle West Channel), and one location at the lower extent of the western channel, just upstream of the confluence with the Broad River main channel (Lower West Channel). Additional water quality sites were also sampled for DO and water temperature periodically during the study (YSI-1 through YSI-8). Level logger data were collected at 3 locations in the upper west channel (Upper Site 1, Upper Site 2, and Upper Site 3), and stream flow measurements were collected at two locations in the upper west channel (Upper Site 1 and Upper Site 2). Each of the monitoring sites are shown in Figures 2-1 and 2-2.



Source: Kleinschmidt, ESRI

FIGURE 2-1 UPPER WEST CHANNEL MONITORING SITES

Source: Kleinschmidt, ESRI

FIGURE 2-2 LOWER WEST CHANNEL MONITORING SITES

3.0 COLLECTION METHODS

The TWC requested that water temperature, DO, and water depth/flow be collected during the testing period. Water temperature and DO were monitored in the west channel area of the Broad River using HOBO U26 Dissolved Oxygen Loggers. The HOBO loggers were attached to floats and weights and deployed at the four monitoring sites on August 1, 2016, and retrieved on August 29, 2016. The loggers were calibrated according to the manufacturer's specifications and were set to collect temperature and DO data on 15 minute intervals. The logger manufacturer, Onset, specifies that the dissolved oxygen monitors have an accuracy of +/- 0.2 mg/L. Data were downloaded on a weekly basis using manufacturer's software and compiled throughout the monitoring period.

Additionally, a calibrated YSI meter was used to collect DO and water temperature approximately once a week when data were downloaded from the HOBO loggers at each monitoring site and at additional sites in the vicinity of the HOBO loggers. These collections were used to verify HOBO logger data.

Calibrated level loggers were also installed in three locations in the upper west channel area. The data collected with these loggers was analyzed to determine how water levels changed in the west channel due to spillway leakage, spillway pulsing, and flows from the Parr powerhouse tailrace. Stream flow was measured periodically at Upper Site 1 and Upper Site 2 to determine stream flow - depth relationship.

During the collection period, SCE&G released discrete pulses from spillway gates 1 and 2 to determine how pulse flows may influence DO and temperature levels at each of the HOBO loggers. Unplanned additional spillway flows related to project operations and reservoir inventory were also released during the study. Our schedule for testing was as follows:

August 1, 2016	deploy monitors – baseline data, no pulse
August 6, 2016	unplanned spill event, approximately 15,000 cfs peak flow
August 7, 2016	unplanned spill event, approximately 7,500 cfs peak flow
August 8, 2016	download data, clean, and redeploy monitors – pulse flow
August 10, 2016	unplanned spill event, approximately 16,500 cfs peak flow

August 11, 2016 unplanned spill event, approximately 9,000 cfs peak flow

August 15, 2016 download data, clean, and redeploy monitors – pulse flow

August 18, 2016 pulse flow

August 22, 2016 download data, clean, and redeploy monitors – baseline data no pulse

August 29, 2016 download data – remove all monitors

3.1 PULSE FLOWS

The pulse flows consisted of discrete releases through spillway gates 1 and 2 for approximately 3 hours. The spills were targeted to release 24 acre-feet of water into the West Channel. Table 3-1 contains specific information of each release.

TABLE 3-1 SPILLWAY PULSE FLOW RELEASES

Date	Release Time	Volume (acre-feet)
8/8/2016	0920-1220	24.33
8/15/2016	0800-1045	24.69
8/18/2016	0830-1130	22.22

TABLE 3-2 UNPLANNED SPILLWAY RELEASE FLOW

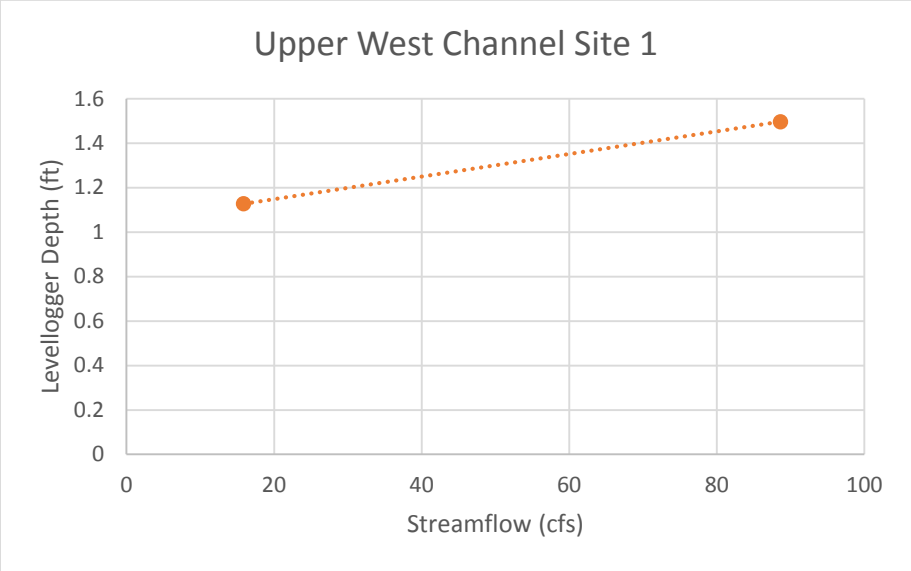
Date	Release Time	Peak Flow (cfs)
8/06-8/07 2016	1000-0745	15,100
8/07-8/08 2016	1600-0445	7,420
8/10-8/11 2016	0700-0130	16,600
8/11/2016	0930-1800	9,220

3.2 STREAM FLOW DATA COLLECTIONS

During installation of the stream monitors, field personnel noticed that stream flow from the tailrace area was passing into the west channel. Flows from the tailrace could affect DO and temperature levels in the west channel; therefore, Parr tailrace elevation was compared to level logger information to determine how streamflow in the two areas may be connected. Using standard USGS stream gaging methods, field crews measured streamflow at Sites 1 and 2 in the Upper West channel to establish a stage-discharge relationship.

4.0 RESULTS

There was a positive relationship between streamflow (turbines and/or spillway) and water levels in the west channel (Figure 4-1). Further, Parr tailrace elevations mirrored west channel water levels, suggesting some water released from the powerhouse flows laterally into the west channel and affects water levels in this reach. This relationship is depicted in Table 4-1, which shows stage-discharge estimates (based on Figure 4-1) for the tailrace and level loggers located at sites 1 and 2 in the upper west channel. As water levels in tailrace increase (i.e. discharge from the powerhouse increases), higher flows are observed in the west channel.



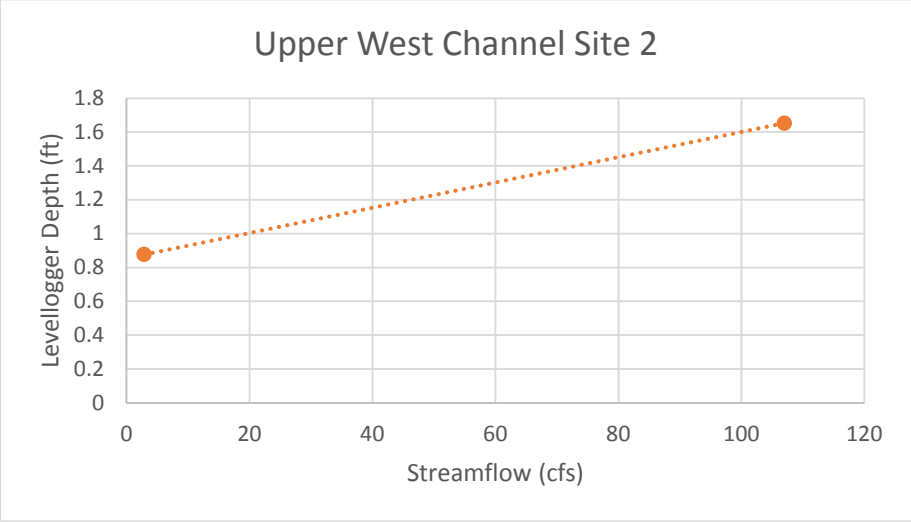
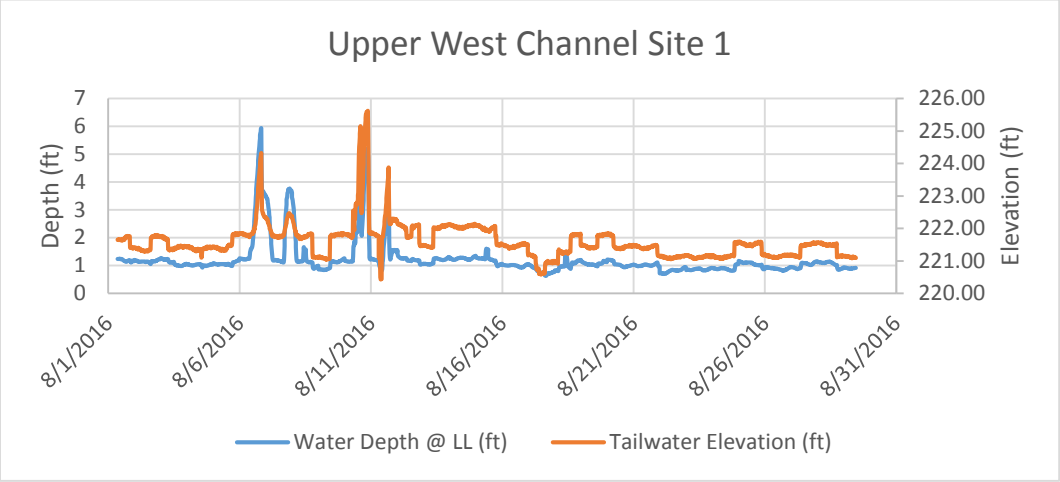
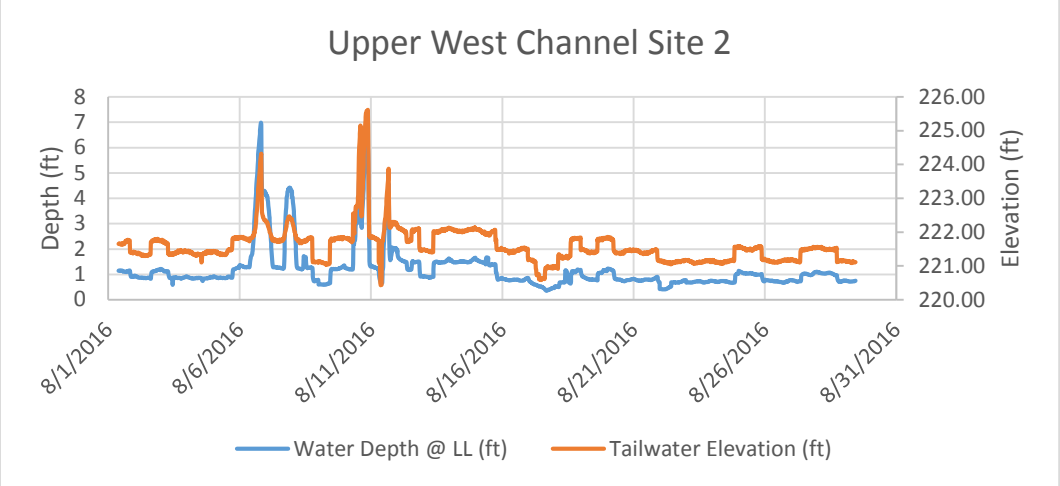


FIGURE 4-1 STREAM FLOW DATA FOR LEVEL LOGGER 1 AND 2 LOCATIONS





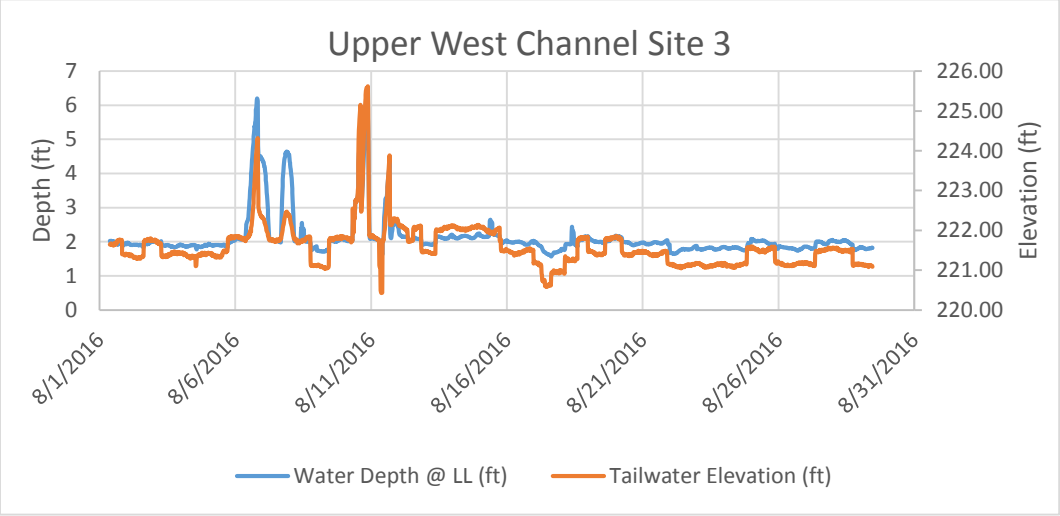


FIGURE 4-2 STREAM FLOW DATA FOR LEVEL LOGGER 1, 2, AND 3 LOCATIONS

TABLE 4-1 STREAM FLOW DATA FOR UPPER SITE 1 AND UPPER SITE 2

SITE 1		
FLOW (CFS)	**LEVEL LOGGER DEPTH (FT)**	**TAILWATER ELEV. (FT)**
16	1.13	221.34
20	1.15	221.70
40	1.25	221.85
60	1.35	222.00
80	1.45	222.10
89	1.50	222.20

SITE 2		
FLOW (CFS)	**LEVEL LOGGER DEPTH (FT)**	**TAILWATER ELEV. (FT)**
3	0.88	221.36
20	1.00	221.60
40	1.15	221.70
60	1.30	221.80
80	1.45	221.95
100	1.60	222.00

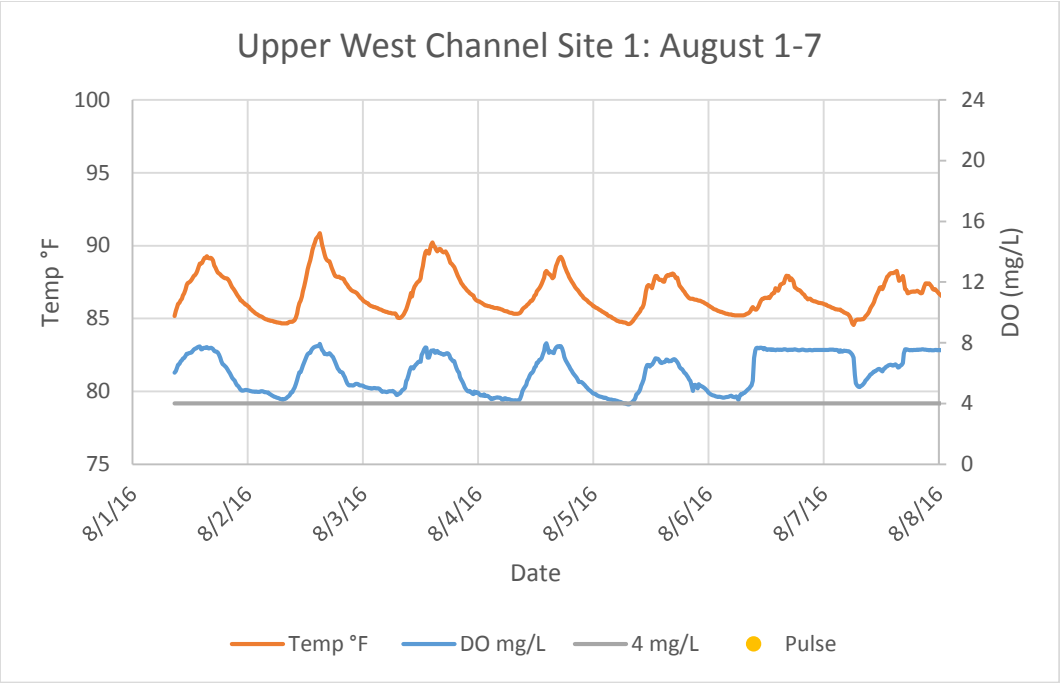
4.1 DISSOLVED OXYGEN AND TEMPERATURE DATA

A summary of DO data collected during August is included in the following sections.

August 1-7, 2016

During the week of August 1-7, DO levels briefly dropped below 4 mg/L at the Middle West Channel Site, but DO levels greater than the DHEC standard of 4 mg/L (SCDHEC 2012) were observed for most sampling days at all 4 sites. Field crews noted considerable debris had accumulated around the Middle West Channel HOBO logger during the 8/8 download. The accumulation of debris around the logger could have caused the extremely low DO readings by the logger, which would not be representative of true river conditions. Diel fluctuations in both temperature and DO levels were observed. This week did not contain any planned pulse, but an unplanned operational spill of approximately 15,000 cfs (peak flow) occurred on August 6 and an unplanned operational spill of approximately 7,500 cfs peak flow occurred on August 7. These spill events did not appear to influence DO levels at the Upper or Lower Sites during or after the spills. The Middle Site DO levels appear to have improved with the large spill (Figure 4-3). Minimum and maximum DO and temperatures for each collection site are presented in Table 4-2. Upper Site 2 is a shallow side channel and appears to experience the largest diel swings. DO and temperature collected by YSI are presented in Table 4-3. Comparisons of DO

and temperature data collected via HOBO and YSI are presented in Table 4-4 and verify the accuracy of the HOBO collections.



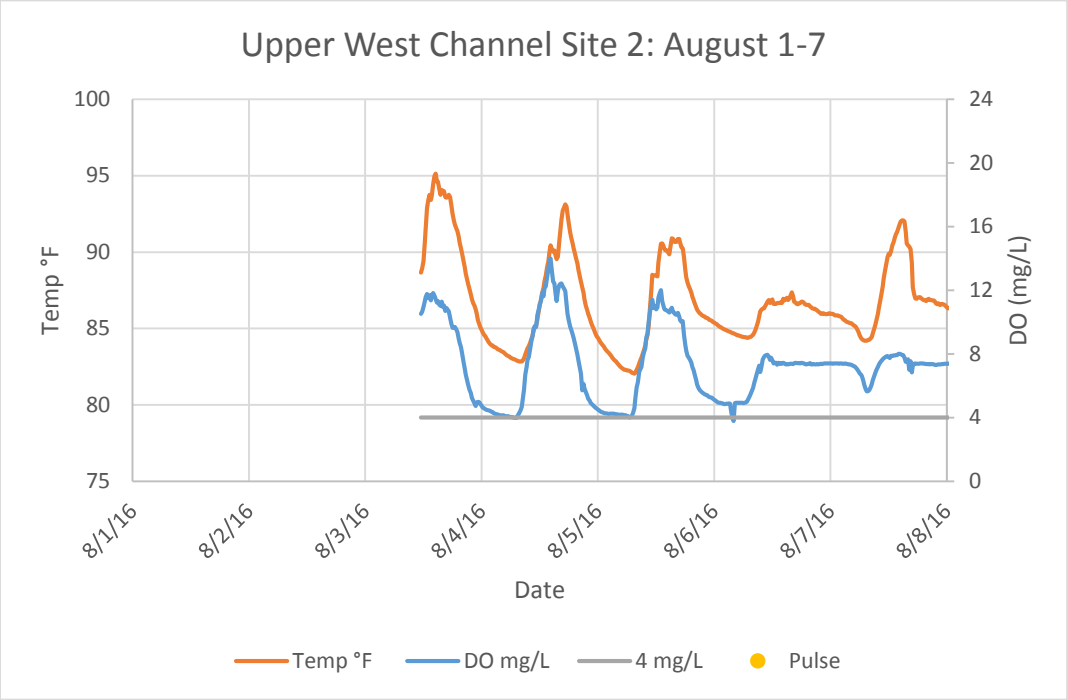
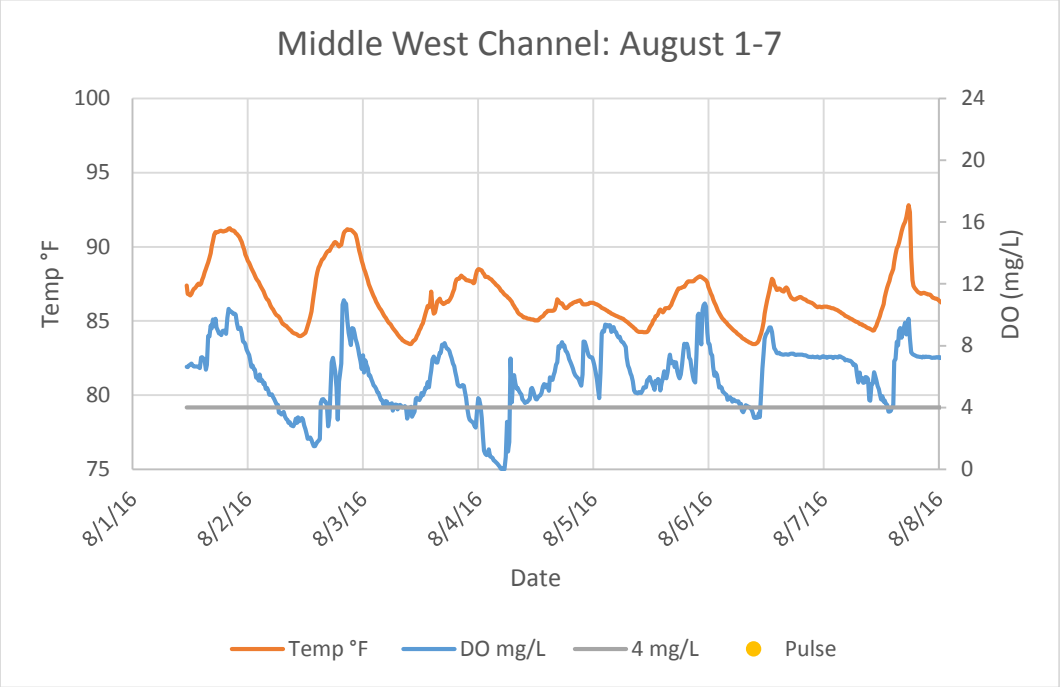


FIGURE 4-3 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS – AUGUST 1-7



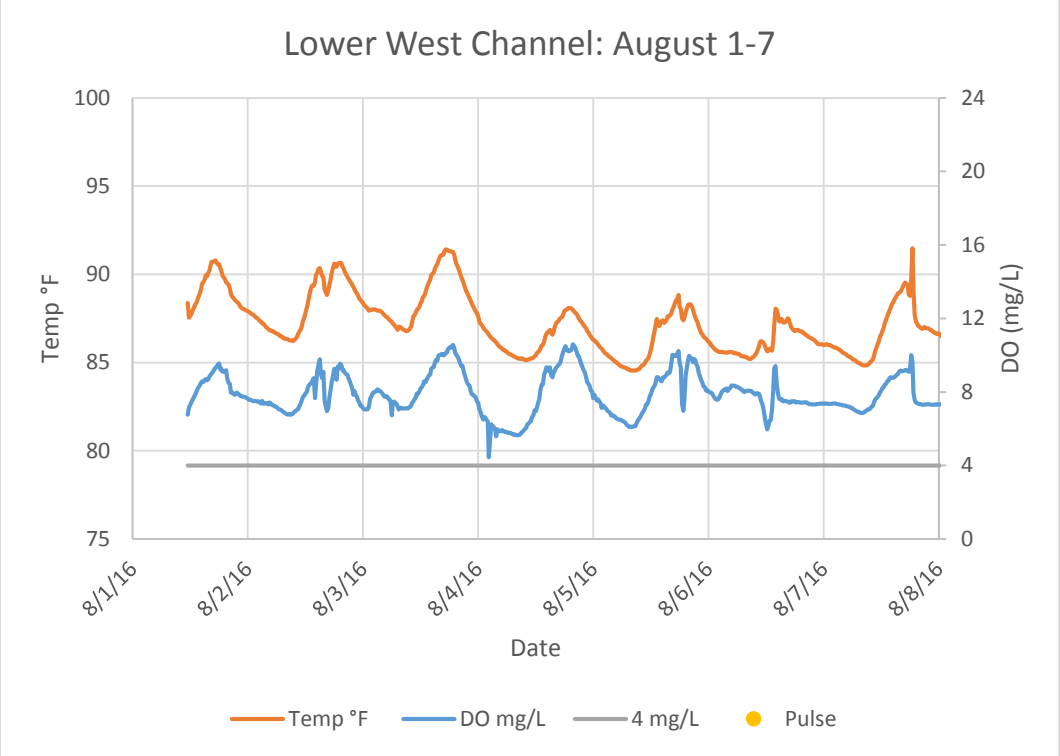


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FIGURE 4-3 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS – AUGUST 1-7

TABLE 4-2 MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AND DISSOLVED OXYGEN FOR AUGUST 1-7, 2016

AUGUST 1-7, 2016						
	TEMPERATURE (°F)			DISSOLVED OXYGEN (MG/L)		
	MAX	MIN	AVG	MAX	MIN	AVG
Upper West Site 1	90.86	84.56	86.66	7.97	3.94	6.03
Upper West Site 2	95.14	82.04	86.84	13.99	3.79	7.34
Middle West	92.80	83.44	86.60	10.94	0.00	6.04
Lower West	91.47	84.56	87.26	10.59	4.45	7.91

TABLE 4-3 YSI SPOT MEASUREMENTS FOR AUGUST 1, 2016

Location	Time	YSI DO (mg/L)	YSI Temp (°F)
YSI 1	0800	4.59	84.6
YSI 2	0815	5.19	85.3
YSI 3	0840	5.60	85.3
YSI 4	0847	5.73	86.0
YSI 5	0855	5.72	86.0
YSI 6	0858	5.24	85.8
YSI 7	0905	5.95	85.1
YSI 8	n/a	n/a	n/a
Middle West Channel	1100	6.50	86.9
Lower West Channel	1130	6.36	87.1

TABLE 4-4 YSI DO VERIFICATION FOR AUGUST 1, 2016

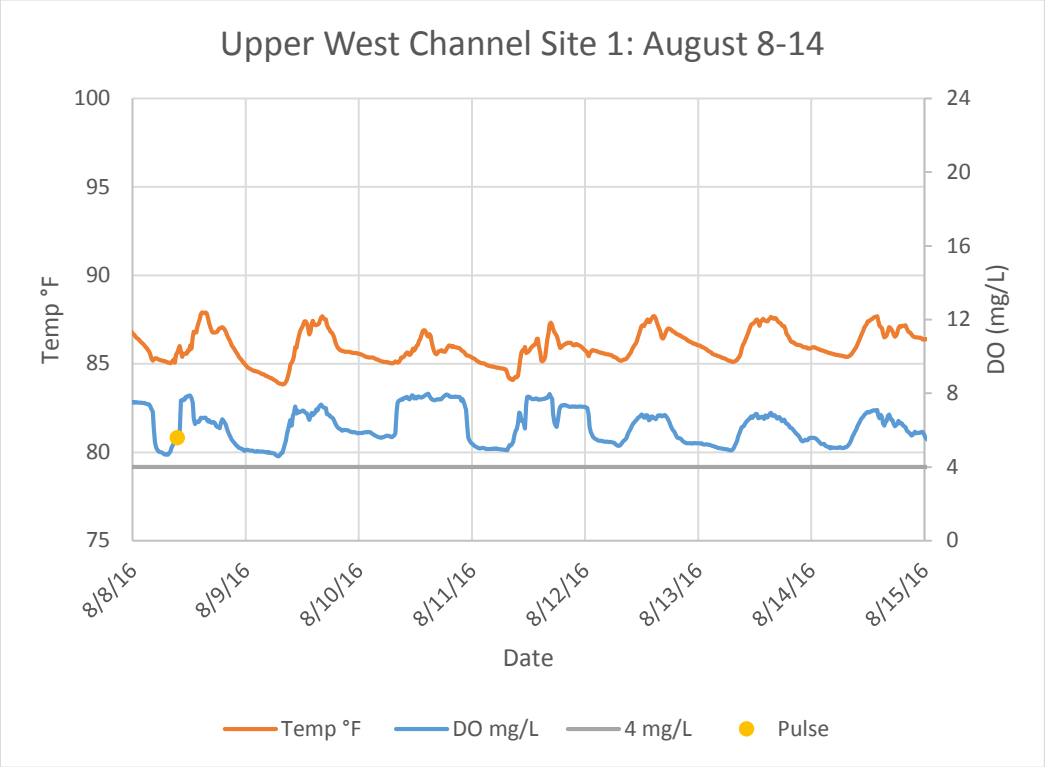
Location	Time	YSI DO (mg/L)	YSI Temp (°F)	HOBO DO (mg/L)	HOBO Temp (°F)
YSI 2	0815	5.19	85.3	6.03*	85.17*
YSI 7	0905	5.95	85.1	**	**
Middle West Channel	1100	6.50	86.9	6.63	87.40
Lower West Channel	1130	6.36	87.1	6.77	88.38

* First HOBO data point taken at 0845

** HOBO deployed on 8/3/16

August 8-14, 2016

During the week of August 8-14, DO levels briefly dropped below 4 mg/L during one day at Upper Site 2, but DO levels greater than 4 mg/L were observed during all other sampling days at all sampling sites. Diel fluctuations in both temperature and DO levels were observed at all sites (Figure 4-4). Minimum and maximum DO and temperatures for each collection site are presented in Table 4-5. Upper Site 2 again experienced the largest diel swings. There was a pulse of approximately 24 acre feet on August 8. DO and temperature collected by YSI prior to and during the planned pulse are presented in Table 4-6. These data show that the planned pulse provided a slight increase in DO during the pulse. There were also unplanned spills of 16,500 cfs peak flow on August 10 and 9,000 cfs peak flow on August 11. None of the spill events appeared to significantly affect DO readings in the west channel. However, these unplanned spills would have provided some flushing of the west channel and could have helped to improve overall water quality. A comparison of YSI and HOBO readings again showed that the HOBO's were collecting accurate data (Table 4-7).



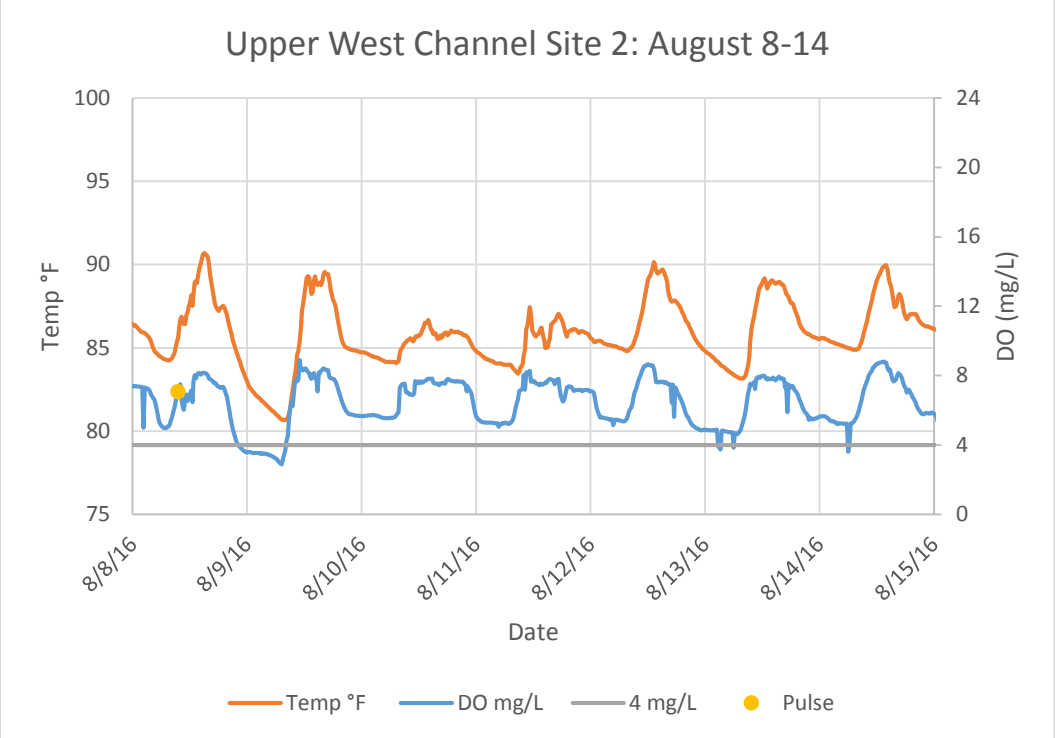
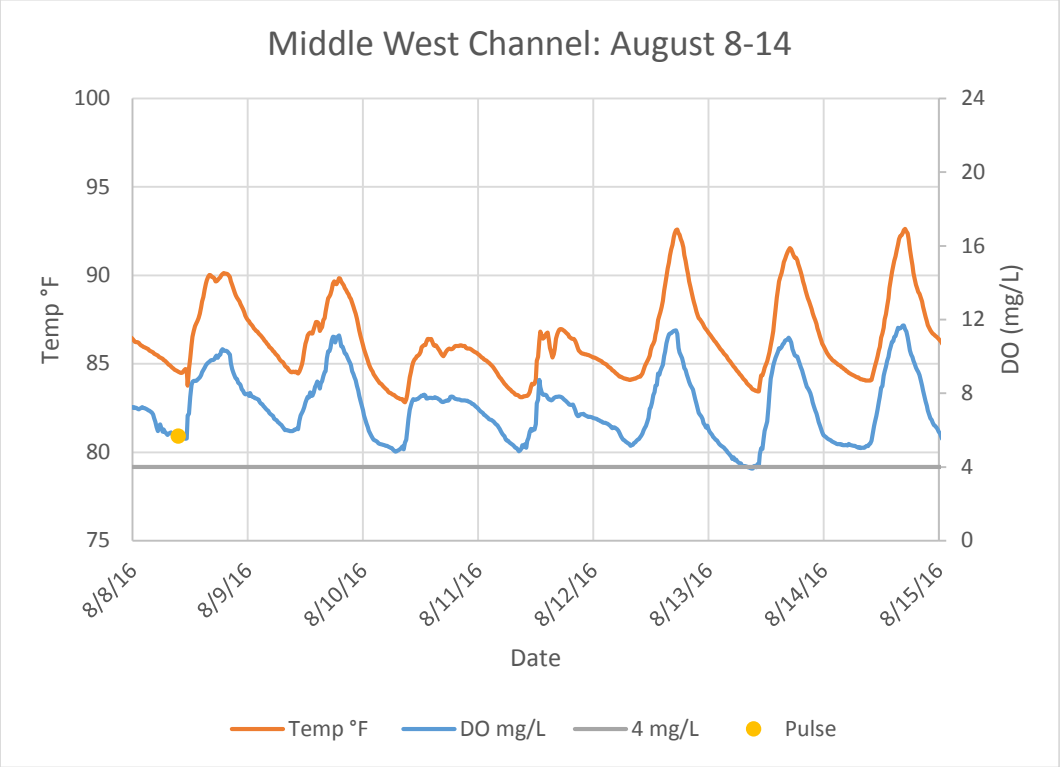


FIGURE 4-4 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS - AUGUST 8-14, 2016



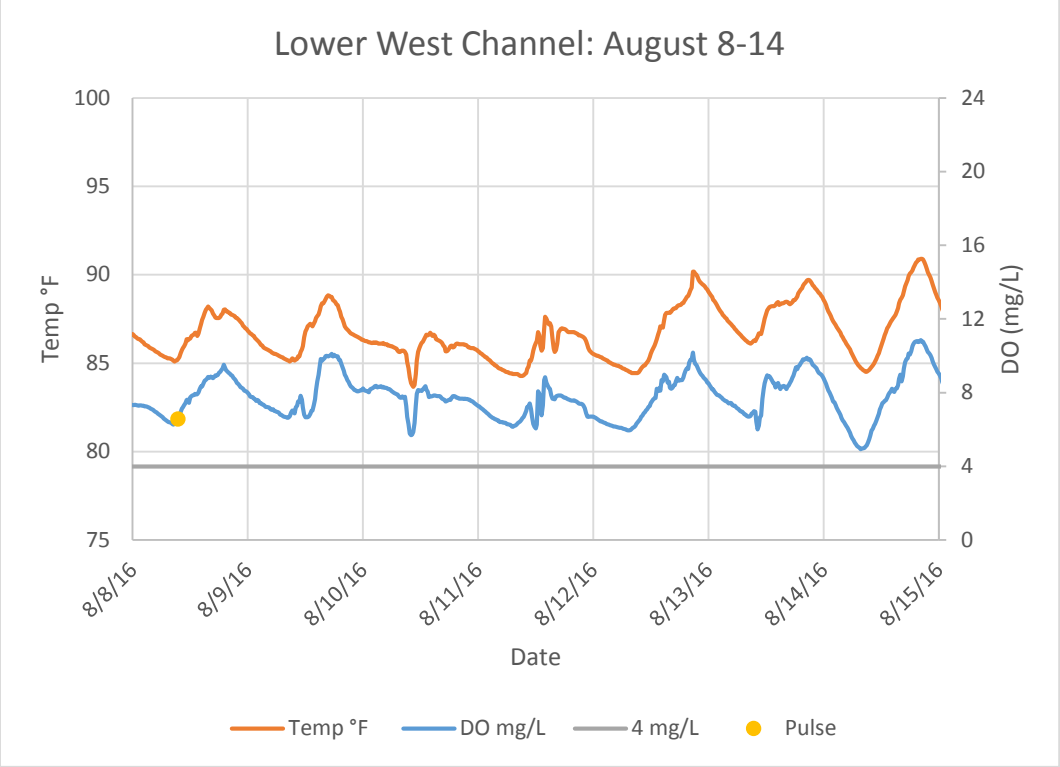


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FIGURE 4-4 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS – AUGUST 8-14, 2016

TABLE 4-5 MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AND DISSOLVED OXYGEN FOR AUGUST 8-14, 2016

AUGUST 8-14, 2016						
	TEMPERATURE (°F)			DISSOLVED OXYGEN (MG/L)		
	MAX	MIN	AVG	MAX	MIN	AVG
Upper West Site 1	87.91	83.84	85.97	7.97	4.58	6.20
Upper West Site 2	90.68	80.67	85.85	8.90	2.89	6.46
Middle West	92.62	82.83	86.41	11.68	3.91	7.28
Lower West	90.90	83.66	86.70	10.86	4.93	7.75

TABLE 4-6 YSI SPOT MEASUREMENTS FOR AUGUST 8, 2016

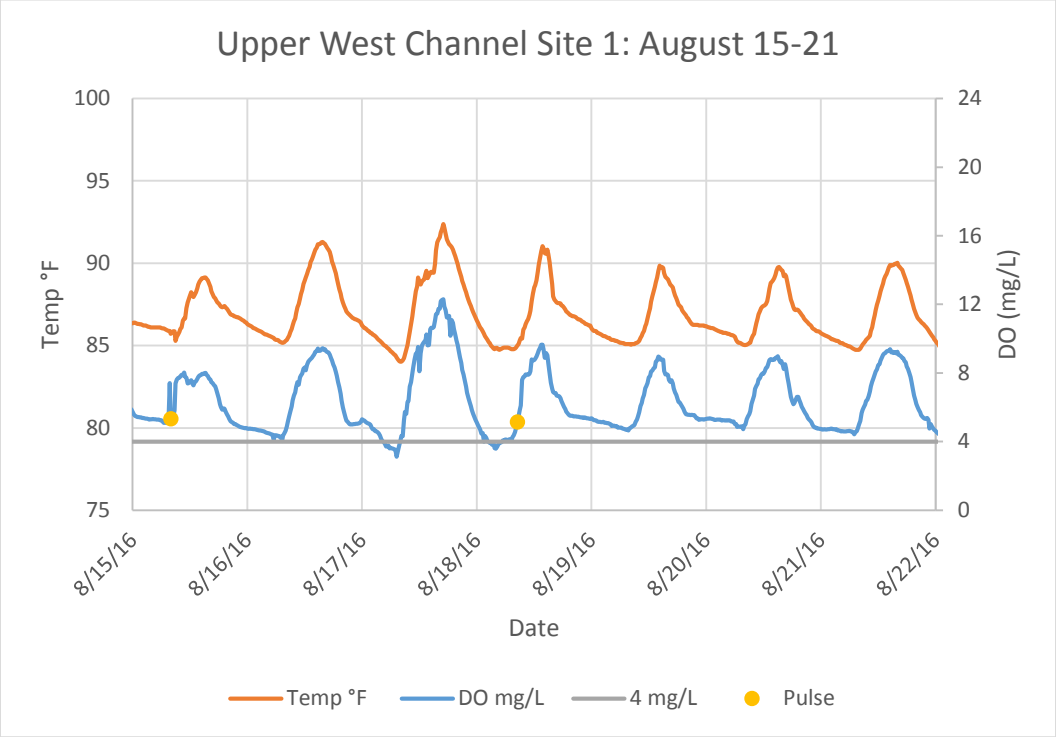
	PRE-PULSE			DURING PULSE		
LOCATION	DO (mg/L)	Temp (°F)	Time	DO (mg/L)	Temp (°F)	Time
YSI 1	5.49	85.1	0850	7.26	85.8	1100
YSI 2	5.11	85.3	0853	7.12	85.6	1028
YSI 3	5.24	85.5	0903	7.11	85.5	1031
YSI 4	4.80	85.6	0906	7.12	85.5	1033
YSI 5	4.91	85.8	0910	7.19	85.6	1036
YSI 6	5.13	85.8	0913	6.58	86.0	1038
YSI 7	6.49	86.0	0919	5.65	86.4	1041
YSI 8	6.26	86.4	0935	6.61	87.3	1046
Middle West Channel (Bridge)	n/a	n/a	n/a	6.42	84.9	1130
Lower West Channel	n/a	n/a	n/a	7.21	86.4	1149

TABLE 4-7 YSI DO VERIFICATION FOR AUGUST 8, 2016

Location	Time	YSI DO (mg/L)	YSI Temp (°F)	HOBO DO (mg/L)	HOBO Temp (°F)
YSI 2	0853	5.11	85.3	5.59	85.06
YSI 7	0919	6.49	86.0	6.81	85.35
Middle West Channel	1130	6.42	84.9	6.80	83.77
Lower West Channel	1149	7.21	86.4	7.45	86.36

August 15-21, 2016

During the week of August 15-21, DO levels below 4 mg/L were observed at several sites over several days, but never remained below 4 mg/L for more than several hours. Diel fluctuations in both temperature and DO levels were observed at all sites (Figure 4-5). Minimum and maximum DO and temperatures for each collection site are presented in Table 4-8. Upper Site 2 again experienced the largest diel swings. There were pulse flows of approximately 25 acre feet on 8/15 and 8/18. Both of the spill events appeared to have positive effects on DO levels in the Upper and Middle Sites. DO and temperature collected by YSI prior to and during the planned pulse are presented in Table 4-9. These data show that the planned pulse provided a slight increase in DO during the pulse. No unplanned spills occurred during the week. Comparison of the YSI readings and the HOBO logger data again showed that the HOBO's were collecting accurate data.



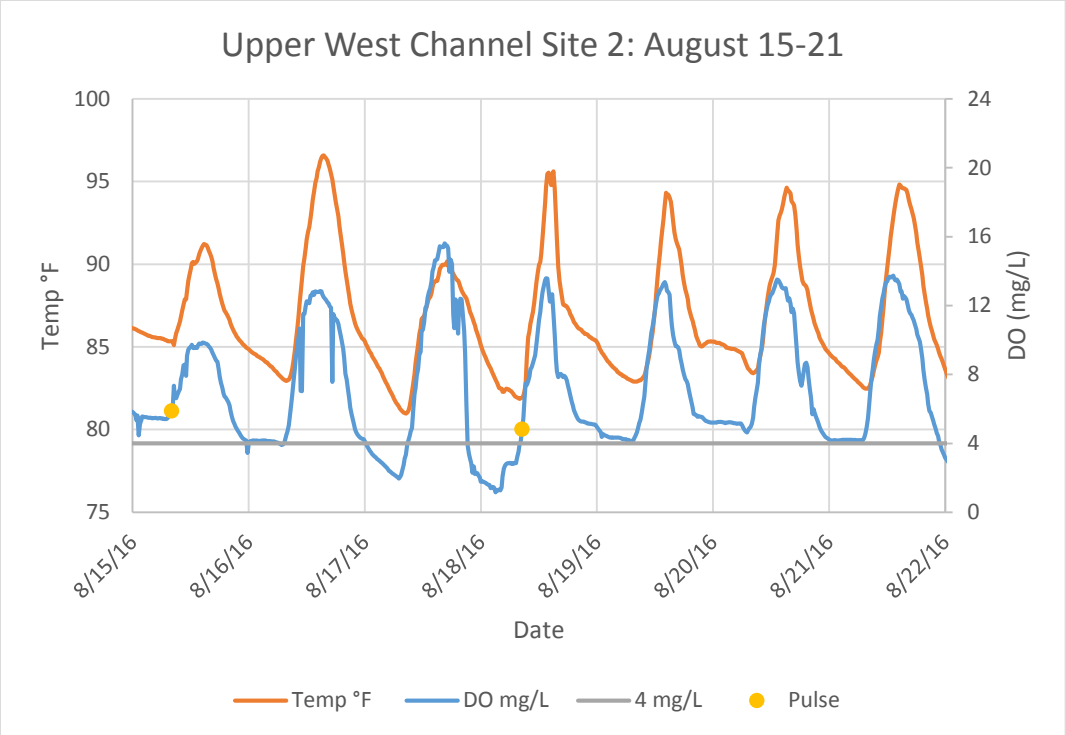
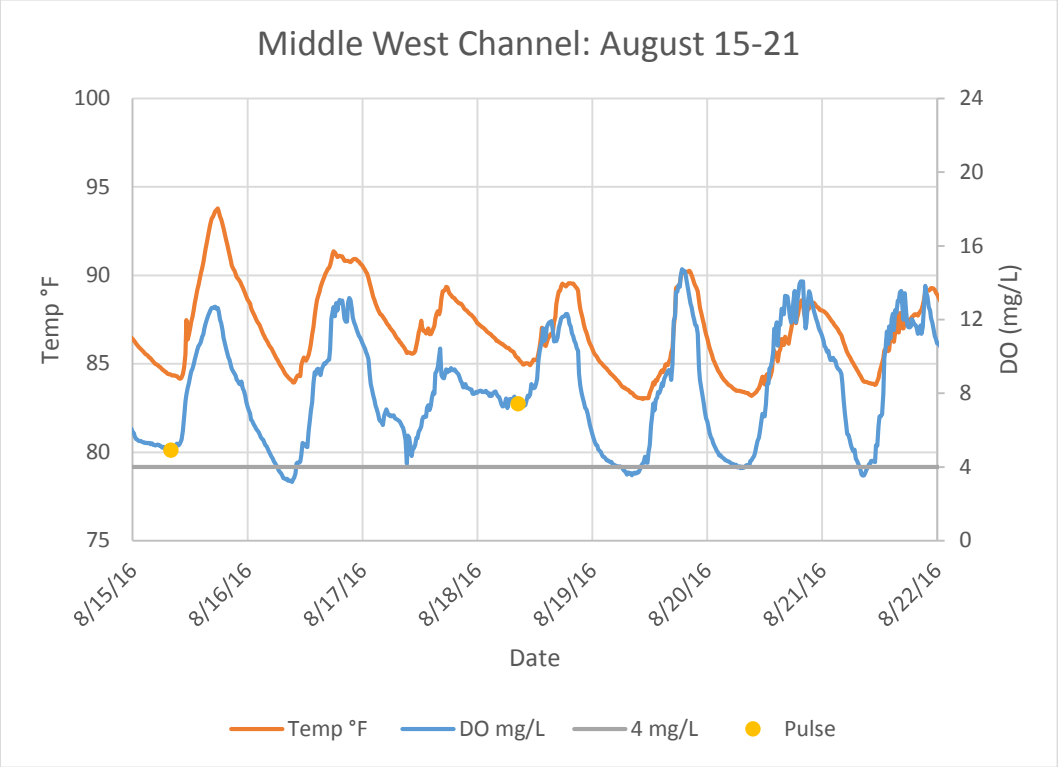


FIGURE 4-5 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS - AUGUST 15-21, 2016



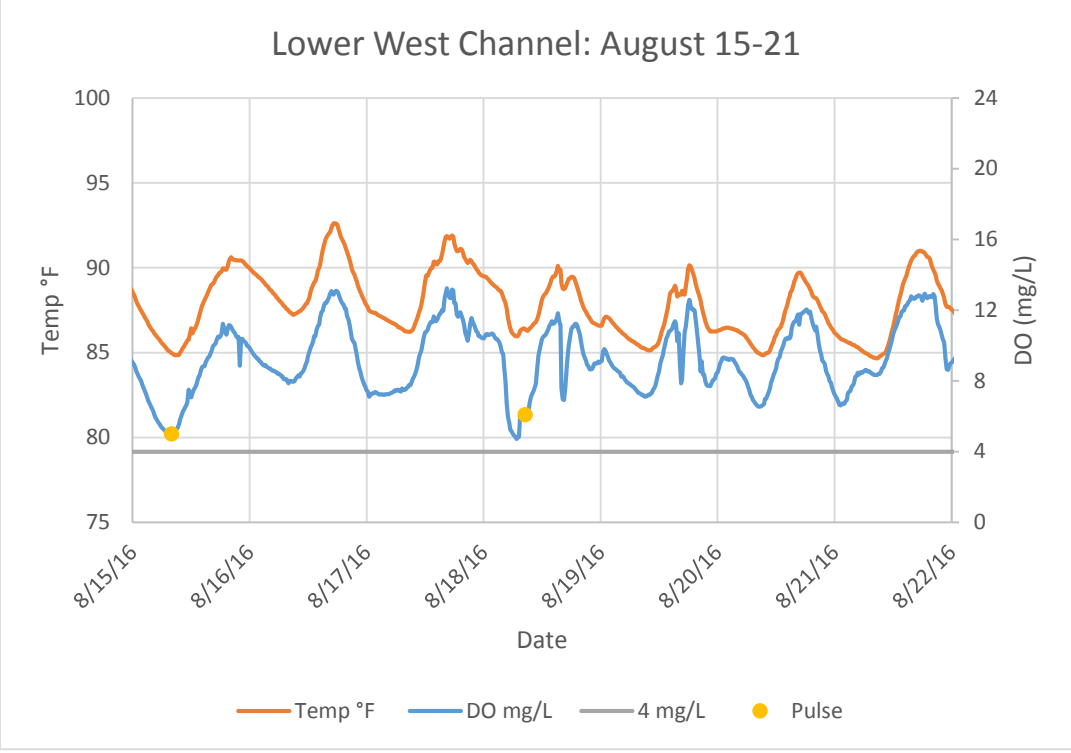


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FIGURE 4-5 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS – AUGUST 15-21, 2016

TABLE 4-8 MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AND DISSOLVED OXYGEN FOR AUGUST 15-21, 2016

AUGUST 15-21, 2016						
	TEMPERATURE (°F)			DISSOLVED OXYGEN (MG/L)		
	MAX	MIN	AVG	MAX	MIN	AVG
Upper West Site 1	92.37	84.02	86.97	12.30	3.12	6.38
Upper West Site 2	96.58	80.96	86.87	15.61	1.15	7.19
Middle West	93.78	83.01	86.82	14.74	3.18	8.13
Lower West	92.62	84.67	87.84	13.23	4.72	9.24

TABLE 4-9 YSI SPOT MEASUREMENTS FOR AUGUST 15, 2016

	PRE-PULSE			DURING PULSE		
LOCATION	DO (mg/L)	Temp (°F)	Time	DO (mg/L)	Temp (°F)	Time
YSI 1	5.40	85.5	0747	8.36	86.7	1023
YSI 2	5.50	86.0	0753	8.15	86.5	1020
YSI 3	5.45	86.1	0800	8.13	86.4	1017
YSI 4	5.44	86.1	0807	8.17	86.6	1015
YSI 5	5.44	86.1	0810	6.91	86.9	1013
YSI 6	5.31	85.6	0812	6.75	87.0	1011
YSI 7	6.59	85.7	0816	7.92	87.1	1000
YSI 8	5.91	85.9	0821	7.60	87.2	1008
Middle West Channel (Bridge)	n/a	n/a	n/a	8.00	86.7	
Lower West Channel	n/a	n/a	n/a	6.57	86.0	

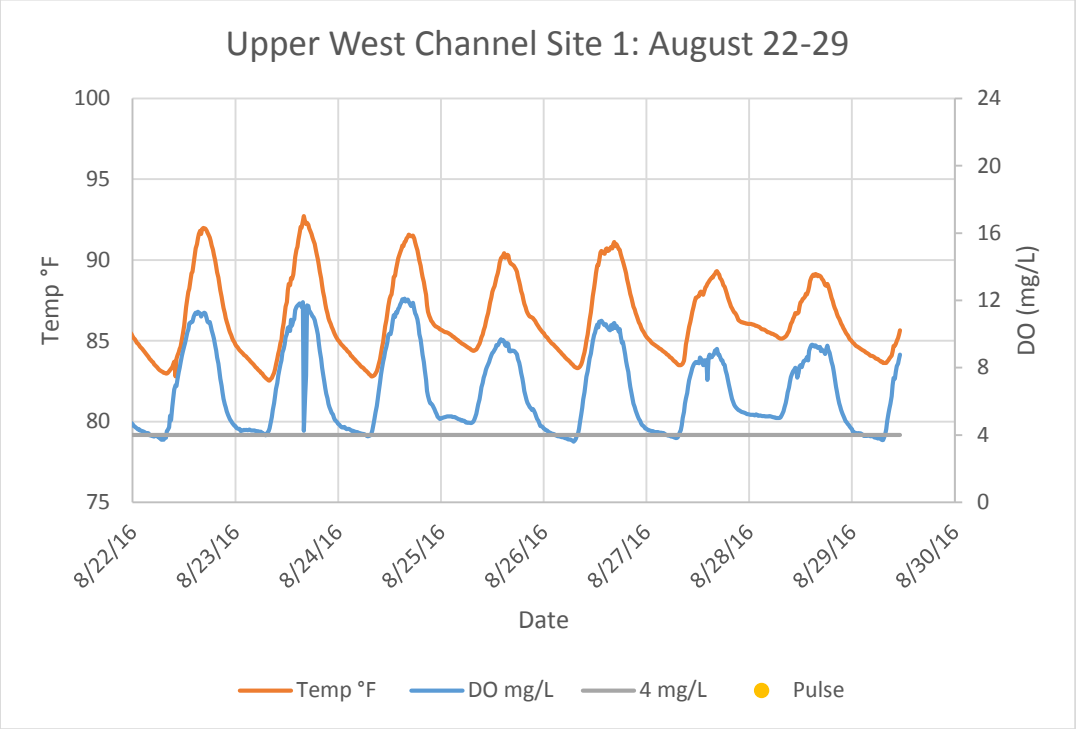
TABLE 4-10 YSI DO VERIFICATION FOR AUGUST 15, 2016

Location	Time	YSI DO (mg/L)	YSI Temp (°F)	HOBO DO (mg/L)	HOBO Temp (°F)
YSI 2	0753	5.50	86.0	5.33	85.71
YSI 7	0816	6.59	85.7	6.00	85.35
Middle West Channel		8.00	86.7	8.29	86.36
Lower West Channel		6.57	86.0	7.07	86.43

* Middle and Lower times estimated to be 1130 and 1200

August 22-29, 2016

During the week of August 22-29, there were no planned or un-planned spillway releases. There were a few DO excursions at the Upper Site 1, Middle, and Lower sites during the week (Figure 4-6). The largest diel fluctuations were observed at Upper Site 2, with DO levels dropping below 4 mg/L and rising up to 21.73 mg/L during a single 24-hour period (Table 4-11). DO and temperature data collected by YSI verified these DO spikes (Table 4-12). This increase in diel fluctuation is likely the result of low flows (no pulse & reduced generation) during the week and a rapid increase of vegetation at the two Upper Sites. Field crews noted a very large increase in the abundance of aquatic vegetation (Hydrilla and Spirogyra) during this last week of testing throughout the upper reach of the west channel (Photo 4-1; Photo 4-2).



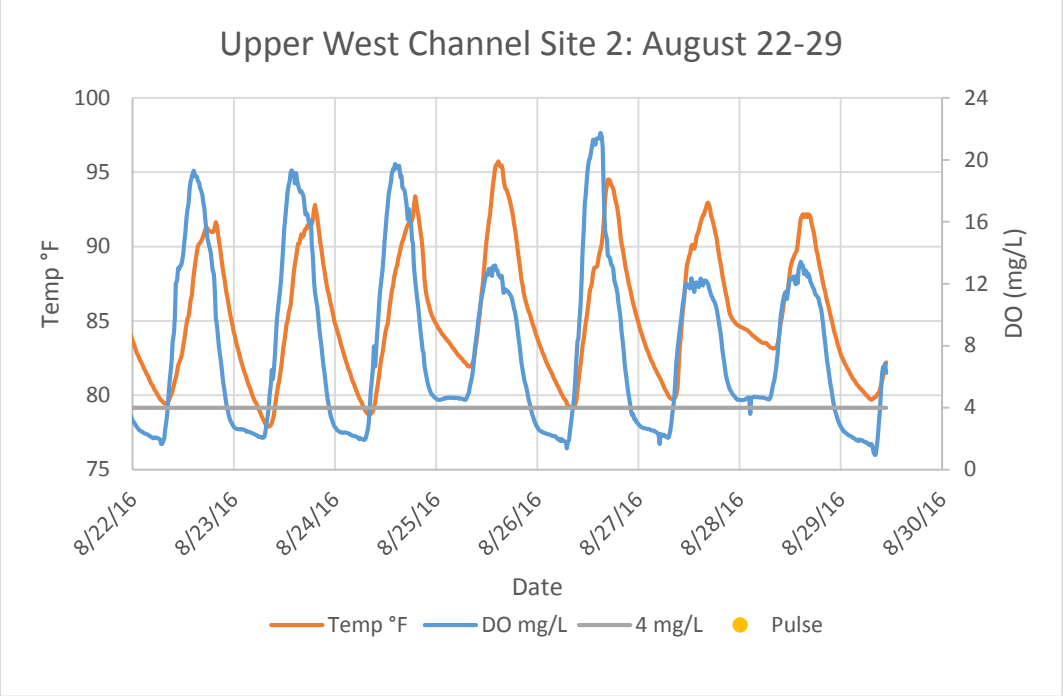
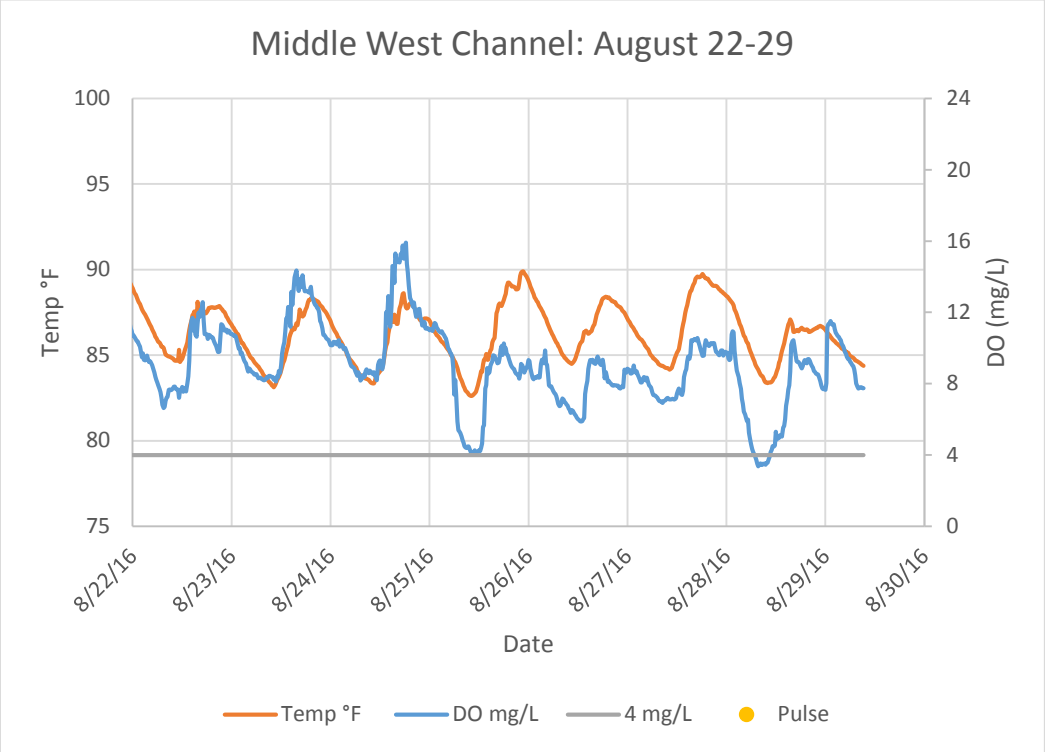
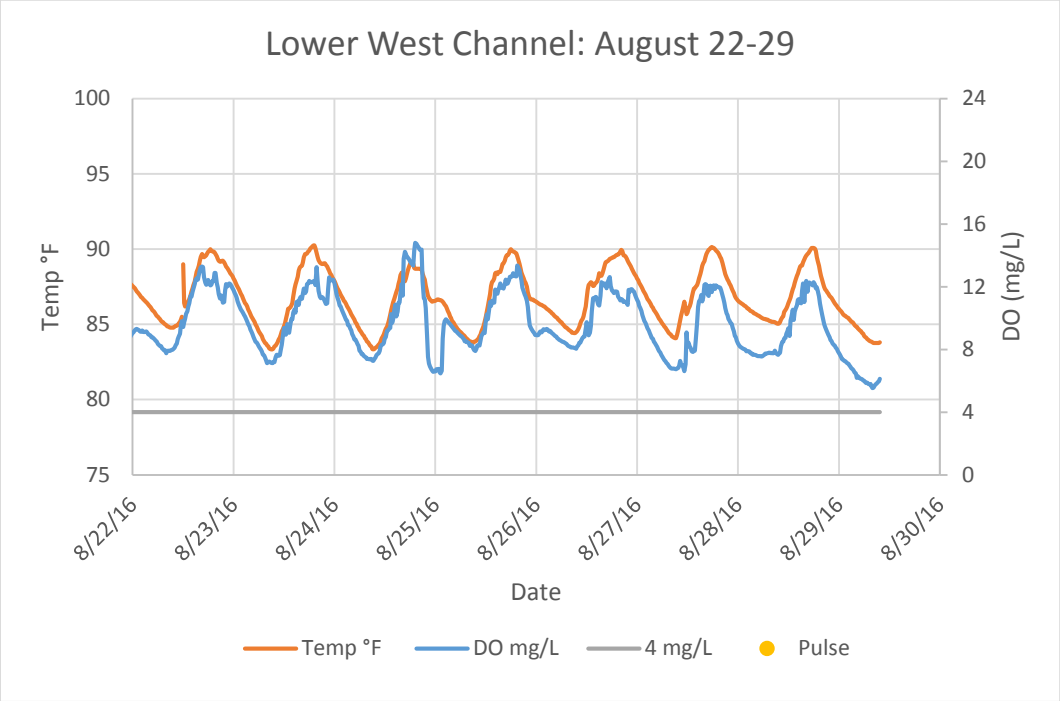


FIGURE 4-6 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS - AUGUST 22-29, 2016





(CONTINUED)

FIGURE 4-6 DISSOLVED OXYGEN AT THE UPPER, MIDDLE, AND LOWER WEST CHANNEL LOCATIONS - AUGUST 22-29, 2016

TABLE 4-11 MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AND DISSOLVED OXYGEN FOR AUGUST 22-29, 2016

AUGUST 22-29, 2016						
	TEMPERATURE (°F)			DISSOLVED OXYGEN (MG/L)		
	MAX	MIN	AVG	MAX	MIN	AVG
Upper West Site 1	92.73	82.54	86.41	12.11	3.60	6.68
Upper West Site 2	95.72	77.90	85.37	21.73	0.95	7.90
Middle West	89.89	82.62	86.24	15.91	3.37	9.00
Lower West	90.25	83.34	86.73	14.81	5.54	9.64

TABLE 4-12 YSI SPOT MEASUREMENTS FOR AUGUST 22 & 29, 2016

	August 22, 2016			August 29, 2019		
Location	DO (mg/L)	Temp (°F)	Time	DO (mg/L)	Temp (°F)	Time
YSI 1	8.58	83.7	0950			
YSI 2	7.18	83.8	0954	9.26	86.0	1124
YSI 3	6.97	83.8	1002	7.70	85.1	1037
YSI 4	6.34	84.4	1004	8.68	86.2	1114
YSI 5	7.13	84.0	1006	9.06	85.6	1111
YSI 6	12.80	83.7	1046	13.60	84.9	1109
YSI 7	12.97	81.5	1013	15.05	83.7	1057
YSI 8	8.13	81.3	1026	11.22	83.5	1047
Middle West Channel (Bridge)	7.18	84.7	1115	7.69	84.2	0925
Lower West Channel	0.42	85.6	1133	6.70	83.8	0940

TABLE 4-13 YSI DO VERIFICATION FOR AUGUST 22, 2016

Location	Time	YSI DO (mg/L)	YSI Temp (°F)	HOBO DO (mg/L)	HOBO Temp (°F)
YSI 2	0954	7.18	83.8	6.94	82.8
YSI 7	1013	12.97	81.5	12.04	81.18
Middle West Channel	1115	7.18	84.7	7.2	85.32
Lower West Channel	1133	10.10	85.6	9.57	85.32

TABLE 4-14 YSI DO VERIFICATION FOR AUGUST 29, 2016

Location	Time	YSI DO (mg/L)	YSI Temp (°F)	HOBO DO (mg/L)	HOBO Temp (°F)
YSI 2	1124	9.26	86.0	8.78	85.64
YSI 7	1057	15.05	83.7	6.84	82.22
Middle West Channel	0925	7.69	84.2	7.75	84.38
Lower West Channel	0940	6.70	83.8	6.12	83.8

PHOTO 4-1 UPPER REACH OF THE WEST CHANNEL (NOTE MULTIPLE POCKETS OF AQUATIC VEGETATION)

PHOTO 4-2 HYDRILLA AND SPIROGYRA IN THE UPPER REACH OF THE WEST CHANNEL

Comparison of 2015 and 2016 August Data

The 2015 report noted that the HOBO monitor in the Upper West Channel was frequently fouled by vegetation wrapping around the monitors and proposed that this fouling resulted in erroneous data collections. During 2016, the HOBO monitors were checked weekly and remained free of vegetation fouling.

The Upper West Channel 2015 data experienced large diel fluctuations for the entire month, with DO ranging from highs up to approximately 21 mg/L down to DO levels at or near 0 mg/L. The Upper Site 1 – 2016 data did not show these drastic swings and rarely documented DO below 4 mg/L. The Upper Site 2 – 2016 data was similar to the 2015 DO observations only during the latter part of the month when no pulsing flows were experienced. Upper Site 2 also had an abundance of aquatic vegetation throughout the study period and likely influenced the diel shifts observed during the last week of August 2016. The 2016 data showed that the Upper West Channel sites do not all experience DO levels consistently below 4 mg/L. The 2016 test also showed that pulsing spillway flows periodically during the summer improve DO levels in the Upper West Channel area.

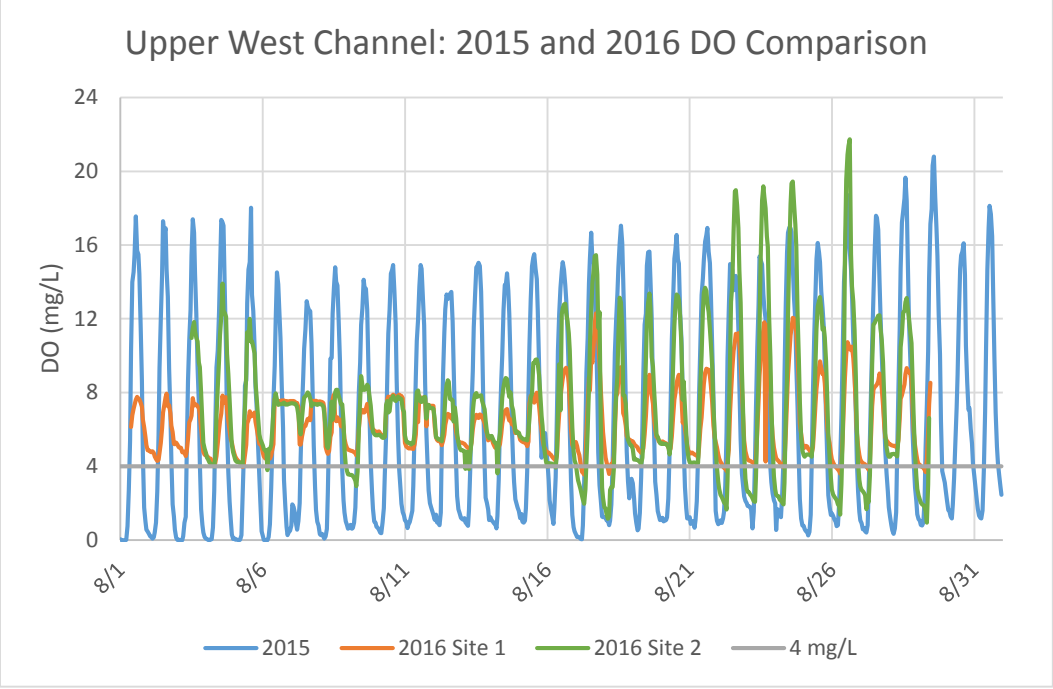


FIGURE 4-7 DISSOLVED OXYGEN AT THE UPPER WEST CHANNEL LOCATIONS - AUGUST 2015 AND 2016

Daily maximum DO levels in the Middle West Channel were higher in 2016 than in 2015. Diel fluctuations were also more pronounced in 2016. However, lower DO levels occurred during 2015 for most days in August. Diel fluctuations became more pronounced in 2016 towards the end of August (at the same time that the abundance of aquatic vegetation increased), whereas the fluctuations in 2015 remained relatively constant. It is likely that checking and cleaning the HOBO loggers weekly during 2016 resulted in better data. It appears that the spillway flows (both planned and unplanned) helped to increase the observed DO levels in 2016.

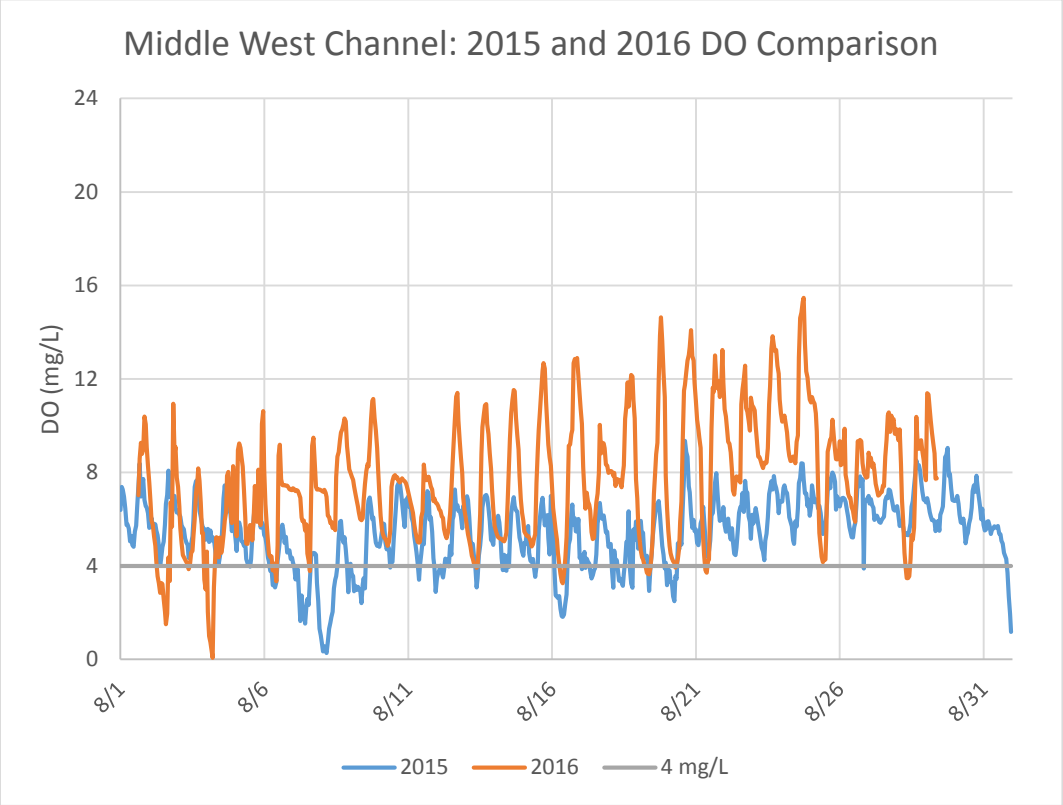


FIGURE 4-8 DISSOLVED OXYGEN AT THE MIDDLE WEST CHANNEL LOCATION - AUGUST 2015 AND 2016

DO levels were generally higher in 2016 than in 2015 at the lowest reach. Both years experienced diel fluctuations, with DO levels in 2015 reaching overall lower levels than those observed during 2016. The Lower West Channel site appears to be most affected by turbine operations as river flows back up into this area. DO levels for both of the years rarely dropped below 4 mg/L and this site should continue to meet DO standards in the future.

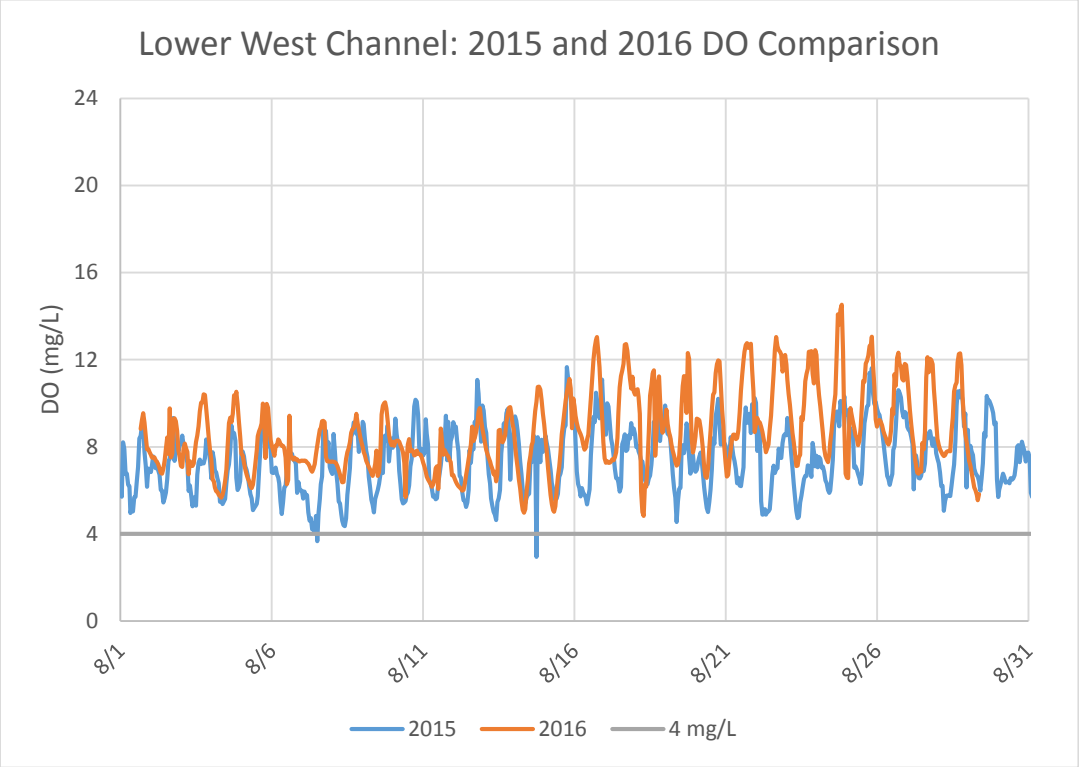


FIGURE 4-9 DISSOLVED OXYGEN AT THE LOWER WEST CHANNEL LOCATION - AUGUST 2015 AND 2016

5.0 DISCUSSION

DO levels generally remained above the DHEC standard of 4 mg/L (SCDHEC 2012) during 2016, with diel fluctuations in both temperature and DO occurring throughout the study. Greater fluctuations in DO were observed later in the month as aquatic vegetation increased and spillway flows were curtailed. Unlike the original 2015 study, where equipment was continually fouled by aquatic vegetation, equipment during this 2016 study was kept clean, suggesting that the results of this study offer more accurate readings for DO experienced in the west channel during the late summer period.

DO levels in 2016 were generally greater than those observed during 2015, reaching higher levels, and not reaching minimum levels observed during 2015. Equipment was kept clean in 2016 through frequent site visits, and by placing equipment in locations where fouling was less likely to occur. Conversely, equipment in 2015 had spirogyra wrapped around it on several occasions, which likely affected those results. DO levels in the upper and middle west channel did experience increased daily spikes in DO levels as August progressed, which may be due to the increased amount of aquatic vegetation that was observed during the latter half of 2016. While some vegetation, particularly spirogyra, was observed during 2015, an abundance of Hydrilla was observed during 2016. Hydrilla was not observed during the 2015 study and is a new exotic species for the area that will influence the west channel habitat conditions in the future. Further, the large unplanned spillway releases that occurred early in the 2016 study may have influenced the study results by retarding the dominance of aquatic vegetation in the west channel.

Overall, water quality in the west channel seems to be most impacted during the later summer months, when stream flows are typically lower, temperatures are warmer, and vegetation growth is at a higher level. The planned smaller spillway pulses appeared to have had a positive effect on DO levels in the west channel, as observed DO levels were measurably increased with each of the planned pulse events. The pulses of approximately 25 acre-feet, in combination with the unplanned spills, were able to maintain higher levels of water quality in the West channel.

The study also determined that water levels in the west channel are strongly influenced by flows from the powerhouse and indicate that tailrace flows enter the west channel. An increase in the amount of water passing through the powerhouse will increase the amount of water in the west channel and should help to improve DO levels in the west channel.

It is possible that the higher DO levels observed during 2016 were a result of both the flows to the west channel from the tailrace combined with periodic spills of approximately 25 acre feet. More data over several years may be needed to fine tune the frequency and amount of spills that are needed to boost west channel DO levels during the late summer.

6.0 REFERENCES

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Kleinschmidt Associates. 2015. Water Quality in Downstream West Channel Study Report. Parr Hydroelectric Project (FERC No. 1894) South Carolina Electric and Gas Company. Cayce, South Carolina. April 2015.